mediaX at Stanford University

# highlights + reflections

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**2001-2022**

*Two Decades of Pragmatic Multidisciplinary Discovery Collaborations*

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mediaX at Stanford University

mediaX is the affiliate program of H-STAR Institute of the Stanford Graduate School of Education.

*To all the researchers with whom we shared adventure and discovery, and to our members who made it all possible*

mediaX at Stanford University: Highlights + Reflections 2001-2022.
Two Decades of Pragmatic Multidisciplinary Discovery Collaborations.



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# Contents



**Also Available**

The Catalyst Culture Playbook: mediaX at Stanford University

Smart Workspaces

Team Performance in a Networked World

Questions for the Future: Passing the mediaX Torch

# Acknowledgments

With curiosity, challenge, inquiry, and discovery, mediaX coalesced a community of over three hundred researchers to actively collaborate on research grants — including 178 Stanford faculty members, 118 graduate students who received research support, and researchers from 45 companies and other institutions. Over a twenty-one-year period, this fluid community shared questions, observed phenomena, evaluated what they observed, and shared their insights. A separate volume, *The Catalyst Culture Playbook*, describes how and why the mediaX community created bridges that spanned the often-separated worlds of academia and business. Incorporating the voices of affiliated academic and industry researchers, the playbook suggests ways of conducting experiences of pragmatic multidisciplinary discovery collaboration with sustained dialogue among siloed departments by leveraging modest resources for bold experiments.

This book highlights six virtuous cycles of inspiration and insights during those two decades (2001-2022). With each topic as a lens, we reflect somewhat chronologically on how the evolution of fundamental socio-technical and cultural changes influenced the dialogues between academic and business colleagues, and how those intersections influenced industry-inspired, faculty-driven inquiry at Stanford University. As examples of exploratory paths, these six broad topics call to mind the mix of context, values and competences required to address socio-technical systems in mutually beneficial relationships. They are highlights, like skipping stones across deep pools of knowledge.

Corporate members enjoyed early conversations featuring insights from these inquiries as they attended mediaX conferences, workshops and seminar programs. The scholarly publication of insights generated from these explorations and related research results often appeared several years later, accommodating the time required for peer-review publications. These works contributed to many disparate fields of knowledge.

Socio-technical systems continue to be in flux, with today's and tomorrow's challenges evolving from yesterday's solutions. Questions and insights evolve together. It is our hope that the highlights described here will remind readers of past challenges, and opportunities that developed from their solutions, changing and growing with continued engagement and exploration. Our purpose here is to encourage those who want to participate consciously in the construction of a positive human society, in which technological advances in media serve to enhance and empower humans.

A deep thank you to mediaX founders, faculty leaders, staff, corporate affiliates, and extended teams for their participation and inspired contributions. From conversations with them, **Questions for the Future** have been curated and are summarized here, with examples available online, through a link provided by the QR code. We invite you to elaborate and pursue any or all these nine questions — and, importantly, we invite you to identify other questions based on your personal experiences and professional contexts.

**As a teaser, we ask:**
***How might university-industry collaborations provide leadership for intellectual risk-taking, research design, and knowledge creation?***

**Martha G. Russell**

Executive Director

Image Credit: Linda A. Cicero / Stanford News Service

# About mediaX

From 2001 to 2022, media X was the affiliate program, first of CSLI and then of the H-STAR Institute after its formation in 2005, extending (depending on the period) from either the Office of the Dean of Research or the Stanford Graduate School of Education to over two dozen interdisciplinary labs at Stanford. mediaX brought innovative companies and researchers together to explore thoughtful uses of information technology across industries.

mediaX initiated research through strategic engagements with our members, typically investigating how the relationship between people, media and technology could be enhanced, augmented and improved. mediaX programs provided opportunities for people from high-impact companies to interact with Stanford University researchers.

In 2022, as mediaX ceased formal operations, thirty-one programs, centers and labs at Stanford included one or more aspects of the intersection between people and digital media as their research focus. The legacy of mediaX — partly described in this book — continues in these 31 Stanford programs and in the community that is still alive and growing.

The combination of Silicon Valley's entrepreneurial culture, actively engaged industry partners, Stanford thought leadership, and the energetic creativity of bright, motivated graduate students infused mediaX activities with unique opportunities to capitalize on the full intellectual, technological and cultural resources at Stanford University.

Image Credit: Linda A. Cicero / Stanford News Service

# Reflections on mediaX

*When I first heard the name, "mediaX," I thought it referred to a magic bullet that would become the perfect new media. I was partially correct. I learned that the secret sauce is the human-human connection that is fundamental to the 'media equation'. Technology can be an enabler.*

**Tatsuro Ichihara**

Former Technology Executive at OMRON

*I first began talking with Byron Reeves and Keith Devlin about mediaX in June 2000 as I was being recruited to develop a new doctoral program in the learning sciences and technology design for the Stanford School of Education (now the Stanford Graduate School of Education). Byron and Keith had just made a fund-raising presentation at Microsoft Research Labs to seek out mediaX funding, and in my meeting with them at Stanford, I received a copy of the slide deck they were using and learned that they sought to establish "a new Stanford center for applying research about people to the design and study of interactive media." I was enthused to join this ambitious enterprise and did shortly thereafter.*

**Roy Pea**

David Jacks Professor of Education & Learning Sciences at Stanford Graduate School of Education and (Courtesy) of Computer Science, Faculty Director of mediaX, Co-founder and Director of H-STAR Institute

*From being a simple connection point— bridging Stanford University to the business community — mediaX morphed into a dynamic constellation of networks.*

**Harlan Kennedy**

Experience Design Strategy Consultant

*mediaX can be characterized by the idea of "engineered serendipity". Over and over, attentive listening and careful, curated planning would create opportunities for explorative minds to find and build connections — across disciplines, across organizations. Even my introduction to mediaX began with a chance encounter followed by swift identification of shared interests and opportunities to grow together. mediaX members didn't join just to find answers — they joined to explore together. Questions were key — they created the points of intersection. Perspective was essential — particularly curiosity and gracious engagement. With these, the community learned together.*

**Elizabeth Wilsey**

mediaX Director of Community Relations

*Our engagements with mediaX were an act of hope. It was a belief in the role of interdisciplinary thinking and collaboration between academia and industry in solving tough problems.*

**Aman Kumar**

mediaX Distinguished Visiting Scholar

*Qitian and mediaX have worked together to formulate frontier opportunities for the early diagnosis, rehabilitation training, and growth empowerment of children with autism. The collaboration has stimulated fruitful applications in Guangzhou Children's Hospital with efficient cooperation and gratifying results. We look forward to using design thinking to lead Chinese young people to the forefront of international innovation and build a bridge for fostering innovative talents with world-class universities. This kind of cooperation, sincere and pragmatic, benefits the general public, and everyone can feel the strength.*

**Weina Wang**

CEO of mediaX member Guangzhou Qitian Technology Company

*Konica Minolta's (KM) interest in the Knowledge Worker Productivity theme focused on measuring productivity and creativity. Several research projects selected for mediaX funding approached these challenges. After the projects started, young engineers and researchers from Tokyo participated in the research as visiting scholars. Being able to discuss various topics with university researchers was a very valuable opportunity so KM's researchers could get in touch with the ideas and insights of Stanford researchers and participate in the human network of mediaX. One of the mediaX research projects of interest to KM was spun out from Stanford University as Spire [Health]. KM researchers participated in the early days of this startup.*

**Hiroshi Tomita**

mediaX Distinguished Visiting Scholar and Representative of the National Information Institute of Japan and former President of mediaX member Konica Minolta US

*Inspiration and innovation often come to be at the intersection of different bodies of knowledge. It's all about sharing different approaches and opening the mind to alternatives. If we come in and we don't have an open mind and a willingness to change our assumptions, then whatever people are presenting wouldn't be relevant because we wouldn't listen. Because mediaX created such a trusted environment and family atmosphere, it allowed people to listen and absorb those different styles of exploration, to learn about a different approach they might not have taken but which could open up a completely new universe for them.*

**Maria Frank-Kinslow**

Senior Consultant in Organizational Effectiveness at Slalom, former Program Manager of Prototypes in Workplace Effectiveness at Genentech, mediaX member liaison for Genentech and former doctoral student with Renate Fruchter

*mediaX found a way to facilitate, fund, and support often-risky, blue-skies research projects whose wide inter-disciplinary nature cut across two or more departments or schools. The framework developed was win-win-win for all three groups involved:*

- ***Faculty** were able to obtain valuable funding to supplement their main funding streams, including the support of graduate students who needed to complete their projects after the main funding had ended; in some cases, they also gained access to (sometimes expensive) tools that the company had developed and were willing to make available to the university for the duration of the project.*
- ***Industry** partners could benefit from discussing their leading-edge research plans with carefully selected groups of Stanford faculty and researchers and, in the case of top tier members, could in addition ensure that research was conducted on issues of direct relevance to their interests.*
- ***mediaX** was able to take an "overhead" percentage of the member fees to help fund the administration of the program.*

**Keith Devlin**

Emeritus Senior Research Scholar, and Founding Executive Director of mediaX

*Throughout the changes in memberships, changes in faculty participation and changes in campus administrations, the intentions of mediaX stayed fixed on how to ask relevant questions about issues at the intersection of human sciences and information technologies, create and maintain a culture of intellectual pluralism and mutual respect, and sustain engaging conversations focused on opportunities.*

**Martha Russell**

Executive Director of mediaX

***Additional reflections online***

# Engagement, Games and Learning

> *"Media psychologists volunteer to closely monitor the media devices, services and content that exist in the real world. Those are the things that our research is about. Research about the psychology of emotions, for example, is not only about how emotions are experienced psychologically. Importantly, the research is also about how emotions are linked to particular pieces of media — the words, pictures, sounds, sequences, and interactions that make up commercial media products. Across all topics in media psychology, this means that scholars need to keep track — extremely close track as media become more diverse and complex — of the technologies that companies are building, and maybe even more importantly, the technologies that they will build in the future."*
>
> – Byron Reeves

*Highlights*

1 Graphical user interfaces and digital avatars enhanced interaction and permitted quantifiable evidence of engagement, useful for digital media in both education and commerce.

2 Studies of engagement explored cognitive, emotional, cultural, and technological factors.

3 Insights about the power of engagement attracted attention in the learning sciences, among corporate offices seeking to measure and improve worker productivity, and marketers seeking to persuade and sell.

4 With the convenience of mobile computing ubiquity, digital media consumers became content producers of their own digital experiences and monetized their influence.

5 The reciprocal nature of digital media in offering services in exchange for data includes both implicit and explicit expectations.

6 Metrics for digital media that began with page views are evolving to attitude and behavior changes, including arousal measured by diverse sensors.





When mediaX at Stanford University launched in 2001, cloud services, software as a service, social media, video calls, virtual worlds, remote collaboration, and the apps and platform economy were concepts and prototypes, not yet commercial products. Experimental demonstrations were only beginning. After twenty-one years of asking questions, conducting research, and sharing insights, what was then called 'media' has expanded far beyond page views of static information and has become central to always-on digital life and digitized work.

Across these two decades, the adoption of new media has been fueled by engagement. So it's not surprising that the concept of engagement has been a focus for researchers from many fields — psychologists, educators, marketers, designers, and engineers. Engagement involves attention but also implies an emotional, cognitive, or behavioral connection with participation through curiosity, interest, optimism, or passion.

Multiple facets of engagement stimulated inquiry and insights for mediaX research and program initiatives. Studies on the social intelligence of machines[1] provided a foundational understanding that humans are hard-wired to attribute relational qualities to their interactions with machines.[2] Perspectives on the nuanced contexts of learning[3] clarified that engaged learners interact on multiple levels — with content, with their environment, with instructional technologies, and with other people.[4]

## *GUIs and Avatars*

In the early days of mediaX, graphical user interfaces (GUIs) on the World Wide Web emerged and widened the experiential choices for engagement through interactive online games with multiplayer participation[5] and with distributed learning communities.[6] Through online interfaces, people engaged with other people; they also engaged with an implied "other" — the machine itself or messages that were computer-mediated.[7] Curiosity and interest fueled search and interaction, and automated responses could be adapted for personalized services.[8]

Engagement quickly became the coin of the digital realm as advertisers capitalized on the engaged connection, implied by attention that was evidenced in page views, click-throughs, 'stickiness' dwell-time, actions such as purchases or referrals,[9] and channel preferences.[10] Technologies, such as multi-dimensional data structures,[11] highspeed 3D shape digitization, interactive panoramic cinema,[12] and eye-tracking,[13] were explored to improve the function of media interfaces.

With expanded functionality, interactive GUIs inspired mediaX-sponsored research projects on how student-designed digital avatars[14] and interactive tutorials influenced and improved learning outcomes.[15] Other mediaX projects explored how avatar embodiment not only influenced the perception of self and "other"[16] but could also transform social interaction in immersive contexts, for example, allowing a teacher to enact the materially impossible — to simultaneously have eye contact with every online pupil.[17]

## *Interfaces and Intermediaries*

HTML and the standardization of browsers created a rich sandbox of technical opportunities. Long known to educators as an essential component of learning, engagement jumped the chasm from in-person to digital as computer-based training was provided online and empowered the learning experiences of children[18] and adults.[19] mediaX responded to this development by convening thought leaders intrigued by opportunities for interaction and engagement in games and learning. The prescient 2004 Games and Learning Conference[20] convened academic and business experts to discuss insights from mediaX research and explore new questions prompted by envisioned market opportunities.

In subsequent years, scholars took several approaches to investigating engagement. Some studied the context of engagement.[21] Some explored metrics for the various types of media through which engagement took place.[22] Some studied the cognitive processes of engagement;[23] others studied the culture.[24] Explorations included potential applications for high school,[25] middle school[26] and adult markets.[27] Research questions, methods and market opportunities crisscrossed the intersections of human sciences and advanced technologies that were already the nexus of mediaX interests. This inspired new investigations, harnessing technological advances and adapting them for research purposes, resulting in new digital interfaces through which researchers could study human experiences in games and learning.

For example, the advent of 360-degree video capture and playback opened new types of interface experiences,[28] as well as new pathways for studying human activities in real-world and virtual spaces. Using an adapted camera technology, initially developed by DARPA (Defense Advanced Research Projects Agency), and DIVER (Digital Interactive Video Exploration and Reflection), a web-based collaborative video annotation system,[29] this new tool offered researchers and students unprecedented opportunities to observe and analyze the nuanced context of behaviors associated with engagement in learning.[30] Insights from research on engagement in learning fueled the design of early interactive learning toys for children and digital tools for both students and scholars of the learning sciences,[31] as well as the use of contests as catalysts for classroom learning,[32] and the creation and application of simulations for surgery students in medicine.[33]

***Classrooms pushing boundaries.*** Between 2002 and 2010 mediaX promoted innovative use of classroom facilities, made possible by generous funding from the Wallenberg Foundation and managed by H-STAR; these media-equipped classrooms offered smartboards, interactive projection screens, video capture on four sides, and Steelcase mobile desks, chairs and whiteboards. These classrooms — and the researchers who used them — encouraged and embraced the use of technology to push boundaries for learning by using advanced video tools and bringing collaborators together virtually across geographical distances.[77]

Lucy, a 360 degree video capture device, was adapted for use in over 3000 American classrooms to provide new teachers and their mentors opportunities for feedback and discussion, with the goal of making new teachers great teachers quickly.[29] Adapted for the consumer market, the Dot360 accessory for mobile phones allowed individuals to capture full-surround moments and share them.


***Nuanced behaviors of learning.*** To enhance instruction and learning, the DIVER™ Project developed an application for video transcription, logging, annotation, comment, and sharing of video used in learning environments, including video from 360 degree panoramic capture.[30]

## *Purposeful Engagement*

As bandwidth and connection speed continued to improve and define Web 2.0,[34] the popularity of three-dimensional online spaces invited studies of engagement in virtual spaces, including World of Warcraft as a class location,[35] experimental corporate meetings in Second Life,[36] and new reward systems embedded in distributed multi-player games.[37] During this time, interest in the power of games for engagement attracted attention in the learning sciences and also among corporate offices seeking to measure and improve worker productivity.

mediaX activities on engagement for learning embraced a broad spectrum of contexts — life-long and life-wide. In addition to classroom learning, this emphasis included explorations into learning that occurs within industry contexts, such as the transfer of expert knowledge to novice workers,[38] skill-building and retraining opportunities,[39] and a consistent demand for developing the talent pipelines important to sustaining business success. In many corporate environments, the term "games" initially met with resistance because the term implied fun, rather than serious work, and a similar effect was seen in education. Nevertheless, scholars, educators and managers were drawn to experimenting with game contexts to understand the potential of the emerging concept of gamification[40] for productively transforming work and learning.

By Fall of 2017, the mediaX Conference Learning Pathways in a Period of Dynamic Change explored aspects of engagement related to talent development as both a global and local challenge.[41]

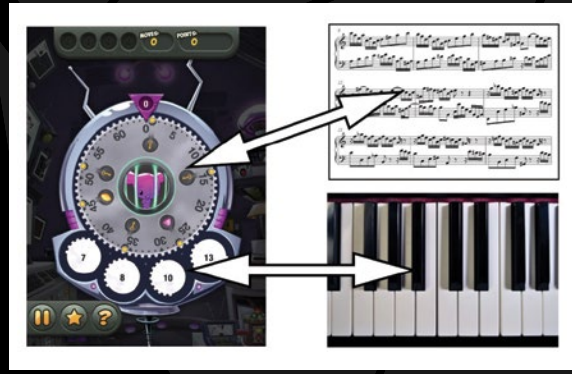
Two potential levers for encouraging engagement with online content were scale and distribution. Inspired by the possibilities of future opportunities, mediaX encouraged the imagination of solutions:

- What if a digital game architecture could be designed to support the learning of mathematical concepts, similarly to how a piano enables a variety of musical styles and levels of complexity?[42]
- What if learning experiences were flipped — with online tutorials for basic concepts allowing more class time devoted to discussion and feedback?[43]
- What if online interactions included personalized needs identification and coaching?[44]
- What if software for RNA molecular design could be gamified to enlist thousands of ideas for new RNA molecules for medical intervention?[45]

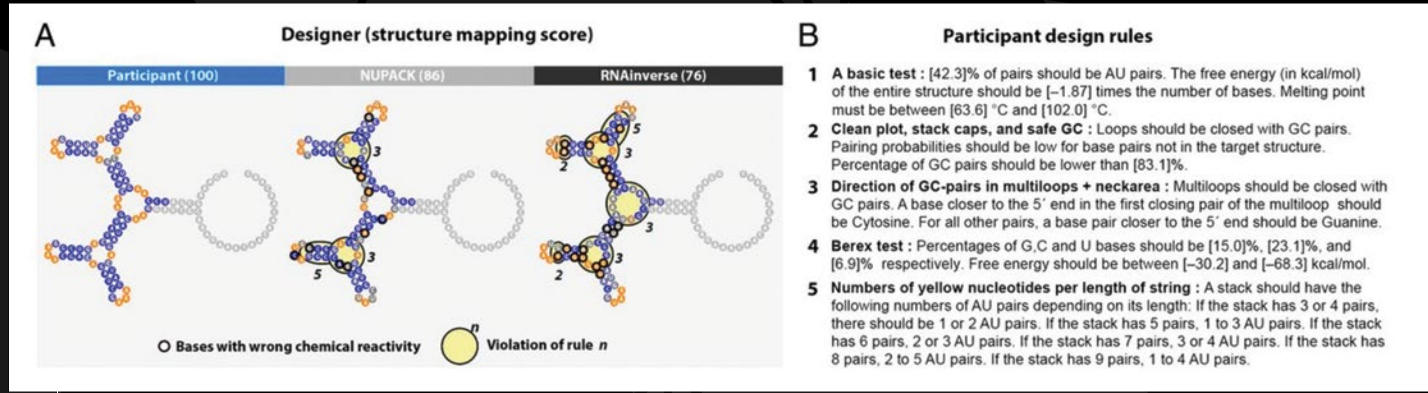


***Distributed multi-player games.*** By studying online games, Reeves and colleagues identified organizational and strategic challenges similar to those faced by business managers: recruiting, assessing, motivating, rewarding, retaining. They posited that online games could be understood as a simulator for leadership.[37] Image credit: Robert Carter

***Corporate meetings in Second Life.*** The immersive scenes and player performance dashboards in the 2004 multiplayer World of Warcraft informed Byron Reeves' definition of gamification's rules of engagement.[36]



***Digital math games.*** The drive cogs of the BrainQuake Gears puzzle are analogous to a piano keyboard. Given a symbolic musical score (notes positioned on a staff), pressing the keys on a piano the appropriate way will result in the music represented by the notation being bought to life and experienced (when the tune is played). Analogously in the BrainQuake puzzle, given the collection of symbolic items positioned on the large wheel represented, rotating the small drive cogs in the appropriate way will result in the mathematics that the items represent being brought to life and experienced (and the problem will be solved). Different scores/items will operationalize in different tunes/math. Image by BrainQuake.[42]




***Gamifying molecular design.*** RNA design rules proposed by EteRNA participants. (A) The best designs from each design agent (EteRNA participants, NUPACK, and RNAInverse) were annotated with violations of the top 5 rules proposed by participants, which were assessed by sparse linear regression; (B) the five rule statements used for EteRNABot. The numerical parameters in brackets were optimized to best explain the results from a training set based on starting values proposed by participants.[45]

## *Mobile First, Pause at Will*

Concurrent with academic research, market penetration of mobile phones, wireless connectivity, and personal printers created a sea change in location, access and ownership of content and communication. Social media emerged. A new appreciation for life-long and life-wide learning attracted the attention of educators and learners.[46] Content, including videos, became openly shared, and open education resources proliferated. New rewards for engagement took the forms of free search, points for freebies or cost discounts, distribution of individually created content, reputation ratings, and personalized services.

Scholars studied how mobile content influenced student engagement,[47] for example, how students' thinking skills could be enhanced by using cloud-based information to create historical perspectives[48] or assessed with gamified interactions,[49] how copyright clearance could be automated, and consumer-generated content could be monetized,[50] and how the engagement and participation of remote teams of students depended upon their access to and use of communication technologies.[51]

As HTML5 became the convention, the dimensionality of online experiences offered more viewing options and increased the ability of the user to control their online experiences. This increased users' online switching behaviors, and mobile enabled surfing anywhere.

"Mobile first" became the mantra of interactive experience designers, and the "pause" button became an important design consideration — in commerce and in education. Creative Commons licensing offered conventions for sharing and protecting creative content.[52]

The pause symbol was used on early cassette recorders (not players). When "Stop" was pressed during recording it left a noise as the recording head was physically moved away from the tape. The "Pause" mechanism—which didn't move the head away—was added and left no unintended noise on the recording. The digital pause button repurposed the symbol and gave consumers control over how long and how much digital content they consumed.


***Hybrid context for learning.*** First issued in 2002, Creative Commons licenses help creators retain copyright while allowing others to copy, distribute, and make non-commercial uses of their work; a CC license ensures licensors get the credit for their work that they deserve.[52]





## *Metrics and Meaning*

Although page views and click-throughs have survived as market metrics, experience designers soon recognized that gamification could heighten engagement and prolong user interaction. In response to interest, mediaX created regular seminars on the art and science of games[53] to showcase results and insights from academic research as well as inspiration from market testing of technological and product innovations.

With the advent of non-invasive testing and measurements for cognitive function, academic research was able to more deeply explore the meaning of engagement in games and learning with questions such as:

- How did the similarity of collaborators' brain activity correspond to their engagement?[54]
- How could portable neuro-measurements record levels of engagement in natural learning contexts?[55]
- How could instantaneous feedback of emotion from visual facial cues help neuro-diverse learners respond appropriately and in a timely manner to social interaction?[56]
- How could agents for self-regulation improve learning engagement?[57]
- How could learners' engagement be optimized in immersive environments in which context was integrated with audio and visual information, such as virtual reality?[58]
- Why does perceived interaction with a live human opponent activate different areas of the brain than the perception of interacting with a computational opponent?[59]
- What impact could immersive experiences have on real-world experiences for behavior change?[60]

## *Reciprocity and Sharing in Engagement*

With digital devices increasingly mediating learning experiences, new opportunities arose for understanding the processes of engagement and learning, particularly regarding reciprocity with automated agents and in immersive environments.[61] (See Bots and Intelligent Agents. Also see Immersive and Virtual Environments.)

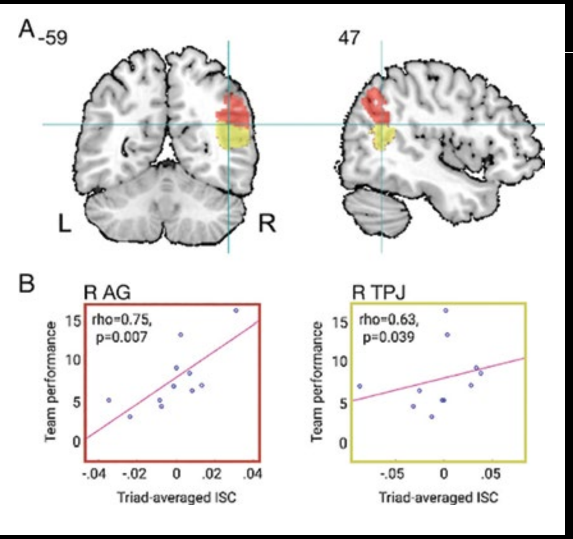
In 2015 a mediaX research Theme[62] explored state-of-the-art innovations in digital and blended learning technologies, along with their implications for teaching, learning practices and pedagogies. Multiple projects emphasized learning platforms with various forms of media that permitted exploration of context and meaning, such as sharable annotations of digital text that guided reflection and comparative analysis on academic topics.[63] These platforms, such DIVER (Digital Interactive Video Exploration and Reflection)[64] and Lacuna Stories,[65] augmented asynchronous discussion boards with real time multi-dimensional communication tools.[66]

Fast forward. Earlier perspectives on the power of distributed intelligence for learning[67] were revisited in 2020, within new contexts. In discussions exploring the Human Requirements for Immersive Learning,[68] mediaX thought leaders emphasized distributed intelligence's consequences for learning,[69] the pros and cons of virtual learning environments,[70] and the use of sensor technologies such as eye-tracking[71] to measure, digitize and characterize key elements of the human learning experience.[72]

Further expanding the exploration of engagement in work and learning, mediaX called attention to the reciprocal nature of the learning that occurs in the relationship between humans and machines.[73] Discussions on discovery, curiosity, feedback, and empowerment prompted exploration of computational curiosity and how it might engender novel understandings of human learning.[74]

These forays stimulated curiosity and invited questions about the feedback loops needed for learning between people and machines,[75] including large language-learning models, such as GPT-3 (Generative Pretrained Transformer 3). They raised ethical issues about humans' interactions with data and appropriate access to the information their behaviors produce.[76]

Engagement continues to be a vital force in both games and learning. New questions about the human experience will arise from new forms of engagement.




***Brain activity of engaged collaborators.*** In research by Manish Saggar, distinct areas of brain activity were found to be associated with engagement and collaboration. Additionally, increased synchronization among teammates was observed to be positively associated with team performance.[54]


***Large language-learning models.*** In 2018 mediaX Distinguished Visiting Scholar, Peter Norvig, described capabilities, confidence parameters and algorithms that can generate human languages on the basis of very large text-based data sets, sometimes at the petabyte scale.[176]

*How might socio-technical systems be leveraged to cultivate a sense of curiosity, agency and creativity, facilitate lifelong learning, and create pathways for future personal growth opportunities?*

## questions for the future

***There's more we can do together than any of us can do alone.***

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# Immersive and Virtual Environments

*What makes VR special is the paradox that it feels real but there are no rules. You can create earthquakes, fast-forward in time, you can change your physical appearance. Anything an animator can imagine is possible in VR. It feels real, and the brain tells you that it's real. This is what we call presence. But in VR there is no real.*

– Jeremy Bailenson

## Highlights

**1** Decades before the COVID pandemic, Stanford researchers who experimented with immersive environments pushed the boundaries for learning by virtually bringing collaborators together across geographical distances.

**2** Researchers studied the human elements in immersion and the potential for virtual experiences to solve business problems, improve worker productivity, and facilitate learning.

**3** Immersive environments continue to present challenges for preservation and archival because of the changes in technology platforms and backend functionality.

**4** Practicing relationship-building interactions and gestures in virtual world onboarding sessions was vitally important to enabling "hallway conversations" and other networking opportunities typically enjoyed at mediaX conferences and other collaboration in-person events.

**5** Sound design, identity sharing and nonverbal signaling were highlighted as key opportunities for future development in immersive experiences.



***Remote ensemble performance.*** Professor Chris Chafe played his "celleto" with Berkeley musician Roberto Morales, left, in Wallenberg Hall during an intercontinental jam session June 18, 2004, using an early version of Jack Trip's sophisticated minimal latency teleconference technology that solved the problem of digital delays. Projected on the screen are Hogne Moe, left, and Oyvind Berg, who "virtually" joined the concert from the Royal Academy of Technology in Stockholm. The quartet played three improvisational concerts as part of the "Point 25" project (the title refers to the one-quarter-second delay of the Internet broadcast) sponsored in part by the Wallenberg Global Learning Network. Audience members in Stanford and Stockholm also were able to watch each other.[78]


***Virtual teams.*** MediaXWorks, a 2007 environment using QWAQ software, (a) created an archive of digital presentations (b) for conference participants' reference following on-campus meetings.[80]

***Virtual walk-throughs.*** Use of the software evolved with QWAQ's technological enhancements, permitting remote student teams in Civil & Environmental Engineering classes to execute inherently 3-D models inside the virtual environments, allowing virtual walk-throughs of their designs.[81]


***Mixed reality performance.*** The Sirikata immersive platform enabled animation in virtual worlds (c) to be linked to musical performances in the physical world. (d)[86]



For mediaX, the move to immersive and virtual online interactions started well before the onset of the 2020 pandemic. mediaX and the Human Sciences and Technologies Advanced Research (H-STAR) Institute at Stanford had been exploring immersive experiences for more than fifteen years before the pandemic presented a social context for rapid adoption.

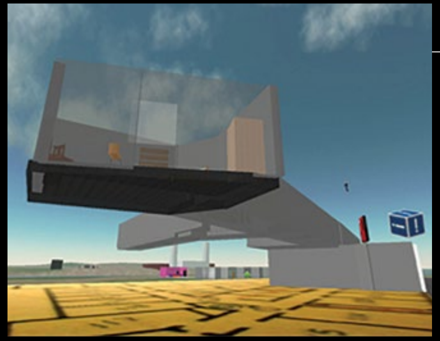
## Pushing Reality's Boundaries

Between 2002 and 2010 mediaX promoted innovative use of classroom facilities, made possible by generous funding from the Wallenberg Foundation and managed by H-STAR; these media-equipped classrooms offered smartboards, interactive projection screens, video capture on four sides, and Steelcase mobile desks, chairs, and whiteboards. These classrooms — and the researchers who used them — encouraged and embraced the use of technology to push boundaries for learning by bringing collaborators together virtually across geographical distances.[77]

One such engagement in 2004 was an online musical experiment to see if it was possible for musicians playing in countries over six thousand miles apart, and audiences watching those performances from around the world, to feel (and behave) as if they were attending the same event.[78] Four musicians played an improvised jazz session, with two on a Stanford stage, and two in a Stockholm location. The audience was similarly distributed and performed a continuous 'wave' that went from the Stanford audience to the Stockholm audience, projected on screen in each location. The event capped off with a holographic representation which allowed the U.S. audience to enjoy after-performance coffee and cakes, at three in the afternoon, while the Swedish audience drank beer and nibbled bar snacks at midnight!

Virtual environments and immersive experiences appeared frequently in mediaX programs. mediaX incorporated elements of virtual reality into key events in 2007, including archival presentations in the IEEE Smart Camera Systems Conference[79] and the mediaX Conference on Virtual Collaboration for Remote Teams[80] in a 3D environment, MediaXWorks. As software for 3D environments, bandwidth, and digital processing evolved, mediaX experimental activities also evolved to test boundaries and understand opportunities. Civil and environmental engineering classes leveraged 3D environments for virtual walk-throughs.[81]


***Virtual museum exhibit.*** In collaboration with Bornholms Kunstmuseum in Denmark, Jeffrey Schnapp and the Stanford Humanities Lab replicated the museum in a 3D environment, (a) connected audiences visiting a physical museum to that virtual world, (b) and allowed interaction between physical and virtual visitors. (c)[84]



***Sirikata.*** Physical artifacts from Life Squared, Lynn Hershman Leeson's 1973 SFMOMA exhibit that explored alternate personal identities, were converted to digital objects, permitting the exhibit to be re-enacted in Second Life and visited by avatars reflecting an international audience.[88]


***Meru.*** The Meru project addressed issues of scalability and federation in 3D worlds by separating the components of a virtual world: the simulation of the world, the simulation of individual object behaviors, and the storage and distribution of the content of the world.[89]

In 2008, mediaX-funded research projects on the Theme of Advanced Human-Communication Technologies[82] leveraged innovations in 3-dimensional worlds. Cross-disciplinary collaborations between computer science researchers working on virtual sensor networks[83] and humanities researchers seeking to augment art and museum exhibits[84] stimulated the creation of two new 3D platforms for multiple types of avatar interaction with in-world objects as well as with other avatars. The Sirikata immersive platform[85] enabled musical performances in a virtual world,[86] animated an archived museum exhibit,[87] and connected virtual and physical participation in a museum exhibit.[88] The Meru platform expanded opportunities for the in-world presence of complex shapes and allowed interaction between virtual and physical control systems.[89] Another project in this Theme investigated the interaction of discourse and presence in virtual worlds.[90]

In step with this growing emphasis on immersive media, many mediaX initiatives took a particular emphasis on opportunities for education. Instructional technologies for medical students leveraged haptic feedback in simulated medical procedures using virtual reality.[91] By digitizing series of two-dimensional medical images and linking them to each other, three-dimensional images were created for augmented reality anatomy instruction for medical students.[92]

The Wallenberg Summer Institute, created to increase outreach to the Silicon Valley community, explored the use of video games in education,[93] engaging global teams across distance, time,[94] and virtual representations of culture,[95] and remote collaboration, interaction and telepresence.[96] Demonstrations of immersive experiences included working and learning in Second Life,[97] and researchers flagged the challenge of preserving knowledge in virtual worlds.[98] As law scholars studied how first principles of law applied in virtual spaces,[99] humanities scholars explored the heuristics of immersive spaces. Mixed reality museum exhibits enabled visitors to animate their collections through personalized digital exhibits.[100]

## Collaboration in Immersive Environments

The expanded use of immersive environments began to change conversations, collaborations and interactions, and mediaX responded to this in the 2009 Wallenberg Summer Institute by exploring social connectedness in ambient intelligent systems,[101] social media collaboration,[102] new metrics for new media,[103], software for visualization,[104] concepts of collective, connective, and distributed intelligence,[105] and insights about new work practices that were being adopted from multi-player games.[106] (Also see Engagement, Games and Learning.)

As 3D, 360-degree video and immersive worlds continued to influence collaboration, discovery and learning, mediaX encouraged discussions about the human requirements for immersive experiences.[107] Experiments[108] showed that virtual experiences generated measurable physical and emotional responses, such as anxiety when walking across a plank above a deep virtual pit. Studies showed that the psychological impact of virtual experience persisted in a manner akin to real-life experiences.

Seed grants for concept-proving projects developed new insights to further explore technologies, their applications, and their influence on workflow[109] and work team collaboration.[110] Research highlighted the importance of understanding the human element in engagements with immersive applications,[111] the potential to solve business problems with multi-player games,[112] and opportunities to improve knowledge worker productivity with insights about social interaction in the context of human-machine interaction and sensing.[113]

At the 2015 mediaX Conference on the Experience of Immersion, Stanford labs and mediaX members alerted the wider mediaX community to the sensory, cognitive, technical, and expressive frontiers of immersive technologies while demonstrating innovative applications of virtual and augmented reality.[114] This exploration activated curiosities about human encounters with various types of immersive media. Academic and business researchers invited the identification of measurable phenomena associated with users' attention, engagement, and retention of information during and following immersive experiences.[115]




***Innovative applications.*** Virtual reality enabled research to study the psychology of immersive experiences, interactive behaviors and their impact on mindset and identity. The virtual reality of "walking the plank" (a) aroused real feelings and emotions; immersed in the experience of being a superhero saving a life, (b) a person's sense of altruism and ability to solve problems was shown to be strengthened by the virtual experience.[115]

***Digital sound design.*** By understanding the physics of sound, auditory experiences could be engineered virtually; the sounds of the physical world, such as a shattering piggy bank, could be computationally constructed.[119]

***Augmented anatomy.*** Early instructional tools that linked layers of two-dimensional digitized images gave way to innovative augmented anatomy tools that permitted medical students to engage in virtual surgery experiences.[92]

***Immersive medical training.*** Decision making skills require observation and judgment and benefit from practice. Research insights inspired commercial applications of immersive environments for professional training. By presenting medical professionals with complex situations requiring information filtering and prioritization for strategic decision making, the Simtab VR environment allowed physicians to practice awareness and judgment for emergency treatment scenarios as well as routine procedural practices.[116]

***Learning physical tasks in VR.*** Immersed in 360 video capture, athletes practiced rapid decision making with opportunities for revised choices and behaviors following feedback.[117]



Interest in the use of virtual worlds and immersive environments for training and skill-development resurfaced. Early virtual worlds that were constructed to build emergency room skills for medical students were adapted commercially for training and skill building in medical communications and routine safety procedures.[116] Insights about the impact of virtual experiences on learning were adapted for rapid-fire decision-making contexts, leveraging the opportunity for feedback to modify behavior in subsequent trials.[117]

Key issues in sensing and feedback emerged in mediaX-sponsored industry-university round-table discussions. Participants from academic and corporate organizations agreed that measures and metrics for detecting human emotion in sensory-rich digital environments are essential to develop appropriate technologies and applications. The mediaX-initiated Research Themes on Ontologies in 2019 and Taxonomies in 2020 leveraged these insights. (See Thinking Models.)

Likewise, interest in immersive experiences prompted new questions and insights into technological frontiers and psychological dimensions of immersive storytelling[118] and encouraged more fully understanding principles of sound design[119] that leveraged humans' rapid response and precise acuity for identifying the point of origin of acoustic signals.[120] With the rapid adoption and ubiquity of video-conferencing during the 2020 Covid-19 pandemic, "Zoom fatigue" emerged as a common malady and a new research topic.[121]

## Immersion for Human Connection

Having been familiar with Zoom since its introduction at the 2008 workshop on Virtual Collaboration for Remote Teams,[122] mediaX sought to create new engagement opportunities in which global members could experience a sense of presence, connection and immersion — in the absence of the campus visits which most members made annually. Partnering with an experienced virtual world organization, mediaX co-developed a virtual environment called mediaXploration. Using both video webinars and in-world experiences, mediaX hosted a pioneering virtual retreat on The Human Requirements for Immersive Experiences in Collaboration, Discovery and Learning.[123] Scheduled in mediaXploration over several days to accommodate seven countries and five time zones, the immersive experiences enabled personalized avatars to deliver presentations and hold discussion sessions in virtual breakout rooms.[124]

Building on that experience, and while the pandemic continued to prohibit travel to campus, mediaX hosted its 2020 Global Innovation Leadership Program in the mediaXploration virtual world, with the topic focused on situated activity, distributed intelligence and action.[125] (Also see Thinking Models.) mediaX leveraged feedback and a 'netiquette" for deeper engagement.[126] Collaborators, including workshop facilitators and mediaX staff, harvested their experiences and insights to encourage further development of immersive environments for professional conferences.[127]

Insights included the awareness that while participants gained a sense of presence in the virtual environment, they missed the ability to see the faces and body language of colleagues, important for networking and social exchanges. Participants observed that prior to the conference, the onboarding experience of practicing relationship-building interactions and gestures in the virtual world was vitally important to "hallway conversations" and other networking opportunities typically enjoyed at mediaX conferences. These observations on virtual conferencing inspired the articulation of a process for developing new ontologies and taxonomies for participation in virtual environments[128] and a case study that applied Installation Theory to conceptualize a linguistic taxonomy for presenters in virtual environments. They also served as a case study for a goal-oriented approach to redesign, using the robust analytic and idea-generating framework of Multilayer Installation Design.[129] (Also see Thinking Models.)

Building on that experience, the mediaX 2021 Global Innovation Leadership Program on Futures Literacy was also held in mediaXploration, as a multiplatform event, combining Zoom and mediaXploration sessions over the course of two weeks.[130]

Working to understand the most valuable ways to engage with participants in mediaXploration, each of these events hosted in mediaX was experimental in nature, bringing years of learning about immersive experiences to life while opening new pathways for discovery. Feedback from participants across these activities affirmed this approach as consistent with the mediaX ethos — a willingness to embrace novelty and co-develop insights about people and their experiences in both digital and hybrid contexts.

***Participant insights.*** Debrief session in a Breakout Room of mediaXploration during GILP 2020 — mediaX team, presenters, participants, and facilitators.[127]

***Futures literacy.*** The final foray into the virtual world of mediaXploration took place in February 2022 and included a cultural adaptation for the workshop's Brazilian participants, ending the week with a "Carnaval" party. Participants enthusiastically accessorized their avatars and danced with the help of a mirror ball, which enabled a personalized choice of dance gestures for each avatar.[130]

*How might researchers inform the co-evolution of technology-media-human relationships in ways that assist people in building bridges and facilitating communication between generations and across boundaries of expertise and experience?*

# questions for the future

***There's more we can do together than any of us can do alone.***





***Endnotes***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# Bots and Intelligent Agents

*"Laptops, phones, cars – all the things I've built - they're all robots. It's critical to recognize that the robot and the human have to be a team. For effective teamwork, their exchanges must include information, emotion, and knowledge - the meaning of information. Information is easy. Emotion, one of the major determinants of human communication, is hard. The exchange of information's meaning is very difficult to engineer. Humans and robots each operate within complex adaptive systems, each having differing capabilities, and are themselves interacting with socially complex adaptive systems that are external to both. The new set of design requirements for robots requires that robots can relate to humans with information, emotion and meaning and have a keen awareness of socially complex adaptive systems.[131]"*

– Larry Leifer

## *Highlights*

**1** Robots and computerized agents exist in all shapes, sizes, and systems — implicit as well as explicit.

**2** The design of robots' and agents' persona includes physical characteristics, such as eye: head ratio, eyes/vision, visible mechanics, and the age appearance of the robot, as well as the bot's back story.

**3** The advent of semi-autonomous vehicles provided opportunities for the experimental exploration of the data exchanges, interactions and dependencies that occur between car and driver, and among cars and pedestrians.

**4** In health care, as in education, professionals emphasize the complexity of decisions and judgments often necessary in both routine and exceptional situations for high-quality service delivery involving automated agents.

**5** Automated AI systems must be designed for operations within the human loops already in existence, which are based on human expertise and their experience in decision-making for complex situations.

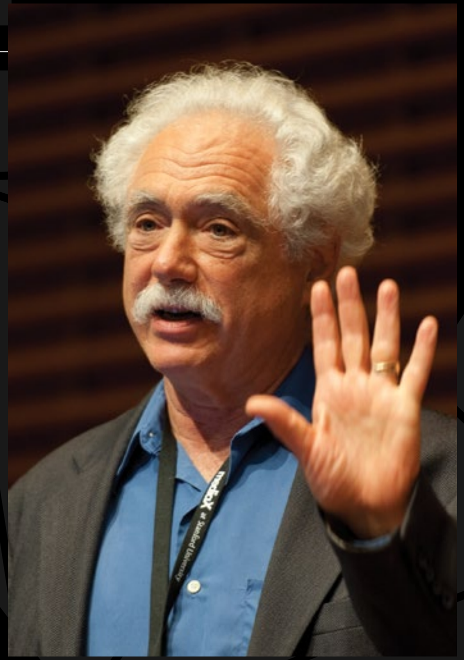
**6** Results from studies of humans' perceptions of automated agents point to the need for transparent AI, as well as explainable and potentially tunable AI, along with models to identify ethical errors in algorithms.

During its twenty-one years of operation, mediaX worked with faculty from all seven Stanford schools and with members around the world to examine how mutually beneficial relationships between people and media — broadly defined as information and communication technologies (ICT) — could be formed and nurtured. The field of human computer interaction introduced dimensions of humanness that influenced research agendas.[132] As the capabilities of crowd-powered systems[133] and artificial intelligence advanced, mediaX inquiries probed the interaction between humans and the computational operating agents of digital machines, a new nexus for human sciences and advanced information technologies. Drawing on the Silicon Valley ethos, mediaX's investigations and events focused on opportunities, especially when those opportunities were defined by current problems.

## Human-Bot Relationships

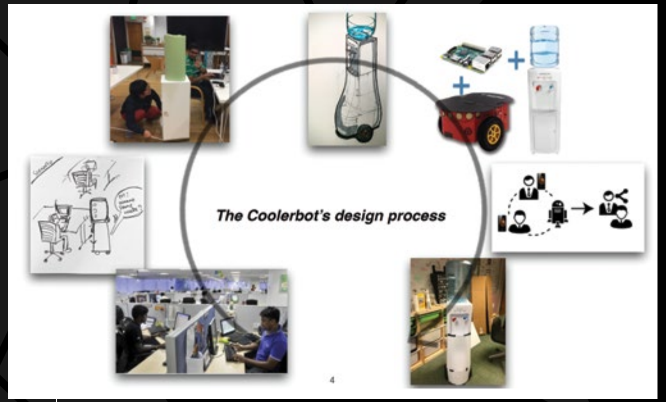
Robots and computerized agents played strategic roles throughout mediaX research themes. They existed in all shapes, sizes, and systems - and appropriately so, since humans differ widely in their embodiment, rationality, emotions, and social behaviors. The concept of design thinking for engineering guided many explorations of humans in relationship to their automated devices.[134] Every human is enmeshed in specific economic and political environments, as well as a global environment.





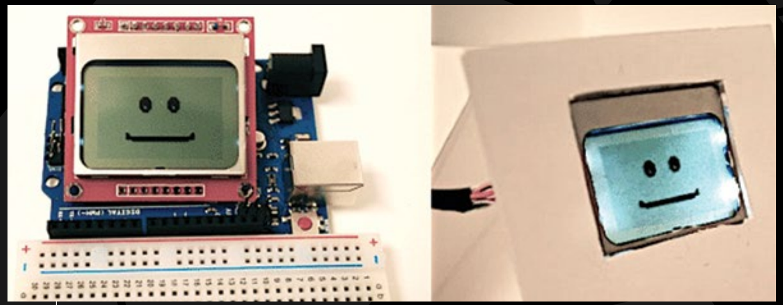
***Human computer interaction.*** At the 2013 mediaX Conference, Professor Terry Winograd reviewed the original framing of HCI (human computer interaction) as dealing with the "human information processor" and described the ongoing expansion of the field's perspective on the human side of the interaction; he described how the field had introduced new dimensions of human-ness, which have then influenced the research agenda pursued by computer scientists.[132]

***FORPHEUS.*** A ten-foot, fully automated table tennis robot demonstrated the programmable ability to both enhance engagement and coach learning; it stimulated new perspectives on teamwork between people and machines.[138]




***Robotic watercooler.*** To develop the concept of a Watercooler Robot, a team from the Stanford Center for Design Research employed a user-centered design protocol to develop and test the effectiveness of agent-based communication to bring co-workers together around a mobile watercooler through social messaging.[144]

***Crowd-powered systems.*** Also at this conference, Michael Bernstein introduced the concept of crowd-powered systems and described innovations to create "dream teams" by algorithmic optimization of team selection and management.[133]



***Embedded agents.*** Students' responses to automated agents built into instructional tools were tested, revealing that embedded agents were preferred by students and perceived to deliver less stressful learning experiences.[136]


***Nonverbal communication of robots.*** To support patient compliance with medication regimens, the robot Mabu took up long term residency in patients' homes, establishing an ongoing relationship-based dialogue specific to each patient.[158]

An individual human's activity is part of multiple collective and interactive groups. Sociotechnical systems that could interact with humans as individuals were a primary focus for mediaX inquiries.

mediaX projects included a tiny two-inch by two-inch Arduino computer that guided the human in programming the device, giving agency to the human — an ability to take action — while exploring the advantages and disadvantages of animating the device as it was being built. A striking outcome of this study was discovering the influence wielded by an intelligent agent engaging in short, meaningful conversations, based on a constructed personality.[135] The study found evidence that a shift from external to embedded agents positively influenced engagement and recall while not affecting learners' perceptions of the agent.[136] Embedding the agent also made the learning task feel less stressful. Similar findings from studies in automobiles were leveraged in voice-based vehicular navigation systems.[137]

In larger dimensions, a ten-foot, fully automated table tennis playing machine,[138] FORPHEUS, demonstrated a robot's greater degree of agency in adapting its play to create both satisfaction and challenge for the human opponent. Originally designed as a demonstration to draw attention at corporate trade shows, the robot's proven ability to both enhance engagement and coach learning led to new understandings of teamwork between people and machines.[139]

Insights from each research project opened new inquiries into how agents and bots could interact with humans through gesture,[140] sound,[141] and remote control.[142] They also alerted developers to the cautions which need to accompany such applications:[143]

- Could a robotic watercooler promote interaction among colleagues?[144]
- Could a click on a website signify a user's trust?[145]
- Could a swarm of tiny robots be programmed to teach concepts of physics?[146]
- Could shapes be transmitted with digital instruction, allowing collaborators to remotely share and manipulate objects?[147]
- Could tactile contact with a humanoid robot be arousing?[148]
- Could agents use sensors to capture individuals' physical movements and use sound to improve the precision of a person's movements?[149]
- Could providing visual clues about the emotional state of another person improve interpersonal interaction for children on the autism spectrum?[150]

In 2018, researchers in Stanford's Social Media Lab explored human perception of and receptivity towards a vast universe of robot persona, revealing how people interpreted certain physical characteristics, such as eye: head ratio, eyes/vision, visible mechanics, and the age appearance of the robot.[151] In line with mediaX's ongoing prioritization of human needs, these insights enabled more thoughtful design of social robots.

In addition to physical characteristics, mediaX robot research highlighted the relational elements necessary for developing trusting, productive exchanges between people and machines. One visiting scholar introduced Mabu, a tabletop robot with the capacity to personalize interactions with patients dependent on long-term compliance with pharmaceutical treatments.[152] Repeated interaction provided insights into how a bot's dialogue could be personalized to build trust in long-term relationships.[153] The bot's personal disclosures, based on its crafted backstory, evidenced the unique characteristics of automated interaction with digital agents required for long-term use.

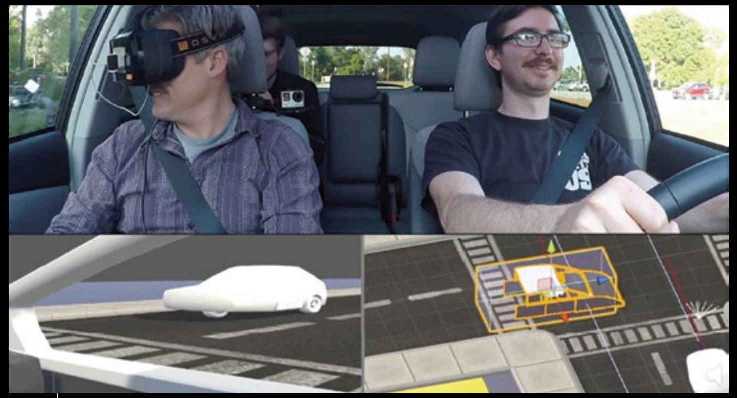
Building on these insights, mediaX hosted a panel series on Creating AI Conversations. Experts from both Stanford and industry explored short-term and long-term discourse with automated agents including: behavior change;[154] personality and voice;[155] children's interaction with robots;[156] race, gender, and ethnicity;[157] and voice user interface design and nonverbal communication.[158] In a workshop co-sponsored by mediaX and the School of Medicine's Center on Presence, medical and health care professionals discussed the potential uses and design requirements for automated agents that could support professionals caring for seniors in residential living arrangements. In health care, as in education, professionals emphasized the complexity of decisions and judgments often necessary for both routine and exceptional situations in high quality service delivery.

## Autonomous Cars as Bots

As the 2004 DARPA challenge encouraged experimentation[159] and as "driverless cars" were OK'd for streets in Silicon Valley,[160] autonomous vehicles became a frequent example of the new era of human-machine interaction, driven by sensor-dependent, context-aware operations. Advances in computing and remote sensing technologies such as LIDAR (Light Detection And Ranging),[161] as well as media attention, increased the awareness and anticipation around automated cars. mediaX collaborators highlighted the ethical and social issues regarding autonomous cars.[162] Many of these questions were probed using Stanford's Driving Simulator[163] and experimental conditions constructed to test new frontiers.

***Interrupting the driver.*** To better understand drivers' preferences for and responses to timing and periodicity of voice-based automobile agents, both real and simulated experiences were tested.[168]

***Driving simulator.*** A life-size surround driving simulator permitted experimenting with drivers' responses to situations and conditions requiring rapid value-based decision making.[163]



***VR headset in moving car.*** A research team in Stanford's Center for Design Research uses the "wizard of Oz' method (the research confederate in the back seat as software agent controlled the interface) to better understand the opportunities for passengers' infotainment options.[169]

Topics explored include:

- How do driving style, context, and culture interact to inform the design of Heads-Up Displays in cars? [164]
- How can data-efficient techniques inform computational models of human behavior that can aid in developing control algorithms for safe and efficient interactive autonomy?[165]
- How does data transfer between different layers of infrastructure in cities improve citizens' experiences?[166]
- Could automotive software learn when a driver was receptive to guidance?[167]
- What is the best timing and approach for an automated vehicle system to interrupt its driver for important communications? [168]

The frontier of autonomous vehicles also provided opportunities for the experimental exploration of the exchanges, interactions and dependencies that occurred for passengers,[169] between car and driver, and among car and pedestrians.[170]

## Human-Agent Collaboration

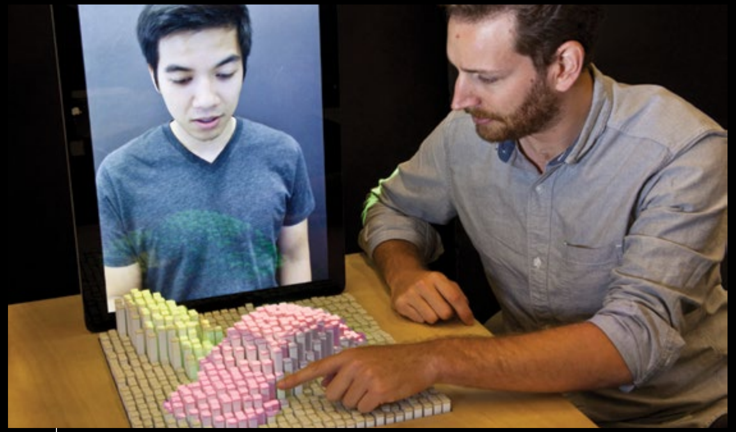
Not all bots have physical forms. Automated agents range from physically embodied robots to software programs – sometimes explicitly identified as the "other" actor in an online relationship. An automated agent is other times invisible backend software, such as the voice-activated help systems that answer many phone calls and provide chat interfaces, or such as Siri or Alexa, or on haptic telepresence interfaces.[171]

The expanding capabilities and applications of intelligent machines called for a more sophisticated understanding of the relationships between people and AI. Studies of individuals' understanding of how interactive, personalized websites operated helped explain humans' perceptions of automated agents[172] and contributed to designers' understanding of human-agent collaboration, including the need for transparency. (Also see Trust, Technology and Transparency.)

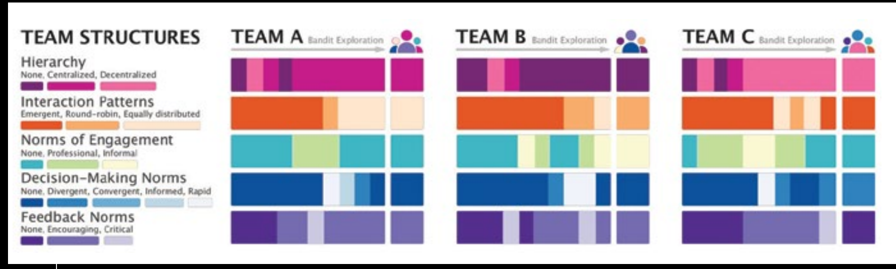
Confidence and trust in team members can make or break a project, and studies showed that these perceived qualities are also integral to the relationships users have with digital assistants and Artificial Intelligence (AI) collaborators.[173] The 2017 Human AI Collaboration Conference[174] surfaced thought leaders' perspectives on these and other key questions:

1. On which tasks will machines with AI be able to out-perform humans?[175]
2. What can help establish confidence, certainty and collaboration in the new partnerships between human and artificial intelligence?[176]
3. How can intelligent machines enhance the human experience and how can that enhancement be assessed?[177]

***Swarm robots.*** Ubiquitous robotic interfaces (URI's) — multi-robot interfaces capable of mobility, manipulation, sensing, display, and interaction — were programmed to interact directly with the user and indirectly through surrounding objects.[146]



***Haptic telepresence.*** The ability to render form introduced agent-based opportunities for collaborators, including Sean Follmer of the SHAPE Lab, to touch, grasp, and manipulate dynamic physical content and tangible objects, in both nearby and remote environments.[171]




***Automated team management.*** The prototype of DreamTeam, a project management support tool to select team members and coach their interaction for productivity, received positive feedback from participants and stimulated discussions about corporate team management practices.[179]

Through a 2015 mediaX Research Theme focused on smart office workflows,[178] scholarly teams pursued novel insights pertaining to technology's influence on collaboration and the future of work. Several projects within that theme leveraged computation to optimize team structure and management,[179] with insights for how computers and machines could partner to advance teamwork and productivity.[180]

## Designing Algorithms for Humans

mediaX explorations also addressed the politics behind the algorithms that drive automated agents, raising awareness around how the choices made when constructing and implementing algorithms could reproduce and even reinforce, social, racial and economic inequalities.[181] Recognizing the potential of biases to influence both the physical forms of bots and the software algorithms that govern them, mediaX presentations and workshops encouraged participants to consider how bias and noise — conscious or unconscious — might be permeating their designs. The 2018 Conference on AI for Culturally Relevant Interactions[182] delved into this topic more deeply, drawing on research[183] and exploring cultural and social interactions with big data,[184] machine learning, and artificial intelligence.[185]

While the idea of keeping the human in the loop gained purchase within the tech community, mediaX encouraged the perspective that AI systems must be designed for operations within the human loops already in existence, which are based on human expertise and experience in decision-making for complex situations.[186] Discussions with members and with the broader mediaX community expanded to explore not only transparent AI, but also explainable and potentially tunable AI,[187] as well as models to identify errors in ethical AI.[188]

Never a one-size-fits-all approach, the wide reach and scope of mediaX inquiry enabled opportunities for knowledge generation, exploration of potential applications, and possibilities for enhancing human experiences. Like a North Star, the synergy of insights across projects inspired the next generation of questions and guided mediaX initiatives with the goal of preventing today's solutions from becoming tomorrow's problems.





*How might sociotechnical systems anticipate and build in a commitment to the human ethical values of respect, diversity, equity, inclusion, and justice for mutually beneficial implementation — for both individual and collective wellbeing?*

## questions for the future

***There's more we can do together than any of us can do alone.***

### Endnotes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# Sensing and Feedback

*"Humans are pre-eminently sense-making animals. They seek patterns to find order and predictability in the worlds that they experience. The physical, social, and representational worlds play central roles in human cognition and sense-making. Learning scientists study how children and adults employ their sense-making apparatus to engage in sense-making activities. Humans also make meanings – with spoken word, with gesture, with symbolic representations, with information and communication technologies. In interactions, we see the intertwining of humans as meaning-makers and as sense-makers."*

– Roy Pea

## *Highlights*

**1** Humans are sense-making animals and use their sense-making apparatus to make meaning of the world around them.

**2** Research on individuals' uses of a particular tool at a specific point in time led to exploratory studies of tool re-use over time, and then to research into how information technologies enable the remote and shared use of new tools.

**3** Sensor-based tracking of physical movements opened the door to facial tracking for emotion analysis and gesture analysis for behavioral intent.

**4** Studies found that feedback from affective computing and emotion-based personalization influenced users' opinions of the quality, trustworthiness, and complexity of a system, as well as their memory of content.

**5** Novel applications from research insights on sensing and feedback found their way into games, marketing, workspaces, learning environments, organizational productivity, and transportation sectors.

## From Measurement to Interaction

At the turn of the Twenty-First Century, sensing and feedback had already emerged as strategic frontiers for interactive digital devices and applications. Developers in a wide range of fields, including education, entertainment, healthcare, and business, needed insights about humans' uses of devices to guide their development of sensors and associated feedback mechanisms.

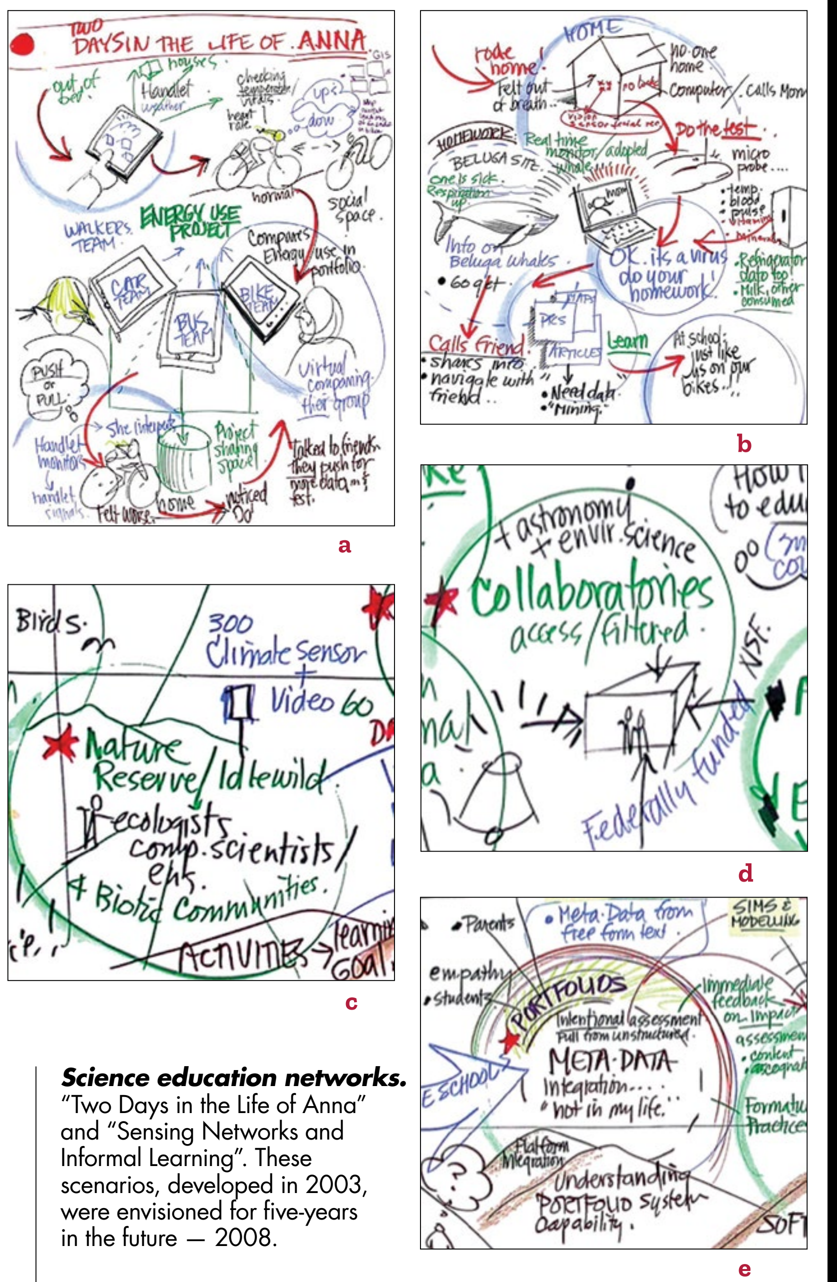
When mediaX Research Themes began in 2001, they explored sensors and feedback from the standpoint of human communication and learning. Themes subsequently expanded to include investigations of people's relationships with their digital agents. Insights based on an individual's use of a particular tool at a specific point in time led to exploratory studies of tool re-use over time, and then to research into how information technologies enabled the remote and shared use of new tools.[189]

In 2003, mediaX initiated research that sought to inform the development of haptic[190] and visual tracking[191] and sensing tools,[192] as well as the psychology of their use.[193] Later, mediaX-funded research projects explored how feedback from teaching agents could increase accuracy and reasoning for learners and how interactive agents could motivate engagement.[194] Subsequent research also explored the social psychology of digitally-tracked and computer-mediated communication between individuals, first in the physical world,[195] then expanding into virtual worlds, and into hybrid environments.[196] Opportunities afforded by smaller and faster integrated circuits stimulated thinking about applications for personalization. And as early as 2008, building on new capabilities for distributed collaboration, science education networks explored distributed interaction and encouraged the use of data probes and software tools to analyze communications.[197]

Over the course of two decades, information technologies with sensing capabilities became the engines of media relationships and were embedded across life experiences — in commerce,[198] entertainment,[199] learning,[200] and wellness.[201] New insights about human sensing and the neurophysiology of the brain inspired the adaptation of those principles to hardware and software; and, reciprocally, new sensor and feedback technologies were applied to investigations of the human experience.[202]

## From Interconnected to Ubiquitous

By 2007, the interconnected digital world had exploded, enticing a wide variety of users via games, shared digital media, and participatory social networks. At the same time, computers increasingly supported both laborers and knowledge workers. It became important to understand what insights about people and technology were needed for designers to better assess opportunities for the




***Science education networks.*** "Two Days in the Life of Anna" and "Sensing Networks and Informal Learning". These scenarios, developed in 2003, were envisioned for five-years in the future — 2008.

Anna is equipped with a notebook tablet size device called a *handlet*, which can record different colors of the light spectrum — red, green and blue wavelengths, and also has a GPS system.

Anna gets out of bed, (a) and her handlet lets her know what time it is and provides health status. (b) Anna's handlet it is part of a sensing network and connects to her classmates. Anna is also part of a school group doing a project on energy use and transportation. (c) The teacher's role is to provoke a culture of inquiry in the science class. The students embark on a project where they communicate with and begin to convince other classes around the country to share their data (d) so they can get a larger sample size for their study, creating an "intellectual commons". (e)[132] productive use of sensors in human-machine interactions — in work, as well as in leisure, and from both technical and behavioral perspectives.

mediaX seed grants attracted projects that used sensors for tracking and explored how feedback from that tracking influenced attitude and behavior.[203] These projects also investigated human perception of liminal spaces, studying experiences in immersive games to understand how transparent performance dashboards energized the self-organization of humans in mission-oriented remote interactions.[204] The interaction of physical objects with their virtual counterparts and the implications of synchronizing virtual worlds with physical ones were explored for both artistic[205] and cultural expression.[206]

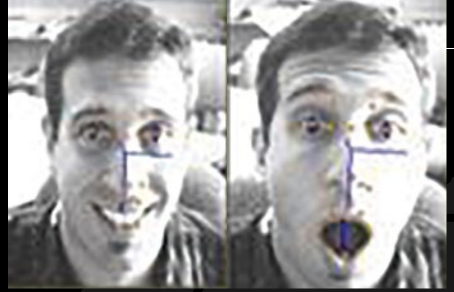
Research into "if" and "how" an interface should reveal the detection of a user's emotions was conducted alongside studies into the effects of feedback, information, and recommendations based on sensor-detected mood. Studies found that feedback from affective computing and emotion-based personalization influenced users' opinions of the quality, trustworthiness, and complexity of a system, as well as their memory of the content.[207]

Applications and extensions of these research results led to experimentation on the use of sensors and feedback for emotion detection to improve automated assistance to drivers,[208] as well as identifying intervention opportunities to improve the gait of children with difficulty walking.[209] Other mediaX-supported projects explored perception,[210] persuasion,[211] trust,[212] and multi-tasking[213] related to computer technology and its broad influence on human communication. These studies placed a priority on the potential to leverage computer- and/or sensor- embedded objects and context-aware computing[214] for the development of new design and prototyping methods,[215] as well as for novel communication systems.

By 2010 it became clear that tracking and sensing technologies opened new opportunities to create stories in ways that not only included the audience but also adapted to it. Each person in the audience was increasingly in control of their personal media experiences — selecting and creating content, changing browser locations at will — making their own stories.

Storytelling fundamentals, such as scene,[216] characters,[217] emotion,[218] and suspense,[219] were parsed into components that could be guided digitally by sensors and feedback mechanisms. Personalized media experiences emerged and sharing became globalized. Sensory experiences were increasingly mediatized, provoking new research questions about technologies used for collaboration and teamwork,[220] generating evidence that synchrony was an important measure of team productivity[221] and creativity.[222]



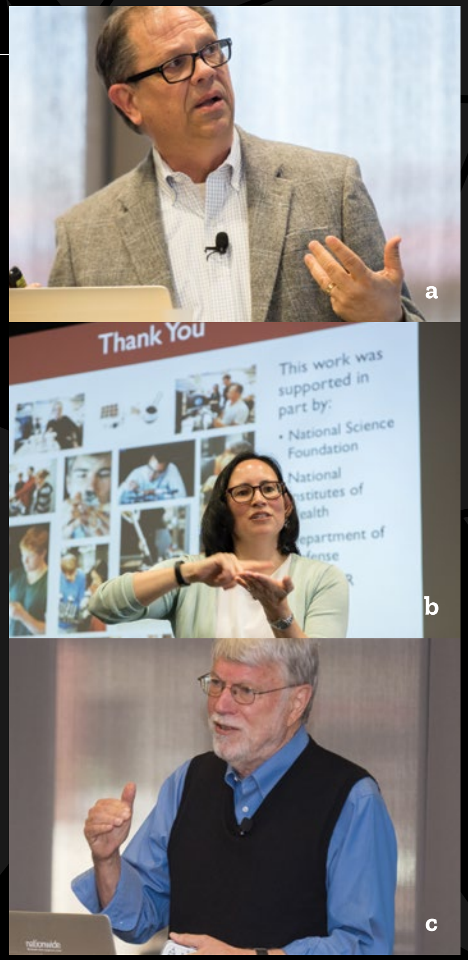


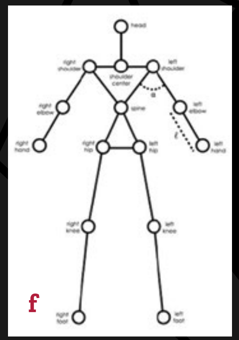
***Morphing with familiar faces.*** Face monitoring permitted computational detection of emotion.[230]


***Big data.*** The 16th Annual Delta Conference on changes in media technology, co-hosted by mediaX and Accel Partners.[223]



***Sense-making and making sense.*** At the Sense-making and Making Sense Conference in 2017, Bill Newsome describes the neuroscience of sense-making, (a) Allison Okamura describes how haptic feedback extends human sense-making based on touch, (b) and John Seely Brown offers perspectives on human sense-making in a post Alpha-Go world. (c) [247]






***Self-similarity.*** Facial morphing (d) suggested opportunities to leverage the psychological principle of self-similarity [228] — that people respond more favorably to the familiar, especially when it includes likenesses of themselves.

***Exercise behaviors.*** The favorable response to self-similarity was used in applications (e) that sought to motivate and persuade.[229]

***Gesture and emotion.*** Sensor-based tracking of physical movements (f) literally opened the door to gesture analysis [226] and

***Interpretation of gesture.*** Role identification. (g)[227]

***Augmented human relationships.*** Research also showed that the detection of emotional states to improve social interaction could be accelerated with feedback from facial tracking that was communicated with visual signals. (h)[242]

## From Personal to Personalized

New and fast-growing businesses seized the opportunity to bring together big data, cloud services, and SaaS (software as a service). Presentations at the 2010 mediaX Accel Partners Delta Symposium described how sensors and tracking were being used to improve user experiences in fast-growing companies leveraging big data, such as VMWare and in new companies such as Dropbox, Cloudera, Prezi, and Lynda.com.[223] By 2013, the perceived potential of commercial opportunities for sensors had exploded. In rapid succession, convenings of mediaX thought leaders cultivated the vision. The Trillion Sensors Summit, co-hosted by mediaX, forecast the ubiquity of sensors, and led to a roadmap for the development and global commercialization of sensors.[224]

At the annual 2013 mediaX Conference, presenters described the use of sensing and tracking technologies for deeper understanding of the social psychology of virtual human interaction.[225] Insights revealed that face monitoring permitted emotion detection.[226] Sensor-based tracking of physical movements literally opened the door to gesture analysis.[227] Facial morphing suggested opportunities for immersive experiences to leverage the principle of self-similarity[228] — people respond more favorably to the familiar,[229] especially when it includes likenesses of themselves or people they recognize,[230] responses that could be assessed with facial tracking methods.[231]

mediaX's co-sponsorship of professional organizations' meetings, such as TEDxStanford, the Society of Motion Pictures and Television Engineers, the American Marketing Association, the Institute of Electrical and Electronics Engineers (IEEE), the Internet of Things (IoT), IEEE Smart Cameras, and Quantified Self amplified the awareness of sensors used for personal tracking, and brought attention to the opportunities for sensor-embedded tools that might improve the human experience.[232]

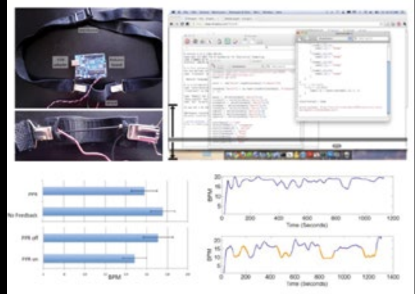
Indeed, the user's experiences were changing dramatically and many sought to make sense of these changes. mediaX thought leaders sought to understand them. Presentations at the mediaX 2014 Conference on The Science and Technology of Feedback explored the human predisposition to embed feedback in a personal story,[233] the impact of peer feedback in social media, the influence of persuasion strategies,[234] and the feedback effects on workplace productivity.[235] Data from the personal use of mobile devices revealed new findings on the shortening of users' attention spans on mobile devices, and the mediaX community was alerted to an upheaval in scientific inquiry resulting from analyzing naturally-occurring digital data to generate hypotheses, rather than as the final step in theory testing.[236]

## From Sense-Making to Making Sense

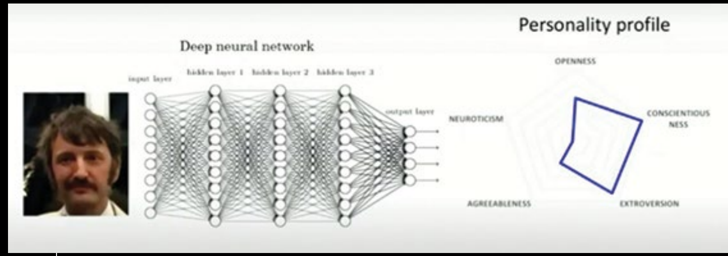
Over the next few years, novel applications for sensing and feedback found their way into games, marketing, workspaces, learning environments, and transportation trends. The use of sensors for semi-autonomous piloting of cars and other vehicles benefitted from new interest in embedding sensors in large infrastructure projects — such as buildings and cities. The mediaX co-sponsorship of the 2016 and 2019 Disruptive Technology & Digital Cities Summits[237] brought cognitive, social, psychological, and anthropological insights to bear on construction technologies, city planning, and transformation of the instructional infrastructure for transportation systems.[238]

Stanford scientists and corporate technology developers began to shift their attention to understanding how sensor technologies could improve worker productivity and influence mutual understanding between humans and machines. (Also see Bots and Intelligent Agents.) They explored the role of sensors in improving work styles, role choices for robotic teammates[239] and understanding the human brain during creative collaboration.[240] Researchers presented techniques for better understanding automated context sensing, models for understanding the continuum of human-machine collaboration on the data-wisdom spectrum, and how computational sensing, analysis, and influence systems could enhance decision making[241] and augment human relationships,[242] as well as organizational and systemic capabilities.[243] Research offered insights on how learners explore,[244] collaborate[245] and respond to critical feedback.[246]

***Visual tracking.*** In research by Terry Winograd and team, GazeTracker software was built on open-source Computer Vision libraries (OpenCV) and used machine learning to identify faces in the image, then looked within the face region to identify eyes. Simple image processing (erosion/dilation) separated the pupil and the glint images, and ellipse-fitting provided the center of the pupil and the glint. The relative position and distance of the glint was then used to determine the gaze vector.[191]

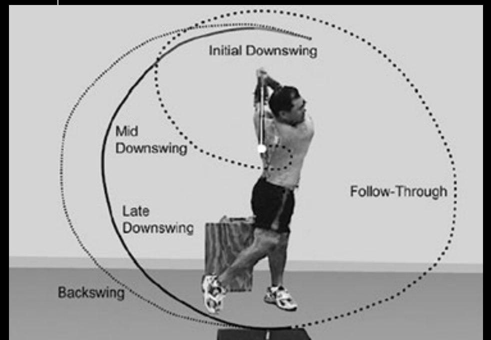


***Tracking stress.*** The initial experimental method for Calming Technologies research, by Neema Moraveji, Roy Pea, and team, later evolved to a startup company that created the SPIRE HEALTH product.[201]




***Personal attributes for e-commerce.*** Algorithms can identify tiny nuances and combine them with many pieces of information, such as personality traits. Using deep neural network analysis of millions of facial images and personality traits, Michal Kosinski's research showed that algorithms can predict personality and intimately derived characteristics from facial images as accurately as a co-worker.[198]

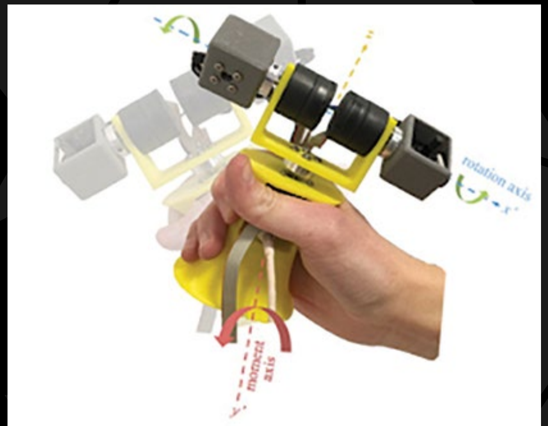
***Sensing biomechanics.*** With the goal of identifying biomechanical factors of specialized activities to provide a basis for strategic training and injury prevention that might be adapted for gait improvement in disabled children, Amy Ladd and Jessica Rose captured three-dimensional kinematics and kinetics of professional golfers and found that within-person measures were more actionable than between-person measures, as potential indicators for corrective feedback.[209]



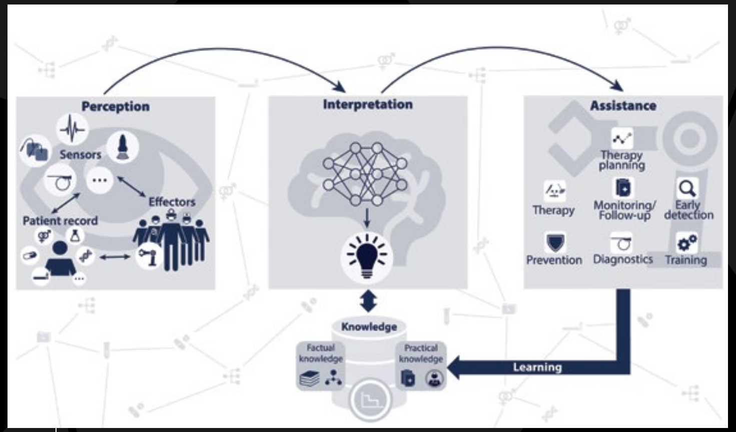
These provocative insights inspired a renewed emphasis on how humans make sense of the world around them - the human mind as a sense-making organ, in the context of the whole body, the whole person, and in community with other humans. The 2017 mediaX Conference on Sense-Making and Making Sense[247] highlighted the intertwining of humans' interactions as both meaning-makers and as sense-makers. Of special interest was how humans, given tremendous variability in expression, interpret symbolic systems for shared meaning — from gesture, language and mathematics, to computer code, and immersive worlds and games.[248]

Advances in the neurosciences invited social scientists and engineers to explore the role of the brain in cognitive, affective and activity-based responses to media of all types. Researchers in the mediaX community discussed recent developments in the cognitive neuroscience of sense-making,[249] as well as advances in sensors and feedback mechanisms to simulate human touch in new surgical tools[250] and to provide touch-based remote controls.[251] Researchers shared new insights about the human propensity to frame events as a story[252] and perspectives on the integration of human and artificial intelligences to make sense of change.[253]

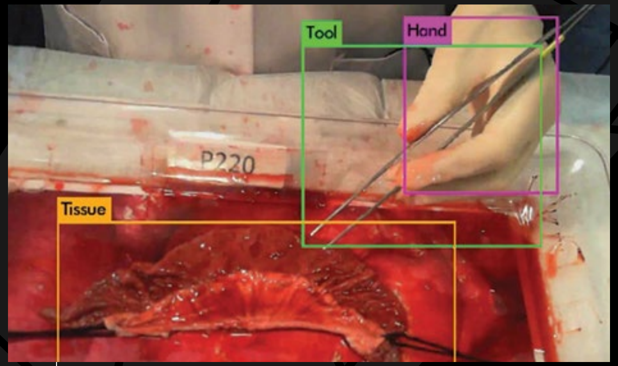
Key issues in sensing and feedback emerged in several mediaX-sponsored industry-university round-table discussions motivated by collaboration opportunities in virtual reality and augmented reality. Participants from both academic and corporate organizations encouraged the development of commonly accepted measures and metrics for sensing human emotion in sensory-rich digital environments, agreeing that, in both academic research and industry technology development, these were essential for describing the human experience in digital contexts. This identified need to create standardized metrics and meaning was an important signal for the mediaX-initiated Research Themes on Ontologies in 2019 and Taxonomies in 2020. (See Thinking Models and Tools.)




***Haptic tethers.*** Researchers in the Stanford CHARM Lab developed and tested a "tether system" – a wearable haptic interface based on three vectors of motion that enabled the robot to communicate intent to the user via silent, private, bidirectional vibration patterns - and a model that predicted users' decisions. Their research showed that haptic communication shifted two key parameters of the predictive model — the user's "safety buffer" radius and the user's expectation of the robot's future velocity.[251]

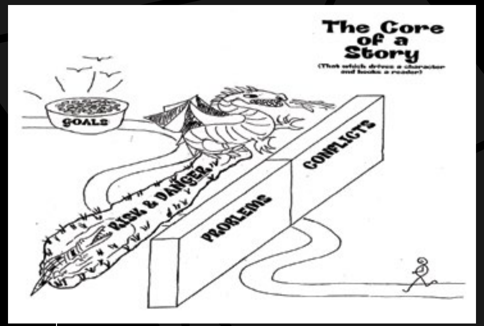



***Enhanced decision making.*** A cycle of perception, interpretation and intervention provided a framework for understanding the integration of novel technologies for surgical tools, using both automated machine learning and human sense-making.[241]




***Human experience in digital contexts.*** Research in Stanford's Technology Enabled Clinical Improvement (T.E.C.I.) Center created an algorithm capable of localizing and identifying objects (e.g. Hand, Tissue, Tool) needed to improve simulation tools for training and testing surgical students.[19]


***Engineering interactive learning.*** Research in Nick Haber's Stanford Autonomous Agents Lab developed a taxonomy for curiosity that could be tested experimentally with computational tools.[150]




***Stories evoke emotions.*** The "make sense mandate" of human brains exerts neuroscience effects on influential strategic narratives and storylines.[216]

*How might human science insights guide the development and deployment of technologies to enable work to be done more pleasantly and, ultimately, with more human-to-human connection and wellness?*

## questions for the future

***There's more we can do together than any of us can do alone.***





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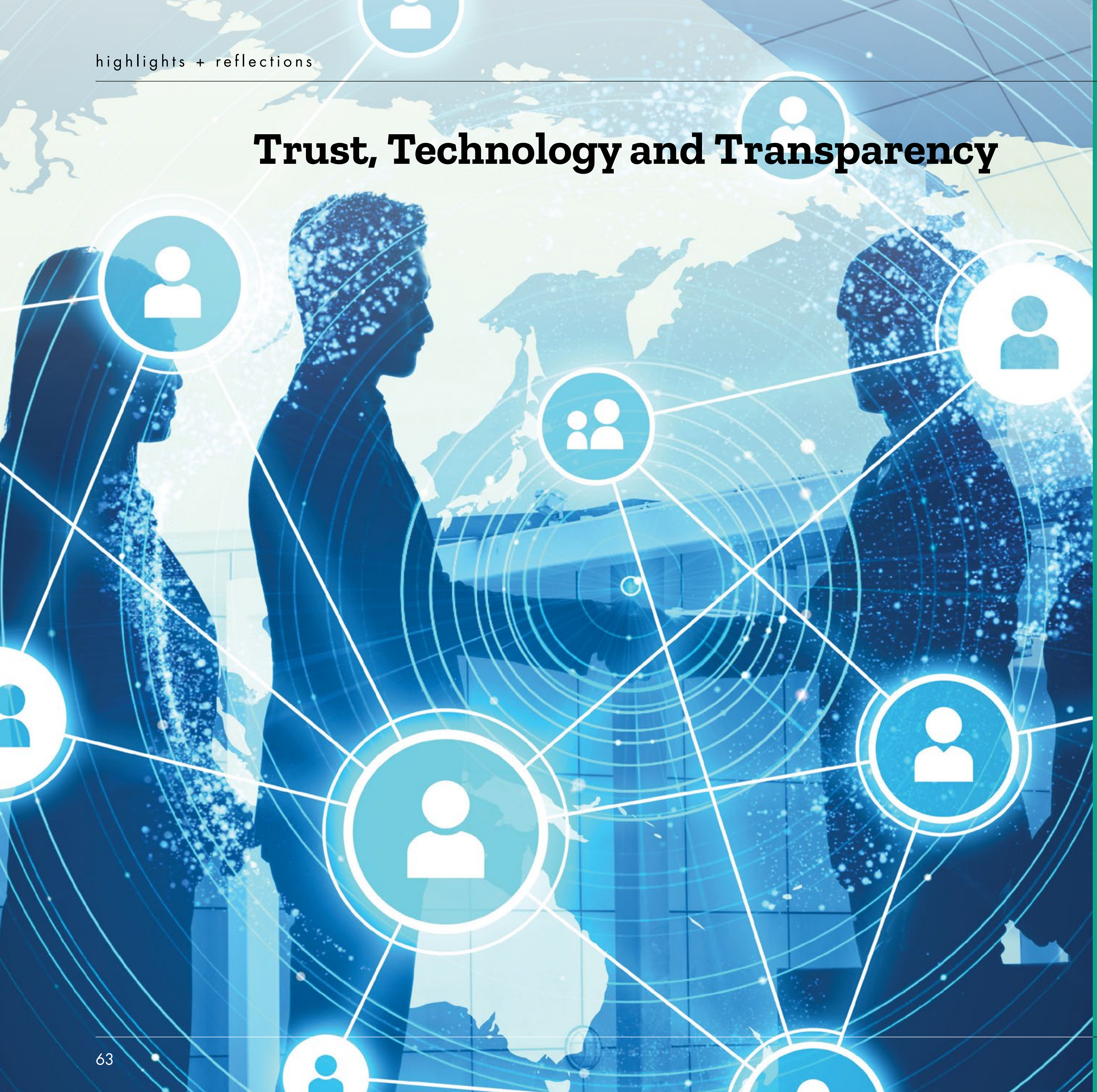
# Trust, Technology and Transparency



“1 *Flattery is under-rated; it's effective.*

2 *We like people who are like us, but it's a disaster to try to make yourself only half like another person.*

3 *Build teams by creating identification - a sense we are a team — and a sense of interdependence.*

4 *Negative emotions are the most important ones in the workplace. Dialogue with active listening allows people to reflect on a negative experience and take steps to make it better.*

5 *To persuade, focus on expertise and trustworthiness; show that you care.*”

– Cliff Nass

Key take-aways from *The Man Who Lied to His Laptop.*[254]

***Learning about people from machines.*** Cliff Nass, Professor of Communication, frequent and influential mediaX collaborator. Pictured here in Stanford's driving simulator, Nass studied drivers' interactions with their cars, finding that drivers feel more engaged with the car's computer voice if they believe the computer is installed in their car, as opposed to a wireless connection to a distant computer.[254]

Image credit: https://news.stanford.edu/news/2008/may7/cars-050708.html

## *Highlights*

**1** The design elements of human-computer interaction exert a contextual influence on how users process digital information, influencing their perceptions of trust, reliability, and authority.

**2** Studies of the persistence of personal data to predict behaviors, habits, personalities provided understandings about trust.

**3** The "digital estate" surfaced as a new metaphor for situating digital activities and recognizing the self in the digital medium — with privileges, responsibilities, and the ability to transact assets, as well as highlighting the importance of data preservation.

**4** Trust is a foundational pillar in collaborative relationships for teamwork, human-machine partnerships, e-citizenship, and wellness; and the human tendency to trust becomes vulnerable when trust in institutions is undermined, increasingly commonplace in 2022.

**5** Cognitive security involves protection against malicious online and offline influences at multiple scales and relies on situational awareness, resilience, and engagement to address disinformation threats.

**6** The "black-box" systems of automated intelligent agents and algorithm-driven interactions require concerted and diligent improvements in the multi-disciplinary education of both new and experienced people working with socio-technical systems.

**7** Understanding the conditions that help to build trust and avoid ethical errors in AI-based systems is fundamental to the non-linear, multi-faceted, and globally connected world we live in.



Across many mediaX initiatives and funded projects, one recurring research question has been: ***What are the insights, concepts and tools that help create mutually beneficial, safe, and open collaborations in a world of automated intelligent agents, algorithm-driven interactions, and machines that can learn?***

Studies confirmed that design exerts a contextual influence on how users process digital information.[264] In light of this, mediaX's explorations of the wide range of human-computer interactions have been strongly rooted in the importance of trust as an essential ingredient for healthy relationships and functioning societies.

### Trust in Human-Machine Relationships

As early as 1994, pioneering understandings of how people interact with machines called attention to the instinctive human tendency to treat interactive technologies as social actors.[255] Studies exploring the psychology of people's interactions with media coined the term "gamification", and investigated users' responsiveness to rewards, transparency of performance, its influence on trust in teamwork, and fluidity in interactive roles.[256] The ChiMe Lab (Communication between Humans and Interactive Media) worked on the psychology and design of human-computer interaction[257] and had a profound influence on mediaX's philosophy and approach.[258] This research described how moods and emotions are engaged online,[259] and how these elements relate to trust,[260] memorability and persuasion.[261] They included questions about how user experiences shape and are shaped by a user's personal self—a "digital persona". Cultural influences on mindset and values were brought to light in design creativity[262] and socio-economic influences on services.[263]

### Trust in Digital Interactions

Awareness of the digital traces that remain from online interactions grew as consumers questioned online advertisements that were suspiciously targeted and as personal images placed on social media sites reappeared to haunt the people in them. mediaX researchers explored patterns of collection, persistence, and re-use of data as characterizations of habits, personalities and behaviors. Results from those studies provided insights about trust and transparency. The ephemeral nature of human conversation was contrasted with the monetization of data from aggregated records of online personal information and clicking behaviors.[265] In related work, research on trust in digital living revealed how digital records of online behavior were being used to characterize humans and predict psychological traits with surprising accuracy.[266]

As early as 2013, social media provided a focus for a mediaX workshop exploration on how trust, reliability and authority were determined in online interactions.[267]

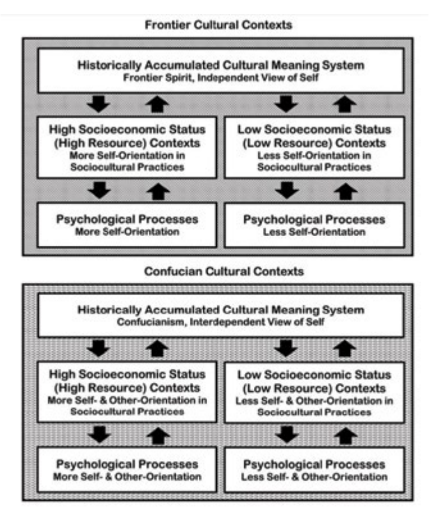
A publication which followed the workshop examined how authenticity, reputation and influence emerge online, and described innovative tools and methods for analysis.[268] The "digital estate" surfaced as a new metaphor for situating digital activities and recognizing the self in the digital medium — with privileges, responsibilities, and the ability to transact assets, as well as highlighting the importance of data preservation.[269] mediaX stimulated user-centered examinations of the rich ecosystem of digital technologies, possessions, interactions, and experiences that surrounded online media usage in a Research Theme on digital estates and legacies.[270] This theme invited Stanford researchers to envision novel ways to think about the blurring boundaries between the physical and digital worlds and their impact on personal identity.

Parameters of audience engagement, seen as transparent social footprints,[271] informed changes to how content was created, curated, and consumed. Scholars in several disciplines noted new opportunities to monetize audience attention and explored patterns in the 2008 workshop on Monetizing Audience Engagement.[272] These changes were accompanied by an evolution from traditional to digital publishing, and publishing-on-demand.[273] The rise of the user as content creator signaled significant economic and talent changes for the media industries and the legal system of copyright.[274] With these changes came the awareness that trust in traditional sources of authority was eroding.[275]

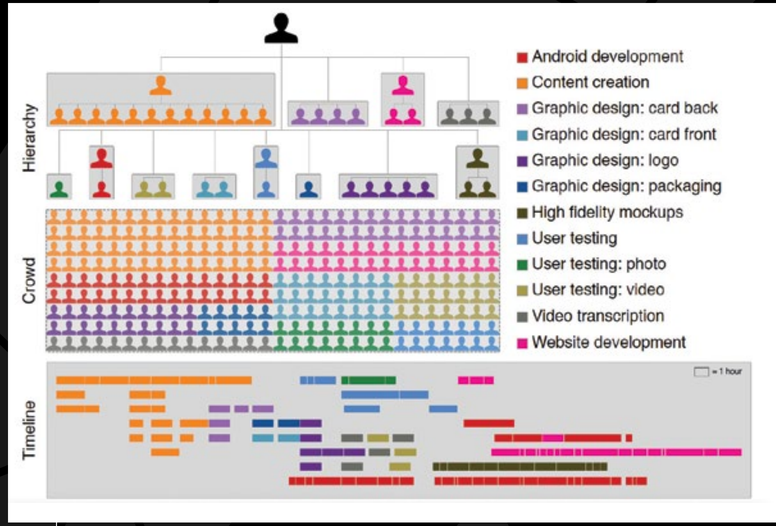
Extending inquiry from the personal to socially impactful, the importance of trust and transparency to productive teamwork and workplace technology experiences was highlighted in a range of mediaX research initiatives on the future of work, productivity, teamwork, and collaboration. The productivity of remote teams was shown to be positively correlated with transparency of team members' access to communication technologies and states of engagement. An iterative process leveraging that transparency allowed team members to not only build awareness of their local conditions and make their local conditions transparent and visible to the rest of the team but also provided a feedback mechanism regarding engagement, alignment of expectations and synchronicity of potential engagement levels.[276]

Using a novel annotation system to code the verbal and nonverbal exchanges among team members, patterns of interaction that included questions, requests for additional information and attempts to creatively combine individual ideas were shown to result in the generation of more creative ideas by teams.[277]

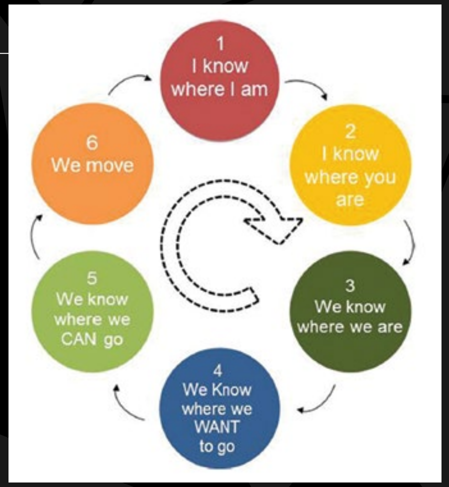
With trust as a foundational pillar in collaborative relationships, the 2015 mediaX Conference explored Connected Productivity Platforms.[278] Presentations highlighted technologies and applications touching on key issues of the human-machine partnership,[279] such as e-citizenship,[280] truth and deception,[281] and data



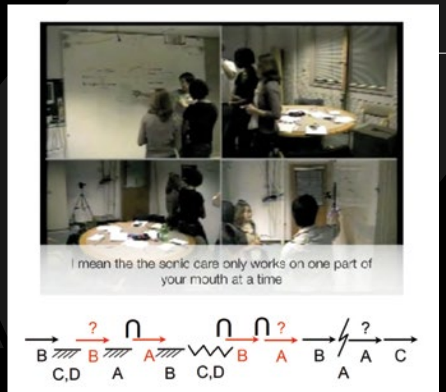

***Culture and mindset.*** Cultural contexts exert strong influences on mindset and differ strongly in values related to independence and interdependence of self in relation to others. These differences are important for media of all types.[263]




***Flash organizations.*** With increased work opportunities and engagements generated on crowdsource platforms such as Mechanical Turk, opportunities arose to study the temporary interaction of digital workers in "flash organizations". The organizational structure of such teams assembles in direct response to the project's evolving needs, and then disbands once the work is complete.[287]




***Team transparency.*** The "Six Steps to Engagement" framework offered three feedback loops as triggers to improve the transparency of the local and global collaboration context and behavior, and three choice-decision-commitment steps toward improving the work environment and increasing knowledge work productivity.[276]




***Coding verbal and nonverbal exchanges.*** Using Interaction Dynamics Notation, group conversations were scored on a moment-to-moment basis, revealing that questions and "yes" patterns move a team into concept space.[277]


***Trust in communities.*** Truth and trust are integrated into socio-technical systems[290], as described at the mediaX Conference on Transparency and Trust in a World of Social Bots.[291]
Image taken from:
https://sml.stanford.edu/news/truth-trust-and-technology

management for wellness.[282] Also included were emerging issues such as open source,[283] collective intelligence,[284] and data collection and sharing to enable collaboration.[285]

One exploration of digital living and digitized access to labor explored the concept of "flash organizations"[286] — crowds that are computationally structured like organizations. In experimental conditions, researchers enabled the automated engagement of crowd workers in structured roles and included continuous reconfiguration of those structures to direct the crowd's activities toward complex goals.[287] The capability of automated team management systems to leverage transparent performance dashboards for engagement and productivity was also demonstrated.[288]

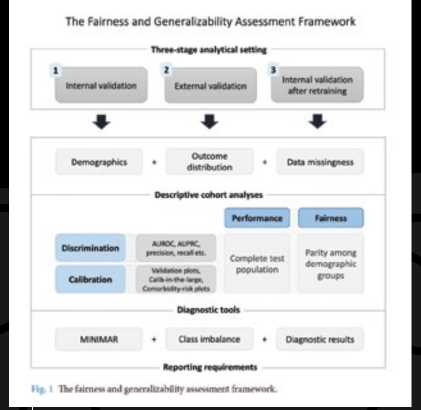
To understand how trust influences communication in online communities,[289] the importance of the "truth bias" — the natural tendency to trust other people and messages — was stressed as a key aspect of healthy communities in mediaX workshops.[290] Importantly, this human tendency to trust becomes vulnerable when trust in institutions[291] — including sources of information and news [292] — is undermined. This has been increasingly commonplace in 2022.

By 2018, the topic of trust and transparency in human-computer interactions had risen to the forefront for scholars, business people, consumers, and educators. Researchers studied how people judge the credibility of

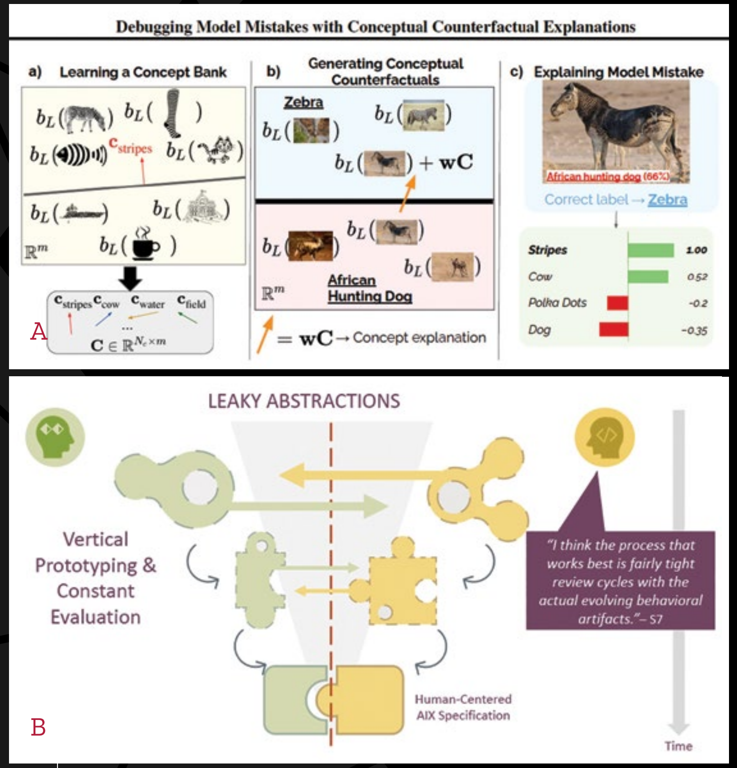


*Trust changes and morphs within society. The decline of trust in traditional institutions, including media, is contrasted with the increase of trust in networks, some of which become institutions through their brands. The explosion of the written word — recordability — gives us the ability to track deception. Text messages, social media and shared video allow discrepancies to be observed now as never before. Recently, our society experienced a moral panic — when a society has a conversation with itself about something it thinks is dangerous and morally important. The problem with that panic button has been its impact on trust. We have to trust each other in order for language to work. When we can build trust in our communities, we build resilience.*

*– Jeffrey Hancock*




***Fairness and generalizability.*** Empirical evaluation studies help to keep biased AI models from using dangerous feedback loops that may reinforce systemic health disparities faced by minority populations. This fairness and generalizability assessment framework helped raise broad awareness of the pervasive challenges around bias and fairness in risk prediction models.[311]

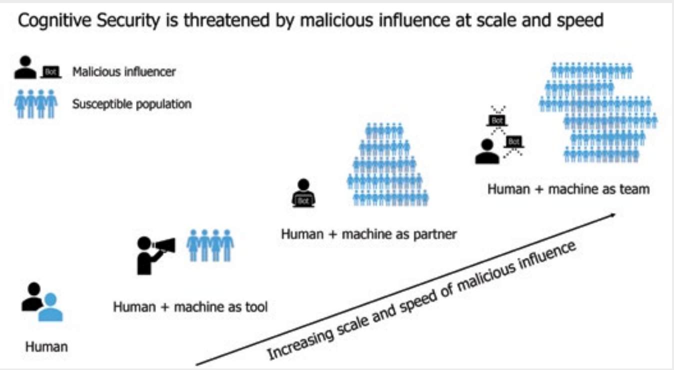



***Counterfactual explanations.*** (A) A systematic approach, conceptual counterfactual explanations (CCE), explains why a classifier system makes a mistake on a particular test sample in terms of human-understandable concepts. With data from a learning concept bank a), counterfactual explanations are generated b) and concept activation vectors c) describe the model's mistakes. [312]
***Leaky abstractions.*** (B) By sharing leaky abstractions, referring to sharing low-level details about design and engineering throughout the building process, UX designers and AI engineers are supported in collaboratively designing human-centered AI experiences (AIX) from observations and usage scenarios. [313]



digital content, finding that fake and falsified information was often perceived to be true and original.[293] Educators created instructional programs to help digital readers spot fake news.[294] mediaX organized a series of panel discussions that delved into the research, concepts and tools that could help create open collaborations in a world of automated intelligent agents, algorithm-driven interactions, and machines that can learn what humans cannot explain, commonly called "black box systems".[295] The series included panels focused on the changing role of trust and transparency in Interdisciplinary Research Collaborations,[296] Human-AI Collaborations,[297] and Personalized Algorithms.[298]

The mediaX community repeatedly embraced "wicked problems" — the complex, multifaceted issues that are typical of the open, nonlinear systems that frequently involve people and machines. During the COVID-19 pandemic, when travel to campus was limited, mediaX conducted an extended webinar series on thinking tools for wicked problems.[299] Key issues raised and discussed included ecosystemic resilience,[300] futurism,[301] virtual reality,[302] trust in the workplace,[303] human-robot interaction, global health. Many of the topics explored throughout these sessions, as well as the mediaX community's greater body of work, reference information-technology-intensive operations, or human-machine interactions highly reliant on computation and data exchanges. Of relevance to these functions is the issue of cognitive security, a perspective concerning protection against malicious online and offline influences at multiple scales[304] —from individuals to nation-states. In this webinar, attention was drawn to considerations of situational awareness (involving detection & attribution), resilience (with a focus on critical thinking) and engagement (which includes people and machines working together to address disinformation threats).[305]




***Cognitive security.*** The increasing possibility of malicious online and offline influence, at scales ranging from individuals to nation-states.[303]

Bringing together Stanford scholars and industry partners for an exploration of key issues in authenticity, reliability, reputation, transparency, and trust, the 2018 mediaX Conference examined Transparent and Trust in a World of Social Bots.[306] (Also see Bots and Intelligent Agents.) That deep dive included intersections between media, information technologies (computation, algorithms, machine learning, AI and the Internet of Things), and human sciences (social and psychological sciences, policy, communications, law and political science).

The growing importance of trusted technological intermediaries in a "remote first" world was addressed in a mediaX webinar series on these topics.[307] Building trusted ecosystems in education and healthcare,[308] fostering interoperability in data ecosystems,[309] and developing trusted agents[310] were identified as critical pathways to a future in which humans will flourish.

Technologies are no longer only tools; they are collaborators, as well as important intermediaries in relationships. In many cases, they are integrally involved in decisions that influence lives. A necessary element to the trust and technology loop depends on the data on which intelligent technology systems function — especially AI training models. In engagements with members and the community, mediaX highlighted the need to critically and empirically evaluate AI models and their data-based feedback loops,[311] methods to increase the explainability of AI systems,[312] and how increased and earlier communication between user experience (UX) designers and AI engineers can lead to the creation of more human-centered AI systems.[313] Understanding the conditions that build trust and avoid ethical errors in AI-based systems[314] is fundamental to our non-linear, multi-faceted, and globally connected world.

*How might developments in information technologies facilitate interpersonal dynamics and interactions to foster and renew trusting and mutually beneficial relationships between people, between people and systems, and among systems?*

## questions for the future

***There's more we can do together than any of us can do alone.***

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# Thinking Models and Tools

*“By combining hindsight with insight into where we are now, one can create a view to strategic foresight. Patterns can be recognized but rarely repeat exactly. People with agency, with creativity, and with a vision can imagine different futures. We tell stories of the future to ourselves and to others by juxtaposing things that are not connected and seeing the fascinating possibility of connecting them. mediaX has always stood for pragmatic transdisciplinary experimentation.”*

– Michael Shanks

## *Highlights*

**1** The explosion of data available at a micro-level and the ubiquity of machine learning models ignited a shift in inquiry methods from controlled experiments and ethnographic observations to data-driven insights about humans.

**2** mediaX embraced the philosophy that shared language can generate shared understanding and repeatedly entertained the recurring questions of how to communicate about the unknown and align on ground truths, measurements, and data interpretation from multi-disciplinary explorations and real-life experiences.

**3** The thinking models highlighted by mediaX embraced complexity and urged co-creating a desired future by encouraging participants to embrace new insights, proofs-of-concept, and new questions intended to inspire innovation.

**a** Innovation Ecosystems are characterized by relationship networks that generate sustainable, productive output through shared vision.

**b** Strategic Leadership focuses on the capability to maintain and control destiny, including the control of algorithms that autonomously develop disembodied new knowledge.

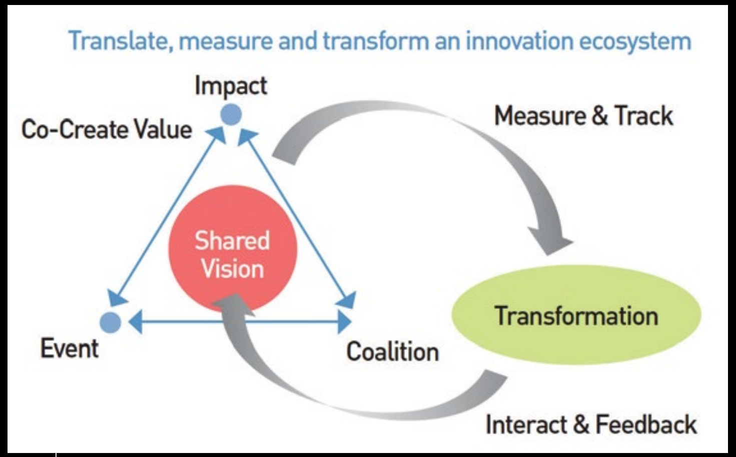
**c** Design Foresight revolves around a view of the future with insights on next steps, what to build and why; it is closely related to Design Thinking, which emphasizes mental models for empathizing and sequential prototyping to test and learn pathways for innovation.

**d** Installation Theory draws insights from physical, social, and environmental structures that surround human behavior, enabling exploration of user-centered distributed intelligence through activity-centric design.

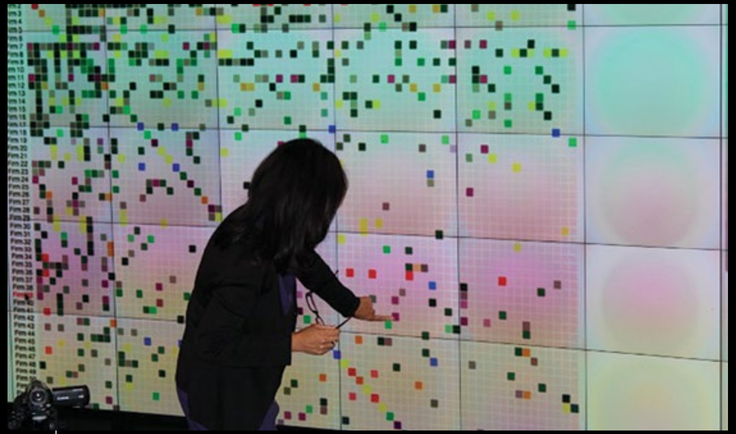
**e** Futures Literacy builds on the innate human capacity to imagine better futures, to discern and make sense of changing complexity, and to better understand humans' role in the future.

**f** The Delphi Mapping tool combines the Delphi method, technology sequence analysis, cross-impact assessment, and modified scenario mapping.

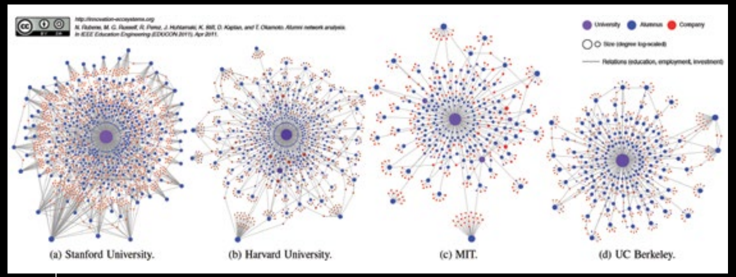





***Relational capital.*** Innovation ecosystems leverage relational capital to create shared vision, through which new coalitions of people whose shared vision of co-created value result in transformation.[349]



***Data visualization.*** Sharing visualizations of data that inform factors for consequential decisions helps decision teams clarify assumptions, identify missing information, and discuss strategic options.[346]



***Alumni networks.*** Stanford encourages innovation, entrepreneurship and collaboration among students; alumni actively collaborate as founders and funders of new businesses, illustrated by dense networks of relational capital.[348]



The pace of innovation represented by the nexus of Silicon Valley and Stanford University has historically represented — and still bestows —a beacon and a challenge to businesses wishing to remain competitive. mediaX addressed this challenge by stimulating the creativity of its affiliates through events designed to co-create models for thinking about problems and opportunities, as well as to share the tools to investigate and apply effective approaches to their work. New thinking models included contextual decision-making, data-driven insight development, and new languages for shared understanding.

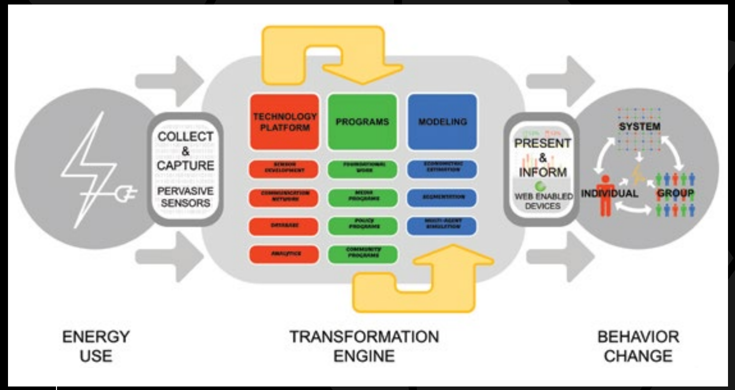
mediaX activities encouraged the consideration of multiple scenarios and envisioned ecosystems within and outside of work environments to assure sustainable, productive output. It accomplished this by unpacking language to assure effective communication and embracing uncertainty to view contextual complexity, including the dynamic forces that influence an organization's operations and success.[315] These and other thinking models were explored at seminars and collaborative work events which encouraged participants to embrace new insights, proofs-of-concept, and new questions for sparking innovation. The thinking models mediaX highlighted embraced complexity and encouraged co-creating a desired future, including strategic inflection points in organizations[316] and behavior pathways in humans.

## Thinking Models for Data-Informed Analysis of Behavior

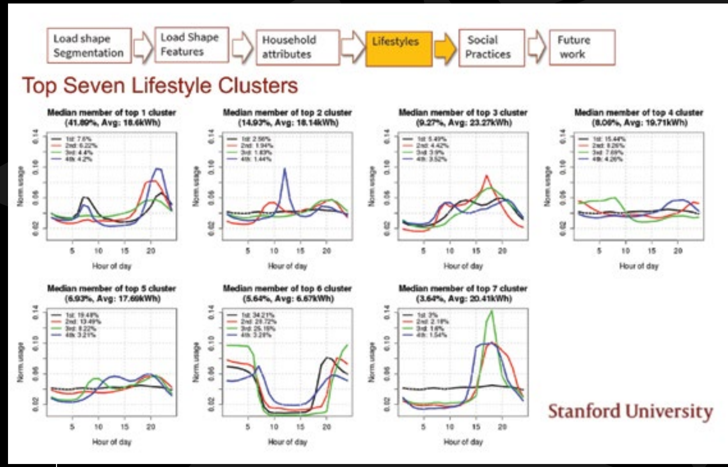
As data collection, storage, and processing became increasingly powerful, and then ubiquitous, mediaX research and presentations examined data-driven decision making and analytics – from both descriptive and predictive perspectives. As early as 2013, mediaX highlighted practices around the quantified self,[317] using personal data to understand daily life at a personal level. Individual engagements in the digital world grew, not only through text, but also with home voice assistants,[318] sensor and geo-location data, labels and tags, and user journeys.[319]

Evolving from the cyclical nature of data collection, analysis, action, and evaluation, new methods to inform insights bloomed.[320] For example, insights from research on behavioral market segmentation — the quantified home — were developed using data by tracking energy-efficient households.[321] Using smart-meter data, researchers were able to model actual energy use on an hourly basis and found significant variance from previously assumed energy consumption models, leading to new concepts of lifestyles and market segmentation.

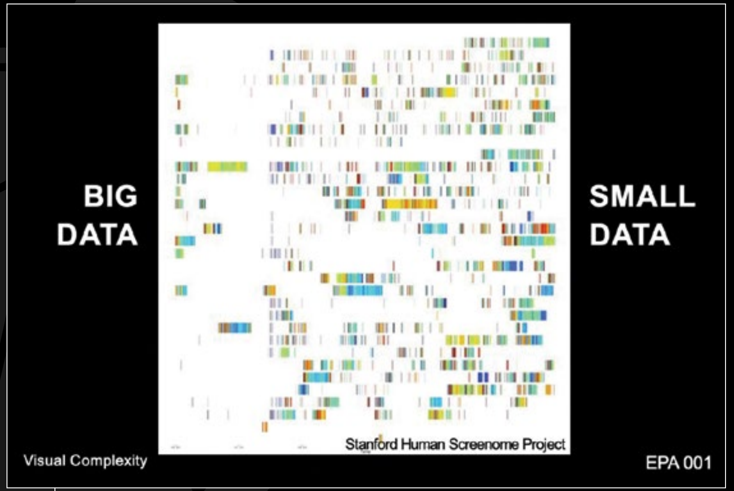
The explosion of data available at the micro-level and the ubiquity of machine learning models ignited a shift in inquiry methods from controlled experiments and ethnographic observations to data-driven insights.[322]



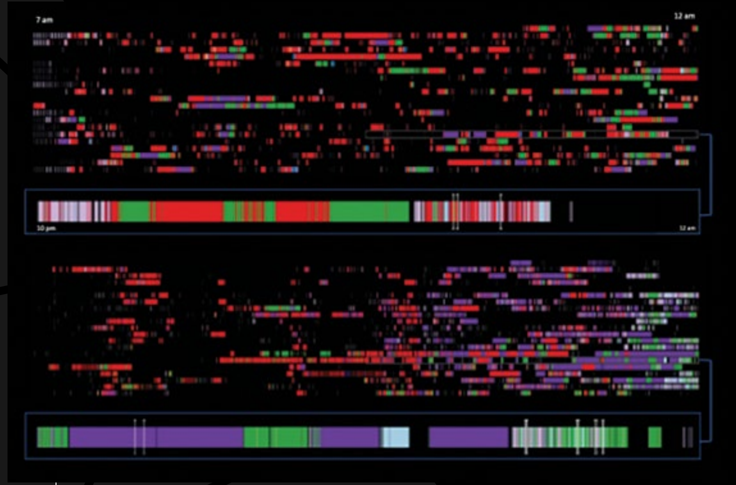

***Tracking households' energy use.*** The diffusion of new technology is dependent on adoption by users. To activate behavioral changes, residential data was collected, transformed, and then presented to users for information and feedback regarding their energy use.[321]




***New analytical methods.*** Using smart-meter data, researchers were able to model actual energy use on an hourly basis and found significant variance from previously assumed energy consumption models, leading to new concepts of lifestyles and market segmentation.[320]




***Screenome content.*** Capturing screen data at 5-second intervals, researchers explored it with multiple perspectives — small data at the level of the individual and big data when looking for patterns across smartphone usage. By color coding the time spent for one individual's use of a mobile phone and laptop over 24 hours on screen according to Screenomics, researchers identified the startlingly small amount of time spent in one view before switching to another screen. Subsequent studies revealed that more adrenaline was activated by the users' anticipatory response of the switch than by the excitement generated by new content.[327]



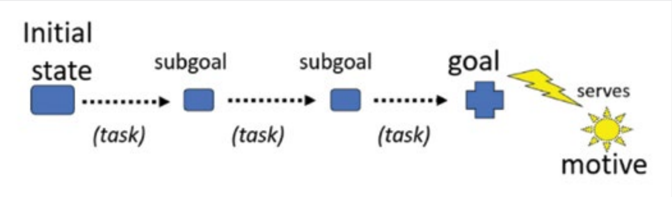
***Human screenome.*** Screenomes, time-sensitive content records of digital screen use, are shown for two adolescents over 21 days, 6am to midnight. The small vertical bars indicate whether the screen was on during each 5-second interval of each day, and the type of digital application used at each interval. Patterns of the vertical bars over several days reveal the content interests of each person.[328]

Exploration expanded from experimental, top-down methods to bottom-up analysis driven by sensor-derived data. As early as 2012, projects exploring behavioral signatures of collaboration and creativity were using facial scanning for emotion detection[323] as well as synchronous brain scanning techniques[324] and developed algorithms to identify synchrony and collaboration.[325] Novel eye-tracking technologies provided digital video of a user's gaze during tasks that were aggregated with talk-along explanations to reveal combined attitude-behavior-meaning context for attention-engagement studies.[326] With minute-by-minute assessment of attention and engagement through smartphone use,[327] the "human screenome" was introduced in 2020,[328] generating new insights on the pace and heterogeneity of screen usage[329] and upending social scientists' temporal concepts of engagement.[330]

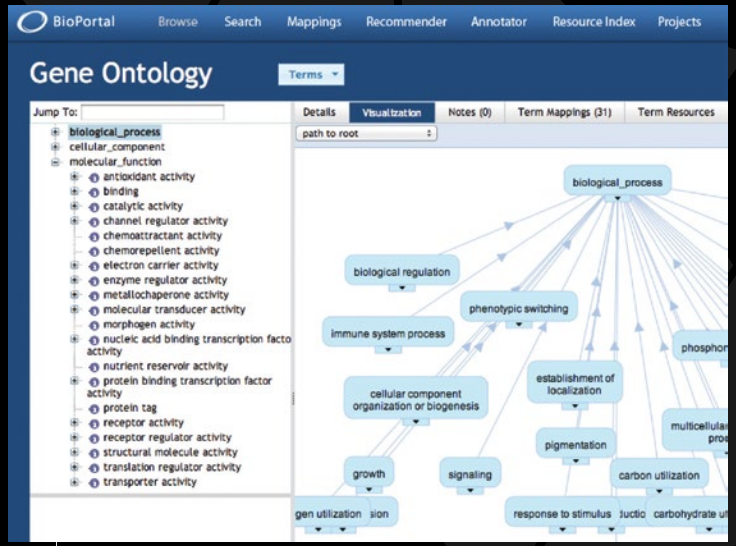
By 2014, mediaX discussions explored how opening access to data created possibilities for new business activities and innovative services, democracy and citizen participation,[331] more effective administration, education, and research. Successful and unsuccessful uses of the same data by different teams in the same organization were also assessed[332] as part of the 2017 Research Theme on potential, performance, and productivity,[333] revealing the need for a shared language to productively communicate uncertainty and ambiguity, as well as the influence of interpersonal relationships and personal networks on analysts' choices when selecting data sources.[334]

## Thinking Models: Language for Shared Understanding

As industry professionals and academic researchers explored horizon topics, a recurring question was how to communicate about the unknown. This challenge has received attention in fields such as medicine.[335] In identifying new human science and media technology challenges to tackle, it was not uncommon to discover that the language and terminology presently available were insufficient to describe the possibilities of the present or the future. In 2020 and 2021, two mediaX Research Themes addressed this gap by exploring the evolving landscape of terminologies, taxonomies,[336] and ontologies.[337] Independently, yet concurrently, the National Academies of Science Engineering and Math addressed the need for accelerating the development of new ontologies in the behavioral sciences.[338]




***Installation theory.*** Ontologies of human activities are complex. Activities are subject-centric, specific to a subject, and performed from the perspective of the subject, in the context of layers of affordances that provide action pathways. Human activities can be analyzed as a series of typified tasks with subgoals that serve a motive.[342]




***Ontologies in medicine.*** Using an example from medicine to energize new ontologies in the behavioral sciences, the Gene Ontology displays the interaction and hierarchy of genes and has enabled scientists to agree on common understandings of these terminologies and their relationships.[335]

*Table 3: Activity Grid for networking during Breaks and Transitions from the viewpoint of a conference organizer*

| Task | Actor's Motives and Goals | Contributions from Actor | Actor's Rewards | Installation: Affordances | Installation: Competences | Installation: Regulation |
|---|---|---|---|---|---|---|
| **B&T-1 Agenda** Plan and manage time for networking/ social / break | Excellent coordination of multiple actors with diverse goals within the conference time frame. | Provision adequate resource and personnel. Explicit recognition of content and relational goals for presenters and attendees. Pre-determine time reminders and other assistance for presenters. Pre-determine interventions needed from support and technical staff. Prepare fallback plan and resources. | Smooth, timely coordination of technical and support personnel. On-time launch, breaks, sessions, adjournment. Expressed satisfaction of presenters and attendees. Social recognition. Possibly financial reward or professional promotion. | Explicit timeline /run-sheet for distribution to technical and support personnel as well as presenters. Conference agenda and timeline to share with attendees – in multiple formats, updatable. Multiple communication channels with presenters, technical and support personnel. | Articulation of dual goals - content and relational. Communication skills to inform and manage guide session start and end. Knowledge of planning tools and software. Professional networks and accreditations. | Pre-conference testing of presentation media and logistics, audio/visual and navigation. Multi-channel announcements of timeline to attendees. Predetermined time reminders and other assistance for presenters. Accreditation for decision-making, budget clearance. Backup plans to accommodate time delays due to technical issues. |

***Multilayered installation design.*** Taking the perspective of a conference organizer, the Activity Grid analysis for breaks and transitions specifies the conference organizer's motive, goals, contributions, and rewards. The related analysis of affordances, competences and regulations provides insights for re-design of the installation, in this case for conferences in virtual reality environments.[345]

***This is so important and fascinating — what you guys are all doing. I think there's some clear room for cross pollination and how you're each thinking about your work. What might be missing is that for anyone who's trying to define or create taxonomical understanding, you have to start thinking of things like context, start thinking of things like the epistemological boundaries of what you're doing, start thinking about what's algorithmic or what's heuristic, even within the taxonomies. There's a common understanding that seems to be missing, but you guys, just by talking to each other, are so perfectly positioned to build it.***

***– Robert M. Kaplan***

*Co-moderator of mediaX Panel Discussions on Ontologies and Taxonomies for the Human Experience,*
*Chair, Accelerating Behavioral Science Through Ontology Development and Use, adhoc committee of the National Academies of Sciences, Engineering and Medicine*



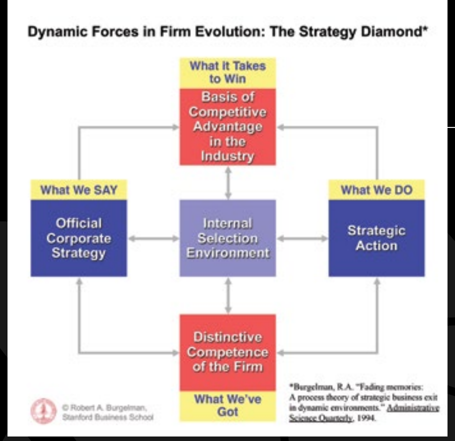


## Thinking Models for Contextual Decision-Making

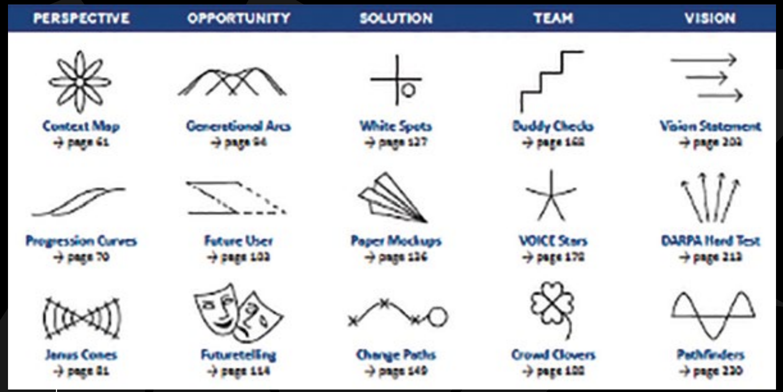
Through the annual Global Innovation Leadership Program, initiated in 2014 for mediaX members, industry leaders gained insights into the contexts of their opportunities and how they might approach challenges as invitations for innovation. Through week-long, project-based learning experiences, business leaders collaborated in teams on Grand Challenges of intentionally broad topics, such as energy, mobility and wellness. Importantly, these topics were broader than the scope of participants' everyday work, enabling them to engage with each other without disclosing competitive information. Collaborators helping to facilitate the workshops included THNK School of Creative Leadership, the Silicon Valley Innovation Leadership Group, and the London School of Economics and Political Science.

Workshop participants explored thinking models such as Foresight & Innovation,[339] Design Thinking,[340] Futures Literacy,[341] Installation Theory,[342] Delphi Mapping,[343] and Innovation Ecosystems.[344] These models offered a variety of ways to examine the contexts informing human behavior, information technology and decision-making.

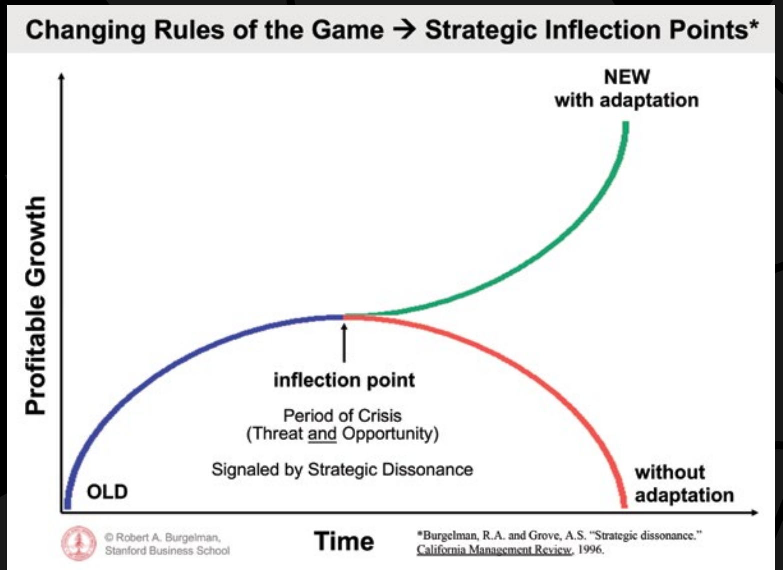
The mindset and thinking tools of Design Thinking, which emphasizes mental models for empathizing and prototyping to test and learn about pathways to innovation, can be used to design anything from toothbrushes to educational




***Strategic leadership.*** Participants in mediaX workshops learned to understand dynamic forces that influence an organization's operations and success.[315]

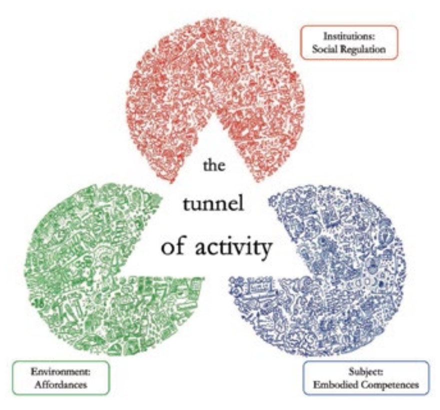


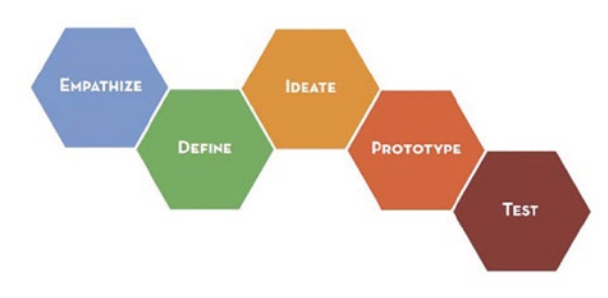

***Foresight and innovation.*** Janus Cones, a tool for strategic foresight, looks backwards and forwards in time to identify the timing of historical events and how timing affects potential future events. Other strategic foresight tools identify opportunities, solutions, teams, and vision.[339]




***Strategic inflection points.*** Participants in mediaX workshops were encouraged to identify and take advantage of strategic inflection points in their decision-making.[316]

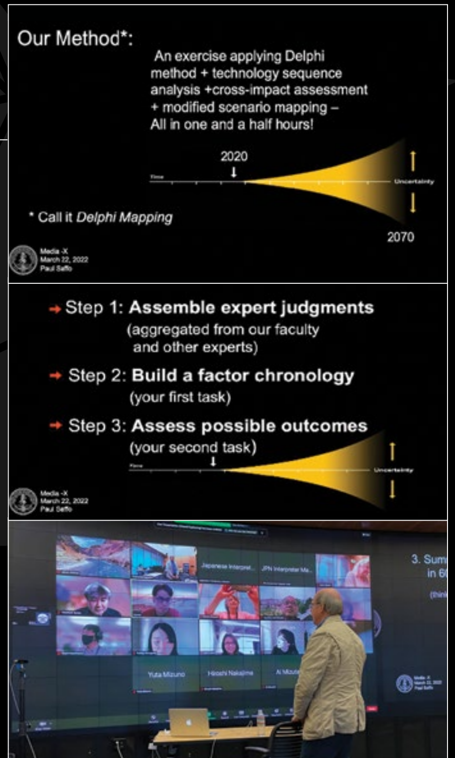
***Installation theory.*** Installation Theory is a global activity analysis and design framework that combines into a pragmatic system a series of general theories of behavior, mainly ecological psychology, situated and distributed cognition, intelligence and actants, social constructionism, social representations, and Activity Theory. The three layers of an installation simultaneously scaffold and constrain the behavioral path.[342]




***Design thinking.*** Design thinking emphasizes mental models for empathizing, and sequential prototyping to test and learn pathways for innovation.[340]

***Delphi maping.*** Using the Delphi Mapping method for future scenario extrapolation, the mediaX March 2022 workshop, led by Paul Saffo, explored potential future scenarios for Leveraging AI for Complex Decisions.[343]




software to robotic tools. Design Foresight revolves around taking a view of the future to know where to go next, what to build and why. Methods exercised in this framework focus on radical innovation of a magnitude that influences tranformational changes in products, markets and organizations — such as moving from gas to electric-powered vehicles. Similarly, Futures Literacy reflects a universally accessible skillset that builds on the innate human capacity to imagine better futures and to develop the capacity to discern and make sense of changing complexity. Its toolkit allows people to better understand the role of the future in what they see and do, for example as they are charting the business growth opportunities created by innovations in R&D departments.

The premise of Installation Theory rests on the impact of physical, social, and environmental structures on human behavior, enabling exploration of user-centered distributed intelligence through activity-centric design. For example, how environmental design influences behavior via action pathways can be articulated and then incorporated into the design elements of immersive environments or into behaviors for bots and intelligent agents.[345]

The Delphi Mapping tool, another thinking model to inform entrepreneurial activities, combines the Delphi method, technology sequence analysis, cross-impact assessment, and modified scenario mapping. A preliminary forecast is made by combining expert judgments on a topic, such as the future of AI-generated knowledge and machine learning without human intervention. Those perspectives are subsequently refined through a recursive process. This model leverages the effectiveness of iteratively assessed, informed intuitive judgment.

The concept of Innovation Ecosystems — complex social, economic, and technical systems characterized by relationship networks that generate sustainable, productive output — served as an oft-used thinking model at mediaX, evolving with new context at each touchpoint. Data visualization software allowed researchers to create visible, data-driven artifacts for decision support.[346] In 2017, for instance, mediaX explored Innovation Ecosystems for AI-based Education, Training and Learning,[347] probing the networks of interdependent firms and mutually beneficial relationships in the emergent ed tech ecosystem. The program offered insights into the relationships between various stakeholders and change-makers, including Stanford alumni,[348] highlighting relational capital,[349] context and shared vision for value co-creation, as well as investigating the process of teaching and learning itself. Speakers presented insights from research results in organizational sociology,[350] cognitive neuroscience,[351] AI in education, education policy,[352] learning sciences, STEM education (Science, Technology, Engineering, Math), lifelong and life-wide learning,[353] platform and ecosystem innovation models,[354] information visualization,[355] education marketing, and intelligent textbooks.[356]

As mediaX members continued surfacing topics that reflected priorities for their organizations, they explored a wide variety of ecosystems and methods for visualizing them, including identifying startups in the smart energy sector,[357] iterative processes for decision making,[358] advancing the Moroccan education system during the COVID-19 pandemic,[359] and the support system for neurodiverse children.[360]

The deep thinking of Stanford academics and the experimental applications of their labs provided framing and processes to investigate topics that transcended individual categorization — in areas such as memory, learning, and well-being. This work enabled diverse academic and industry researchers to align on ground truths, measurements, and data interpretation from a variety of activities and experiences, including computational thinking.[361] Bridging industry and academic priorities, as well as disciplines and fields of interest, mediaX embraced the philosophy that shared language can generate shared understanding.[362]

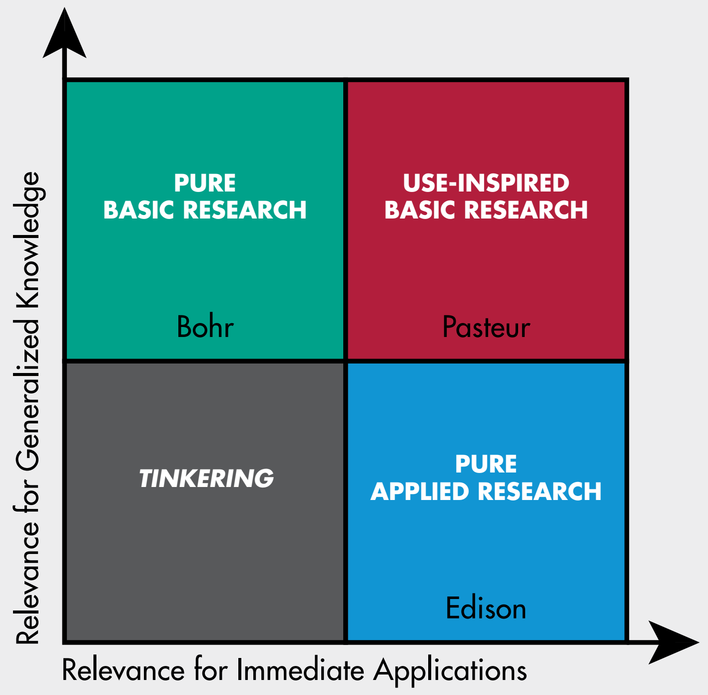
The twenty-plus year history of mediaX encompassed the rise of social media platforms, smart phones, algorithmic decision making, autonomous vehicles, ubiquitous sensor technology, the quantified self, robotic assistants,

***Academic research wants to be basic research, but it needs to be use-inspired; it needs to be driven by real problems that real people have. It's easy to solve the problems that you see around you - at arm's length within the university environment - and to make assumptions based on those observations. Those are dangerous assumptions. Being in touch with a much, much broader set of stakeholders is critical to making sure that what we're doing is really solving real problems.***

*– Michael Bernstein*

augmented and virtual reality, remote and distributed work, and more. A hybrid blend of virtual and physical media experiences characterized digital lifestyles by 2022.

Participants from both industry and academia have commented that mediaX guided them to new ways of thinking about complex issues and pressing problems. By seeing problems as opportunities, context as a key element of analysis, and collaboration as a spark for creative solutions, mediaX and its affiliates opened new pathways for discovery.[363]




***Pasteur's Quadrant.*** A thinking model that describes fundamental yet use-inspired research, Pasteur's Quadrant references the type of studies Louis Pasteur did a century ago, which laid the foundations of microbiology.[363]

*How might corporations, universities and organizations develop structures, technologies, and decision pathways to productively empower people to make progress toward resolving the societal challenges of today and tomorrow?*

## questions for the future

***There's more we can do together than any of us can do alone.***

***See Appendix 4 for more questions.***





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# Appendices





## APPENDIX 1
## Emergence and Evolution of mediaX

**mediaX at Stanford University and the H-STAR Institute 2001-2022**

For more than two decades, the mediaX program at Stanford University served to pose and explore questions arising from the development and implementation of high bandwidth internet services and related products. In pursuing these questions, mediaX created innovative links between experts in industry and academics, contributing to improved productivity, creativity, and leadership in both sectors.

**Origins of mediaX**

Founded in 2001, mediaX at Stanford University originated from a mutually beneficial collaboration on social intelligence of machines between Tatsuro Ichihara, former Vice President of OMRON, and the co-authors of *The Media Equation*, Stanford Professors Byron Reeves and Cliff Nass. The mediaX program took inspiration from the research agenda for high bandwidth communication (IPV6 protocols) in the social sciences, created at the 1999 Internet2 Socio-Technical Summit (I2ST), held at the University of Michigan and led by Dr. Martha Russell, interdisciplinary industry-academic program veteran then at the University of Texas at Austin. Reeves served on the planning committee for this Summit; he and Charles (Chuck) House (at Intel at that time) each delivered keynote addresses.

**Provost Etchemendy endorses mediaX as cross-campus interdisciplinary program**

Championed by Philosophy Professor John Etchemendy (Stanford Provost at that time), who envisioned a cross-campus interdisciplinary program under the administration of the Dean of Research, Charles Kruger, mediaX came into existence in 2001. It began as an industry affiliate program of the Center for the Study of Language and Information (CSLI), expanding the original outreach mission established earlier by Philosophy Professor John Perry. Communication Professor Byron Reeves, Director of CSLI, became the Founding Faculty Director of mediaX at Stanford University, and Mathematician and CSLI Research Scholar, Dr. Keith Devlin, became the first Executive Director. Under their leadership, mediaX broadened the linguistics focus of CSLI's affiliate program to include humanities, cognitive science, media, and computer science, with outreach to companies exploring human interaction with digital devices and socio-technical systems. Industry memberships grew from founding member OMRON to include companies in Japan and the US.

**H-STAR Institute is created with mediaX as its affiliate program**

In 2001, Roy Pea came from SRI International's Center for Technology in Learning to Stanford University as a Professor in the Graduate School of Education. He brought with him a portfolio of research and industry relationships and established the Stanford Center for Innovations in Learning (SCIL), which introduced to Stanford University a research agenda on technologies related to human learning sciences. The shared corporate interests of mediaX and SCIL were acknowledged as Byron Reeves and Roy Pea became Faculty Co-Directors of mediaX in 2002.

Incorporating educational technology into its research focus, mediaX expanded its intellectual scope, prompting Pea and Reeves to create the Human Sciences and Technologies Advanced Research (H-STAR) Institute as the academic umbrella for mediaX and SCIL. mediaX moved outside CSLI and into H-STAR. Focal interests for industry affiliates of mediaX were identified as education, entertainment, and commerce; and a competitive seed grant program was created to attract Stanford researchers to problems about the thoughtful human uses of information technologies that would be of interest to mediaX members.

In 2004, to allow faculty attention to be devoted to academic responsibilities, Keith Devlin accepted the role of Executive Director of what would be H-STAR, and Dr. Ellen Levy, Stanford PhD in Cognitive Psychology, became Executive Director of mediaX. During this period mediaX membership grew to include legacy and innovative media companies, primarily in the US and Japan, eager to understand the impact of the Internet on their content development and dissemination of products and services. Under the direction of Dr. Levy, engagements of mediaX programs with the Silicon Valley venture community intensified, and following her interests in new ventures, Dr. Levy joined the early crew of Linkedin.com.

**During its first decade H-STAR established a strong program of Visiting Scholars**

In the Visiting Scholars program, promising young investigators came for a year of affiliation with a Stanford faculty member to engage in intellectual pursuits and immerse themselves in the Stanford/Silicon Valley culture.

As foreseen by the I2ST Summit, collaboration technologies began to capture interest as one of the most compelling applications for high bandwidth Internet services. Chuck House, industry veteran from Hewlett Packard and Intel, came to Stanford in 2006 as Executive Director of mediaX, establishing an informal board, the mediaX Distinguished Visiting Scholars, as an advisory group. He also established the Summer Institute at Wallenberg Hall at Stanford, which provided annual workshops on mediaX research themes for the wider community. In 2007 Dr. Russell joined these initiatives as she became Associate Director of mediaX.

**mediaX weathers the recession of 2008 and expands globally**

The economic turndown of 2008 was felt especially hard in Silicon Valley, and resources for the academic pursuit of human science and information technology research diminished, driving research resources into companies' internal research and development programs that sought to retain and grow their media businesses and become more productive. Both Reeves and Pea expanded their research agendas with large interdisciplinary and inter-institutional research programs funded by federal agencies. In 2011, Reeves stepped aside as Co-Director, and Pea became the sole Faculty Director of H-STAR and mediaX.

*continued*

In the wake of Stanford's decision to streamline the administration of institutes, the administrative home of mediaX was moved to Stanford's Graduate School of Education (GSE), the home of Pea's faculty appointment. Responding to the intensified need for human talent for innovative media, Mr. House accepted the position of Chancellor of Cogswell College in 2011, at which time Dr. Russell became Executive Director of mediaX, with a renewed focus on the human dimensions of information technologies to improve personal identity, agency, and productivity. During Dr. Russell's tenure, mediaX membership expanded to include a wide range of industry sectors and experience, with a global footprint extending from the US to European countries, Brazil, New Zealand, China, Taiwan, and Morocco. Focal topics expanded to include Wellness. Participants in academia and industry shared an appetite to expand their thinking about the future and appreciated the sustainable advantage of collaborative discovery and innovation.

Throughout its work with Stanford researchers and corporate members, mediaX consistently created an environment designed to stimulate multidisciplinary inquiry on problems of interest to industry through strategic engagements between Stanford researchers and corporate members, typically investigating how the relationship between people, media and technology could be enhanced, augmented, and improved. Applications of Stanford research insights contributed to the increased effectiveness of digital technologies used by consumers and improved the productivity of people using digital technologies in the workplace.

**Additional programs for campus and industry interaction complemented the research agendas:**

- Regular conferences for the broader community
- Workshops for professionals and executives
- Themed conversations tailored for each member
- Personalized assistance for members wanting to establish specific research or consulting engagements with Stanford faculty members
- Seminar series to explore key questions, feature thought leaders and provide networking opportunities
- Video playback of event recordings, made available to the broader community. See: youtube.com/mediaxstanford
- The Global Innovation Leadership Workshop, to address leadership skills needed by mediaX industry liaisons wanting to use insights gained at Stanford to motivate change related to creativity, long-term thinking, ethics, and sustainability

**mediaX innovates using long-distance collaborative technologies**

As the COVID-19 pandemic forced "shelter-in-place" at Stanford and around the world, mediaX developed a virtual reality environment, mediaXploration, to host many of its large group activities. Seminars and conference events were adapted for online delivery, including the use of Zoom — an innovation that was first presented to mediaX in 2007 at a mediaX conference on the future of remote video communication. Each event included experimentation with new formats for presentation and discussion, including the introduction and use of several 3D virtual worlds.

**mediaX poses a legacy of "Questions for the Future"**

mediaX supported a focus on learning, gamification, remote communications, user-centered design, human-computer interaction, digital instruction, and — more recently — new terminologies to build a common vocabulary to describe human experiences in the digital world. Many Stanford labs and several university-wide programs have embraced the important questions raised by the community of mediaX members, including digital identity, personalization, potential and real reciprocity, and ethics for a human-centered mindset toward digital information technologies and socio-technical systems.

Questions surfaced in mediaX research initiatives, conferences, and seminars brought together research interests and insights for pragmatic opportunities. The objective of these interactions was to inspire new ways of thinking and develop insights for shared vision. While mediaX programs have already initiated inquiries on some of these questions and organizations around the world are tackling one or more of them, the challenges are still considered open.

Questions for the Future, *Appendix 4*, have been curated from fall 2021 interviews with over 50 mediaX faculty and industry affiliates. They have been enriched with results of mediaX research and programs over the past 21 years. Addressing these opportunities will significantly influence our future world.





## APPENDIX 2
### mediaX Research Themes

Twenty-one mediaX Research Themes were identified through conversations between mediaX academic and corporate colleagues. Those Research Themes are identified here, condensed into eighteen Themes.

Using resources from membership fees, project awards were made to 121 research teams, including researchers from 31 Departments and all 7 Stanford Schools (Business; Earth, Energy & Environmental Sciences; Education, Engineering, Humanities & Sciences; Law; Medicine). For many Projects, additional information is available on the mediaX website.

**2001 Social and Computing Sciences**
*What insights about people and technology are needed to better understand the cognitive, behavioral and visual aspects of information processing?*

**2002/2003 Sensing and Control**
*How can we better understand advances in the use of sensing and video technologies for education, health care and business?*

**2003 Learning and Training**
*How can we better understand advances in the digital technologies for education, collaboration and well-being?*

**2003 Video Processing, Cataloging, Retrieval, and Reuse**
*How can we better understand and develop automated systems to support video libraries?*

**2004 Social Interaction and Collaboration**
*How can we better understand and use interactive technology for social interaction and collaboration in productivity contexts?*

**2004 Mobile Devices in Collaboration**
*What insights about people and technology are needed to better understand mobile device form factors, applications and connectivity?*

**2004 Emotion Detection from Facial Expressions**
*How can we better detect and understand emotions from facial expressions captured in video — especially for use in driver monitoring for automotive safety?*

**2005 Online Media Content**
*What insights about people and technology are needed to better understand the technological, social and legal ramifications of the growing ability to personalize online content?*

**2006 Human-Machine Interaction and Sensing**
*What insights about people and technology are needed to better understand the use of sensors in human machine interaction?*

**2007 Virtual and Physical Realities**
*What insights about people and technology are needed to better understand the rise of the digital and virtual, and its intersection with real and physical worlds?*

**2011 Productivity of Knowledge Workers**
*What insights about people and technology are needed to develop metrics that can be used to measurably increase the productivity of knowledge workers?*

**2012 Future of Content**
*What new insights can inform the way individuals and organizations will consume media and the way such content will be curated for learning?*

**2012 Publish on Demand**
*What insights about people and technology are needed to ride the sea change of publish-on-demand into the future?*

**2015 Insights from Digital Learning**
*How can we better understand innovations in digital and blended learning technologies, and their implications for teaching, learning practices and pedagogy?*

**2015 Memory, Estates and Legacies**
*How might insights about people and information technologies inform the identification of the digital estate as a new metaphor for situating digital activities and recognizing the self in the digital medium?*

**2017 Smart Office Work Flows**
*What insights about people and technology are needed to better understand workflow, communication and productivity in sensor-rich environments?*

**2017 Potential, Performance, Productivity**
*What insights about people and technology are needed to better understand potential, performance and productivity in the workplace?*

**2019 Ontologies of the Human Learning Experience**
*How can we leverage ontological models to better understand the human learning experience?*

**2021 Taxonomies for Differentiation and Personalization**
(a collaboration with Stanford's Transforming Learning Accelerator)
*How might we develop a shared language representing the uniqueness of human experiences, to enable personalized learning opportunities?*

## APPENDIX 3
## Names and Titles

While the individuals listed here are named in quotes and pictures, many more members of the mediaX community are featured in the endnotes with references to their scholarly work and publications. Many thanks to all who contributed to the mediaX exploratory journey.

**Oyvind Berg**
*Harmonix*

**Michael Bernstein**
*Associate Professor of Computer Science and Member of Stanford's Human Computer Interaction Group*

**Chris Chafe**
*Duca Family Professor of Music, Director CCRMA*

**Adelaide Dawes**
*mediaX Program Manager*

**Keith Devlin**
*Emeritus Senior Research Scholar and Founding Executive Director of mediaX*

**Sean Follmer**
*Assistant Professor of Mechanical Engineering, and, by courtesy, of Computer Science*

**Maria Frank-Kinslow**
*Senior Consultant in Organizational Effectiveness at Slalom, former Program Manager of Prototypes in Workplace Effectiveness at Genentech, mediaX member liaison for Genentech and former doctoral student with Renate Fruchter*

**Jeffrey Hancock**
*Harry and Norman Chandler Professor of Communication and Founding Director of Stanford's Social Media Lab*

**Tatsuro Ichihara**
*Former Technology Executive at OMRON*

**Robert M. Kaplan**
*Co-moderator of mediaX Panel Discussions, Chair, Accelerating Behavioral Science Through Ontology Development and Use, adhoc committee of the National Academies of Sciences, Engineering and Medicine*

**Harlan Kennedy**
*Experience Design Strategy Consultant*

**Michal Kosinski**
*Associate Professor of Organizational Behavior at Stanford University Graduate School of Business*

**Aman Kumar**
*mediaX Distinguished Visiting Scholar*

**Amy Ladd**
*Elsbach-Richards Professor of Surgery and Professor, By Courtesy, of Medicine (Immunology & Rheumatology) and of Surgery (Plastic and Reconstructive Surgery)*

**Larry Leifer**
*Professor of Mechanical Engineering and Director, Hasso Plattner Design Thinking Research Program*

**Hogne Moe**
*Kunstnerisk leder i Prøysenhuset*

**Roberto Morales**
*Composer and Researcher*

**Neema Moraveji**
*Founder of SPIRE, Leader of the Calming Technology Lab at Stanford University, and former doctoral student with Roy Pea*

**Cliff Nass**
*The late Professor of Communication and (Courtesy) of Computer Science, Education, Law, and Sociology and Director of the Communication between Humans and Interactive Media (CHiMe) Lab*

**Bill Newsome**
*Harman Family Provostial Professor of Neurobiology at the Stanford University School of Medicine, and the Vincent V.C. Woo Director of the Wu Tsai Neurosciences Institute*

**Peter Norvig**
*mediaX Distinguished Visiting Scholar and Director of Research, Google*

**Allison Okamura**
*Professor of Mechanical Engineering and (Courtesy) Computer Science*

**Roy Pea**
*David Jacks Professor of Education & Learning Sciences at Stanford Graduate School of Education and (Courtesy) of Computer Science, and Faculty Director of mediaX, Co-founder and Director of H-STAR Institute*

**Byron Reeves**
*Paul C. Edwards Professor of Communication and (Courtesy) of Education and Senior Fellow at Stanford's Precourt Institute for Energy, Founder of mediaX, and Co-founder and Emeritus Director of H-STAR Institute*

**Jessica Rose**
*Professor of Orthopaedic Surgery*

**Martha G. Russell**
*Executive Director, mediaX at Stanford University and Senior Research Scholar, H-STAR Institute*

**Paul Saffo**
*mediaX Distinguished Visiting Scholar, Adjunct Professor, Mechanical Engineering-Design*



**Manish Saggar**
*Assistant Professor (Research) of Psychiatry and Behavioral Sciences (Interdisciplinary Brain Science Research)*

**Jeffrey Schnapp**
*Carl A. Pescosolido Professor in Romance Languages and Literature and Founder/Faculty Director metaLab at Harvard University, former Co-director of Stanford Humanities Lab*

**John Seely Brown**
*Former Chief Scientist of Xerox Corporation and Director of Palo Alto Research Center (PARC)*

**Michael Shanks**
*Professor of Classics, Program Leader for Stanford's Foresight and Design Innovation Group*

**Hiroshi Tomita**
*mediaX Distinguished Visiting Scholar, Representative of the National Information Institute of Japan and former President of mediaX member Konica Minolta USA*

**Weina Wang**
*CEO of mediaX member Guangzhou QiTian Technology Company*

**Jason Wilmot**
*mediaX Director of Communications and Events*

**Elizabeth Wilsey**
*mediaX Director of Community Relations*

**Terry Winograd**
*Professor of Computer Science, Emeritus*

## APPENDIX 4
## Questions for the Future

At the turn of the 21st Century, humanizing insights regarding information technologies inspired developments in the social intelligence of interactive machines. Just over twenty years after mediaX began its catalytic activities, as academic and industry researchers intensified their ongoing exploration of social machines, they leveraged a new generation of tools to explore the human mind and human and artificial intelligences working together.

The read-only Internet of Web 1.0 was followed by web 2.0's interactivity that allowed users to produce and share content globally. The semantic Web 3.0 introduced technology that permitted domain-specific ontologies to reason about data accessed through cloud services, rather than merely matching keywords, letting apps communicate with each other. Web 4.0 has promised mechanisms for people and machines to communicate with each other, using middleware with read-write-execution-concurrency that may function as an operating system, sometimes referred to as Industry 4.0.

In reference to the expansive opportunities for social impact that may arise from an era of artificial intelligence, perhaps to be designated as Web 5.0, mediaX asks how can we jointly imagine and pursue the questions needed to achieve Society 5.0,[1] which has been framed as a purposeful effort to create a new social contract and new economic models with full incorporation of the technological innovations of the 4$^{th}$ Industrial revolution.

The following Questions for the Future have been inspired by mediaX faculty and industry affiliates. They have been enriched with the results of mediaX research and programs over the past 21 years. While mediaX programs have already initiated inquiries on some of these questions, and organizations around the world are tackling one or more of them, the challenges are still considered open. Concerted collaboration is needed to develop insights and implement solutions. These questions, and others that derive from them, are intended as resources to be shared widely, as the next generation of opportunities for our future comes into view.

1 ***Curiosity to Drive Purpose*** — How might socio-technical systems be leveraged to cultivate a sense of curiosity, agency, and creativity, facilitate lifelong learning, and create pathways for future personal growth opportunities?

2 ***Insights for Dignity and Wellbeing*** — How might socio-technical systems anticipate and build in a moral commitment to the human ethical values of diversity, equity, inclusion, and justice for mutually beneficial implementation — for both individual and collective wellbeing?

1 Society 5.0. Japan Council for Science, Technology and Innovation. (2017). Society 5.0. https://www8.cao.go.jp/cstp/english/society5_0/index.html

3 ***Humanized Workflows*** — How might human science insights guide the development and deployment of technologies to enable work to be done more pleasantly and ultimately with more human-to-human connection and wellness?

4 ***Communication Across Boundaries*** — How might researchers inform the co-evolution of technology-media-human relationships in ways that assist people in building bridges and facilitating communication between generations and across boundaries of expertise and experiences?

5 ***Stories for Sustainability and Growth*** — In what ways can media, media platforms and storytelling be leveraged to develop new understandings of the physical world and how humans interact with it, to inform and motivate actions towards a more sustainable future?

6 ***Trust-Enhancing Technologies*** — How might developments in information technologies facilitate interpersonal dynamics and interactions to foster and renew trusting and mutually beneficial relationships between people, between people and systems, and among systems?

7 ***Protected and Secure Identity*** — How might the emerging technology of ubiquitous computing, context awareness and embodiment be channeled to improve lives while protecting privacy and personal identity?

8 ***Empowerment Through Institutions*** — How might corporations, universities and organizations develop structures, technologies, and decision pathways to productively empower people to make progress towards resolving the societal challenges of today and tomorrow?

9 ***Meaningful University-Industry Collaboration*** — How might university-industry collaborations provide leadership for intellectual risk-taking, research design, and knowledge creation?

***What questions are driving your future?***

*There is so much more we can do together than any of us can do alone.*

mediaX
at Stanford University

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