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CHI 2019

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The 2019 ACM CHI Conference on Human Factors in Computing (https://chi2019.acm.org/) was themed around "weaving the threads of CHI. . .-people from different disciplines, cultures, sectors, communities, backgrounds. . .weaving together into one community, with the common purpose of technology that works for people and society."

The conference took place on May 4–9 in Glasgow, U.K. This year's CHI was the biggest to date, with over 3800 participants from 68 countries. It included workshops, papers, demos, and presentations that touched on new technologies and societal themes, which will impact current and emerging trends in pervasive and ubiquitous computing. We highlight several of these trends in this paper, including Internet of Things (IoT) in smarthomes, privacy and security, AR/VR, health, and new interaction modalities. We also focus on several cross-cutting areas, including an increasing focus on understanding and supporting varied populations and platforms.

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SENSING AND IMPLICATIONS OF IOT IN SMART HOMES

Several papers focused on IoT-enabled devices, particularly in "smart home" contexts. Themes included approaches for better sensing objects and activities within the home (using smart devices) as well as looking at the interpersonal, security, and privacy implications of such devices from the perspective of end users.

Sensing

Many IoT devices have limited awareness of the context around them (e.g., recognizing who, or what other objects, are nearby). Laput and Harrison proposed and demonstrated SurfaceSight, an approach that enriches IoT experiences with rich touch and object sensing by incorporating LIDAR (Light Detection and Ranging) into the

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base of IoT devices, providing an expansive and *ad hoc* plane of sensing above surfaces on which the devices sit.

Laput provides a live demo of how object recognition and tracking next to a smart speaker could be used to help people with cooking activities and instructions.

Other papers on sensing in the home included Hsu *et al.'s* presentation of Marko, a system for behavioral sensing in homes that used passive radio frequency signals to identify people, behaviors, and activities. They described an algorithm for identifying users in the home, and an automatic labeling approach for bootstrapping the system in new settings. This approach can be used to help researchers more unobtrusively gather data about activities and interactions in smart home environments. Tan *et al.* also proposed a method for multiuser tracking and activity recognition that leveraged existing commodity Wi-Fi devices and did not require additional dedicated sensors. They described how this system could be used to simultaneously track multiple people doing different activities (in close proximity) within a living room environment.

Social Dynamics and Considerations for IoT Adoption and Multiuser Control

In addition to novel sensing approaches for IoT devices, several papers also took a qualitative approach to understanding social and privacy-related implications of families adopting these devices in the home. Emaini *et al.* interviewed consumers about their expectations for privacy and security features of smart home devices prior to purchasing them. They found that many users, unprompted, expressed both privacy and security concerns and had a desire for better labeling or third-party rating of such devices. Yao *et al.* also explored ways of enhancing IoT technologies for privacy using a co-design approach with a diverse set of participants.

Finally, Geeng and Roesner explored interpersonal privacy concerns and access controls by examining tensions between household members around device selection and installation, usage, and information sharing. These insights provide guidance for designing devices to support multiuser interaction, access control, and permission setting, particularly for people who are not the main owners or administrators.

PRIVACY and SECURITY

Privacy and security research in HCI has been increasingly prevalent over the last few years. This trend continued at CHI 2019, with work covering an ever-expanding range of areas and topics, from populations with specific needs to security and privacy for ubiquitous devices.

Populations With Specific Needs

At this year's CHI, we observed a focus on the security and privacy needs of populations that may face specific challenges. Nicholson *et al.,* for example, focused on cybersecurity information seeking in older adults. They found that this group struggled with security language issues beyond those previously found in general populations. Because of these challenges, one of this group's main sources for cybersecurity was the media and social resources, such as family. At the other end of the age spectrum, Zhao *et al.* researched children's perceptions of online privacy risks. They were surprised to find that the children studied demonstrated a good understanding of some online security concepts, such as information oversharing or keeping real identities a secret. However, some more technical concepts, such as tracking, tended to be beyond the children's comprehension.

Several papers also focused on financial status and privacy and security. For instance,

Sleeper *et al.* found that challenges associated with financial insecurity can correspond to online privacy and security practices and behaviors. Similarly, Ahmed *et al.* provided insights into how to design for privacy in shared mobile phone use scenarios, a common behavior in families that cannot afford individual devices.

Off the Desktop

Privacy and security needs have long moved beyond desktops (and mobile phones). We may interact with a plethora of electronic devices that potentially store, collect, and use personal information. Another major theme at CHI was privacy and security across different interaction paradigms.

Mayer *et al.* presented work on shoulder-surfing resistant password entry for gamepads. Gaming is increasingly a social experience, making it increasingly likely that users will need to authenticate with such systems in the vicinity of others. This paper provided insights into the need to rethink existing authentication approaches for such systems.

With the increasing prevalence of intelligent assistants, security and privacy for interactions with these modalities was also a topic of interest. Kwak *et al.* presented a secure system that used voice biometrics and other security measures to minimize the risk of unintended interactions with smart home devices, for example, orders being placed in someone else's name. Similarly, Marques *et al.* highlighted the need to carefully consider assumptions around private versus public spaces. They showed that unauthorized access to smartphones is a significant risk, even (and potentially especially) in situations that one might consider safe, such as in the home.

RISE OF AR/VR

The most popular keyword at CHI 2019 was AR/VR, with more than 90 papers. This interest in AR/VR can be explained by the proliferation of new devices and the increased availability of AR/VR on common smartphone platforms. Key topics this year included design and evaluation, accessibility and health, sensing and sensation, and collaboration.

Understanding AR/VR Design

Several papers focused on guiding AR/VR designers. Speicher *et al.* identified six working definitions of mixed reality with perceived differences for AR, and developed a conceptual framework to better characterize AR/VR application design. Hirzle *et al.* presented a design space for gaze interaction, covering human depth perception, and technical requirements to guide interaction design for VR headsets. Nebeling and Madier studied AR/VR templates used by design practitioners and developed 360proto to rapidly create AR/VR apps from paper sketches.

Understanding users' feelings toward AR/VR objects and increasing realism were major goals this year. Poretski *et al.* found that participants experiencing a virtual dog over three weeks in AR developed stronger feelings of relatedness and psychological ownership than the participants with the dog in a fully virtual environment. Lee *et al.* presented TORC (Touch Rigid Controller), a hand-held controller that allows users to feel virtual objects' texture and compliance via touch. Tsai *et al.* developed the ElasticVR band equipped with servo motors and mechanical brakes to enhance VR realism based on stepwise resistive force and impact levels applied to a user's hand. Samad *et al.* developed a method to simulate weight of virtual objects by adjusting the rendered position of users' hands to alter their displayed movements and make the objects appear lighter/heavier.

Making AR/VR for All

There was also a focus on making AR/VR accessible to broader audiences. Zhao *et al.* presented tools in SeeinVR to make VR more accessible to users with low vision based on audio and visual enhancements. Visually induced VR sickness is an issue causing lower VR adoption, especially among women. A study by Zayer *et al.* experimented with increasingly restricted field-of-view designs for spatial navigation to effectively mitigate VR sickness in both sexes.

To support designers, Kwan and Fu's Mobi3DSketch explored three-dimensional mid-air sketching techniques with smartphones; Wacker *et al.*'s ARPen expanded this to bi-manual phone and pen interaction. Subramonyam *et al.* developed affinity lens, helping users find notes, cluster

information, and summarize insights from affinity diagrams. For information workers, Li *et al.* explored ways to merge physical and digital paper documents. They designed the HoloDoc system to enrich the interaction via an augmented interaction layer using an AR headset like the HoloLens.

Using AR/VR Everywhere

In the next few years, we can expect AR/VR to be used increasingly in user evaluations and in many new contexts. Voit *et al.* presented a study comparing AR, VR, online, lab, and *in situ* methods to evaluate early-stage designs of smart artifacts. They showed that, in most cases, method, such as the novelty effect with AR biased participants, did impact study results.

PlaneVR provided an example of VR in the field, exploring the social acceptability of VR for in-flight entertainment. A new prototype with features to smoothen the transition between the virtual and real worlds, supporting user interruption and spectator experience, showed higher social acceptability.

HEALTH AND HCI

CHI 2019 offered many opportunities for those interested in health. As in previous years, health research emphasized the interplay between technology, design, and information processing to support individuals, groups, and communities in understanding and managing physical and mental health and wellbeing. This year featured an increased focus on the socio-technical aspects in the health domain, the representation of lived experiences in the design of health technologies, and increasing attention to the health needs of vulnerable and underserved populations.

From Patient Support to AR-Supported Medical Training

CHI researchers shared studies of clinical interactions among patients and providers. These included opportunities for supporting patients and healthcare providers in various clinical settings. Berry *et al.* emphasized the need for representing personal values of patients with chronic conditions in their health management and communication with their providers. Haldar *et al.* discussed shortcomings of patient portals and offered design opportunities to prioritize the needs of patients and caregivers. Gui and Chen shared insights on the work patients, especially families, undergo when facing breakdowns in the current healthcare infrastructure and how they try to overcome barriers to receive necessary services.

Researchers also presented work to support healthcare professionals. This included supporting critical decision making in the clinical context through the use of unobtrusive AI, and how complex, large-scale health information systems, such as Patient Accessible Electronic Health Records, need to be designed to address conflicting needs of different stakeholders. Other contributions focused on the individual work of healthcare providers, offering tablet-based solutions to support in-hospital emergency teams and investigating the effects of telemanipulation in robotic assisted surgery through a critical analysis of the dynamics within surgical teams. CHI-researchers also investigated how to support medical training through technology, offering design recommendations for the use of gesturing tools in surgical training and using augmented reality for wound care training.

Diverse and Vulnerable Populations in Health Research

This year's research also touched on topics related to diverse and vulnerable populations.

In particular, researchers sought to support communities of low socio-economic status in different aspects of health. Harrington *et al.* highlighted the need to acknowledge systematic inequalities and sociocultural aspects while interacting with underserved groups in health. Saksono *et al.* provided recommendations for supporting families in low SES neighborhoods in social reflection on their physical activity data, and Dillahunt *et al.* examined grocery delivery services for increasing access to healthy and affordable food in transportation-scarce and low-resource areas.

Researchers further presented solutions for supporting the health needs of children of diverse backgrounds. Kyfonidis *et al.* proposed an interactive tool for children with Type 1 diabetes that seeks to prepare them for transition

to health self-management. Antle *et al.* presented a neurofeedback app that can help children in lower socioeconomic status schools improve their ability to self-regulate anxiety. Antle further encouraged the CHI community to critically evaluate how technology that quantifies children's experiences can affect a child's identity formation, understanding of agency, and acknowledgment of epistemic authority. Marcu *et al.* drew attention to the barriers that parents and schools face in collaboratively identifying problem behaviors and providing appropriate interventions.

Many health technologies are designed to provide support and diagnosis but require additional consideration when applied to sensitive conditions. Singh *et al.* discussed how online HIV resources fail to provide emotionally adequate support for individuals seeking potentially anxiety provoking information. Furthermore, while HIV status disclosure can increase awareness and decrease feelings of isolation, Warnet *et al.* argued that designers need to consider how individuals manage existing tensions between health stigma and privacy. To ensure adequate support for women affected by perinatal depression, Doherty *et al.* proposed the use of mobile devices for mental health screenings in pregnant women. Tutia *et al.* drew attention to the elderly female population by sharing design considerations for intimate technologies in menopause.

Designing for Lived Experiences in Health

Researchers also sought to better represent lived experiences in the design of health technologies. Snyder *et al.* presented sense-making challenges related to the representation and interpretation of personal data from individuals with bipolar disorders, offering benefits, risks, and limitations of participatory approaches for designing personal data visualizations accounting for their lived experiences. Feuston *et al.* challenged researchers and designers to reflect on how the design of technological solutions for managing mental illness in everyday life can also inadvertently perpetuate and instantiate stigma.

Other work focused on the lived experiences of self-tracking. Raj *et al.* introduced contextual frames as sensitizing concepts in the design of self-management tools in diabetes management, arguing that an individual's support needs change depending on context. Desai *et al.* examined the role of predictions—forecasting blood glucose—in helping people with diabetes make food choices. Schneider *et al.* emphasized the uncertainty associated with predictions by examining the behavioral and emotional effects of different design choices for communicating fertility in a self-tracking application.

Researchers emphasized lived experiences of individuals with neurological diseases and their caregivers. Hodge *et al.* called for a representation of the family as a whole in the design process of technology supporting the lived experience around accepting change associated with dementia, while Foley *et al.* proposed design considerations that promote collaboration, agency, and social identity in advanced dementia care.

NEW INTERACTION MODALITIES

CHI has always featured novel interaction techniques and modalities. While desktop systems are becoming of less interest to researchers, interactions involving (multiple) handheld devices are of steady interest. In addition, researchers continue to investigate skin interaction techniques, where the skin is deformed or muscles are electrically stimulated.

Mobile Interactions

While finger input is the most common input modality on interactive devices, "ear input" has not been broadly explored yet. With EarTouch, Wang *et al.* presented a one-handed interaction technique that enabled visually impaired users to interact with smartphones using their ears, using available smartphone sensing technology. This way users can listen to the speech output even in noisy environments without the need for headphones.

While this worked using off-the-shelf hardware, small additions to devices could change interaction capabilities entirely: Zhang *et al.* presented Posture-Aware Pen+Touch Interaction for work on tablets. User interface elements could adapt to the grip of a tablet, the angle of the hand resting on, or even hovering over the screen, recognizing which hand was holding the tablet as well as reacting to props placed on the screen. This paper shows how simple

hardware additions to a device can enable more effective mobile and stationary use.

Multidevice Interaction

Horak *et al.* presented Vistribute, a framework for an automatic distribution of interactive visualizations across multiple different devices, such as laptop, tablet, and smartphone. The authors are able to infer which visualization is best suited for which device based on the set of devices and visualizations under consideration. Brudy *et al.* provide a "Cross-Device Taxonomy" that presents an analysis of over 700 papers spanning the past 30 years in the cross-device computing domain. The authors not only provide a survey of interactions involving multiple devices, but also aimed to stimulate future cross-device research by outlining opportunities and challenges in their research agenda.

On, Through, and Under the Skin

Last year at CHI, on-skin devices were one of the more novel interaction techniques. CHI'19 saw a continuation of this trend. For example, Alhuda Hamdan *et al.* presented Springlets, flexible, nonvibrating shape-changing springs that are attached as stickers to the skin. Springlets create sensations of pinching, directional stretching, pressing, pulling, dragging, and expanding of the skin.

Springlets are small stickers that can pinch or pull a user's skin.

In a similar context, electrical muscle stimulation (EMS) has been used in various contexts in HCI for over ten years. EMS makes muscles move by using painless electric stimuli administered through noninvasive electrodes stuck to the skin. However, being moved by an external force still feels strange and leaves users feeling that they have lost agency over their actions. Kasahara *et al.* presented work on Preemptive Action, where they explored how delaying the onset of an electric stimulus to a muscle allows the user to feel in control while speeding up reaction time, for example, when trying to catch a pen in free fall or when taking a high-speed photograph.

Going deeper, Komkaite *et al.,* analyzed YouTube videos to understand how "insertables," nonsurgical devices that are implanted as the result of personal choice, such as RFID (radio-frequency identification) or NFC (near-field communication) chips, or magnets are used and to learn about challenges that hinder widespread adoption. The authors observed that most of the people decide to get such an implant for access and identification or for playfulness and creative purposes. They note that several obstacles hinder usefulness: lack of support and surrounding technology, lack of ease-of-use and benefit (e.g., the interaction takes longer than with traditional techniques), and limited functionality.

CONCLUSION

As summarized in this paper, CHI 2019 highlighted a range of topics to help guide the research, design, and practice communities. The CHI 2020 will take place on April 25-30 in Honolulu, HI, USA (https://chi2020.acm.org/). We'd love to see you there!

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