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Twelve Agendas on Interacting with Information: A Human-Engaged Computing Perspective

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Abstract: During the coronavirus global pandemic crisis, we have received information from authentic and inauthentic sources. Fake news, continuous rumors, and prejudiced opinions from digital platforms and social media have the capacity to disrupt social harmony, to stall personal development, and to undermine trust on all levels of human interaction. Despite the wide plurality of perspectives, the diversity of contents, the variety of voices, and the many often-conflicting reasons for publishing, our interactions with information on digital devices are progressively shaping such situations and affecting decisions on all levels. We look at the limitations of existing designs and guidelines in the current paradigm, and we ask to what extent researchers and developers can focus and contribute, through their innovations, to the reduction of uncertainty and cases of misdirection, how they can mitigate tensions between information and humans, and how they can contribute to the maintenance and enhancement of worthy human values. Human-engaged computing (HEC) calls for innate user capacities to be enhanced rather than displaced by digital technologies so that the human factor in interactions is fully exploited and truly efficient symbiotic relationships between humans and devices can be achieved. Under the framework of HEC, we propose 12 research agendas from the theoretical, principled, and practical aspects, in order to develop future synergized interactions between humans and information. The present crisis presents us with a good opportunity to reflect on the need to empower humans in relation to the tools they use and to consider the next paradigm shift for designing information interaction.

Keywords: information interaction, human-engaged computing, human–computer interaction

1 Introduction

Covid-19 has significantly impacted the lives of every person on the planet. The world is in pause mode, and people are ordered to stay at home in order to save lives by slowing the spread of the deadly virus. Fortunately, with the fast development of computing technologies and digital services, along with the rapid construction of information infrastructures, people are able to source information from television media, radio broadcasts, social media, and various Internet avenues. Technologies are playing a central, critical, and arguably indispensable role in our daily lives during the pandemic. But the new efficiency afforded by new technologies is a two-edged sword, and each edge is capable of healing or harming human relationships and enterprises. For example, our newly experienced potential for global public supervision in the interests of human health and well-being (World Health Organization, 2020; Lee, 2020) also runs the risk of undermining some freedoms either surreptitiously or via legislation. On the other hand, efficient private and personal access to information, accessible publishing, and new modes of social interaction open the door to the dissemination of fake news, to trolling, and to prejudiced opinions that overwhelm and confuse people more efficiently and effectively than ever before (Rainie, Smith, & Duggan, 2013; Eyal, 2014; Phillips, 2015).

There is nothing in the nature of information that renders information *per se* immune to corruption, misperception, and/or distrust. Restated, our hope and trust in information *per se* are naïve, and it is now evident that the addition of more information cannot resolve the serious “trust deficit” that has emerged with regard to all information and information itself. This should not surprise us because information has always been subject to powers and influences of many types, the main difference now being that the good and the bad, the

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true and the false, the surreptitious and the transparent are transmitted, received, and swallowed globally, and at the speed of light... and from all levels of society and authority.

The challenge of now is not so much about access to information, as people are already overly exposed to information from ubiquitous digital sources and formats, but regarding how to identify and resist the increasing flood of manipulative disinformation (Tang, 2018). This challenge places a burden on researchers to help users synthesize, assess, deselect, and make use of information (Tang, Mehra, Du & Zhao, 2019) and to make wise and discerning decisions. However, although traditional technical actions, e.g., detection, may help enhance the quality of information, they are still limited because they can hardly enhance users' information literacy *per se*. Responding to this situation, how can we, as researchers, not only help ensure that people are secure and satisfied with the information they find via digital media, and that barriers hindering people from accessing essential information for the public can be overcome, but also help people distinguish useful and trustworthy information from rumors, fake news, and fraudulent communications and thereby promote the health and development of their minds and characters in an effort to strengthen their defenses against the negative impacts of deficient media contents and technologies?

This paper aims to raise awareness of how human-computer interaction (HCI) and information retrieval (IR) researchers can help develop and enhance the user's ability to distinguish between inauthentic and authentic information during and after the current crisis. From the recently developed perspective of human-engaged computing (HEC), the next challenge for researchers and practitioners is to facilitate the activation, engagement, and progressive enhancement of the inner capacities of users and thus enable them to distinguish truly edifying information from surrounding noise. We want to encourage researchers to seek methods and insights that maximize the positive assistive aspects of technology and minimize negative dehumanizing factors while achieving synergized interactions (Ren, 2016; Ren, Silpasuwanchai & Cahill, 2019) between humans and technologies with human outcomes as the priority. Informed design decisions regarding the well-being of those who use technologies can only be made when designers fully account for the potential of their technologies not only to strengthen, but also to quantitatively and qualitatively diminish, innate human capacities and potentials.

This paper seeks to accomplish the following: (1) raise the awareness of potential dilemmas for future information interaction development; (2) offer a new perspective to rethink the further development of information interaction; (3) propose research agendas for researchers by considering the general field from three aspects - theoretical, principled, and practical, calling for the exploration of ways to enhance inner human capacities by means of digital technologies. Our current area of specific interest is to find potential solutions that help users identify authentic contents and then evaluate and use them according to their personal and informed integrity. Specifically, we promote constructive understanding of the following research question:

Can we ensure our interaction design processes consciously engage and enhance inner human capacities (e.g., wisdom, intuitive skills, and personal integrity) to help users face future challenges with a sense of personal responsibility, rather than merely developing conventional technologies for functional needs or potentially diminishing their skills and responsibilities through the use of our technologies?

We expect that the HEC perspective can set a clear goal for researchers and practitioners about how to promote innovations to specifically and progressively improve innate human capacities; on the other hand, researchers are capable of recognizing this significance to explore more principles and methods to fulfill and extend these agendas as important information interaction case studies for further HEC practices and applications. We believe that such effects will integrate to contribute toward the next paradigm shift in the field of information science.

2 Related Work

Since we specifically and consciously seek to facilitate wisdom and community compassion rather than mere knowledge as data/information, information is defined, in this paper, as the macroscopic digital content that general users can interact with via computing technologies and online media, which differs from the analytical microscopic data used in information science. We also use the terms "information" and "digital content" interchangeably in this paper. In the following sections, we will state how the general design paradigms of information interaction shift and explain the perspective of HEC values.

2.1 Information Interaction

Information interaction has been one of the most important topics in the field of IR and information science. IR is “inherently interactive” (Savage-Knepshild & Belkin, 1999). Brooks, Daniels, and Belkin (1986) analyzed existing research on IR and proposed that it is critical to understand human-to-human information interaction for the purpose of designing an intelligent information system interface. According to Toms (2002), information interaction is “the process that people use in interacting with the content of an information system”.

Under the umbrella of information interaction, issues such as methods that motivate information interaction (Belkin et al., 2003), models/techniques/systems/apps supporting information interaction design (Yuan & Belkin, 2010, 2014; Yuan, Sa, Begany, & Yang, 2015; Sa & Yuan, 2019), and factors affecting user perception of information interaction design (Begany, Sa, & Yuan, 2016) or information-seeking behavior (El-Maamiry, 2020) have been widely researched. In a Wizard of Oz experiment comparing a spoken language search interface through voice and touch gesture input with a textual input search interface, Begany, Sa, and Yuan (2016) analyzed the transcribed exit interview data and found that such factors as user familiarity with the system, ease-of-use of the system, speed of the system, as well as trust, comfort level, fun factor, and novelty, affected user perception.

During the coronavirus pandemic, researchers from HCI and IR have shared their perspectives according to their expertise to provide various kinds of technical agendas including the following: (1) how data science can facilitate more efficient and timely responses regarding potential cases and crises and develop a reliable and trustworthy information environment (Xie et al., 2020); and (2) how to help the most vulnerable generation, the elderly, get digital information promptly, e.g., by supporting service organizations that cater to seniors (Fingerman & Xie, 2020). There is now a pressing need for researchers and practitioners to rethink methods of information interaction that can help deal with emergencies.

The above work informed that paradigms of information interaction are progressively shaped by the corresponding requirements and concerns of certain periods and states of society in their respective times (Harrison, Tatar, & Sengers, 2007). Defined as “the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community... employed as models... for the solution of the remaining puzzles of normal science” (Kuhn, 1970), the conception of paradigm is regarded as a general perspective for planning problem-

solving methods. The first significant paradigm shift of designing information happened in the 1980s, extending from the system-oriented to a user-centered focus (Dervin & Ninan, 1986). Using the traditional perspective of the system-oriented paradigm, researchers focused on developing input and output methods of IR by evaluating the performance of information systems (e.g., speed, accuracy, and bandwidth), to ensure that essential information can be retrieved effectively and efficiently. With the ensuing user-centered paradigm, researchers sought to improve user experience and user satisfaction while users interact with information; they extended their considerations to noninstrumental factors such as emotional and other subjective experiential indicators (Hassenzahl & Tractinsky, 2006), e.g., satisfaction, pleasure, and trustworthiness. Meanwhile, some new paradigms proposed an ecological framework that connects people, information, behaviors, technology, and context (Nardi & O’Day, 1999; Marchionini, 2008; Fidel, 2012). Nevertheless, at present, as Tang, Mehra, Du and Zhao (2019) commented: “they still tend to be centered on information seeking... and remain questionable whether the transition to an ecological perspective of human information interaction has successfully taken place”. Pushed by the two main emerging technological trends of mobile computing and powerful artificial intelligence (AI) respectively, richer input and output methods of information interaction can be designed based on natural language processing (NLP) and computer vision (CV) on various mobile modalities. However, without concrete definitions of experience and guidelines for technological development, past paradigms gradually lost track of their goals and became vague to designers, and the developments potentially devolved from aiding human needs to satisfying human desires (Bardzell, J. & Bardzell, S., 2015). We also argue that little work has actually addressed the need or development of a philosophical basis that would be capable of generating a reasoned, coherent, and adaptable way forward while maintaining human responsibilities and human interests at the center of such developments (Ren, Silpasuwanchai & Cahill, 2019). A general goal and an inclusive philosophical outlook are needed for future agendas and developments.

2.2 HEC Framework

By contrast with approaches that develop specific techniques to solve problems, the HEC perspective aims to address such information issues as how technologies themselves can facilitate and develop the user’s innate

skills so that they can more confidently deal with the impacts and risks associated with torrents of information that are so diverse in subject, quality, and worthiness.

The HEC framework was proposed (Ren, 2016; Ren, Silpasuwanchai, & Cahill, 2019) and discussed (Farooq, Grudin, Shneiderman, Maes, & Ren, 2017; Niksirat, Sarcar, Sun, Law, Clemmensen, Bardzell, & Ren, 2018) recently. HEC aims to achieve synergized interactions between human capacities and technological capabilities toward high-level wisdom that can enhance human survival probability and help achieve our progressively unfolding potential as human beings (Figure 1). In general, the differences between HEC and conventional HCI are as follows: (1) HEC is positioned as a conception, theory, and value to offer a framework, components, and related principles for guiding researchers and future practices, while HCI is a field of designing computing systems and interactions by understanding wider factors; (2) HEC focuses on developing human inner capacities via technologies and aims to enhance both sides finally, while HCI mainly focuses on exploring factors of systems, users, experience for designing interface, and interactions, without focusing on improving human inner capacities; (3) HEC seeks to evaluate technologies by facilitating human engagement, human enhancement, or human potential, while HCI tends to evaluate technologies by measuring interaction performance, e.g., efficiency and speed.

The HEC framework requires designers to mindfully strive for “synergized interaction” that sustains both humans and computers in *the right balance*, a relationship that consciously honors human investment and human development over device novelty. Restated, it requires designers to realize that all HEC practices and effects aim at developing human ability beyond conventional HCI functional usage. Following the key concepts of HEC, related perspectives have been proposed in, e.g., human-engaged AI (HEAI) (Ma, 2018).

HEC calls for (1) the attainment of engaged humans whose capacities are fully developed, activated, appropriately applied, and progressively enhanced, (2) the development of engaging computers whose role is to enhance and complement human capacities in their significant contexts, and (3) to facilitate interaction relationships according to worthy human priorities. In the HEC theory, human engagement refers to a state of consciousness where human capacities are fully developed, engaged, and exploited, regardless of what tasks or activities are encountered in the moment, by contrast with microfocus on details such as time-on-task, clicks-per-page, attractiveness, positive effects,

or task-dependence (Ren, Silpasuwanchai & Cahill, 2019; Goethe, Niksirat, Hirschy-Douglas, Sun, Law & Ren, 2019). The idea is that all functions, techniques, tasks, and microtasks find optimal integrity, harmony, and efficiency through the mindful engagement of the attentive user. To practice HEC, researchers also need to consciously and deliberately develop their own inner human capacities of awareness and flow, through mindful attention to interactive tasks (Niksirat, Silpasuwanchai, Mohamed Hussien Ahmed, Cheng, & Ren, 2017; Niksirat, Silpasuwanchai, Cheng & Ren, 2019), through aesthetics (Wang, Sarcar, Kurosu, Bardzell, Oulasvirta, Miniukovich & Ren, 2018), trust, focus, sensitivity, and empathy, all of which HEC considers to form the basis for profitable and sustainable human expression in outer performance. HEC considers that the facilitation of deep user engagement with technologies is significantly affected by the corresponding engaging qualities of technologies, which are, in turn, dependent on the researcher/developer’s own capacity to fully engage in the development process. In other words, the qualities of user engagement that produce synergism do not begin at the point of the user’s application of the device but with the habitual engagement practice of the researcher/developers themselves and, thus, also, with those who mentor them. Harmonious engagement and its consequent efficiencies cannot be optimized in the end user if the tools adopted do not bear the qualities of researchers/developers who are mindfully engaged. Engagement is not something experts can impose on their “subjects”; it is organic throughout and, thus, it is an expression of the interdependence of all things.

Thus, to achieve human potentials and well-being, it is necessary to distinguish human capacities from device capabilities, to manifest and develop the respective values of both, to integrate them according to required human values, and to remain pertinent to the ever-changing conditions and demands of humanity.

3 Twelve Agendas

Addressing potential media information issues such as rumors, fake news, trolling, and addictions from the HEC perspective, we seek a path that understands, activates, engages, and progressively enhances inner human capacities through the development of engaging computing technologies and interactions, rather than developing a specific technical solution for tool use only. Toward this goal and based on the theory of HEC,

we propose 12 agendas according to three aspects: the theoretical, principled, and practical aspects (Figure 2).

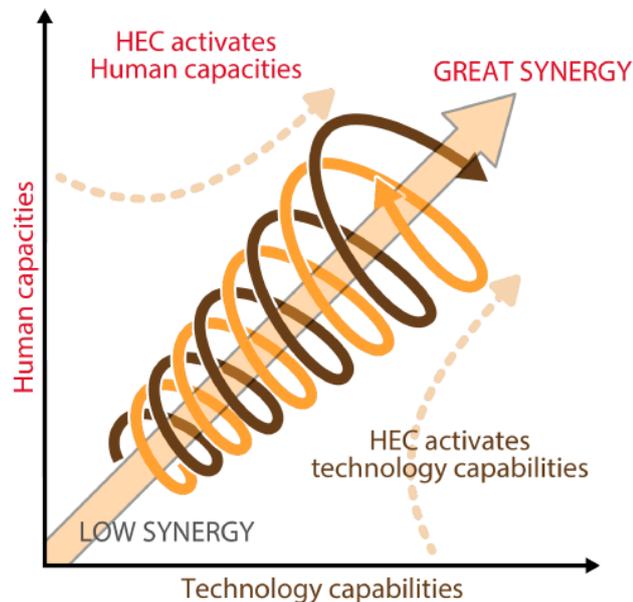


Figure 1. Synergized interaction between human capacities and digital capabilities (Ren, 2016)¹.

Notes: The horizontal axis represents the development of technological capabilities, while the vertical axis represents the development of human capacities. Synergized interaction will be approached when both human capacities and technology capabilities tend to be fully activated, engaged, and enhanced together, while ignoring, deviating, or diminishing any of both sides may result in low synergy. The achievement of HEC will be shaped as a spiral generally, as we researchers need to gradually identify, criticize, understand, and utilize both human capacities and technology capabilities.

3.1 Theoretical Aspect

The theoretical aspect is proposed based on the HEC theory in terms of definitions and components (Ren, 2016; Ren, Silpasuwanchai & Cahill, 2019), and it focuses on how to extend the understanding of both humans and information, clarifying related keywords, and considers a new conceptual interaction framework in the information interaction context. Basically, following the HEC perspective, we ask researchers to reconsider the HCI design paradigm by moving from what we now experience to what we can progressively improve. With this in mind, we seek to create more holistically integrated interface conceptions that exploit micro- and macro views while defining and applying key factors, such as human engagement, and then considering how conventional human and information models could be extended and pertinence progressively sustained while our technological and social backgrounds are quickly changing. A conceptual framework is needed to discuss possible information interaction issues at the level and pace of the human mind. The following questions need to be answered:

- (1) How do we complement or extend the current HCI paradigm regarding human and information models respectively, e.g., by clarifying a hierarchical-level table of keywords? And/or, how do existing conceptual frameworks promote the evolution of human-oriented HCI? Or, what limitations of existing frameworks need to be addressed, modified, or displaced?
- (2) From the HEC perspective, how are we to order the priorities of new design concerns and potentials?

Theoretical aspect	Principled aspect	Practical aspect
<ul style="list-style-type: none"> • Expand the range of models representing human interactions with information • Establish priorities for new design paradigms • Define human engagement taking multiple perspectives into account • Identify the pros and cons, gains and losses relating to technology and how these come about • Identify levels of meaningfulness of information to humans 	<ul style="list-style-type: none"> • Facilitate inner human capacities beyond conventional cognitive, behavioral, and performance factors • Establish a consciously dynamic approach to intra- and interdisciplinary values and ethics • Anticipate social and educational effects beyond the dedicated instrumental intentions of technologies 	<ul style="list-style-type: none"> • Extend our understanding of conventional information interaction tasks • Reposition concrete technical properties and human factors in the HEC context • Develop qualitative and quantitative HEC evaluation metrics • Develop applications to optimize existing designs and realize new manifestations to serve inner human capacities

Figure 2. The key points of the proposed agendas for information interaction development considered from the theoretical, principled, and practical aspects.

¹ © [2020] IEEE. Reprinted, with permission, from [Ren, X. (2016). Rethinking the relationship between humans and computers. Computer, 49(8), 104-108. doi: 10.1109/MC.2016.253].

- (3) After considering views from the fields of humanities, psychology, and pragmatism, how are we to define the state of “the engaged mind” or “the engaged human”? How are we to define “human engagement” with regard to human behaviors and human mind states?
- (4) Why and how can conventional designs address the crisis of digital content, e.g., “trust deficits”? Considering conventional approaches to design, can we better identify the positive potential and negative effects of technical factors and then find balance or trade-offs between the positive and the negative and find an elevated “middle way”?
- (5) How can we identify, evaluate, and classify the worthiness of information to humans? What distinguishes different genres of information?

3.2 Principled Aspect

The principled aspect is proposed based on the HEC theory in terms of principles (Ren, Silpasuwanchai & Cahill, 2019), which calls for the articulation of human capacities and ethics/values that assist designers to be conscious of the need to positively engage end-users as intelligent and responsible factors. As an essential human requirement, the expression of the achieved human capacities while accessing and interacting with available information should be a suggestive and promising design path toward future technological development. Meanwhile, we must be careful to critically evaluate the technical factors that would be applied or developed because we have already experienced and evidenced the effects of rumors, trolling, and addictions and how they were formed and channeled through conventional instruments and practices. To achieve synergized interactions and to avoid the diminishment of human values, HEC requires researchers and practitioners to be conscious of such principles whether they apply specific insights in further designs or not, i.e., to make widely informed decisions regarding inclusions and omissions in design and innovation.

The following preliminary statement regarding design principles can be extended by researchers and practitioners in future:

- (6) Develop and extrapolate on considerations regarding how to improve and exploit inner human capacities beyond conventional cognitive, behavioral, and performance factors when designing information interactions.
- (7) Establish a consciously dynamic approach to intra- and interdisciplinary goals, values, and ethics. On

the one hand, accept the potential that designs and innovations may produce very negative effects (antibiosis) (Ren, Silpasuwanchai & Cahill, 2019) beyond the specific tasks and purposes for which a device or system may be designed, e.g., effects on the realized and potential mental capabilities of developing children; disregard for and/or diminishment of respective human values and value systems; the degeneration of mental capacities such as thinking skills, reason, and unquantifiable comprehensive conditioning qualities like empathy and compassion, as well as contravening or ignoring of rights. On the other hand, users are required to grow and be willing to realize their own capacities with the assistance of facilitating augmentations and technological factors. HEC assumes that humans want to be empowered rather than disenfranchised by their tools.

- (8) The design aspects of information interfaces and interactions have peripheral and collateral social and educational effects beyond their dedicated instrumental intentions. These collateral effects progressively shape the way users interact with information and with life itself. Interaction designs should be aligned with respective human values to produce maximum benefits in real human contexts and over the long term rather than merely focusing on the speed and volume of data traffic in the short term.

3.3 Practical Aspect

The practical aspect considers “Engaging Computers” as the corollary to fully engaged human participants, i.e., the consideration and development of computers that are specifically designed to sustain and enhance innate human capacities is a particular component of the HEC theory and is essential to the goals of the HEC framework (Ren, 2016; Ren, Silpasuwanchai & Cahill, 2019). This aspect is concerned with how to rethink tasks, evaluation methods, and future applications in information interaction design according to HEC principles and priorities. It also seeks to extract, create, and present practical guidelines and to design engaging technologies that incorporate, exploit, and facilitate human capacities. We are particularly interested in the following questions:

- (9) How can we extend our understanding of conventional information interaction tasks, e.g., searching, retrieving, or posting, and how can we establish and facilitate the real significance or purpose of the humans behind such tasks?

- (10) How can we reposition concrete technical properties and human factors in engaging information interaction design?
- (11) How can we develop qualitative and quantitative metrics for engaging information interaction to evaluate long-term effects on humans and, thus, to generate practical guidelines regarding the potential positive or the negative factors?
- (12) How can we develop concrete applications or methods to optimize existing designs, e.g., current social media? Can we achieve new information applications or manifestations for promising directions serving inner human capacities, e.g., human mindfulness?

4 Raising Awareness

We proposed 12 research agendas from three aspects in order to help designers rethink the design of information interactions for future development. The fundamental HEC design principles are concerned with how humans can sustain and improve their innate capacities while interacting with information and technologies and, conversely, how design guidelines can avoid diminishing innate human skills and capacities. The improvement of human skills and capacities is not only in regard to external or physical performance but also in regard to the development of inner capacities and responsibilities. This approach may help render humans immune to diminishment through their use of powerful technologies.

In sum, the critical problem that gives rise to the above agendas and discussion is how to develop suitable evaluation criteria for HCI researchers and practitioners to respond to the rapid development of the world and to align our work with human values and survival.

Alan Kay shared his insights into “human universals”, which are functions that all humans or civilizations can evolve naturally, (e.g., language, stories, and basic tools) and also the “nonuniversals”, which are progressive inventions that we are less genetically predisposed to, e.g., writing, progress, and model-based science (Merchant, 2017). As evaluative criteria for the advancement of designs, a tool should facilitate the adoption of human “nonuniversals”. Kay gave the example of the superiority of the telegram over the telephone saying that the telephone still keeps the human universal of spoken language but the telegram facilitates the “nonuniversal” art of writing. This view does not ignore the importance of a new tool or interaction, but it focuses more on what could have been better with a new perspective. For

example, Dynabook, a key idea of Alan Kay, influenced by Douglas Engelbart (1962) and Papert (1980) and conceived 50 years ago, aimed at teaching children to be “media guerrillas” when identifying information. It was designed as a media platform to practice “learning by doing”, but not merely as another new computer (Kay, 2011). According to the HEC perspective, we regard inner human capacities like personal discernment and critical judgment to be fundamental to human maturity and to be developed based on the above perspective of augmenting human intelligence (Engelbart, 1962). We believe that the next promising evaluation criteria would value “holistic human engagement” across micro and macro levels.

Toward further HEC practices or case studies of “Engaging Computers”, information interaction has more potential to develop inner human capacities than other interactions due to its global presence. However, as information, techniques, and interactions were too closely integrated and too rapidly developed to reveal clear borders among them, it also posed a great challenge for designer groups to learn understand and distinguish meaningful contents from the flood of ambiguous and misleading information. Despite this, faced with both emerging opportunities and inevitable challenges, researchers and practitioners should still remember their increasing ethical and educational responsibilities to humans while reconsidering and designing new and better information interactions.

Researchers should contribute to the development of human “information immunity” through technologies as an essential step toward realizing more fully synergized interactions. One important challenge would be to facilitate this kind of consensus without compromising respective values and traditions. We expect, during or after the current (COVID-19) crisis, that the research community of HCI and IR will be able to conceive and develop more engaging manifestations of these agendas in different and more wholesome directions, e.g., information media, telemedicine, tele-education, service design, and visualization, and thus help build more highly synergized and coherent relationships among governments, communities, individuals, and enterprises to prepare for future challenges without diminishing the integrity and sacredness of private, personal, and cultural values.

5 Conclusion

Under the umbrella of the HEC framework, we wish to raise awareness of the potential to develop synergized interactions between humans and information in order to improve innate human capacities, specifically, the ability to discern authentic and reliable information, to address information interaction issues with respect to human well-being (e.g., immunity to online rumors and so on). We therefore presented 12 research agendas from the theoretical, principled, and practical aspects. The theoretical aspect mainly focuses on how to engage and extend the understanding of humans and how to form a conceptual interaction framework for developing a trustworthy information interaction context. The principled aspect calls for more attention to human capacities and ethical issues while designing interactions. The practical aspect lists open questions about how to rethink tasks and evaluation methods, in addition to presenting future directions for information interaction. We encourage researchers and practitioners to deeply consider how techniques and methodologies in the information interaction context can help humans improve their minds while solving problems in the real world. This adaptable approach will facilitate the understanding and implementation of ensuing paradigm shifts in the fields of HCI and IR by offering a fuller evaluation of human potentials and HEC-based applications.

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