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Editor in Chief

Contents

- From the Editors in Chief** pp. 145–148
We Shape Our Tools, and Thereafter Our Tools Shape Us
Pertti Hurme and Jukka Jouhki

Original Articles

- ✦ *Conceptualizing the Self: A Critical Analysis of the Self as a Discursive Trend in Human–Computer Interaction Research* pp. 149–179
Henrik Åhman
- ✦ *Aligning Information Technologies with Evidence-based Health-care Activities: A Design and Evaluation Framework* pp. 180–215
Kamran Sedig, Anthony Naimi, and Nicole Haggerty
- ✦ *Embedding Preschool Assessment Methods into Digital Learning Games to Predict Early Reading Skills* pp. 216–236
Anne Puolakanaho and Juha-Matti Latvala

- Acknowledging the Manuscript Reviewers for *Human Technology*** pp. 237–241
(Nov. 2015 to Nov. 2017)

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From the Editors in Chief**WE SHAPE OUR TOOLS, AND THEREAFTER
OUR TOOLS SHAPE US**

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The quote in the title above, by Marshall McLuhan's contemporary John M. Culkin (1967, p. 70), reflects the fundamental viewpoint of *Human Technology*. We are interested in—if not fascinated by—the two-way relationship between humans and technology. Humans create inspiring and empowering technologies but also are influenced, augmented, manipulated, and even imprisoned by technology, depending on the situation and the interpreter. Culkin continued, in a McLuhanesque vein, that, through technology, “These extensions of our senses begin to interact with our senses. These media become a massage” (p. 70). Indeed, most media—and technology in general—have become “a massage,” that is, more than mediators of messages. Technologies pertain not only to making everyday lives more efficient, safe, or healthy but also to entertaining people. For example, the Internet, originally developed for military purposes, nowadays functions as a tool for information and a platform for a plethora of applications helping people in their everyday lives. However, many people use the Net mostly for entertainment purposes and, to paraphrase William Gibson (1996), the science fiction writer who coined the term “cyberspace,” that's exactly what is so great about it. The complex development of the human–technology relationship has given people new avenues for enjoyment and communication while also boosting the efficiency of societies. From all this, grave concerns may ensue but also utopian enthusiasm. *Human Technology* is interested in both, and everything in between.

Currently, it is estimated that 50 billion Web pages are available on the Internet, most of them accessible to anyone (Internet World Stats, 2017). The ethical stand of *Human Technology* has been for openness since the journal's inception in 2005, when the first editorial team and publisher decided to publish peer-reviewed scholarly manuscripts open access and Web-based only. At that time, open access publishing was a small but growing philosophy, but they believed—and we, the next-generation editorial team, continue to believe—that “information wants



to be free,” as Stewart Brand, editor of the *Whole Earth Catalog* famously told Steve Wozniak, the co-founder of Apple Inc., about 20 years earlier at the first Hackers Conference (Brand, 1984; Gans, 2015). Today, that perspective is more important than ever: Open access is much like an academic creed connecting like-minded content publishers, authors, and audiences around the world. Not surprisingly, open-access publishing is visibly gaining in popularity (Hurme 2015).

Universities and funding organizations increasingly favor open access publications, encouraging and even demanding researchers to use open access channels for publishing their grant-based research dissemination. Sometimes, the commercial model of major publishing houses, where access to research requires a subscription, seems to defy the idea that research is in the service of the public. When the work of authors, reviewers, and editors is used for making profit, the new knowledge generated in research tends to remain exclusive in nature, and accessible only to those who can climb over a paywall.

The publisher of *Human Technology*, the Open Science Centre of the University of Jyväskylä, is a pioneer in making research of all kinds available to anyone. The Jyväskylä University Digital Archive presents a good example of an institutional repository that provides free and easy access to content created by the university’s academic community.

Academic journals such as *Human Technology* assure the quality of articles they publish by employing a transparent procedure, providing detailed instructions to authors, using external reviewers for evaluating the submissions, and drawing on an international board of advisors. They also rely on the services of external assessors in verifying their goal of quality scholarly publishing (Hurme & Crawford, 2017). *Human Technology* has been awarded the peer-review label of the Federation of Finnish Learned Societies to indicate that the journal fulfills the Societies’ requirement in its peer-review process. Our journal also is fully indexed by the Directory of Open Access Journals. And, since 2016, *Human Technology* has been indexed by Scopus, which is a major milestone for any journal.

The last 3 years, during which Dr. Pertti Hurme has served as editor in chief, *Human Technology* has published articles across a gamut of topics. Some of the articles are theoretically oriented, focused on, for instance, immersion and presence, affective and persuasive technologies, and embodied interaction. The majority of articles are empirically based addressing a diversity of topics such as the history of computer programming, games and learning, technology for helping the elderly, social media in crisis and emergency management, memes in virtual communities, and movement-based interaction design. In the 3-year period, two special issues of *Human Technology* have been edited by guest editors. These issues have presented research on human–technology choreographies, that is, the relationships of body, movement, and space. The articles discussed the relationship of technology and choreography in a novel way from perspectives such as movement, space, walking, dance, music, interaction, biomonitoring, multimodality, and embodiment. Two additional thematic issues are in preparation, one focusing on the interaction of art and semiotics in the design experience and technology and the other presenting research into the experiential component of the design of interactive systems for the work environment.

The present issue of *Human Technology* has three articles and our biennial acknowledgment of our reviewers. The first paper focuses on the self in human–computer interaction, the second on health information technologies and evidence-based health care, and the third on reading skills and digital learning games.

Henrik Åhman examines the self, first in human–computer interaction (HCI) research literature, where his qualitative content analysis shows that the self is time and again presented as a relatively stable, coherent, and individual entity. The second part of his article contrasts these findings with an in-depth analysis of philosophers’ views on the self, specifically Friedrich Nietzsche, Michel Foucault, Jacques Derrida, and Mark C. Taylor. Their thoughts lead to considering the self as a malleable construct. Åhman’s conclusions may have a far-reaching impact on HCI research.

Many countries are undertaking intense efforts toward improving their health-care systems and, in this work, information and communication technologies play a vital role. In particular, the growing emphasis on evidence-based health care (EBHC) demands the use of technologies to assure quality decisions by health-care providers. **Kamran Sedig, Anthony Naimi and Nicole Haggerty** examine this challenging area. The authors focus on joint cognition systems as a means to integrate better health information technologies (HITs) into EBHC processes. Their goal is to bridge the gap between stakeholders, HITs, and EBHC in support of quality outcomes for health-care practitioners and, ultimately, patients. For that purpose, they present an extensive analytical framework, DETECT, to assist in designing, deploying, and evaluating the integration of HITs into EBHC activities and settings.

In their article, **Anne Puolakanaho and Juha-Matti Latvala** embark upon an exploration of a means of assessing reading skills via an online learning platform. The lack of reading skills can lead to marginalization, whereas good reading skills improve the possibilities for learning and personal growth and provide a wider range of options for finding one’s place in society. Based on empirical data, the authors compare the power of the GraphoLearn digital learning platform in predicting reading skills to those of traditional pencil-and-paper tests. Their conclusion is that digital tasks are as efficient as traditional tests in predicting reading outcomes. The article adds to the large body of evidence on the advantages of the GraphoLearn (formerly GraphoGame) learning environment published in this journal and elsewhere. Together the three articles in this issue of *Human Technology* address timely questions of the relationship between human beings and technology.

Finally, all scholarly journals that uphold ethical standards for quality rely fundamentally on a process of peer review. Throughout the years, editors of *Human Technology* have invited experts from a diversity of fields to review manuscripts of possible publishable quality related to their expertise area. In this way, the editors assure that the papers published in this journal meet the standard of quality prior to publication. So, every second year, we publish a list of these scholars who volunteer their time and knowledge in evaluating the manuscripts and in recommending ways in which the research reporting can be improved. No matter what the ultimate decision on a manuscript, we editors and the publisher of *Human Technology* remain indebted to the contributions that these scholars make to quality publishing and the advancement of the field of human–technology.

In January 2018, a new editor in chief, Dr. Jukka Jouhki, will assume the reigns of *Human Technology*. Jouhki is an anthropologist who has studied technology as a cultural phenomenon from various aspects, for example, mobile technology in rural India, information society visions in urban South Korea, and online gambling in Finland. Under his guidance, the human aspect of human–technology interaction will be further emphasized within the meanings, values, and experiences of technology. Dr. Jouhki will be joined by an associate editor, Dr. Sakari Taipale,

a social scientist with extensive experience in technology research, such as mobile telephony and social robots. We also welcome a social media editor, Tanja Välisalo, M.A., who will facilitate an improvement in the journal's online presence. And our long-time managing editor, Barbara Crawford, M.A., will continue her dedicated work.

As *Human Technology* moves into future, the editorial team is open to expanding our traditional interest in the mainstream issues of humans and their technologies to include explorations of the more controversial and perhaps even ethically challenging issues in human–technology research and activity. Our approach to these and other topics is being formulated at the moment, but we look forward to broadening the discourse of the human component of technology use in *Human Technology* in 2018 and beyond.

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CONCEPTUALIZING THE SELF: A CRITICAL ANALYSIS OF THE SELF AS A DISCURSIVE TREND IN HUMAN–COMPUTER INTERACTION RESEARCH

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Abstract: *In human–computer interaction (HCI), the human often has been conceptualized as a user. Although this notion has illuminated one aspect of the human–technology relationship, some researchers have argued for the need to explore alternative notions. One such notion becoming increasingly frequent in HCI is the self. In this paper, a study of how the self is described in 88 HCI research publications is presented. Four main aspects of the self are identified: instrumental, communicative, emotional, and playful. These four aspects differ, yet they present the self as stable, coherent, and individual. However, these characteristics have been criticized by several contemporary philosophers. This paper presents arguments from poststructuralist writers as a foundation for advocating the need to develop further these positions within HCI. The theories of Mark C. Taylor, who combines poststructuralism with complexity theory, provide a framework for viewing the self as relational to the extent that interaction becomes an existential process and thus interactive technology constitutes an existential arena.*

Keywords: *HCI theory, literature analysis, the self, human, poststructuralism, Mark C. Taylor.*



INTRODUCTION

Human–computer interaction (HCI) has always been a discipline with a tripartite focus, studying not only technology but also the human and his/her interaction with technology. However, this tripartite focus is not always well represented in the research. Even though a lively discussion is ongoing in HCI circles regarding how to understand and conceptualize technology, the frameworks for understanding the human are less frequently discussed.

Traditionally, the human in HCI has been discussed in terms of the user (see, e.g., Bardzell, 2009; Cooper & Bowers, 1995). Performing a quick search in the ACM Digital Library¹ reveals that approximately 95% of all papers presented at the annual ACM Conference on Human Factors in Computing Systems (CHI) mention the user, a number that has been nearly constant since the turn of the millennium. Moreover, other ways of discussing the human can be found. For example, the *Oxford Dictionary of English* defines the self as “a person’s essential being that distinguishes them from others” (Stevenson, 2010, p. 1613). The self can thus be understood as a word that specifically points to that which characterizes a certain human being. Notably, since the turn of the millennium, the use of the word self has increased significantly in areas of the HCI community, which indicates a possible shift in the way the human is understood and talked about within the HCI field.

This paper is an attempt to describe and analyze the assumptions regarding the human as the self that informs HCI research. The first part of the paper presents the results of a literature analysis on how the self is described in HCI research papers. The second part is a critical analysis of these findings from the perspective of one of the critical traditions in 20th-century philosophy. The third part is a constructive reading of Mark C. Taylor’s philosophical project with the purpose of suggesting that there is a theoretical position in his ambiguous and sometimes contradictory philosophy that can inform HCI research on the self.

The purpose of this paper is thus not to state a number of implications that an HCI researcher can easily apply to his/her research. Rather, the purpose is to contribute to a discussion on what the self might be and to do so by presenting a number of theoretical positions that can function as resources with which a researcher can engage in an ongoing reevaluation of the self in HCI.

METHOD

A study of how discourse functions in a domain can roughly be structured in two different ways. One approach is to choose a phenomenon and investigate which words people use to represent this phenomenon. Another approach is to choose a term and investigate which phenomena are referred to when people use this term. Because this paper is aimed at exploring and understanding what researchers mean when they talk about the self, I have chosen the latter approach. This means that I have focused only on the specific search term *self* rather than also including synonyms or supposedly adjacent terms such as user, person, or human in the search process.

Another demarcation that needs to be made concerns the definition of HCI. Defining the domain of HCI is difficult due to its complex history that has developed through an oscillation among industry, state, and academia. As Jonathan Grudin (2012) showed, HCI has evolved in

relation to several adjacent disciplines focused on the connection between humans and technology. According to Grudin, HCI can be approached from either a broad or a narrow perspective. From a broad perspective, HCI would include human factors, computer science, information systems, and library and information science because they all focus on the relationship between humans and technology and have contributed to the development of journals and conferences that are now considered core to HCI, for example, the CHI conference. From a narrower perspective, the term computer–human interaction could be used to describe computer science, ACM SIGCHI (the ACM Special Interest Group on Computer–Human Interaction), and the CHI conference. When I conducted my literature searches, I approached HCI in what might be called a semi-narrow fashion, focusing primarily on the CHI section of the ACM Digital Library but also including Google Scholar material that claimed to discuss the relationship between humans and technology within an HCI context.

With these two demarcations, I performed a temporally unrestricted literature search (in February 2015) in the CHI section of the ACM Digital Library. I then added literature found in Google Scholar through searches in which I combined the search term “the self” with different variations of HCI (i.e., human computer interaction, human–computer interaction, and HCI). In total, the searches resulted in 126 journal articles and conference papers. After an initial screening in which I excluded articles where the term the self only occurred in reference lists or in marginal comments, 88 articles remained and composed the dataset for the analysis. Although some of the literature was published in the early 1990s, the majority of the articles were published 2004–2014, which is consistent with this paper’s focus on the contemporary use of the self.

The purpose of the analysis of the literature search results was not to construct a taxonomy of mutually exclusive categories into which individual articles could be sorted. Rather, the purpose was to identify patterns and themes within the literature and to use these to formulate qualitative categories that could be used as analytical tools for understanding broader theoretical currents in HCI research. For this purpose, I used a qualitative, inductive content analysis (Elo & Kyngäs, 2008; Thomas, 2006). This approach suggests that a single article can contain many different themes, thus allowing a single article to appear in several different categories. Through an iterative close reading of the material, guided by questions such as “How is the key search term described?”, “What characteristics are mentioned in relation to the search term?”, and “In which context does the text situate the search term?” specific text segments in each article were identified and coded with key labels. Because I did not apply an a priori coding system, the process resulted in a large number of key terms, many of which were redundant. After reducing redundancy through a clustering of the key labels, a number of main themes emerged, from which the final categories were then formulated (see Figure 1).

RESULT OF LITERATURE ANALYSIS

In this section, I present the findings of the literature analysis. I have identified four main categories of literature according to which the self can be described: instrumental, communicative, emotional, or playful. Within each of these categories, I have clustered the description of the articles around two or three main themes.

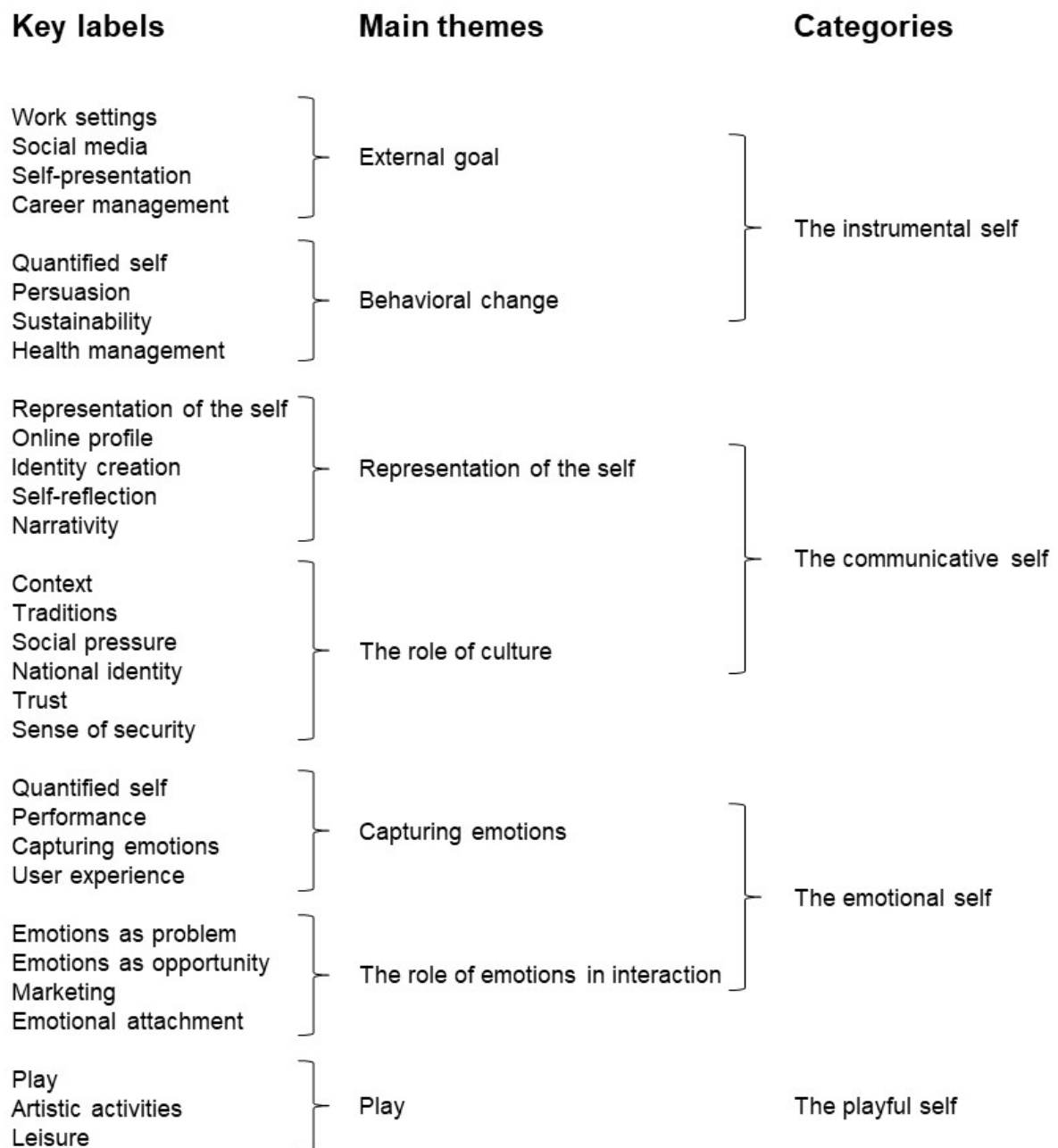


Figure 1. Overview of the clustering process as part of the analysis of the term *self* found in the literature surfaced within the HCI area of the ACM Digital Library.

The Instrumental Self

Since Lucy Suchman's work in the 1980s (e.g., Suchman 1987), much of the research in HCI has described the self as a contextual being whose actions are governed not only by individual

rationality, but also by social and cultural forces. However, despite this historical emphasis on the context, one of the strongest categories in the discourse on the self analyzed in this paper is research in which the self is described primarily as a being whose thoughts and actions are characterized by rational, instrumental considerations on how to reach particular goals.

External Goal

Many of the articles in this category of research approached instrumental goals as something external to the self. In their article “The Truth About Lying in Online Profiles,” Hancock, Toma, and Ellison (2007) discussed the correspondence between online dating profiles and the people who have created the profiles (see also Fiore & Donath, 2004; Toma, Hancock, & Ellison, 2008). The authors argued that, even though the process of initiating romantic relationships has always been characterized by a tendency to “engineer” one’s self-presentation in order to make a positive impact on a potential romantic partner, the online arena is particularly exposed to such deceptive strategies. The authors compared the online presentations of 80 individuals active on online dating sites with their offline physical appearances and found that deception in these profiles is frequent but that “the magnitude of the deceptions is usually small” (Hancock et al., 2007, p. 449). They explain the latter point as the “anticipated face-to-face interaction” (p. 452), which functions as a force balancing the strategic instrumentality of the self with the given physical facts. Therefore, the self is described as a rational being who strategically balances the risk of being exposed as a liar against the potential positive rewards in terms of a possible romantic relationship. In short, the self is described as a demarcated entity that uses its rational characteristics in strategic manipulation of entities external to the self. Similar results were discussed by Pilcer and Thatcher (2013), who found that people’s Facebook activities are often strongly influenced by instrumental considerations related to strategic career management.

Yet another example of research portraying the self as a strategic being acting to reach instrumental external goals is Nov, Naaman, and Ye (2008), where the authors analyzed the role that various motivators play in the process of tagging content on Flickr. The authors found that the process of tagging was strongly influenced by strategic considerations concerning instrumental goals that the users were striving to achieve in relation to particular social contexts. Thus, to conclude, even though the articles in this theme focus on the social dimensions of technology, they nevertheless describe the self as fundamentally instrumental, acting strategically in pursuit of an external goal.

Behavioral Change

Although the literature described above presents the self as engaged in instrumental acts through which it potentially can change an external object, many articles in the instrumental category focus on instrumental acts where the own self is the object (e.g., Choe, Lee, Lee, Pratt, & Kientz, 2014; Kehr, Hassenzahl, Laschke, & Diefenbach, 2012; Khovanskaya, Baumer, Cosley, Vaida, & Gay, 2013; Moraveji, Akasaka, Pea, & Fogg, 2011; Schiphorst, 2011; Scott, Barreto, Quintal, & Oakley, 2011; Zaczynski & Whitehead, 2014). Much of this literature is focused on behavioral change, often in relation to health and bodily fitness (e.g., Gao & Mandryk, 2012; Grimes & Harper, 2008; Lee & Dey, 2014; Mamykina, Mynatt, & Kaufman,

2006; Meyer, Simske, Siek, Gurrin, & Hermens, 2014; Zhou, Sun, & Yang, 2014). For example, Maitland and Chalmers (2010) analyzed technology designed to support cardiac patients in their efforts to change their behavior through increased awareness and self-reflection. The authors argued that, even though enforced rehabilitation programs may result in partial changes in the patients' physical activity, cognitively based motivations are needed to extend this change to other forms of health-related activity and, in this process, self-monitorial technology may be a valuable tool. The authors contended that increasing the patients' knowledge and self-awareness is a powerful tool in the process of achieving behavioral change. Furthermore, it was suggested to be highly ethical to ground behavioral change in an increased self-awareness and acknowledgement of the patient's psychosocial needs: "Facilitating the ability to retake control of one's life is fundamental to the process of cardiac rehabilitation. We therefore suggest that designing explicitly to support the self-determination of behavioural change will not only increase the likelihood of the technology being adopted but will also complement psychosocial aspects of cardiac rehabilitation that are often overlooked in favour of physiological and behavioural outcomes" (Maitland & Chalmers, 2010, p. 1219). This illustrates a conviction that the self, given adequate information, can (a) reach an understanding of what is best for him/her and (b) act rationally based upon that information. Thus, the self is described as a strategic creature that can make informed decisions, gain control over its own life, and practice self-determination. However, this means that questions regarding possible connections between cardiac rehabilitation and things like emotional bindings, substance abuse, and existential anxiety are left unaddressed. So, despite the authors' claims that they included dimensions that have so far often been overlooked in research, achieving behavioral change is still primarily described as a rational, instrumental process.

Maitland and Chalmers (2010) mainly focused on how the individual self can change his/her behaviors through interaction with technology. However, the literature also provided researchers who emphasized the social situatedness of these processes of change with the argument that behavioral change is the result of the self using technology as a mediating tool to connect to other selves. One such example is Laschke, Hassenzahl, Diefenbach, and Tippkämper (2011), who analyzed a technological artifact designed to persuade people to act more environmentally friendly by saving water. Similarly to Maitland and Chalmers (2010), Laschke et al. (2011) emphasized that it is vital that the individual can experience a degree of control over which goals to reach in order to successfully change a particular behavior. However, equally important is the idea that increased self-awareness can be gained through a comparison between one's own behavior and the behavior of others. This utilizes one of the most powerful resources for change, namely competitiveness: "Through its fuzzy, ambient feedback [*sic*] participants were encouraged to set personal goals, to compare themselves to others, and to monitor their progress. This could even result in competition" (Laschke et al., 2011, p. 642). So, while Maitland and Chalmers (2010) primarily described the increased self-awareness as an individual phenomenon, Laschke et al. (2011) focused on the social contextuality of these aspects of human beings, thus indicating that an important part of the behavior of the self is relationally constituted (see also Gabrielli, Sabatino, Munoz, Marchesoni, & Mayora, 2011).

The Communicative Self

The second category of articles presented other elements of the relational aspects of technology. In this line of research, the self is described as a relational being that uses technology for communicative purposes, to establish a connection with other selves. As can be expected, many of the authors of these articles explored social media such as Facebook and Twitter, but some research focused on other kinds of online environments.

The Representation of the Self

A frequent theme in these articles was how online activities, such as creating profiles, relate to the self (e.g., Farnham & Churchill, 2011; Ozenc & Farnham, 2011; X. Zhao et al., 2013; X. Zhao, Schwanda Sosik, & Cosley, 2012). For example, as noted above, Hancock et al. (2007) explored how selves are being represented in online environments. Researchers in this category often describe a representation as something that results from instrumental considerations, indicating possible discrepancies between the self and the online self. This perspective can be found in several other articles as well (e.g., Ducheneaut, Wen, Yee, & Wadley, 2009; Ellison, Heino, & Gibbs, 2006; Nov et al., 2008; Pilcer & Thatcher, 2013; Shami, Ehrlich, Gay, & Hancock, 2009).

However, other approaches to the relationship between the self and its online representation have been identified. For example, Nie and Sundar (2013) argued that the ways people shape their representations online are less motivated by strategies for making a particular impression on others than by an interest in using these technologies as opportunities to articulate one's identity to oneself through a self-reflexive move (for similar discussions, see also Fox, Bailenson, & Tricase, 2013; Helmes, O'Hara, Vilar, & Taylor, 2011; Marathe & Sundar, 2011; Odom, Zimmerman, & Forlizzi, 2011).

Authors of other articles attempted to avoid a focus on instrumental, rational behavior by suggesting that online selves result from unconscious processes and therefore can be seen to accurately reflect aspects of the self. For example, De Choudhury, Counts, and Horvitz (2013), in an effort to understand the connection between online posting and postpartum depression, statistically analyzed patterns of posting, linguistic style, and emotional expression in Twitter posts made by 376 women. Rather than only focusing on identifying explicit references to depression, the authors argued that it is possible to identify indirect markers, that is, linguistic style and frequency of posting, in the Twitter texts. These markers can be used to draw conclusions concerning the psychological status of the women: "Whether in the form of explicit commentary, patterns of posting, or in the subtleties of language used, social media posts bear the potential to offer evidence as to how a person is affected by life events" (De Choudhury et al., 2013, p. 3267). One such indirect marker that the authors mentioned was "the frequency of use of first-person pronouns," which, they claimed, "has been found to be a correlate of depression" (p. 3268). It is important to note, however, that the study was not limited to identifying and describing the connections between posted online patterns and the current status of the self, but also aimed at developing tools that can prognosticate future statuses of the self. Through a comparative analysis of prenatal and postnatal posting patterns, the authors suggested four main measurements (engagement, ego-network, emotion, and linguistic style) that they argued can be used to predict with an accuracy of 71% the risk that an

individual woman who is about to give birth will exhibit extreme emotional changes in the early postnatal period. Because such changes previously have been found to be related to depression, the authors suggested that this research can help identify individuals who have an increased risk of suffering from postpartum depression. Taken as a whole, this line of research indicates that the online representation of the self not only reflects the selves that individuals currently are but also the selves that these people are likely to become.

The Role of Culture

Many studies of the self as communicative emphasized cultural and social aspects. The main thrust of this argument is that the self, far from an isolated being, can be described as fundamentally influenced by, or even constituted by, traditions and norms. These influences are thus seen as having a strong impact on the character of the self as well as the self's engaged interactions. In their study of the differences in social media practices between American and Chinese users, C. Zhao and Jiang (2011, p. 1130) drew on the theory of the bicultural self, which suggests that contemporary Chinese individuals are a combination of a social-oriented self "rooted in a traditional Chinese conceptualization" and an individual-oriented self that has "emerged and developed under Western influences, along with modernization." Based on this view of individuals as combinations of both traditional and modern character traits, the authors posited that this cultural tension would be visible in the profile images that the users posted. They proposed that the collective character of traditional Chinese culture would result in Chinese users being "more likely to use group photos in their profile picture" (C. Zhao & Jiang, 2011, p. 1130), yet, consistent with the emerging individualism in contemporary China, they would be more likely to use the customization opportunities of digital technology to alter the pictures. Contrary to the researchers' assumptions, however, the Chinese users were found not to use any group photos as profile images while the American users did, despite the collectivistic character of the former culture and the individualistic character of the latter. In the case of customization, the authors' assumptions were, however, confirmed; Chinese users showed a tendency to customize their profile pictures and present a "polished" version of themselves far more often than their American equivalents did.

The reasons for these differences are not entirely clear. On the one hand, the results of this study contradict "the western-individualism, eastern-collectivism theory" (C. Zhao & Jiang, 2011, p. 1131), indicating that clear-cut, traditional assumptions of cultural influence may be inadequate as explanatory framework for understanding online practices. On the other hand, however, the research did identify considerable differences in the way individuals from different national cultures represented themselves through profile images. So, although the role of cultural influence is complex, online self-presentation is not just an individually motivated activity. It portrays the individual self as contextualized and fundamentally influenced by cultural norms and societal practices, even though these are continually being renegotiated.

Other studies focusing on the differences between Western and Chinese users' online practices and their connection to national culture have come to similar conclusions (see, e.g., Liao, Pan, Zhou, & Ma, 2010; Scissors, Shami, Ishihara, Rohall, & Saito, 2011). Jiang, de Bruijn, and De Angeli (2009) can be said to further deepen the analysis of the role of culture by emphasizing that cultural norms do have an impact on not only the self's online expressions but also on how those expressions are being perceived by others' selves: "People from different

cultural backgrounds rely on different cues when forming impressions of others” (p. 684). It is important to emphasize that culture, in this context, is not limited to national or regional culture but needs to be understood as a broader concept entailing facets such as corporate or religious cultures and identities and practices associated with demographics or subcultures, and so forth. For example, Raban, Danan, Ronen, and Guy (2012) studied impression formation in a corporate context and suggested that corporate practices and norms often crosscut national boundaries and that these practices could be valuable in order to understand people’s online behavior. Pfeil, Arjan, and Zaphiris (2009) focused on demographics and argued that differences in the way people represent themselves on MySpace can, to some degree, be related to age. Older users tend to express themselves in a formal and official manner, whereas teenagers tend to be informal, emotional, and use more self-references. So, even though the definitions of culture vary in these articles, their authors all suggested that the individual self is embedded within cultural contexts that influence the way the self communicates.

Another aspect of culture is how the trust that exists within communities affects the self (e.g., Riegelsberger, Vasalou, Bonhard, & Adams, 2006; Romero & Markopoulos, 2005). In these articles, the self was described as trying to preserve its own identity while being exposed to otherness, thus emphasizing the difference between the self and the other.

For example, Yarosh (2013) explored the possibility of using technological tools in 12-step programs, such as Alcoholics Anonymous (AA) and Narcotic Anonymous (NA). One of the most important principles in AA and NA is anonymity. The purpose of these groups is to offer a place where anyone can feel free to join and share experiences around his/her substance use without the risk of being identified and perhaps publicly stigmatized as a consequence of his/her struggle with addiction. Moving the AA meetings from the traditional face-to-face context to, for example, an online environment presents specific challenges regarding how the principle of anonymity can be maintained. According to Yarosh (2013), these challenges have two components. First, a question arises regarding an individual’s comfort in trusting the functionality of technology. For example, there might be concerns whether cloud storage of personal data is, in fact, a secure storage location or whether a risk exists that the data could be leaked to people outside the trusted community. Second, some people might question whether it is possible to trust other people’s behavior on a new technology. As a respondent in Yarosh’s (2013, p. 3417) study stated, “Even if there are rules that you don’t post other people’s names, you know somebody will at some point. So what happens then?” So, trust that has been established over time in social contexts is not automatically transferred to their online counterparts, but needs to be reestablished, on both a technical and a social level.

The Emotional Self

The third category of articles focused on emotions. As a core aspect of the self, emotions need to be accounted for in any research trying to understand the self and its interaction with technology.

Capturing Emotions

Many of the articles in this category focused on the possibilities for capturing the users’ emotions during interaction (e.g., Cardoso, Romão, & Correia, 2013; Huisman, van Hout, van Dijk, van der Geest, & Heylen, 2013; Pollak, Adams, & Gay, 2011). One such potential is to create better

interactive systems. According to Epp, Lippold, and Mandryk (2011, p. 715), the tendency of interactive systems to “provide inappropriate feedback, interrupt the user at the wrong time, and increase frustration” is often a consequence of the inability of the systems to recognize and adapt to the use context. The obvious solution to these problems would seem to be in developing context-aware systems; but, according to the authors, such systems are often both invasive and costly and are thus not always desirable. Instead of continuing trying to develop systems that can recognize location and other contextual data, Epp et al. (2011) suggested that one possible solution would be to develop systems that can capture the emotional status of the user and then utilize this information for a proper adaption of the system. These authors explored methods to analyze keyboard input patterns in order to identify connections between these patterns and the emotional status of the user. The results of their study suggested that it is possible to model “six emotional states, including confidence, hesitance, nervousness, relaxation, sadness, and tiredness—with accuracies ranging from 77.4% to 87.8%” (Epp et al., 2011, p. 716). So, the work of Epp et al. suggests that there is a clear connection between emotions and keystroke dynamics and that emotions therefore need to be considered an integral part of the self.

The Role of Emotions in Interaction

While Epp et al.’s (2011) research focused on the positive potentials of emotions (see also Cairns, Pandab, & Power, 2014; Conci, Pianesi, & Zancanaro, 2009; Harbich & Auer, 2005; Karapanos, Zimmerman, Forlizzi, & Martens, 2009; Salminen et al., 2008), other researchers explored the negative aspects of emotions. For example, Sas & Whittaker (2013) studied how people manage digital possessions that are no longer wanted and that are considered having a negative impact on the self and the self’s interaction with computer systems. By interviewing 24 people who had gone through a romantic breakup, the researchers wanted to identify the emotional connections between the respondents’ digital belongings and those of their former romantic partners, as well as how these connections had changed after their relationships had ended. The study explored a broad variety of digital possessions that had played either a communicative or a symbolic role in the relationships (e.g., records of conversations, contact information, relationship statuses in social media, photos, videos, music). The respondents described how, when the relationships ended, they had applied various strategies for establishing distance from their former romantic partners and how they considered erasing digital possessions as an important part of this process. However, due to the nature of digital possessions, implementation of such clean-slate strategies was next to impossible. As formulated by one respondent in the study, “Facebook doesn’t help because he can still contact my family even if I don’t speak to him. He could get in contact with my little sister or auntie on Facebook. That hindered [moving on] because every time I thought I had got to the point of moving on, something would happen that would take me back to square one” (Sas & Whittaker, 2013, p. 1826). So, this study provides an example of how human entanglement with technology creates historical sediment that is experienced not only as a positive aspect of contemporary technologies but also, at times, as challenging and upsetting when the sediment of digital possessions affects the self. (For research reflecting technology as a complex arena impacting both positive and negative emotions, see, e.g., Panger, 2014; Toma, 2010; Vasalou, Joinson, &

Pitt, 2007). Given the increased use of social media, it does not seem far-fetched to suggest that these complex aspects of technology will become an increasing challenge in the future.

Based on the insights into how important emotions are to the self, many researchers have discussed the possibilities of exploiting the positive aspects of emotions related to technology in order to reach certain instrumental goals. For example, in their study of users' emotional attachment to mobile phones, Meschtscherjakov, Wilfinger, and Tscheligi (2014) argued that "mobile attachment emerges when the mobile phone becomes part of the user's self concept [sic]" (p. 2317). This suggests that emotional attachment is not limited to brief, temporary sensations, but needs to be understood as something that relates to fundamental processes that constitute the identity of the self. Meschtscherjakov et al. (2014) presented three main components in the causes of mobile attachment. First, they explored the connection between the functionality and reliability of technology and the self's emotional attachment to it, arguing that it is "very unlikely that a person still experiences a strong attachment to his/her mobile phone when it no longer works properly" (p. 2320). Second, they suggested that emotional attachment is related to the way in which a mobile phone enriches the self. Self-enrichment is described as consisting of four components: (a) past self-enrichment, which means that the mobile phone reminds the self of previous experiences, which resembles parts of the discussion from the article by Sas and Whittaker (2013), even though Meschtscherjakov et al. approached the topic from a more positive perspective; (b) private self-enrichment, which means the mobile phone reflects both who the person is and the ideal image of who the person wants to be; (c) public self-enrichment, which is the actions that the individual takes to signal affiliation to a specific group; and (d) collective self-enrichment, which is similar to public self-enrichment, but reflects the affiliation on a more symbolic, ideological level that shows that the self has internalized certain norms and values that are appreciated within a specific group. Third, Meschtscherjakov et al. (2014, p. 2322) indicated that emotional attachment also relates to the way a mobile phone gratifies the self "through any combination of sensorial pleasures experienced during interaction."

So, clearly, the researchers in my analysis approached emotions from many different angles. Many studies presented emotions as being both a potential creative resource and a serious challenge to be overcome. Nevertheless, several researchers expressed the conviction that the emotional dimensions of the self are core to understanding the interaction between humans and technology.

The Playful Self

The fourth category of research explores the playful self, which is a self characterized by aspects of life, such as engagement (Lindtner, Mainwaring, Dourish, & Wang, 2009), fun, enjoyment and immersion (Gerling, Miller, Mandryk, Birk, & Smeddinck, 2014; Gonzales, Finley, & Duncan, 2009; Hwang, Holtzman, & Resnick, 2011; Mekler, Bopp, Tuch, & Opwis, 2014). Although the notion of play is sometimes connected to gaming, it is vital to separate the two. Play, in this context, is defined as a nonutilitarian activity where interaction is its own purpose; that is, it is not motivated by any kind of external teleology, even though there were examples of research where playfulness is used instrumentally to achieve a particular goal (e.g., Lindley, Harper, & Sellen, 2008). Many of the articles on gaming included aspects of nonutilitarian interaction. Others, however, focused more on the instrumental, and in this sense

utilitarian, character of gaming, such as gaming as social activity (Wohn, Lee, Sung, & Bjornrud, 2010) or gaming as an explorative tool (Bardzell, Bardzell, Zhang, & Pace, 2014), which illustrates that playfulness and gaming are not equivalent.

The nonutilitarian character of playfulness must not be taken as an indication that playfulness is something superficial and unrelated to the constitution of the self. On the contrary, many researchers suggested that playfulness is an integral component in the self. For example, Birk and Mandryk (2013) stated that play relates to both the idealized self and the real self, arguing that there is a strong connection between the playful game and the individual's self-perception and cognitive self-reflection. This theme was further developed by Mekler et al. (2014), who performed a review of 87 quantitative studies focusing on game enjoyment in an effort to summarize the field's perspective on this theme. In their study, they often approached gaming as a nonutilitarian activity similar to the suggested definition of playfulness. They argued that the enjoyment a player experiences is not a random momentary sensation but depends on the compatibility between the playful activity enacted in the game and the needs and values of the self. For example, they found research where players described how they had experienced a sense of guilt when playing games that contained components that somehow deviated from the moral beliefs of the player. As a result, games containing violence and torture were often described as less enjoyable, which indicates that portraying play as a mere superficial escapism isolated from everyday life is misleading. On the contrary, play is intimately related to the fundamental constitution of the self. In an effort to express this connection between play and enjoyment on the one hand and the self's identity on the other, Mekler et al. (2014) cited Lazzaro's suggestion to call game enjoyment "serious fun," indicating that play could relate to deeper aspects of the self, such as values, thoughts, and feelings.

Similar argumentation can be found in an article by Seay and Kraut (2007), where the authors discussed negative effects of gaming and how the powerful dynamics of play often utilized in computer games can lure an individual into situations and emotional modes that negatively influence the self. Such negative consequences can be physical (e.g., dry eyes or carpal tunnel syndrome), emotional (e.g., depression or low self-esteem), or social (isolation or detachment from families and friends). Many previous studies suggested that a phenomenon such as escapism is an important factor in developing problematic use, but Seay and Kraut argued that the main factor determining whether a player could develop problematic use is the individual's ability to self-regulate. The concept of self-regulation is described in the article as the ability to see rationally and self-reflexively one's own behavior (self-monitoring), compare that behavior to external standards, such as the behavior of other people (self-evaluation), and to administrate consequences based on those evaluations ("self-consequation"; p. 831).

Seay and Kraut's (2007) account depicted rational, reflexive cognition as an important control mechanism that can organize drives, pleasures, and escapism, and thus protect the well-being of the self. This implies a conflict of interest between the rational, cognitive character of the instrumental self, on the one hand, and the playful self, on the other. In this conflict, these authors seemed to favor instrumental rationality over playfulness.

But What About the Other Selves?

Looking at these four selves (the instrumental, the communicative, the emotional, and the playful), it is obvious that other aspects of the human are not present in this categorization.

One such aspect is the embodied self. As has been pointed out by, among others, Harrison, Tatar, and Sengers (2007), the body has historically been very important in HCI, but the phenomenological approaches common in recent research have brought the embodied self back into the center of attention in a new way (e.g., Dourish, 2004; Höök, Jonsson, Ståhl, & Mercurio, 2016; Klemmer, Hartmann, & Takayama, 2006). However, even though the bodily aspects of the human are important perspectives in HCI, they are almost entirely absent from the discourse on the self analyzed in this paper. With a few exceptions (e.g., Epp et al., 2011; Giraud, Courgeon, Tardieu, Roatis, & Maitre, 2014; Schiphorst, 2011; Wang, Turaga, Coleman, & Ingalls, 2014), discourse on the self does not include the body as a strong analytical component. As I noted in the Introduction, the *Oxford Dictionary of English* defines the word *self* as referring to that which distinguishes a person from others (Stevenson, 2010, p. 1613). Given this assumption in normal usage that the word *self* refers to that which defines an individual human being, it is quite surprising that most HCI researchers discussing the bodily aspects of the human do not use the word *self*. Is this a reenactment of the old Cartesian dichotomy between body and mind where mind rather than body is considered to be that which defines a human being? Or, could the discrepancy between the bodily perspectives of contemporary HCI research and the nonbodily perspectives offered in the discourse on the self be a consequence of the discourse's origins in early research regarding online environments? Much of the research on online environments explored the potentials of the new, abstract, intangible phenomenon that came to be known as cyberspace and, as a consequence, bodily aspects of the interaction between the human and this intangible phenomenon were marginalized to a point where it was sometimes discussed as a limitation from which digital technology could break free.

Because the discourse on the self is becoming increasingly important when discussing the human in HCI, one can ask what this absence of the body in the published discourse reveals about the direction of the domain and the way it understands the human. Will the discourse become a formation for research focusing on nonbodily aspects of the human that can exist parallel to the research focusing on the physical body as an indispensable part of the human? Or will the increasing use of references to the self in HCI research result in a shift away from the bodily aspects central to contemporary HCI and towards something else? Suggesting an answer to those questions is outside the scope of this discussion. Yet, it is important in this context to acknowledge that when HCI researchers talk about the body, they do not primarily refer to it as the self, or conversely, when they talk about the self, they often do not include bodily aspects of human life. Actually, the same thing can be said about many other aspects of the human that are absent from the categorization of the four selves. Nevertheless, even though they may be important perspectives of the human in regard to HCI research and design, they currently are not part of the published discourse on the self.

The Stable, Coherent, Individual Self

Through the literature analysis, I have identified four different descriptions of the self: the instrumental self, the communicative self, the emotional self, and the playful self. These perspectives often blend but they are nevertheless clearly identifiable as different ways of understanding the self. Despite the differences between these categories, they have some

important characteristics in common. Below, I will briefly describe three of these characteristics as presented in the literature.

First, in many of the articles, the self is described as a fairly stable entity. Changes might occur, but such changes often are seen as epiphenomenal to the self, rather than something that affects the fundamental, ontological constitution of the self. For example, in analyzing the effects of interaction, several researchers discussed emotional changes (e.g., Gerling et al., 2014; Panger, 2014; Toma, 2010), cognitive changes (e.g., Fox et al., 2013; Vasalou et al., 2007) or behavioral changes (e.g., Fox et al., 2013; Laschke et al., 2011; Maitland & Chalmers, 2010; Yarosh, 2013). Yet, although emotions, cognition, and behavior are important components of the self, one can question whether these three aspects alone constitute the self. Arguing that the self is reducible to these three components would, for example, exclude someone who is temporarily unconscious and therefore unable to think, feel, or act. So, the literature mainly describes the self as an entity that, behind such epiphenomenal changes, remains a stable, ontological entity.

Second, the self is portrayed as a coherent entity. Some researchers identified and discussed the complexity of the self, but these authors often interpreted this complexity as connected to things such as societal roles (e.g., Farnham & Churchill, 2011; Ozenc & Farnham, 2011; X. Zhao et al., 2012) or different phases in the interaction with technology (e.g., Karapanos et al., 2009; X. Zhao et al., 2013) rather than to the actual ontology of the self. In addition, some research (e.g., Kehr et al., 2012; Yarosh, 2013) focused on people's experience of conflicting drives, for example, someone who both wants to eat chocolate and lose weight or someone who is committed to keeping sober but who realizes that biological and chemical drives work against this decision. However, in these lines of research, the tensions experienced are not acknowledged as constitutive to the self, but rather considered to be exceptions to the norm. As such, they constitute problematic conditions that need to be overcome, rather than something constitutive of the self on an ontological level.

Third, the self is portrayed as an entity that has been, from the start, demarcated from other entities, be they human or nonhuman. Many articles in this review provided studies on how the self is affected by external entities of varying kinds, but the analyses do not describe the self as such to be originally conditioned by these relations. The relational impact is seen as secondary to an already existing individual self. Even in research on the communicative self, the self is described as ontologically separated from other people. Some of the researchers in this analysis portrayed the communicative process in terms of a simple process of transmitting information (e.g., De Choudhury et al., 2013; Hancock et al., 2007; Ozenc & Farnham, 2011; Raban et al., 2012; C. Zhao & Jiang, 2011). Others, however, acknowledged that this process is one of mutual exchange in which the sender is also a receiver and where communication is not only a form of transmission but also a form of relation (e.g., Riegelsberger et al., 2006; Romero & Markopoulos, 2005; Wohn et al., 2010; X. Zhao et al., 2012). However, even in the latter category of research, the separation between subject and object remains firm, and interaction is not seen as having a direct impact on the ontology of the self. In research that focused on the self in online environments, there were examples where the self was described as emerging through interaction, but even in those articles (e.g., Fox et al., 2013; Raban et al., 2012), there was often a clear, ontological distinction between the online selves (i.e., a person may have multiple) and an assumed authentic, actual self. Any impact that an online self might have upon the real self is seen as something purely

additional rather than constitutive to the self. However, a few exceptions to this individualistic approach were found, and these exceptions typically were found in research on the connection between culture and the self (e.g., Jiang et al., 2009; C. Zhao & Jiang, 2011). These authors often positioned the self in relational networks, even though sometimes it was unclear whether the influence of these networks on the self lay on a behavioral level or an ontological level. In other words, is the self a product of its surrounding culture to a degree where it can be seen as ontologically relational or does culture merely influence the way an already existing self communicates?

So, the HCI research literature analysis presented in this paper can be said to sketch a view of the self as a relatively stable, coherent, individual entity whose core characteristics precede interaction. However, this view of the self has been seriously criticized by scholars in various domains. For example, in philosophy, which has been recognized as an increasingly important resource for developing HCI (Bardzell & Bardzell, 2015; Fällman, 2007, 2011), this stable, coherent, individual self has been seriously criticized for a long time. Therefore, in the following section, I will briefly describe such critique from three philosophers who have had a major impact on the philosophical approach to selfhood: Friedrich Nietzsche, Michel Foucault, and Jacques Derrida. I have several reasons for choosing these three. They are usually acknowledged as three of the most powerful critics of modern selfhood. Furthermore, they represent three different philosophical epochs and propose three different philosophical approaches to selfhood. However, even though there are differences in their respective analysis of selfhood, a theoretical continuity exists between them insofar as Foucault and Derrida explicitly built upon and comment on Nietzsche's theories. Thus, they belong to the same critical tradition in European philosophy.

A CRITICAL ANALYSIS OF THE SELF

One of the most well-known philosophers discussing the self is Friedrich Nietzsche. Although his philosophy is complex and, according to some (e.g., Müller-Lauter, 1999), contradictory, it is evident that he is highly critical of the notion of a coherent, stable self. According to Nietzsche (1901/1968), what contemporary researchers call the self or the subject is nothing more than a collection of often-contradictory impulses. He suggested that this diversity is something that is veiled by a generalizing dynamic present in language. In his early essay, *On Truth and Lies in a Nonmoral Sense*, Nietzsche (1873/1979) argued that language works by generalizing, by erasing differences, and by ignoring particularity: "Just as it is certain that one leaf is never totally the same as another, so it is certain that the concept 'leaf' is formed by arbitrarily discarding these individual differences and by forgetting the distinguishing aspects" (p. 891). The same generalizing tendency based on linguistics can be seen, according to Nietzsche, in everyday use of the word self as well. Nietzsche (1901/1968) argued that, by using concepts like self and subject, people have come to believe that behind the disparate drives that are observable in human beings, there is some kind of unified entity that can be called the self. This idea can be found in his later writings as well. In a notation from 1887, Nietzsche wrote that the subject (i.e., the self) "is the term for our belief in a unity underlying all the different impulses of the highest feeling of reality"

(Nietzsche, 1901/1968, p. 268). So, according to Nietzsche, the coherent self is not an actual essential being but a linguistic construction.

However, this does not mean that the self is entirely empty or without possibilities for identity. On the contrary, the fact that the self is a linguistic construction means that there is a possibility for establishing new or alternative selves; if the self is a fictional story, then that story can be retold in other, more appealing ways. (For an in-depth discussion on the arguments for and against Nietzsche's view of linguistic selfhood, see Leiter, 2002; Nehamas, 1985/2002). By breaking free from the deceiving, oppressive, socially constructed linguistics (i.e., the relational aspects of language), one's linguistic self can be established as a free-standing entity. The creative potential of language in relation to the self thus lies in an individualizing move that separates the self from being influenced by the group or, in Nietzsche's terminology, the herd. According to Rüdiger Safranski (2003), this is what Nietzsche tried to achieve in his own life. Safranski argued that "self-configuration through language became a passion for Nietzsche" (p. 55) to the extent that he "sought to organize his life as a quotable foundation for his thought" (p. 27). This means that, to Nietzsche, "the essay was a mode of living" (Safranski, 2003, p. 28), a creative possibility that he suggested is available to his reading audience as well, which is evident in Nietzsche urging his readers to become "the poets of our lives" (Nietzsche, 1882/2008, p. 170). Thus, the linguistic foundation of selfhood suggests a malleable character of the self, which constitutes a sharp contrast to the self as a stable entity proposed in much of the HCI research.

Following the fascists' misuse of his writings in the early 1900s, Nietzsche's philosophy was considered obscure by many scholars. However, in the 1950s, his ideas were taken up by, among others, the French philosopher Michel Foucault, who spent a substantial part of his philosophical career—from his studies of madness in early modern Europe during the 1950s through his 1980–81 lecture series on the hermeneutics of the subject at the Collège de France—elaborating Nietzsche's ideas in order to explore the relationship between individuals and society. What is interesting with Foucault's perspective on this relationship is that he did not present the concept as a one-way street (Hutton, Gutman, & Martin, 1988). The individual is not reduced to a societal product nor is society reduced to a construction made by individuals. Rather, the influence is seen as mutual. Society constitutes and changes the individual who, in turn, changes both society and himself/herself. In much of his early work, Foucault focused on the impact of societal structures on the individual. Whether exploring the asylum, the prison, or the education system, he described the individual as contextually situated and thus fundamentally constituted by societal norms. He described how, historically, medical professionals have used medical diagnoses as tools for maintaining societal structures of power by constructing collective identities among groups of unwanted citizens who can then be institutionalized or subjected to other kinds of derogatory or disciplinary treatments (Foucault 1964/1992). He noted how the legal system and the idea of normality that emerged in the 19th century do not only have a repressive dimension, but also a productive dimension through which members of society are encouraged to engage in disciplinary processes that shape the way the individuals think and act (Foucault, 1975/1987). Thus, the cognitive and moral identity of the individual is a result of the person engaging in societal structures. However, society is not the only influence shaping the self. In his analyses of the hermeneutics of the self, Foucault explored how individuals shape their own selves, in other words, how they act upon themselves in order to shape their identities. In these works,

the self is described as a project that the self can finalize through various kinds of exercises (Foucault, 1982/2005).

An objection can be made that, as a historian, Foucault investigated only how the self had been described during different epochs, rather than personally observed, and this does not necessarily tell researchers anything about his view of what the self actually is. However, to Foucault, description is inseparable from essence. A central point in his argumentation is that how one talks about people changes the people and that this change can, in fact, be studied through analyzing artifacts such as medical records and events such as criminal acts. Furthermore, not only does discourse change an already existing identity, but identity is itself a consequence of discourse. According to Foucault, the self is discursively constituted, which means that the self can be understood as neither stable (because discursive practices change over time) nor individual (because discourse is, by definition, a societal function).

Jacques Derrida shares Nietzsche's and Foucault's view of the self as a linguistic construction, although in a slightly different manner. According to Derrida (1972/1982), the subject "is inscribed in language" and, as such, "is a 'function' of language" (p. 15), which means that the self is linked inextricably to the dynamics of linguistics. These dynamics were analyzed by Derrida throughout his philosophical career and have often been described in terms of *différance*. The concept *différance* suggests that meaning emerges through the differential dynamics between codependent signs rather than through simple identity and, because the self is linguistically based, the same differential dynamics characterize the self (Derrida, 1967/1973). In other words, the idea of a unified, individual self needs to be replaced by a view of the self as a relational creature characterized by otherness.

The complexities inherent in the idea of the self were further explored in Derrida's (1967/1973) elaboration of Hegel's discussion on the consequences of deictic expressions. Derrida took a simple example of someone saying, "I see a particular person by the window" (p. 92) and argued that the complexities and uncertainties that occur when such an expression is transferred over temporal and spatial boundaries are not accidental problems to be overcome, but instead should be understood as fundamental characteristics of language. In fact, Derrida suggested that they constitute the very possibility of language. Language functions by referring to a here and now that is never immediately present, which means that language, seen from a referential perspective, refers to things that are actually absent. In that sense, words are traces rather than labels. However, Derrida's substituting *labels* with *trace* does not suggest that presence can be rejected in favor of simple absence. Such either-or claims would only increase the dualistic ontology it aims to disrupt. Instead, trace should be understood as something haunting and disturbing the picture proposed by referential logic, indicating that any representation (including the representation of the self) always entails its opposite, thus contradicting the idea of the unified, individual self.

A similar perspective can be found in the essay "Signature Event Context" from the book *Margins of Philosophy* (Derrida, 1982), where Derrida discussed the breakdown of isolated subjectivity and exemplified this through a discussion of the connection between the self and its linguistic representation. He argued that, in order to be an individual, unique self, the subject needs a unique representation, in other words, a signature. However, the connection between the self and its signature is highly complex. In order for the signature to be recognized, it cannot be entirely unique and particular, but also repeatable. Rather than a unique event, the process of representation therefore is always a process of doubling, of copying, of citing. In its

attempt to secure its uniqueness and originality, the self becomes like everyone else; the self becomes other. The “iterability” of the signature is thus both a requisite for the unique individual and an indication of the impossibility of uniqueness. So, whether the concept is called *différance*, trace, or the iterability [sic] of the signature (Derrida, 1988), these concepts all articulate a fundamental critique against the unified, individual self.

These three philosophers all come from similar theoretical positions. The subject-critical arc—from Nietzsche, via Foucault, to Derrida—has been widely discussed and, although the three philosophers differ on important points, they share a skepticism towards the idea of the self as unified, stable, and individual (e.g., Boyne, 2013; Megill, 1987; Peters, Olssen, & Lankshear, 2003). It is important to note that this critique is not limited to these three subject-critical philosophers. Similar arguments have been presented by theorists as diverse as Sigmund Freud (1901/2002), Jean-Paul Sartre (1946/2007), Julia Kristeva (1982), and Paul Ricoeur (1992). Yet, from the literature analyzed in this paper, it seems that the impact of these approaches on the discourse on the self has been quite limited.

HCI LITERATURE PROBLEMATIZING THE SELF

Although fewer in number, several HCI researchers addressing the discourse of the self acknowledge the need to explore alternative aspects of the self (e.g., Bardzell, 2009; Bardzell & Bardzell, 2008a; Schmidt, 1997). An early attempt was Sherry Turkle’s studies of virtual reality (Turkle, 1994, 1996, 1997). These studies explicitly drew on postmodern philosophy; yet even though they often have been discussed and quoted in HCI (e.g., Bardzell & Bardzell, 2008b; Suchman, 2007), there are few explicit traces of that influence in the articles analyzed in this paper. Nevertheless, more recent research seems to be exploring these aspects. For example, among the researchers discussing the complexity of the self in relation to professional or societal roles, some do so in ways that tend to challenge the boundaries between roles and ontology to an extent that suggests that interaction can actually change or even constitute the ontology of the self, even though this is seldom explicitly claimed in these texts (e.g., Akah & Bardzell, 2010; McCarthy & Wright, 2005; Nóbrega & Correia, 2011; Park & Zimmerman, 2010; Petrelli, Van den Hoven, & Whittaker, 2009; Zimmerman, 2009). Others have taken it even further. In Bardzell et al. (2014), Foucault’s notion of the care of the self (Foucault 1982/2005) is used as an analytical lens in order to understand how the self establishes and changes itself through participation in the online environment Second Life. Through the online interaction, the individual is given opportunities to explore new sides of himself/herself; this process turns out to be not only epistemological but also ontological because it has a radical effect on the most fundamental constitution of the self. Foucault’s theoretical framework has also been used in a similar way by Leshed and Sengers (2011), who discussed online calendars and other technological productivity tools as “technologies of self” (p. 912). Their study showed that people do not use tools like these only to “organize what they do, but also who they are” (p. 912), which means that, far from a given ontological being, the self is a continuously changing project.

Similar problematizations of the notion of the self can be found in articles focusing on aging and illness. For example, in recent research that explored the possibilities of technology for improving life for patients suffering from dementia, the self is described as something malleable, historical, and social, for which interpersonal relationships are described as “sites

where self is maintained and constructed” (Wallace, Thieme, Wood, Schofield, & Olivier, 2012, p. 2629) “through reflection, storytelling and dialogue” (Wallace et al., 2013, p. 2617). This suggests that the self is radically relational on an ontological level (see also Eriksson, Artman, & Swartling, 2013; Sun, Ding, Lindtner, Lu, & Gu, 2014). Sas et al. (2013) explored the function of autobiographical memories for maintaining a sense of the self’s identity, indirectly implying that the self is a malleable construct rather than something given. A similar proposition on the narrative character of the self has been made by Andronico, Marti, and Martinelli (2007), who emphasized “the importance of storytelling in the creation of the self” (p. 662). This does not necessarily imply an entirely fragmented self on an ontological level, but it nevertheless illuminates the constructive aspects of the self.

So, there are examples, albeit relatively peripheral, of HCI research that approaches the self from alternative positions that can be seen as part of a subject-critical tradition. Even though it is important to acknowledge and further explore these resources, the HCI discourse on the self still draws primarily upon what can be called a modern view of the self, emphasizing qualities like stability, coherence, and individuality.

Given the philosophical critique that has had such an impact on the way the self is understood in many other academic disciplines, I propose that we as HCI researchers would benefit from revisiting and questioning our own assumptions regarding the self. One possible philosophical resource to use in such a project is the philosopher and media scholar Mark C. Taylor. Much of Taylor’s research consists of attempts to explore how the challenges of Nietzschean philosophy apply to the self in contemporary, technology-based societies. These explorations, in which Taylor draws upon a broad variety of theoretical resources outside of traditional philosophy, such as information theory and complexity theory, often focus on the relationship between the individual and the system. In many ways, this coincides with the fundamental interest of HCI: to understand the relationship between humans and computer systems. The cross-disciplinary character of Taylor’s work, his interest in contemporary technologies, and his focus on how individuals relate to systems make his work particularly interesting to use when trying to understand the conditions for the self in the 21st century and how that relates to the self upon which HCI focuses.

THE SELF ACCORDING TO MARK C. TAYLOR

Mark C. Taylor is highly influenced by the theories of Jacques Derrida and draws on Derrida’s ideas of language as a differential play between a sign and an otherness that “haunts language as a strange exteriority ‘within’ discourse” (Taylor 1993, p. 11). Taylor (1987) argued that, because the subject “is a ‘function’ of language” (p. 135), the self must be understood as characterized by the same differential play between the self and other as language. The consequence of this is that the idea of the individual self as separated from the other must be revised. Just as Ferdinand de Saussure (1916/1986) argued that all meaning occurs through the difference between signs, Taylor argued that all selfhood and all identity occur when confronted by that which is different: in other words, by otherness. This otherness can take various forms: other people, other ideas, other traditions, and other practices. This means that the idea of separating oneself from others in order to establish identity is fundamentally flawed and only leads to loss of identity.

This differential, linguistic play is something that occurs not only between the self and the other but within the self as well, which relates to Nietzsche's critique of the coherent subject (Nietzsche 1901/1968). Taylor (1987, p. xi) wrote: "If authorship is never original but is always a play that is an interplay, then clearly 'I' did not write this text. Or at least 'I' alone did not write it.... If, as some critics have argued recently, the author is an 'institution,' then institutions can, in some sense, 'author.'" Another example is when Taylor (2003) stated, "I, Mark C. Taylor, am not writing this book. Yet the book is being written. It is as if I were the screen through which the words of others flow and on which they are displayed" (p.196). In these excerpts, Taylor suggested that it is impossible to define the boundaries between different individuals when it comes to literary influences, thus implying that it is equally impossible to define the boundaries between individuals as such. So, in echoing Nietzsche, Taylor claimed that underneath the "I" is a multitude of voices and identities that have become hidden through the use of the generalizing term *I* and, thus, a more correct way of describing an author is in terms of an institution or as a screen onto which the words of others are displayed, an argument that is similar to that which Foucault formulated in *Archeology of Knowledge* (Foucault, 1969/1972). In that book, Foucault argued that an author is not a person but a function. While acknowledging that, most often, a text can be attributed to one specific, physical person who has produced the text materially onto a piece of paper, Foucault denied the claim that this person is a homogenous self whose thoughts are a result of the self's creative originality. It is to this critical tradition that Taylor adheres, which is also evident in his foreword to *The Moment of Complexity: Emerging Network Culture* (2003), in which he argued "A work is never the creation of a solitary individual but is always the product of a 'colony of writers' whose thoughts and words circulate through the author" (p. xi). This analysis of authorship suggests that otherness is not something external to which one can relate in different ways. Rather, otherness is something within human beings, something that makes it impossible to assume the existence of a coherent self. Human beings are heterogeneous rather than homogeneous.

Ever since his early works on Hegel and Kierkegaard in the late 1970s (Taylor, 1975, 1980/2000), Taylor has focused much of his research on how to understand this intrapersonal heterogeneity, often through exploring poststructuralist theory. Arguing that poststructuralism offers a way of saving otherness from oppressive identity, he also claimed that it suffers from an inability to acknowledge that systems are not totalizing per se but are rather a necessary condition for selfhood. Insisting on the linguistic constitution of the self, Taylor assumed Gregory Bateson's classical formulation that "information can be defined as a difference that makes a difference," and that "Inasmuch as information is differential, it increases with an increase in differences. Differences, however, can multiply only as interconnections grow" (Taylor, 2003, pp. 139–140). This means that, paradoxically, difference can only exist in connectivity. Isolation inevitably reduces heterogeneity to homogeneity and, therefore, if difference is to be preserved, this difference must be positioned in relation to other parts of a system. To Taylor, this means that systems constitute a presupposition for difference and not a threat to it. To the extent that difference is a core characteristic of the self, this also means that the self does not precede its interaction with the system but is instead a result of the interaction. Thus, the constitution and stability of the self is something temporary that emerges through the interaction between the self and the other.

In order to deepen his understanding of how such nontotalizing systems function, Taylor started exploring different kinds of complexity theory (e.g., works by Henri Atlan, Stuart Kauffman, John Holland, and Stuart Gell-Mann) in the late 1990s. Since that time, he has written several books where he used theories on complex adaptive systems to analyze phenomena as diverse as art (Taylor, 1999), financial systems (Taylor, 2004), theology (Taylor, 2007), and environmental systems (Taylor, 2014). According to Taylor (1999), “Complexity theory constitutes a third alternative between structuralism, in which fixed universal structures exclude time and repress specific differences, and poststructuralism, in which the criticism of the purportedly totalizing propensities of all systems leads to a valorization of differences that share nothing in common” (p. 119). Taylor’s explorations into the field of complexity have attracted the interest of many researchers from mathematics and physics, resulting in the 2004 special issue of *JAC (A Journal of Composition Theory)*; Blakesly & Rickert, 2004), where his analyses and applications of complexity theory were discussed.

Describing what characterizes complex adaptive systems (CAS), Taylor quoted computer scientist John Holland: “The agents in CAS are not only numerous, they are also diverse.... This diversity is not just a kaleidoscope of accidental patterns. The persistence of any given part (agent) depends directly on the context provided by the rest. Remove one of the agent types and the system reorganizes itself with a cascade of changes.... Moreover, the diversity evolves, with new niches for interaction emerging, and new kinds of agents filling them” (Holland, quoted in Taylor, 1999, p. 122). This quote illustrates three points regarding complexity theory that are important to Taylor. First, it offers a possibility to understand difference as an integral part of a systemic structure rather than as something that needs to be excluded in order to establish that structure. Second, not only does the system accept difference but it actually stimulates it through enabling the interaction between multiple components. Third, this interaction is what creates emergent structures, an idea that positions organizational agency among a variety of decentered, differential components rather than with one centralized, hierarchical power.

Viewed through the lens of complexity theory then, the relation between the self and the other, individual and system, is one of mutual dependency. The self is created through its interaction with the system as much as the system is constituted by the interaction between its distributed parts. From this perspective, collapsing difference into identity, heterogeneity into homogeneity, would destroy rather than constitute order, structure, and meaning.

To conclude, Taylor’s specific blend of poststructuralism and complexity theory constitutes a radical critique of the stable, coherent, individual self found in much of HCI discourse. Through his writings, a picture of the self as malleable and relational emerges and suggests new interpretations of the self as well as its interactions.

DISCUSSION

From this brief overview, it is evident that Taylor considers the critiques that Nietzsche, Foucault, and Derrida posed against the modern self to be too substantial and too important to ignore for understanding the conditions for the self in the 21st century. Although Taylor often situated his analyses within traditional linguistic contexts, such as literature studies, information science, and media studies, his conclusions are not limited to these domains:

They apply to any and every analysis of the self, including HCI research on the interaction between humans and computers. What would the consequences be, then, if his theories were applied to the four selves identified in the literature analysis? From my research perspective, his theories do not oppose describing the self as instrumental, communicative, emotional, or playful. However, a strong argument could be made that Taylor offered an alternative interpretation of the connections between these four selves and the qualities of stability, coherence, and individuality.

First, Taylor emphasized that the self is not coherent but always characterized by that which is different from it. Therefore, the demarcations between the various aspects of the self function as membranes rather than as strict boundaries. This has been implied occasionally in the HCI literature, for example, in the articles describing a communicative act as often influenced by instrumental motives (e.g., Ducheneaut et al., 2009; Ellison et al., 2006; Nov et al., 2008; Pilcer & Thatcher, 2013; Shami et al., 2009). However, these kinds of cross-quality influential flows are seldom applied in HCI research as explanatory frameworks for how to understand the interaction between humans and technology. When viewed through Taylor's theoretical lens, interaction is a complex combination of instrumental, communicative, emotional, and playful (and perhaps other) components. No interaction is ever reducible to one mode only. Although this perspective might complicate the analytical task, it might also help designers and researchers understand certain behaviors and interactional outcomes that might otherwise fall outside of the explanatory framework. Thus, this perspective might help researchers avoid a reductionist approach to the studied phenomena.

Second, given how important Taylor considers the interaction between the self and the other to be for the constitution and maintenance of the self (be it instrumental, communicative, emotional, or playful), it is reasonable to suggest that, in his philosophy, interaction serves an existential purpose. This also means that interactive technology becomes an existential arena that is compatible with what many HCI researchers describe but do not always emphasize: Technology today is not an additional layer in society but rather something that permeates all levels of society to the point where it has become increasingly difficult to draw the line between technology and life in the 21st century. Framing interactive technology as an existential arena suggests that designers and researchers steer away from dichotomies in interpreting the relation between the self and technology. The dominating paradigmatic interpretation of the human as a user with its instrumental connotations has sometimes veiled the fact that all interaction (technological as well as nontechnological) changes the self and is a primary precondition for selfhood. Acknowledging this relation between technology and the constitution of the self might deepen the understanding of the role that technology plays in people's lives in contemporary society. Furthermore, it might also contribute to developing the interface to other academic disciplines that focus on existential aspects of human life, for example, the humanities and social sciences.

Given the literature analysis and the philosophical critique presented in this paper, I propose that we as HCI researchers need to reinvestigate our own assumptions regarding the self. How do we perceive and theorize the self and its relation to its surrounding world? The way we answer this question brings not only philosophical implications but also determines the way we approach the self in research, both in terms of the questions we ask and the way we interpret our research results. For example, if researchers assume that the self is an individual entity whose constitution precedes interaction, young people's continual urge in being

connected to, communicating through, and confirmed in social media will be interpreted quite differently than if the assumption is that the self is constituted by its relations.

Furthermore, the understanding of the self also affects researchers' ability to provide relevant contributions to society at large, as well as to other scientific disciplines. I suggest that Taylor's corpus is a valuable philosophical resource for such a reflexive project. The way that he combined the critical tradition of the 20th century with complexity theory and insights into 21st-century technologies makes him particularly relevant to contemporary HCI.

IMPLICATIONS FOR RESEARCH

This research focused on the discourse on the self in HCI publications. Through an inductive content analysis, the paper illustrated how the dominant discourse in recent literature on the self in HCI is rooted in what can be called a modern view of the self. Drawing on poststructuralist theory, the paper then revealed blind spots in this discourse and illustrated how Mark C. Taylor's philosophy can provide theoretical resources for addressing these blind spots and engaging in a reconceptualization of the self. Thus, the findings presented can be used for a renewed, critical discussion on how the notion of the self is conceptualized in HCI theory and research practice. Such a discussion may lead to the identification of new fields of research and alternative interpretations of the motivations underlying people's interaction with technology. One such focus area, which the article identifies as key to understanding the relationship between humans and technology, is the exploration of technology as an existential arena and, relatedly, interaction as an existential practice.

CONCLUSIONS

Through studying the use of the term the self in HCI research literature, I identified four main approaches to the self: the instrumental self, the communicative self, the emotional self and the playful self. Despite the many differences between them, these four selves are described as having three core qualities in common: stability, coherence, and individuality. However, as discussed within the paper, several philosophers during the last century have questioned these assumptions, and I therefore argue for a reconsideration of the current understanding of the self in HCI. I drew on Mark C. Taylor's critical approach to the self and suggest that his philosophy can serve as an interpretative lens illuminating parts of the self that previous HCI research has not recognized. In highlighting Taylor's blend of poststructuralism and complexity theory, I therefore suggest that the self should be understood as radically relational, which means that interaction is an existential constitution process and, as a result, interactive technology is an existential arena.

ENDNOTE

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1. The ACM Digital Library can be accessed at <http://dl.acm.org>

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ALIGNING INFORMATION TECHNOLOGIES WITH EVIDENCE-BASED HEALTH-CARE ACTIVITIES: A DESIGN AND EVALUATION FRAMEWORK

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Abstract: Evidence-based health care (EBHC) has given rise to expectations that decision-making be tethered to more high-quality information. As health information technologies (HITs) acquire an increasingly vital role in the information processes involved in EBHC, a more mature understanding is needed of the relationship between HITs and the EBHC activities they serve. In this paper, we conceptualize HITs and EBHC activities on a common foundation of distributed cognition that treats humans, technology, and the environment as interwoven parts of a whole, dynamic system. From that common foundation, we articulate a basis for achieving a contextually sensitive fit between HITs and EBHC activities by providing a framework (DETECT) of 20 properties that can be used to systematically characterize the fit between HITs and EBHC activities. Designers, deployers, and evaluators of HITs can use DETECT to better anticipate, locate, and diagnose the issues that arise when HITs are used to achieve diverse EBHC commitments.

Keywords: health information technology, evidence-based medicine, distributed cognition, integration, health-care activities.



INTRODUCTION

Health-care practice is fed by more information from a wider range of sources than ever before. Although this presents a great opportunity, the task of better integrating this information into the diversity of activities that make up health care can be a difficult one (Straus, Tetroe, & Graham, 2013). Researchers in evidence-based health care (EBHC), perhaps the most influential force reshaping the use of knowledge and information in contemporary health care (Mykhalovskiy & Weir, 2004), aim to facilitate the use of the best available scientific information to ensure the most appropriate decision-making. EBHC stakeholders (e.g., health practitioners/workers, policy-makers, public health managers) aim to improve health-care outcomes, clinical practices, and efficiency and effectiveness in health-care delivery. Toward this end, EBHC research concerns a range of issues, including (a) summarizing the methods and criteria to rank research (Glasziou, Vandenbroucke, & Chalmers, 2004; Woolf, Schünemann, Eccles, Grimshaw, & Shekelle, 2012), (b) training stakeholders in the skills required to appraise and employ the evidence (Greenhalgh, 2014), (c) developing and updating infrastructures for evidence-based guidelines (Hill, Bullock & Alderson, 2011), (d) clarifying the nature and scope of evidence (Charon, 2006; Goldenberg, 2006), and (e) explicating the relationship of evidence to its context of use (McNutt & Livingston, 2010; Weiner, 2004).

In recent years, researchers contributing to a growing body of health information technology (HIT) literature also have begun to explore how technological advances can be leveraged to contribute to the EBHC agenda (Rodrigues, 2000; Timsina, El-Gayar, & Nawar, 2014). Because HITs provide the means to acquire, appraise, and apply the evidence central to EBHC, they play a pivotal role. Thus, HIT researchers occupy themselves with a wide range of concerns, including:

- The use of automated tools for evidence generation, distillation, or synthesis (Cohen et al., 2010; Kim, Martinez, Cavedon, & Yencken, 2011),
- The integration of evidence across multiple computational sources (O’Sullivan, Wilk, Michalowski, & Farion, 2010),
- Decision support for incorporating evidence-based protocols into clinical workflow (El-Kareh, Hasan, & Schiff, 2013; Sim et al., 2001),
- Standard clinical vocabularies to ensure understanding among systems (Sim, Sanders, & McDonald, 2002),
- Web-based platforms to facilitate physician-patient communication (Swan, 2012), and
- The technological bases for institutional learning and improvement (Abernethy et al., 2010; Bigus et al., 2011).

Despite the shared interests between the EBHC and HIT communities, there is a fundamental disconnect between the two. On the one hand, the dominant conception of EBHC activities assumes that these activities can be defined and understood without reference to the constitutive role that HITs play. For example, models of evidence utilization (Graham & Tetroe, 2007; Green, 2006) tend to portray the generation, synthesis, and tailoring of evidence as an exclusively human-driven activity, without regard for how HITs filter, process, and display that evidence. On the other hand, HIT researchers seek to address EBHC issues by focusing on technical considerations, dealing with the fundamental nature of information and evidence primarily as a peripheral issue. For example, the efforts toward creating contextually sensitive decision-support

systems rely on overly simplistic algorithmic aspects of clinical reasoning and workflow, while the need to support clinical decisions within a dynamic information ecology remains an underdeveloped area of study. We contend that, in order to truly seize the opportunity of better integrating information into EBHC activities, this disconnect must be overcome and greater movement towards harmonization must be made by both researchers and practitioners. Specifically, more must be done to understand the dynamic and distributed context within which stakeholders and HITs interact and cooperate with one another to create and utilize evidence. Parallel with the growth of health-care knowledge, there is a proliferation of HITs (particularly health informatics tools) in the health-care industry. EBHC activities are becoming increasingly dependent on both knowledge as well as HITs. A more nuanced understanding of the relationship between HITs and EBHC activities is becoming increasingly vital. Without a clear understanding of how to conceptualize the relationship between HITs and EBHC activities, a design and evaluation gap exists that limits the effectiveness of HITs in supporting these activities. The purpose of this paper is to contribute to the bridging of this gap.

In this paper, we propose a framework, **DETECT (Design and Evaluation of HITs for EBHC Activities)**, to help with the systematic design and evaluation of HITs to better support the relationship between health-care stakeholders and HITs in the execution of EBHC activities. Three assertions lay at the foundation of our approach. Firstly, while it is increasingly common to see dynamic, relational, and contextually sensitive approaches to knowledge in health care (Nicolini, Powell, Conville, & Martinez-Solano, 2008), these approaches are less common in research conducted from information and cognitive lenses. Rather, dynamic and contextual approaches tend to be sociological, political, or ethical in outlook, while cognitive approaches often retain the individualism, rationalism, and determinism of more traditional research (Hutchins, 1995; Patel, Kaufman, & Arocha, 2002). In this paper, we are committed to exploring cognitive and information phenomena in a dynamic, contextual way. Secondly, the lack of use of cognitive and information-processing perspectives in understanding the human and relational aspects of HITs in EBHC has its ultimate root in the tendency of cognitive science to strip away the body and environment from any active role in information processing (Clark, 2008). In this paper, we discard the traditional dichotomies among mind, body, and environment and, using the theory of distributed cognition, foreground how relationships among these components enable and support the information processing that underlies dynamic EBHC activities. Thirdly, while many researchers have explored empirically the utility of HITs in diverse health-care settings (e.g., evidence-based health informatics; Ammenwerth & Rigby, 2016), a paucity of research remains regarding attempts to contextualize those findings within rigorous theoretical frameworks that encourage systematic analysis of HIT-stakeholder relationships. In summary, the use of HITs to serve the goals of EBHC remains theoretically underdeveloped and lacking in generalizable principles that would allow researchers, designers, and evaluators of HITs to systematically analyze and implement HITs with optimal support for EBHC activities. In this paper, we lay out the DETECT framework of factors to assist those who design, deploy, or evaluate the integration of HITs into EBHC activities and settings.

The balance of the paper is laid out as follows. We begin by investigating the conception of activities found in the EBHC literature by reevaluating the emphasis placed on behaviorist and traditional cognitive conceptions of EBHC activities and recasting them in light of their reliance upon distributed, dynamic, contextual, and emergent cognition. After discussing the characteristics of EBHC activities, we turn our attention to examining HITs, specifically the

difficulties associated with integrating HITs into EBHC activities, partly because of conceptions that obscure their relationships to their environment. This work allows us to articulate a basis for systematic conceptualization of the relationships that bind HITs to stakeholders in EBHC activities. In the last section of this paper, we present DETECT, a framework of general factors that researchers, designers, and evaluators of HITs can use to systematically analyze HIT-stakeholder relationships in the service of seamlessly integrating HITs into EBHC activities.

EBHC ACTIVITIES

EBHC activities rarely are the result of a single stakeholder thinking and acting in seclusion from others or without the aid of external artifacts. Most EBHC activities are dynamic, contextually sensitive, and achieved through the stakeholders and artifacts working in unison. In this situation, information moves back and forth between various stakeholders and artifacts, in different places, and through a variety of media. Consider a team of emergency room practitioners performing a targeted assessment to stabilize a heart attack patient upon her admission. The team will need to obtain vital signs, a medical history, a complete physical exam, several test results, information derived from a variety of sources, including the patient or family, the hospital medical record database, an x-ray machine, and the clinical lab. The information used to stabilize the patient is diverse and variable. The patient assessment and treatment are the result of the coming together of all of these sources of information. To look at each of these information sources as independent entities obscures the dynamic interdependence of the information and the necessary relationships that bind them together in enabling the best decision at the right time.

At its heart, EBHC is intended to help various stakeholders perform activities aimed at making the right decision at the right time. EBHC relies on the deliberate, conscientious, and systematic use of available evidence in diverse activities and settings to improve health care. Evidence in this context can refer to knowledge and information in a variety of forms: the current best scientific research evidence, practitioner expertise and judgment, patient narratives (Charon, 2006), and/or other contextual factors (such as cultural or traditional knowledge; Brownson, Baker, Leet, Gillespie, & True, 2010). Writ broadly in this way, EBHC activities encompass all practices, behaviors, and skills that rely explicitly on information and knowledge across all areas of health care (Gray, 2010).

In today's EBHC climate, activities are more information- and knowledge-intensive than ever before. The characteristics of the information that those activities rely on (e.g., its scope, its quality, and its inherent subjective or objective properties) are, in themselves, factors in shaping those activities. Hence, whether an activity is evidence-based will depend partly on the characteristics of the information that it relies on. For example, the process of safely administering some vaccines, while a relatively simple practice, can require extensive knowledge about the factors that may predispose a patient to an adverse reaction, the characteristics of the infectious disease, and social and demographic information about its spread. Making an evidence-based decision to vaccinate or not must be done within a context that integrates these different sources of information into an apt solution, a process that rarely follows a linear formula. In short, EBHC activities increasingly rely on the appropriate and effective use of high-quality information and knowledge, and assessing whether a decision is

evidence-based requires evaluating it in the context of the characteristics of the information used to support it. Because of this, EBHC activities and the information on which they rely are best understood as connected and associated, rather than analytically separate.

Supporting EBHC activities, then, calls for an understanding of how the characteristics of information shape activities in dynamic EBHC contexts. Until now, however, the EBHC community has not been centrally concerned with considering the characteristics of information and the relationships that bind information to its environment. Rather, implementation of EBHC has tended to focus on the categories or types of information needed for health care, the methodological rigor with which that knowledge is produced, or the skills and practices that allow stakeholders to access it (Sedig, Parsons, Naimi & Willoughby, 2015). Alternately, some attention in the EBHC community has been directed toward the cultural, ethical, or political issues involved in using evidence (Holmes, Murray, Perron, & Rail, 2006). Although these are important factors in successfully employing EBHC, they do not represent the full reality. These approaches stop short of spelling out the implications for how information is integrated and used in dynamic EBHC activities. This failing results in the treatment of EBHC activities in the literature as sterile and lacking nuance. Thus, the presentation here of our survey of some of the common conceptions of EBHC activities provides a useful tool in advancing the goal of closely integrating the human, experiential, medical, technological, and contextual components contained in EBHC activities.

Perhaps the most common misconception is that EBHC activities are primarily a behavioristic enterprise, that is, rooted in tasks. EBHC activities typically are seen as observable or measurable skills and practices, such as teaching physicians the skills to conduct evidence-based inquiry or decision-based interventions aimed at supporting clinical workflow (Greenhalgh, 2014). Associated with this, EBHC activities often are conceptualized in functional, utilitarian, or goal-centered ways, that is, what users do, rather than what users know or should know. As a result, the approach to these activities bypasses the role of information or cognitive dynamics. Thus, this view tends to take a post hoc view of tasks built upon assumptions that the steps to task completion can largely be specified a priori. Here, the ends supplant the means, and analytical primacy is given to the outward and observable aspects of task execution. For example, the labels “decision-making tasks,” “diagnosis tasks,” or “data collection tasks” do not describe the inner workings of how those activities are accomplished, but rather the outcome or product of task accomplishment.

Moreover, even when information and cognition are figured into the analysis of EBHC activities, they tend to be derived from traditional psychological and economic models of decision-making (Bucknall, 2007) that misrepresent cognition as individualistic, rationalistic, and objective (Hazlehurst, Gorman, & McMullen, 2008; Patel et al., 2002; Sedig et al., 2015). Researchers working from the perspective of traditional cognition tend to treat information processing as a purely mental phenomenon and overemphasize the normative, universal, and systematic aspects of human thought. In EBHC, this view directs the attention of those implementing and supporting EBHC activities to the predictable, context-independent, and mechanistic aspects of information use, which are assumed to be executed in much the same manner regardless of the activities they serve, where they are carried out, or the stakeholders engaged in the activity. For example, the tendency to reduce EBHC activities to the mere access of explicit and precodified medical evidence assumes that the cognition used to process that information is itself linear and predictable (Sedig et al., 2015).

Beyond the purely theoretical problems associated with existing conceptions of EBHC activities, there also lies the practical mismatch between those conceptions and the information needs of the modern health-care system; that is, despite the prevailing emphasis in EBHC on information processing that is linear, objective, rational, and predictable, many health-care situations are unpredictable, ill-structured, or defy standardization (May & Ellis, 2001; Timmermans & Berg, 2003). In these cases, evidence, guidelines, or protocols may be unavailable, only indirectly relevant, and/or require extrapolation or other transformations to be useful, leaving the stakeholders to rely heavily on their own unaided judgment (Bohmer, 2009; Green, 2006). For example, in formulating public health policy to address the rising tide of childhood obesity, where little research exists, policy makers may need to use information and evidence whose import does not bear directly on the present problem. Then they will need to make nuanced judgments and interpolations, with no prespecified rule or guideline to guide the process, in order to extend evidence from other policy situations to the current problem.

Ultimately, the problems associated with conceptualizing EBHC activities can be traced to the philosophical orientation of brain-body dualism (Clark, 2008) built upon the assumption that cognitive activities can be understood and supported without a holistic understanding of how the brain, environment, and body work together. Conceptualizations of EBHC activities borne of this position tend to be linear and rationalist because it is assumed that the information and knowledge required to perform any EBHC task can be accounted for with reference to the mental states of the stakeholder(s) in isolation from the context or environment. In contrast, in this paper we suggest that the execution of EBHC activities relies on information processing achieved through a reciprocal relationship among mental, behavioral, and environmental phenomena. In the next section, we elaborate on the theory of distributed cognition as a platform from which to dissolve the underlying linearity of traditional approaches to EBHC activities and systematically investigate the holistic relationships among the brain, body, and environment. This process serves as a precursor to proposing the conceptual framework, DETECT, for better aligning EBHC practice with HITs.

EBHC ACTIVITIES WITHIN DYNAMIC AND DISTRIBUTED COGNITIVE SYSTEMS

Distributed Cognition

The theory of distributed cognition allows for investigating how information and knowledge are used in real-world settings (Hutchins, 1995). Two fundamental assumptions in the theory are that no division exists among the brain, body, and environment and that cognition results from several information sources and channels working together. In health care, distributed cognition has been used to understand the cognitive dynamics underlying medical communication and collaboration (Hazlehurst, McMullen & Gorman, 2007; Hazlehurst, McMullen, Gorman & Sittig, 2003; Nemeth, Nunnally, O'Connor, Klock & Cook, 2005), the various issues related to medical tools and technologies (Horsky, Kaufman, Oppenheim & Patel, 2003; Nemeth et al., 2005; Xiao, Schenkel, Faraj, Mackenzie & Moss, 2007), medical education (Bleakley, 2006; 2010), and medical decision-making (Patel et al., 2002).

Cognition as Distributed and Contextual

Real-world cognition is not the exclusive product of processes internal to an individual's brain, but rather the result of dialectical interaction, coordination, and alignment of the multiple information resources embodied in the body, brain, physical and social environments, and time. As such, the relevant unit of analysis for cognition is not the individual, but rather the "activity system" that comprises the human beings, the artifacts, and the objects in the environment that contribute to the performance of a cognitive activity (Hazlehurst et al., 2008). Cognitive activity, comprising of subactivities, tasks, subtasks, and lower level actions, is an emergent phenomenon, resulting from a number of ongoing relationships between information-bearing structures and processes working harmoniously within an activity system, and thus cognition cannot be understood by examining any one of these pieces in isolation (Sedig & Parsons, 2013).

Cognition as Emergent

Cognitive activities can be described as either simple or complex. Simple cognitive activities are typically elementary processes, such as perception and memory, which can be carried out independent of any specific environment or context (Funke, 2010) and tend to follow a linear, predictable progression. For example, a physician typically can recall many basic medical facts from her¹ long-term memory in response to a situation requiring such information (Ericsson & Kintsch, 1995). Complex cognitive activities, on the other hand, are the emergent product of multiple instances of simple cognitive processes, such as sensemaking, decision-making, learning, planning, and problem solving (Sedig & Parsons, 2013). Knauff and Wolf (2010) identified two characteristics of complex cognitive activities. Firstly, such activities rely on other cognitive processes, such as perception or memory, for their execution. Secondly, they occur in complex conditions. Cognition is complex when it is generally unstable, unpredictable, or impossible to understand without a sense of the broader conditions of its execution. For example, sensemaking may be complex when the information being used is intractable, the activity difficult to initiate and comprising many other tasks and subtasks, or the other variables involved exhibit a high degree of interdependence (Funke, 2010; Knauff & Wolf, 2010; Sedig & Parsons, 2013).

Cognition as Dynamic and Ongoing

Another important implication of distributed cognition is that complex cognition is dynamic and ongoing. Evidence is not a fixed trait, capability, or resource, but rather an ongoing accomplishment that must be constantly reconfigured in light of changing conditions (Orlikowski, 2002; Sedig et al., 2015). Because the interactions among all the factors that bear upon cognition are unpredictable, the cognition underlying EBHC activity is nonlinear and unpredictable, and its outcome or performance can never be specified beforehand (McClelland, 2010). From the perspective of distributed cognition, EBHC activities are contextually realized accomplishments that involve the alignment or coordination of various sources of information brought together in the context of an activity system to accomplish specific EBHC goals and tasks. These sources of information undergo iterative transformations through processes carried out via diverse media, including stakeholders and HITs.

In summary, there exists a clearly dynamic, distributed, and emergent character of EBHC activities and, because HITs nowadays play such a vital role in EBHC executions, our concern here is to understand how HITs can be properly aligned with and seamlessly integrated into EBHC activities. Before we discuss how HITs and stakeholders can be understood to work together in the context of EBHC activities, we briefly address the various conceptualizations of HITs that act as barriers to fully understanding how they participate in dynamic EBHC activities.

CONCEPTUALIZING HEALTH INFORMATION TECHNOLOGY

HITs have not received sufficient attention in the EBHC literature. Despite the different origins and distinct concerns of the two research communities, today the situation is such that the goals of EBHC cannot be adequately discharged without the assistance of HITs. HITs mediate EBHC activities at every turn, yet the mainstream EBHC community remains content to leave HITs as an invisible and unacknowledged substrate upon which EBHC activities rely. In this context, fostering alignment between HITs and EBHC activities is rife with difficulties, as evidenced by the varying degree of success that accompany programs of HIT implementation. For example, the use of HITs in health care often has been characterized by low adoption rates (DesRoches et al., 2008; Jha et al., 2009), misuses, and unexpected failures (Ash, Sittig, Dykstra, Campbell & Guappone, 2009; Karsh, Weinger, Abbott & Wears, 2010). Incongruous use of HITs also can lead to a decline in the quality and safety of health care (Linder, Ma, Bates, Middleton & Stafford, 2007; Zhou et al., 2009), enable faulty decision-making and miscommunication (Niazkhani, Pirnejad, Berg & Aarts, 2009), and give rise to new potential for medical errors (Koppel et al., 2005). In the remainder of this section, we discuss the limitations of four common conceptualizations of HITs and, in the following section, highlight the active information-processing role that HITs play within EBHC activities.

Confusion abounds in the literature about how to conceptualize and define HITs. The problem, although applicable to all HITs, is well illustrated through efforts to define the electronic health record (EHR). Consider, for example, the following statements: “According to the literature, the meaning of EHR is unstable. An EHR has many functions and includes many kinds of data, and it is obvious that there is a need to determine explicitly what EHR means” (Häyrynen, Saranto & Nykänen, 2008, p. 292). Adler-Milstein and Bates (2010) agreed: “There has historically been little agreement on what type of IT system meets this definition [of EHR]” (p. 122). Attempts to define EHRs are generally either too vague to be meaningfully distinguished from other tools or rely on decomposing the system into its functional components, offloading the burden of definitional clarity onto the tools or systems of which they are composed (Jha et al., 2009; Tang & McDonald, 2006). The same problem exists in relation to other HIT systems (Tang & McDonald, 2006), including all new and emerging health informatics tools for the age of big data (Andreu-Perez, Poom, Merrifield, Wong, & Yang, 2015; Fang, Pouyanfar, Yang, Chen, & Iyengar, 2016; Tresp et al., 2016). As a result of this lack of clarity surrounding HITs, it is naturally difficult to understand exactly in what sense HITs can support or improve the quality of EBHC activities.

In general, there are four ways in which HITs are understood to contribute to health-care activities. Firstly, HITs can be categorized in a system-centered way. For example, they can be classified in terms of the system specifications, hardware, or software. Secondly, HITs can be categorized according to the operational or disciplinary context in which they are used. For example, they may be understood from the perspective of clinical informatics, public health informatics, nursing informatics, imaging informatics, or consumer health informatics (Barrett, Liaw, & de Lusignan, 2014; Demir, 2016; Hersh, 2009; Moen & Knudsen, 2013; Shortliffe & Cimino, 2006). Although these sorts of classifications serve to highlight the unique disciplinary differences in the application of technology, they fail to highlight the aspects of HITs that transcend disciplinary boundaries and the role they play in supporting the actual information flow that underlies EBHC activities. Thirdly, HITs have been categorized in terms of their functional capabilities (Faraj & Azad, 2012). Functionality-centered definitions treat HITs in terms of the type of operational goals or tasks that they intend to support (Adler-Milstein & Bates, 2010; Tang & McDonald, 2006). For example, EHRs are defined as such because they support clinical documentation and results management, computer-order entry systems are labeled as such because they support order-entry management, and so on. Looking at HITs in terms of their taken-for-granted features fails to account for the diverse ways they are actually used (Leonardi & Barley, 2010; Orlikowski & Iacono, 2001), pays inadequate attention to the role that HITs play in the dynamic use of information, and provides an insufficient foundation for the design of HITs (Woods, 1998). The result of this misalignment between the actual necessities of EBHC activities and individual-centric cognition is that HITs are bound to fail, or at least unleash a host of unintended consequences (Ash, Berg & Coiera, 2004; Campbell, Sittig, Ash, Guappone & Dykstra, 2006; Koppel et al., 2005), because the assumptions of the psychology of work inscribed in HITs clash too much with the actual nature of real-world EBHC activities (Berg, 2004; Li, 2010; Niazkhani et al., 2009; Wears & Berg, 2005). Fourthly, and finally, knowledge-centered definitions classify HITs according to the knowledge processes they support (Newell, Robertson, Scarborough & Swan, 2009). For example, Alavi and Tiwana (2003) categorized information systems in terms of whether they support knowledge creation, storage, transfer, or application. This framing of HITs would classify, for example, EHRs as knowledge-storage devices, decision-support systems in terms of knowledge application, and order-entry systems in terms of knowledge transfer. Although this approach is a step in the right direction in that it focuses on the role that technologies play in the information flow, it too conceptualizes cognition in a static, context-insensitive way by assigning to HITs a single information role and viewing knowledge as a static and explicit resource. Once again, the situated, emergent, and dynamic role that HITs play in EBHC activities is lost.

The upshot here is that HITs cannot be defined and designed independent of the environments in which they are used. The real limits of extant definitions of HITs lie in the way they obscure, rather than highlight, the complex relationship that binds them to their real-life environments (Ash et al., 2009). Conceptualizations of HITs that preclude the possibility of seeing HITs as one part of a whole context miss the mark and will inevitably foster misalignments between HITs and the activities they support. In the next section we delineate a contextually sensitive conceptualization of HITs that can support systematic investigation of the dynamic relationships that bind HITs to the EBHC stakeholders who use them.

DEVELOPING A JOINT COGNITIVE-SYSTEMS APPROACH TO SUPPORTING EBHC ACTIVITIES WITH HITs

Rather than introducing a definition of HITs as such, our point of departure is to articulate the most fundamental role of HITs, which is to “...maintain, display, or operate upon information in order to serve a representational function” (Norman, 1991, p. 1). This serves as the common context or map to help interested parties assess the effectiveness of HITs and through which more specific aspects of HITs can be investigated. In this regard, the flow of information becomes the mark of a well-functioning HIT. To assess this flow, key questions to pursue include (a) Does the HIT store the right information for the activity? (b) Does it process and analyze the information in ways that support the stakeholder and her activity? (c) Does it represent and display the information appropriately to serve the activities at hand? and (d) Does it provide the right types of interaction to enable the stakeholder to work with the information?

To support EBHC activities, we argue that HITs should be conceptualized not in isolation but as joint cognitive systems (JCSs), a unit of analysis consisting of (a) an HIT and its properties and characteristics; (b) the EBHC stakeholder(s) and their characteristics and needs; and (c) the relationship between the two subsystems from which EBHC tasks and activities emerge. Figure 1 diagrams the components of the JCS. A JCS is the environment or context in which information, HITs, and stakeholders can be understood in light of one another, serving and giving emergence to EBHC activities. In a JCS, the HIT and the stakeholder(s) become coupled in a dynamically coordinated cognitive system, and EBHC activities emerge from the shared pattern of information processing and discourse between them. Within the context of a JCS, HITs go beyond the mere support of stakeholder cognition in that they act as independent participants in the information processing required for EBHC activities. Because of this, a holistic understanding of how to support EBHC activities requires reference to both the HIT(s) and the stakeholder(s) in combination (Ash et al., 2004). Conceptualizing HITs as subsystems or components of a JCS respects the principle that no information-processing device can be defined independent of the

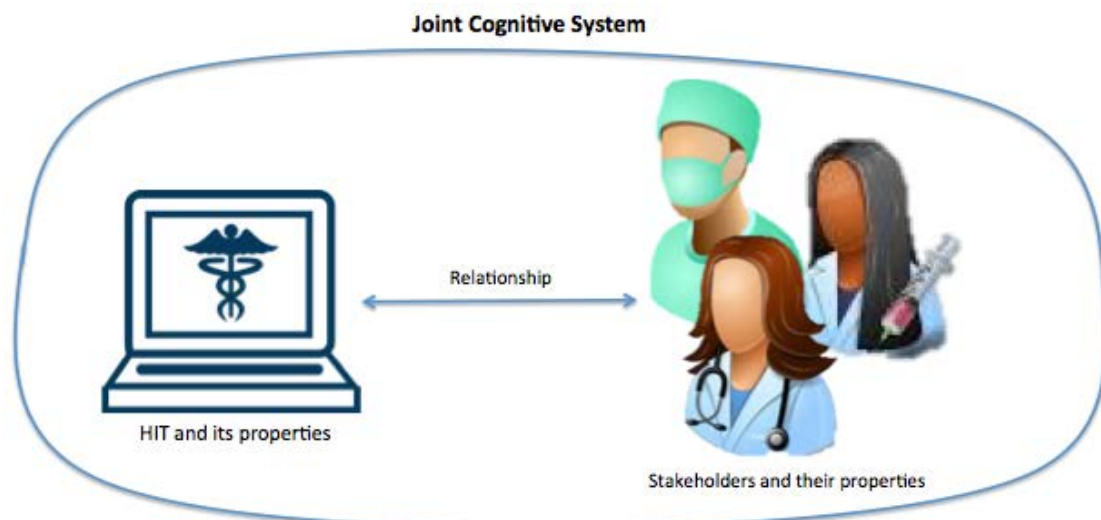


Figure 1. The Joint Cognitive System as a unit of analysis includes the health information technology, stakeholders, and the relationship that binds them.

context or purpose it serves. This perspective bypasses rigid and overly abstract definitions that can fetter analysis and dismisses historical assumptions that cognition is isolated within either the HITs or stakeholders themselves.

To understand how to better facilitate information flow within a JCS, the system could be conceived in terms of five subsystems, or spaces, each of which operates upon information in distinct yet interdependent ways. Collectively and in concert, they give emergence to and distribute the load of EBHC activities. The five subsystems are the information space, the computation space, the representation space, the interaction space, and the mental space (Parsons & Sedig, 2013; Sedig & Parsons, 2013; Sedig, Parsons & Babanski, 2012). Figure 2 displays each of these spaces separately, as well as the information processes that occur within them. Decomposing a JCS into subspaces facilitates analysis of the characteristics of the JCS while keeping sight of the whole system that contributes to robust EBHC activities. We discuss these spaces next.

The Information Space

In the information space, an area of containment serves as the repository of the information used by stakeholders to perform EBHC activities (Sedig & Parsons, 2013). The contents within an information space may be actual or possible, that is, it may already be there or may be generated

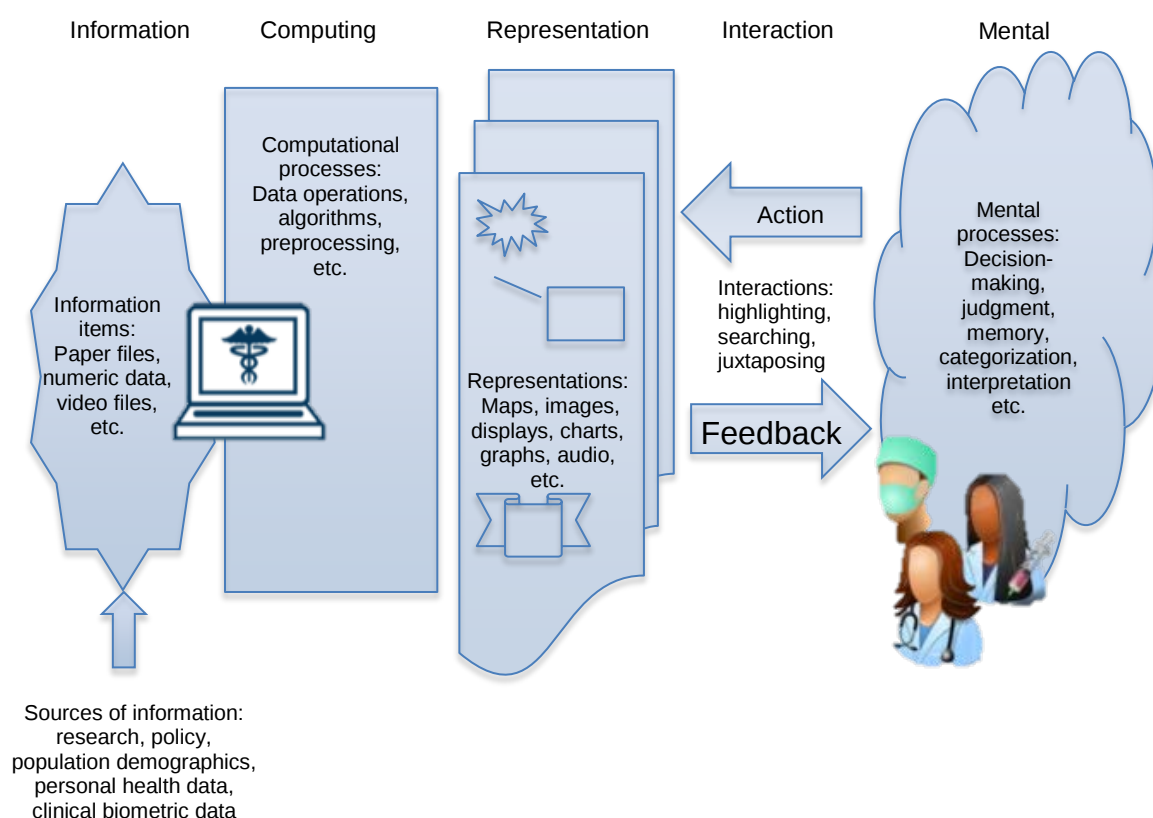


Figure 2. The five spaces that comprise a joint cognitive system and the major functions that characterize each space. The first three spaces represent health information technologies, the last reflects the individual capacities in the stakeholder(s), and the fourth encapsulates the interaction between the technologies and the humans.

on an ongoing basis, as in the case of algorithms or other computational processes. Information spaces can combine and maintain information from many different sources or environments within a single repository, allowing the stakeholder (through the mediation of other spaces in the JCS) to utilize them. Within an information space, many diverse types of data or knowledge (e.g., quantitative or qualitative) can be stored at different levels of abstraction, structure, and elaboration. In this sense, data and knowledge within an information space can be complex and multilayered or simple, atomic, and single layered. To illustrate, if a public health analyst requires community information to make better decisions about the advisability of a regional policy implementation, she may consult a geographic information system database and may store data and knowledge from a wide range of types: demographics, health status indicators, community public health resources, cultural information, and/or community narratives. Although information spaces combine and store information within a single repository, this data and knowledge is inaccessible to stakeholders without the mediation of the other spaces, to which we turn below.

The Computing Space

In the computing space, data from the information space is processed in ways that can render it useful for particular EBHC activities. Although the degree of sophistication of the computational processes depends on the capabilities of the HITs themselves, as well as the needs of the environment, the commonality among the processes within the computing space is that they operate on the data stored within the information space in order to transform it in some way and make it available for EBHC activities. These computational processes can perform functions that range from data cleaning and preprocessing (turning raw data into usable databases) to the computational inferences that have a direct influence on the content of medical decision-making. For example, through text and data mining techniques, HITs can uncover patterns within patient drug response data and integrate them with genomic data to draw pharmacogenetic inferences that might be impossible to make through unaided human cognition. Through subsequent or alternative computational processes, these insights might be made available at the point of care through computational decision procedures, which assist practitioners in targeting drug therapy with the aim of decreasing variability of response. However, data and information will remain latent within the computing space unless made access through representations encoded in the representation space.

The Representation Space

In the representation space, contents from the information space and processed through the computing space are encoded into forms that are sensible to the stakeholder. Because data and knowledge from the information and computation spaces are never directly accessible to the stakeholder, the representation space plays the crucial role of bridging the gap between them through encoding information into diagrams, maps, images, text, videos, sounds, or other representations (Sedig & Parsons, 2016). A representation is “something that stands for something else” (Zhang, 2002, p. 18) and different representations of the same information can have significantly different cognitive effects (Zhang & Norman, 1994). How well the representations signify the information they encode will depend partly on the purpose for which those representations are intended. No representation will be equally suitable for all purposes,

and, because of this, choices about the form and content of representations must be made carefully, bearing in mind the EBHC activities for which the data are intended. For example, global health data can be represented in many different ways (Ola & Sedig, 2016, 2017). The same is true of patient data contained within an EHR, which can be displayed in many different ways (Monroe, Lan, Lee, Plaisant, & Shneiderman, 2013; Rind, 2013; Rind et al., 2011). Among the most common approaches to representing patient information are problem-oriented or source-oriented displays. In problem-oriented displays, clinical data are arranged by the clinical problem, which supports goal-oriented decision-making. On the hand, clinical data in source-oriented displays are arranged according to the location of care, which supports information search and retrieval (Coiera, 2000).

The Interaction Space

Embedded in the interaction space are all actions and the range of subsequent reactions that are possible within an HIT. As stakeholders act upon the possibilities afforded in the interaction space, subsequent reaction, or feedback, occurs within the representation or computing spaces that allow the stakeholder to dynamically explore, transform, and better use the information within the information space. The interaction (action and reaction) possibilities that exist within a JCS are the foundation for rich, multifaceted, continuous stakeholder discourse with the information, which in turn allows for the discovery of new applications of and perspectives on the information. Some interaction possibilities will serve to support strong discourse between the information and the stakeholder (enabling clear and relevant inferences), while others may confuse, distract, or overwhelm thinking. Interaction possibilities should be encoded into the technology while keeping in mind the context and activity they are intended to support. For example, consider a physician who encounters a patient with a little known genetic condition. If the disease is unknown to the physician, she may search for a diagnosis in a medical research databases by correlating aspects of the clinical case with those detailed in the research findings she collects (Demelo, Parsons, & Sedig, 2017; Parsons et al., 2015). Interaction possibilities encoded into the HIT can allow the physician to highlight various aspects or features of the research findings to check for convergences or divergences between the source and target data. Interaction techniques that allow the patient to filter out extraneous details, hone in on certain aspects of the clinical manifestation, and flexibly group the symptoms together in useful ways will help the thought processes of the physician because they support focus, attention to detail, and concentration (Sedig & Parsons, 2013).

The Mental Space

Finally, mental space refers to the mind of the stakeholders, which is the location of internal cognitive processes that contribute to emergent EBHC activities. The mental space is what individual stakeholders bring to EBHC activities, as well as the various mental processes required, depending on the content and form that information takes on within the spaces internal to the HIT. Even though the mental space is vital to understanding the role that HITs play in EBHC activities, because we are concerned primarily with HITs, elaboration on the human dimension of this relationship is beyond the scope of this paper.

Taken together, these spaces form the JCS across which information processing is distributed within EBHC activities (Sedig & Parsons, 2013). Because each space contributes an essential presentation, representation, or process in the transformation of raw data and knowledge into usable and appropriately applied outcomes, the spaces do not exist or operate in isolation from one another; each contributes indispensably to the information flow required for EBHC activities. In order to contribute effectively to the unique needs of any particular EBHC activity, each space must be designed to fulfill its specific role and to work in concert with the others, allowing information to flow freely among them for well-defined goals.

At times, the spaces within a JCS may not be designed sufficiently so that they are consonant with one another or with the nature of the EBHC activities being carried out. This can be regarded as a weakly coupled system (see Brey, 2005, for the concept of weak and strong coupling), where the HIT is configured in a way that disrupts, diverts, or undermines the flow of information needed for an EBHC activity. At other times, HITs are well designed to support the needs of the stakeholders and the EBHC activities they carry out. This can be regarded as a strongly coupled system, where the HIT is responsive to its stakeholders' needs, where the information flow is fluid, and the overall experience of getting the information one needs is coherent and satisfying.

JCSs widen the scope of factors to which interested parties can direct their attention when trying to understand how to design and evaluate an HIT in fulfilling its role to support EBHC activities. Furthermore, by analytically foregrounding the relationships that the HIT has with entities outside of itself, the JCS reminds interested parties that HITs are not static or isolated from their environment but are open and permeable systems, giving information to and receiving it from the environment and co-components. In the next section, we direct attention to the relational properties of an HIT that can influence the effectiveness of a JCS in specific EBHC activities. We present the DETECT framework that can assist designers, deployers, and evaluators of HITs to systematically analyze how characteristics of the HIT influence the coupling and healthy information flow within a JCS. As the number of characteristics and factors that affect human-technology relationships are many and these can be presented from different dimensional perspectives, the framework's factors are not intended to be comprehensive or exhaustive; rather, these provide a starting point for analyzing, designing, and evaluating human-technology relationships that serve dynamic EBHC activities.

DETECT: A FRAMEWORK FOR DESIGNING, DEPLOYING AND EVALUATING HITs FOR EBHC

A framework is a map or structure that helps to identify the elements relevant to a challenge or opportunity and anticipate its systemic outcomes. The spaces of the JCS outlined above have characteristics that influence HIT-stakeholder couplings and the emerging evidence-based activity within a JCS. In this section, we identify characteristics of the four spaces that pertain to an HIT and organize them within the DETECT framework to aid systematic thinking in the context of design, analysis, and implementation of HITs for EBHC activities. The DETECT framework comprises the four levels of factors that correspond with the technological spaces within a JCS (and described more fully above): information, computation, representation, and interaction. Informational factors describe the properties of the data/information used in EBHC

activities; computational factors describe the way information processing within the HIT prepares and transforms information; representational factors qualify how information is encoded and displayed in output structures; and interactional factors are those that describe the action possibilities the HIT provides and the reactions from the HIT. We then show how the design, analysis, and implementation of HITs for EBHC can be improved through systematic thinking afforded by the DETECT framework.

Information

The information space is a repository of the data and materials used by stakeholders to perform EBHC activities. Here we present four characteristics of the information space of a JCS: volume, velocity, variety, and veracity (Chen, Mao, & Liu, 2014).

Volume

Volume denotes how much information or data is contained within an information space (Hurwitz, Nugent, Halper, & Kaufman, 2013). This can pertain to the number of separate data items, as well as to the number of relationships between and among them. Higher volume information spaces, having more data items and interconnections, tend to require more complex cognition for successful EBHC activities; consequently, these situations can be difficult for unaided human cognition to utilize. For example, a public health professional responsible for a program aimed at preventing cardiovascular disease in a large geographical region will require high volumes of epidemiological and other data, at several levels of aggregation—including demographic and geographical information, public health resources, disease prevalence, risk factors (including tobacco smoking, diabetes, elevated cholesterol, obesity, and low physical activity)—and an inventory of past and ongoing public health policies, programs, and interventions (Howe, et al., 2008; Ola & Sedig, 2014; Sedig et al., 2012). Because high-volume information sources can be onerous or impossible to process by the unaided cognition of health practitioners, other spaces within a JCS can assist by filtering, organizing, or presenting data in ways that facilitate program goals.

Velocity

Velocity characterizes the rate at which information is processed and may be conceptualized in terms of the throughput and latency of information processing (Sathi, 2012). Throughput may be thought of as the channel capacity or the amount of mobile information that enters and moves through a JCS, while latency is the rate at which that information is transmitted from one component of a JCS to another. A high latency condition suggests a poor transmission level. Both the throughput and latency of an information space can be vital to the success of EBHC activities. Consider, for example, the monitoring and surveillance activities involved in response preparedness to a potential outbreak of infectious diseases. Because traditional surveillance methods, such as routine hospital or laboratory reports, rely on patient visits, they can be slow as a method of collecting information. High latency methods can be supplemented or replaced by lower latency inputs, such as disease-related content crowd sourced from social media or Web engine searches (Brownstein, Freifield & Madoff, 2009). Ultimately such technological solutions

can serve to increase the rapidity of public health response to disease spread and mitigate its negative impact.

Variety

Variety is the diversity of sources from which information enters an information space. High variety information spaces refer to those that draw on several forms of heterogeneous data. Demands for more complex human cognition increase with high variety information spaces because the diversity of information inputs require correlation and extrapolation among sources whose content may bear differently on the relevant EBHC activities. Take, for example, the variety of forms of data that physicians use in making decisions at the point of clinical care: unstructured medical histories and notes; laboratory test results; hospital admission and discharge records; medication records; MRI, CT and other images; and email or voice message communications from other providers in the clinical team (Raghupathi & Raghupathi, 2014). The tremendous variety inherent in the information used by clinicians at the point of care demands cognitive work to integrate, synthesize, and streamline into a coherent decision. Hence information characterized by high variety should be used to support cognitive activities where synthesis and integration needs are not time-sensitive or pressing.

Veracity

Veracity refers to the assurance that information within an information space is error free (Sathi, 2012). Information spaces may exhibit low veracity when the origins of their inputs are unknown or the data processes on which they rely are unreliable, noisy, or imprecise. For example, program planning in public health that draws on data mined from social media generally exhibits lower veracity than data drawn from more traditional formal techniques, such as experts or routine surveys (Herland, Khoshgoftaar & Wald, 2014). When brought to bear on a particular point of interest in public health planning, social media data can be inflated, exaggerated, or biased by external factors; they may betray a high noise-to-signal ratio; or such information may incorporate a set of premises that render them irrelevant and misleading. By contrast, data from routine surveys that are preformatted to address well-defined public health planning issues and administered to qualified respondents present inherently more reliable and precise information. Because of the added processing associated with compensating for low veracity information spaces, EBHC stakeholders may have a difficult time deriving clear conclusions from them.

Computation

A computing space is where a set of computing models and algorithms operate on information. Six properties of the computation space are reasoning, complexity, input, noise, autonomy, and temporality.

Reasoning

Every computation space employs various reasoning techniques or genres, such as clustering algorithms (e.g., k-means or density-based spatial clustering of applications with noise) or rule-

based models (e.g., decision trees), among others (Silva & Zhao, 2016). Variations in the reasoning capabilities of the computation space can radically change the kind of support offered by an HIT. For example, some health informatics tools function by tapping the collective EHR knowledge of the thousands of providers that utilize them within a country and/or internationally. Thus, when a dermatologist encounters a rare skin disease that reveals an immediate gap in her knowledge, a computation space with clustering capabilities can enable her to access the knowledge from other providers about similar patient visits. When the computation space has the algorithmic capacity to dynamically cluster together patients with similar medical profiles or clinically similar situations, the care provided by the dermatologist can be better informed, more relevant, and more effective.

Complexity

The multifaceted property of complexity refers to the degree of inherent difficulty within the problem or tasks that the computation space can solve, as well as the structural (i.e., number of algorithmic components and their interrelatedness), temporal (i.e., amount of time), and spatial (i.e., storage and computational components) resources that are needed to deal with such problems or tasks. Computation spaces that exhibit a high degree of complexity are able to handle stakeholder tasks that involve high degrees of computation, time, or storage capacity and the rising complexity of HITs open new horizons for clinical practice. For example, advances in computational complexity have recently given rise to the possibility of assembling and sequencing billions of DNA fragments that compose the human genome. These, in turn, give rise to the possibility for personalized medicine, which seeks to tailor preventative or therapeutic interventions to specific groups or individuals. Computation spaces that exhibit a high complexity can assist stakeholders in undertaking EBHC activities that would be impossible with human cognition alone.

Input

Input refers to the data types that the computation space can handle. For instance, some algorithmic models require labeled data (e.g., support vector machines and decision trees need data points with a categorical attribute known as the class attribute or the dependent attribute). Others can work with unlabeled data (e.g., k-Means needs no class attribute in the data), while others may need a specific dependency in the data (e.g., time series data; Silva & Zhao, 2016). For example, deciding the plan of care for a terminally ill intensive care patient may involve reasoning with several inputs of different types, including biometric data, test results, patient preferences and directives, clinical narratives, and chart notes on the patient's history. Depending on the condition and preferences of the patient, the way the attending physician integrates these different types of information can radically alter the framing of and approach to care. A computation space that has the capacity to utilize diverse data types in decision support can be a powerful aid to the physician and improve the quality of treatment offered.

Noise

Computing spaces vary in the degree of tolerance in handling noise, error, and/or unknown attribute values in the data. Noisy data may have spurious omissions or additions, be characterized by systematic measurement errors, affected by the context or background, or compromised in some other way. Some computation spaces are sufficiently equipped to effectively assist EBHC activities through more and better utilized data. For example, a chief public health officer can better understand the factors causing domestic violence in a region by relying on the data collected through the region's hospital system. Using this data, which is often characterized by noise and spurious inputs, will only be possible if the computation space is capable of performing operations upon and deriving value from noisy data.

Autonomy

The degree to which a computation space can act without stakeholder supervision, steering, input, and/or oversight represents its autonomy. While having fully autonomous computing systems is challenging, computation spaces can require varying degrees of human intervention in their operation. For instance, in the case of machine learning, which is becoming an integral part of today's health informatics tools, algorithms may be supervised (e.g., support vector machines and regression), requiring humans to train algorithms with given data to produce viable models; semisupervised (e.g., active learning), requiring less human intervention than the supervised ones; or unsupervised (e.g., k-means), requiring no humans to train algorithms (Fang et al., 2016; Rubens, Elahi, Sugiyama, & Kaplan, 2016; Silva & Zhao, 2016). Naturally, specific types of EBHC activities will benefit from different levels of computational autonomy. Consider two cases requiring different degrees of computational autonomy: detecting brain tumors versus assessing risk of readmission of congestive heart failure patients. The first case involves analysis of brain images and CT scans. For this, a supervised support vector machine algorithm can be used to classify whether or not a patient has tumor. The second case requires a clustering of different patients. For this an unsupervised k-means machine learning algorithm can be used to partition the space of different patients.

Temporality

The degree to which the computation space can handle time-based data and, if so, how often (i.e., at what time intervals) it can receive incoming data defines the temporality of the space. A computation space can work on existing datasets, accept new data at regularly scheduled time points, or deal with instantaneous real-time data. For instance, in a computer-assisted surgical procedure for prostate cancer, the surgeon relies on visualizations and other biometric data current to the second. By contrast, during public health surveillance efforts, the temporality of the computation space can be less frequent, sampling data every day or two. Achieving the right temporality of data sampling is an important characteristic of a properly tailored computation space to the EBHC activities, as is achieving a strong coupling between the HIT and the stakeholder.

Representation

In the representation space, contents of the information space are encoded into representations and made visible to the user. We identify five characteristics of representations that can be manipulated to support a strong coupling within a JCS: complexity, interiority, configuration, type, and density (Parsons & Sedig, 2014).

Complexity

Complexity refers to the degree to which the representations displayed in an HIT are detailed in the number of items, encoded properties, and relationships. Complexity can range in value from low (e.g., a single item with no presented relationships) to high (many items within an elaborate network of relations in the representation space—i.e., the display). When the complexity of representations in an HIT is not commensurate with the EBHC activities for which they are used, human cognitive overload and errors may result (Norman, 2013). Representations that are too simplistic cannot store or display the information necessary for complex tasks, while representations that are too complex can overly tax the perception, attention, working memory, or other cognitive processes of the stakeholder. For example, consider a psychiatrist working on the medication regime of a patient. The task in this case will depend on whether the psychiatrist is devising the drug regime for the first time or merely updating a routine drug regime. In the former case, when the psychiatrist is devising the drug regime from scratch, a more complex representation highlighting many aspects of the problem will help advance the activity smoothly. For instance, patient characteristics, potential drugs to prescribe—including their respective mode, frequency and time of intake, and dosage options—and whether the drugs are name brand or generic may all be immediately relevant. In the case where the psychiatrist is merely updating an already formulated plan, too many irrelevant or redundant details may interfere with the progress of the task, which largely consists of verifying preset measures.

Interiority

Interiority is the degree to which unencoded data items lie latent within the representations, not explicitly encoded, while still being potentially accessible. Values in interiority range from low, such as when all the information is encoded into the representation and accessible on the immediate level to the stakeholder, to high, where most of the information resides below the surface of a representation, yet to be encoded explicitly. A balance must be struck in how much information to encode for a particular task: Too much extraneous information in a representational scheme can be distracting, while too little will force stakeholders to fill in the gap themselves, or seek the information elsewhere. For example, the main menu of hospital EHR systems often provides a balance between the horizontally (which encodes information at the same level) and vertically nested (which embeds information within superordinate classifications) structures. When a practitioner requires more than summary details of the plan of care being executed, she will need to drill down into the vertically nested categories to retrieve the desired details. The way and extent to which information is interiorized can have a significant effect on the speed of access, as well as the interpretive processes of the practitioner.

Configuration

Configuration concerns the principles behind the ordering and arrangement of the information items in the representation space of an HIT. Encoded information can be configured through a number of approaches, including by attributes of the information (e.g., nominal, ordinal, cardinal), perceptual characteristics of the representations (e.g., size, color, font, formatting), or by some principle specified by the designer (e.g., alphabetical vs. chronological). Variations in the representational configurations of an HIT can have a pronounced influence on EBHC activities, obscuring some attributes of the information and highlighting others. For example, in a comprehensive drug information resource, arranging the drugs by their alphabetic name can aid searchability, while obscuring information about potential side effects, possible drug interactions, or the precautions the patient must take in using the drug that could be more visible in a different categorization strategy. In many cases, allowing the stakeholders to control the configuration of the information can assist them to detect easily any patterns, trends, or relationships in the data, bypass irrelevant information, or reorder data to fit a specific activity or need.

Type

The forms in which information is encoded—which may include, among others, plots, charts, images, diagrams, symbols, and text—reflect the type. Different types of representations offer various drawbacks and benefits in use by stakeholders (Larkin & Simon, 1987; Parsons & Sedig, 2014). For example, in reasoning about the influence of long-term eating behavior on chronic illness, charts and diagrams encoding this data can assist medical researchers to identify patterns and discontinuities at a glance and to visually compare different data sets to easily draw insights or conclusions. Although some types of representations, such as charts, plots, and diagrams, help researchers to understand continuous data, other discrete representations, such as symbols or text, are better for precise, detail-oriented EBHC activities. Furthermore, being able to transform one type of representation to another can facilitate the performance of EBHC activities.

Density

Density is a measure of how much information is within a given representation space. Diffuse representations take much space to encode and communicate little, while dense representations express their information compactly. However, if a representation is too dense, it requires a high degree of accuracy and precision and, as a result, can encourage errors. Meanwhile, diffuse representations can undermine the efficiency and speed of EBHC tasks. For example, EHRs used for inpatient care often have to communicate several types of complex, layered, and interrelated information at the push of a button: administrative and billing data, patient demographic and history, progress notes, vital signs, diagnoses, medication lists, and radiological images. If the representational scheme used to assist stakeholders in locating and interpreting the information contained therein is too dense, the stakeholders' attention can become overwhelmed or miss some representations. Density should be used according to the needs of the EBHC activity as well as the experience of the EBHC stakeholders.

Interaction

The interaction space contains all the action and reaction possibilities that are available to the user. We identify five aspects of the interaction space that can be manipulated to strengthen the couplings within a JCS: visibility, flexibility, diversity, complementarity, and directness (Sedig et al., 2012).

Visibility

Visibility concerns the extent to which an HIT makes its interaction possibilities and behavior perceptible to the stakeholder. This includes awareness of the interaction possibilities that an HIT supports, as well as the encoding of a perceptible response when an action or reaction takes place. When interaction possibilities and the actions and reactions that are carried out with them are explicit, stakeholders will often have an easier time using the HIT and will be able to keep better track of the effect of their actions on the HIT. Keeping track of one's actions and their effects is a core task in using HITs effectively. For example, Nemeth and colleagues (2005) studied the use of infusion pumps by stakeholders in medication delivery and concluded that interfaces should provide more explicit information about their past, present, and future states. They found that the substantial programming required, and the array of layered and nested menus with complex branching options, served to confound even the most experienced operators. Stakeholders using the infusion pumps frequently became confused, had difficulty tracking their state of operation, and had to work through several misinterpretations before correctly setting the device. Most clinicians developed coping strategies that were effective but vulnerable to failure. Allowing more conscious control over the visibility of certain interaction possibilities and the state and consequences of interactions can assist stakeholders in better interpreting the HIT, thus laying the foundation for stronger, more coherent relationships within the JCS.

Flexibility

The availability and range of adjustability options that allow stakeholders to manipulate the values of several characteristics of the HIT to suit their needs, circumstances, or goals reflects a technology's flexibility. For example, an HIT that allows the stakeholder to adjust the visibility of its interaction possibilities, rendering some invisible and others visible, is more flexible than one that does not. Highly flexible HITs can allow the stakeholders to adjust a range of characteristics, from those dealing with information, computation, and representation to the interaction possibilities themselves. To further illustrate, consider an HIT that provides decision support to stakeholders in the form of computerized alerts and reference information. Depending on the stakeholders, the work environment, and other contextual factors, it may be useful to manipulate some of the features of the decision support, including the onset, frequency, detail, kinds of information offered, or level of inference carried out by the HIT. Although highly flexible HITs can prove very helpful in some cases, flexibility can sometimes place tremendous responsibility on the stakeholders, requiring them to think through and consciously adjust factors for which they may have little preference. Therefore, at times, rigid structure and predictability are preferable, especially when the EBHC activity is linear or unambiguous.

Diversity

Diversity concerns the number and range of interaction possibilities available to stakeholders. Different forms of interaction will enable stakeholders to gain diverse perspectives on the information and to apply it in multiple ways. Therefore, a high diversity in interaction possibilities can assist stakeholders in their ability to perform autonomous, well-rounded EBHC activities. For example, when a pharmacist seeks to update a patient's drug regime, she will need to investigate, among other things, the relationship between an indicated drug and any potential drug interactions with the patient's existing medications. Diversity in interaction possibilities in an HIT can help the pharmacist perform a range of operations to understand the drug interactions more holistically. An interaction that allows the pharmacist to place drug properties side by side can highlight common properties and side effects, while another interaction that allows the pharmacist to investigate several drugs in terms of a single property can portray the drugs as a common set, highlighting different characteristics. Further, an interaction that allows the pharmacist to translate the form of information presentation from linguistic to animated display to show the mechanism of action can illustrate clearly information that is difficult to grasp with text alone. In this way, diverse interaction possibilities can serve diverse cognitive needs of EBHC activities. Still, too much diversity can be counterproductive. As a rule, HITs should offer a number and range of interactions that are commensurate with the needs of the EBHC activities and the external environment, offering no more nor less variety than is needed for the complexity of the tasks it is used for (see law of requisite variety, Weick, 1979).

Complementarity

The harmony of relationships among interaction possibilities, and how well they work with and supplement each other, forms the complementarity of an HIT. A high degree of complementarity among the interactions allows stakeholders to conduct more coordinated and integrated EBHC activities. That is, although each individual interaction independently supports only one particular action, collectively the interactions can work together and assist stakeholders perform more complicated EBHC activities. Consider the case of a psychiatrist formulating a differential diagnosis and possible etiologies for a patient with a decreased level of consciousness. In using an EHR system to assess differential diagnoses (e.g., street drugs, vitamin deficiency, meningitis), the interaction possibilities may be embodied in such a way as to force the psychiatrist to carry these steps out in a linear and overly restrictive fashion. HITs that respect the organic and interconnected nature of the diagnostic process will make provisions for how different steps of the diagnostic procedure rely upon and influence one another.

Directness

Directness addresses the degree of straightforwardness toward a desired goal or task that is encompassed in the interactions within an HIT. Interactions that are direct allow stakeholders to act on and receive feedback from the desired information without an intermediary, while HITs with indirect interactions have the stakeholders operate upon secondary or ancillary information sources in order to access their object. Direct interactions also allow stakeholders to carry out

EBHC activities parsimoniously, that is, with the fewest number of steps possible. For example, when a community nurse practitioner attempts to understand the seriousness of a patient's symptoms (e.g., abdominal distension and blackened stool), a medical reference database can either allow her to organize information directly through the agency of the symptom of interest or only through the mediation of some other medical category. In the former case, the nurse practitioner can directly form a coherent sense of the seriousness of the symptoms, their potential ramifications, parallel symptoms or conditions to watch for, and which tests may be relevant or irrelevant. In the latter case, however, indirect interaction possibilities force the nurse practitioner to extend and extrapolate her inferences through a source of indirect interest, thus multiplying the number of steps required to access the desired information.

To summarize, the DETECT framework offers 20 factors that designers, deployers, and evaluators of HITs can use to characterize the fit between HITs and the EBHC activities they serve. Each of these factors can be modulated by other factors depending on the type of EBHC activity, the intended user group, or other aspects of the environment. In Table 1, we give an overview and visual summary of the whole framework.

SCENARIOS

This section demonstrates how the DETECT framework can assist designers, deployers, and evaluators to better align HITs with dynamic, real-life EBHC activities. In this section, we illustrate the kind of systematic analysis that DETECT facilitates and the way it can support diagnosis of problems in the design and use of HITs if and when they arise. We outline two scenarios, each illustrating a different pole on the spectrum of cognitive work (Nemeth et al., 2005).

Scenario 1: Public Health Manager Organizing a Substance Abuse Prevention Program

Our first scenario explores the utility of HITs at health-care's blunt end (which includes health management, public health planning, and policy), where EBHC activities are typically more diffuse, broader, and contemplative, rather than fast paced and highly dynamic. Consider a public health manager deciding whether to fund a particular substance abuse prevention program for a midsized city. The main question she is assessing in making this decision is whether there is reason to believe that this program will actually prevent substance abuse in her city. To answer this question, she identifies and assesses research evidence, evaluations of the program from other cities and localities, and local community feedback that are presented in a public health research HIT. Specifically, she is interested in collating and summarizing the criteria to be used to evaluate the efficacy of the program and in applying these criteria to the needs of her city.

In her HIT, the public health manager is reviewing several dozen empirical studies, a few government reports, privately conducted program evaluations, and one community workshop's feedback compiled into a YouTube video (all imported into the HIT on a previous occasion). Because she finds several evaluation criteria in the resources, the public health manager's task in comparing these criteria becomes more complex and subjective. To better understand and synthesize the results, she sifts through the resources to identify and list all the indicators used

Table 1. Properties of HITs Useful in Analyzing Their Alignment with EBHC Activities.

Space	Property	Characterization
Information	Volume	How much data is contained within an information space
	Velocity	The rate at which data is processed within an information space
	Variety	The diversity of sources from which information enters an information space
	Veracity	The assurance that information within an information space is error-free
Computation	Reasoning	The reasoning techniques employed by the computation space
	Complexity	The level of difficulty of problems that the computation space can solve
	Input	The types of data that the computation space can utilize
	Noise	The computation space's degree of tolerance to error or unknown attributes in the data
	Autonomy	The degree to which a computation space can act without stakeholder supervision, steering, input, and/or oversight
	Temporality	Whether the computation space can handle time-based data, and how often it should receive incoming time data
Representation	Complexity	The degree to which representations are detailed in the number of items, properties, and relationships they encode
	Interiority	The degree to which unencoded data items lie below the surface of the representations
	Configuration	The ordering, arrangement, and organization of information items in the representation space
	Type	The forms in which information is encoded (e.g., plots, charts, images, diagrams, symbols, text)
	Density	How much information is within a given representation
Interaction	Visibility	The extent to which an HIT makes its interaction possibilities perceptible to the stakeholder
	Flexibility	The availability and range of options allowed the stakeholder to adjust the characteristics of the HIT
	Diversity	The number and range of interaction possibilities that are available to the stakeholder
	Complementarity	The degree of harmony of relationships among interaction possibilities
	Directness	The degree of straightforwardness of the interactions toward a desired goal or task

to measure program success. Some studies measure efficacy in terms of reduction in substance abuse; others focus on cost evaluation, community satisfaction, or other indirect social outcomes measures (e.g., rates of absenteeism in the community or family violence). The public health manager identifies and compiles the results of the available evaluation criteria to see what conclusions she can draw about the program's efficacy elsewhere. Beyond this, she weighs the conclusions presented in each study in light of the strength of that particular

research methodology: the study design, reliability of the measures, and the strength of the effect. The HIT allows the public health manager to access and display the resources, but it also has some functionality to assist her in comparing the resources along key points of interest. Taken together, the research HIT and public health manager form the JCS that carries out the EBHC activity needed to answer her question. For the benefit of our research aims, examining how each of the constituent spaces of Scenario 1's JCS contributes to the activity will help us assess how these spaces work together to achieve the EBHC activity goal.

The information space in this case exhibits a high volume of information. It also contains a high degree of variety, with surfaced studies containing narrative, qualitative, and statistical evaluation criteria. The data in the studies concern issues as diverse as the rates of substance abuse, which substances are abused, the possible causes of substance abuse, the effect that the substance abuse prevention program had on a range of factors, and the influence of some confounding variables. Because the studies dealing with this particular substance abuse program are few in number, the velocity of the information space is low; however, the veracity is high because the sources provide primarily peer-reviewed information.

To assist the public health manager digest the relevant information, a computation space is designed with the characteristics of the information space in mind. The computation space should be equipped to process diverse data input types, that is, to integrate video, numerical, and text formats. If program evaluation criteria can automatically be culled from different sources, this will assist significantly the manager's decision making. Although a high degree of inputs are needed, the computation space need only possess a low degree of noise tolerance because the data is relatively clean. Additionally, a low complexity of operations on the data will likely suffice the manager's needs. That is, because the public health manager is looking for summaries of existing studies, the HIT will only need to provide simple correlations, trends, or summaries of the information. Because the decision on a program is not fully formalized (i.e., the decision still involves subjective elements), the process of deciding whether to fund this public health initiative will benefit from a computation space that carries out activities in close collaboration with the demands of the public health manager, rather than an autonomous or independent computational space; hence, a low degree of autonomy is desirable. Figure 3 shows each factor of the DETECT framework for this case and categorizes it as high or low.

Because the information in the studies is multilayered and multidimensional, the public health manager can benefit from representations with a high degree of complexity and interiority. Public health interventions are notoriously complex (Rychetnik, Frommer, Hawe, & Shiell, 2002), involving many confounding factors that can increase the manager's cognitive load and distract her attention. A complex representation that encodes these extraneous variables can preserve the rich interconnections characteristic of social health data and encourage holistic and rigorous evaluation. In the same way, representations with a high degree of interiority can assist the public health manager in pacing herself by externalizing aspects of the information only when demanded. This can facilitate a measured, yet in-depth, conversation with the information, allowing the manager to look at multiple aspects of the evaluation criteria she has collected. In turn, such components of the representation space can assist the public health manager in avoiding potential biases in causal reasoning that may attend thinking about complex phenomena (Sterman, 2006). Furthermore, a representation space with a flexible configuration will help aid the public health manager in exploring many facets of the information by arranging it in different ways.

Space	Degree	Characterization
Information Space	↑	Volume
	↑	Variety
	↓	Velocity
	↑	Veracity
Computation Space	↑	Input
	↓	Noise
	↓	Complexity
	↓	Autonomy
Representation Space	↑	Complexity
	↑	Interiority
	↑	Configuration
Interaction Space	↑	Diversity
	↑	Visibility
	↓	Flexibility

Figure 3. Example of a JCS characterization that supports public health cognitive activity

The nature of the information used in this case analysis is social and complex, rather than linear and formulaic. Thus, the public health manager will most likely independently analyze each criterion used to measure program success, as well as how the program fared when considered along those criteria. Although the criteria are clear, they are numerous and distinct. Hence, to assess the program, the manager would most likely prefer to be able to witness her own operations on the data as she formulates her questions, draws inferences, and settles on conclusions. This will allow her to keep better track of her conclusions as she makes judgments relating each criterion to the wider scope of her purpose. Furthermore, because the information is multifaceted, the manager will benefit from having available a wide degree of diversity in the interaction possibilities available to her. For example, allowing the manager to measure the program efficacy by program cost will help her draw conclusions about its feasibility for and

benefit to her own city. Relatedly, perhaps she may benefit from comparing the efficacy of the program in relation to the characteristics of the populations involved in the research.

As articulated in this scenario, both the HIT and the public health manager contribute to the ultimate decision on funding the campaign. As illustrated, using the DETECT framework to systematically guide decisions about the utility of technological parameters in light of the needs of the user and activity can help create more robust EBHC activities. A well-coupled JCS can assist the public health manager draw well-informed and workable conclusions from the rich and multifaceted information in the HIT. On the other hand, an HIT that is not suited to the needs of the manager can obscure the information and hinder the emergence of holistic and rigorous conclusions.

Scenario 2: Psychiatrist Ordering Drugs through a Computer Order Entry System

Our second scenario illustrates the utility of HITs at health-care's sharp end where EBHC activities are more specific, direct, denser, and faster (including medical, nursing, and the pharmaceutical care). Because EBHC environments at health-care's sharp end tend to be more responsive (where the consequences of actions accrue more quickly) and more interdependent (where inputs display more interdependence), the activities carried out in these environments tend to be more sensitive to error and require higher reliability (Nemeth et al., 2005; Weick & Sutcliffe, 2011).

Consider in this instance an inpatient psychiatrist ordering drugs for a newly admitted patient with a bipolar disorder. To design the drug regime, the psychiatrist needs to match any drug to the patient's symptoms; adjust for comorbidities, contingencies, or interactions; and set the administration parameters (i.e., drug type, dose, mode of delivery, onset, duration, and frequency). Figure 4 shows an example of a joint cognitive system that supports a medical cognitive activity.

In ordering drugs for the patient, the psychiatrist typically utilizes the computer order entry (CPOE) system in the ward. The information space that will support this activity is characterized by a low volume. The HIT contains a number of preset drug parameter options (i.e., drug, dosage, frequency, onset, duration, form), patient-specific information about allergies and her current medication regime, and a list of preprogrammed drug incompatibilities. With a tentative drug regime in hand, the psychiatrist uses the drug administration parameters available in the HIT to better formulate an administration plan, seek feedback about the proposed drug regime, and resolve any allergy or interaction problems that the system flags. Because the information in the HIT concerns drug parameters and interactions, the information space is characterized by low variety, and because the data are revised and refreshed several times daily, or upon request, the velocity is relatively high.

To assist the psychiatrist in the activity, the computation space performs certain subtasks of the activity that save time and the psychiatrist's attention. When drug interactions are identified, the HIT can assist the psychiatrist by suggesting alternative drugs with similar profiles and, as a result, this HIT requires a high degree of reasoning. Despite this, the HIT need not be characterized by a high degree of complexity because checking the potential interactions between drugs is defined by a clear method and desired outcome. To support the psychiatrist in keeping track of administration details in an exact way, the HIT can be characterized by a low degree of noise tolerance. Lastly, because the required cognitive processes in order entry

Space	Degree	Characterization
Information Space	↓	Volume
	↓	Variety
	↑	Velocity
	↑	Veracity
Computation Space	↑	Reasoning
	↓	Complexity
	↓	Noise
	↑	Autonomy
Representation Space	↓	Complexity
	↑	Configuration
	↑	Density
Interaction Space	↑	Directness
	↓	Visibility
	↓	Flexibility

Figure 4. Example of a JCS characterization that supports medical cognitive activity.

are narrow and clear, a high degree of autonomy is warranted in the HIT. That is, the HIT should complete whole processes without requiring steering by the psychiatrist because too much required interaction between the psychiatrist and system would interfere with clinical workflow.

In the representation space, representations helpful in serving a robust order entry process will encode information with a low degree of complexity and an approach to configuration that highlights useful dimensions of the information. Firstly, an HIT interface with a high degree of complexity can serve to derail the drug ordering process by introducing unnecessary concepts and ideas into what should be a well-delineated, detail-oriented process. As a rule, unnecessary details (e.g., drug history, generic vs. name brand) should not be encoded explicitly at the level of the representations but should be resolved by placing information below the surface of the representation, to be summoned on demand, or by arranging such decisions beforehand.

Secondly, administration-relevant information can be communicated visually in a well-designed configuration. For example, dosages can be calculated according to patient weight through representations that use relative size; the degree of risk associated with drug interactions through color; and the titration of drugs according to standard dilution ratios can be facilitated through use of position and location. Thirdly, because drug information is a form of explicit knowledge—received through training and education—representations that are very dense often can be learned easily and serve to make the process efficient without confusing the practitioner or endangering patient safety.

Lastly, in the psychiatrist's ability to interact with the HIT, one should expect a high degree of directness, relatively low flexibility, and low visibility. Again, because the process of order entry is a restricted activity rather than open-ended, the HIT's interaction possibilities should constrain and guide the psychiatrist towards her prespecified end. For example, if the psychiatrist seeks to order a dose of lithium for bipolar disorder, she is best served when the HIT guides the activity along closed channels that meet the guidelines of safe order entry practices (rather than, for example, assisting the psychiatrist explore the many pros and cons of lithium). Supporting the same goal, one can expect that the visibility of interactions be low, thus making outcomes of interactions (e.g., errors, omissions, or ambiguities) visible while keeping the process-oriented interactions invisible to the psychiatrist. Lastly, because of the constrained, prescriptive nature of order entry, one might expect that the flexibility of the interaction possibilities to be minimal in that a high degree of freedom in adjusting the parameters of order entry can undermine the streamlined nature of the activity.

This case shows how the evidence-based decision of creating a medication regime is the product of both the psychiatrist and HIT working together. Thinking of these two partners as a JCS and analyzing the dimensions of their relationship helps explain whether and how they can work together well. A strong coupling between the psychiatrist and HIT can assist the psychiatrist in focusing on the important aspects of her job (e.g., reasoning about the manifold consequences of the proposed drug regime, and planning contingencies), rather than getting caught in the details of administration.

IMPLICATIONS FOR RESEARCH AND APPLICATION

In this paper, we provide designers, deployers, and/or evaluators of HITs with a coherent framework with which to identify the factors that mediate the relationships between HITs and their environments. In using the DETECT framework, interested parties will be able to better identify, describe, and adjust the relationships between HITs and the stakeholders performing EBHC activities. By foregrounding relationships and analyzing them systematically, we believe that our approach can assist practitioners avoid the linearity that is characteristic of previous approaches and, as a result, take a step toward the goals of reducing the misalignment gaps that currently exist between HITs and EBHC activities. This can in turn improve the adoption rates of such technologies, maximize their utility, and minimize the errors that are documented across the EBHC literature.

The DETECT framework is not intended to be a faithful description of reality but rather a conceptual toolkit that can help with how HITs that permeate the world of health care should be conceptualized, described, analyzed, designed, and evaluated. We argue that based on the HIT

literature that has yet to present any framework of factors that would allow the achievement of such a coherent set of considerations, this initial attempt can open a new line of research and theorizing, ultimately leading to useful and usable HITs for EBHC activities. The value of the DETECT framework lies foremost in allowing interested parties to operate in a manner that is holistic in attention to the range of factors at play and in the systematic modulating of those factors to ensure a better fit between HITs and EBHC activities. Finally, we advocate a closer rapprochement between EBHC activities and the HITs that are weaving themselves into the medical field's daily fabric.

CONCLUSIONS

The DETECT framework is a step towards a better fit between HITs and the EBHC activities they serve. Yet, DETECT has some limitations. Firstly, a more comprehensive approach would have to take into account literature from health informatics, health information, and health-care knowledge management. But, such an approach would make any single paper or research project unwieldy. So ongoing research employing multiple sources, fields, and methods is advocated. Secondly, it may well be that other researchers could conceptualize a wider diversity of spaces or more characteristics of those spaces. However, in order to concisely describe the framework and some of its immediate applications and leave room for its future expansion, we chose to let any wider conceptualization to lie beyond the scope of the current paper. However, the EBHC and HIT research communities can benefit from what is presented as a launching point for broader and deeper exploration of the concept of using a JCS approach to design and implementation of HITs for successful EBHC activities.

ENDNOTE

1. For simplicity, all third-person singular pronouns are presented in a single form (feminine) but are intended to be gender inclusive.

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EMBEDDING PRESCHOOL ASSESSMENT METHODS INTO DIGITAL LEARNING GAMES TO PREDICT EARLY READING SKILLS

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Abstract: *The aim of this pilot study was to explore the predictive accuracy of computer-based assessment tasks (embedded within the GraphoLearn digital learning game platform) in identifying slow and normal readers. The results were compared to those obtained from the traditional paper-and-pencil tasks currently used to assess school readiness in Finland. The data were derived from a cohort of preschool-age children (mean age 6.7 years, N = 57) from a town in central Finland. A year later, at the end of first grade, participants were categorized as either slow (n = 11) or normal readers (n = 46) based on their reading scores. Logistic regression analyses indicated that computer tasks were as efficient as traditional methods in predicting reading outcomes, and that a single computer-based task—the letter–sound knowledge task,—provided an easy method of accurately predicting reading achievement (sensitivity 95.7%; specificity 81.8%). The study has practical implications in classrooms.*

Keywords: *computer-based assessment, preschool, early reading skills, slow readers, prediction, letter knowledge.*



INTRODUCTION

First-grade teachers typically consider how to identify those children who need special help in learning the basic principles of alphabetic decoding and fluent reading. Furthermore, teachers must determine what kinds of screening methods are most efficient and easy to use in a school environment.

An abundance of freeware and commercial computer games are available nowadays for assessing reading-related skills (Carson, Gillon, & Boustead, 2011; Forster & Souvignier, 2011; Sainsbury & Benton, 2011) and improving those skills (Karemaker, Pitchford, & O'Malley, 2010; Price et al., 2009). An important benefit of digital learning games is that they seem to attract children, thus increasing the opportunity for engagement and motivation (Gros, 2007; Hall, Hughes, & Filbert, 2000; Mioduser, Tur-Kaspa, & Leitner, 2000). Digital learning games and assessment methods offer the possibility to present and repeat instructions and tasks in the same format for all players, and these games typically work with minimal guidance from adults. However, only a few computer games aiming to improve reading skills include a reliable assessment tool for evaluating skills in the initial phase and for predicting reading outcomes. The aim of this study was to explore the predictive accuracy of the computer-based screening measures implemented in the GraphoLearn digital learning environment in identifying normal and slow reading learning. If this study were able to demonstrate easy assessment and prediction of reading skills, such results could be utilized in planning classroom teaching and individual reading training.

The GraphoLearn Learning Environment

GraphoLearn¹ (referred henceforth with acronym GL) is an internationally implemented and studied (e.g., Brem et al., 2010; Hintikka, Aro, & Lyytinen, 2005; Kyle, Kujala, Richardson, Lyytinen, & Goswami, 2013; Ojanen et al., 2015; Ronimus & Richardson, 2014; Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2011) digital learning environment for supporting children in learning to read. Versions of GL have been piloted in about 20 languages, such as English, Swiss-German, Spanish, Chinese, and a number of Bantu languages in Africa. The aim of GL is to improve children's basic reading and writing skills, especially for those who have difficulty learning these skills. The various game versions have been designed for both orthographically transparent and opaque languages, because writing systems vary across languages and have a significant impact on the learning processes of reading (Aro, 2006; Richardson & Lyytinen, 2014; Ziegler et al., 2010). In orthographically transparent languages (e.g., Finnish, Italian, and many Bantu languages), the correspondence between the written letter and speech sound is consistent. For opaque languages (e.g., English, Portuguese, and French), the game works with larger units (like rhymes and words) that behave consistently (Kyle et al., 2013). For detailed descriptions of how the game works, see Richardson and Lyytinen (2014) and Lyytinen, Erskine, Kujala, Ojanen, and Richardson (2009).

The Finnish version of GL, Ekapeli,² is distributed via the Internet and is freely available to teachers, special educators, and parents. Like all versions of GL, Ekapeli focuses on learning the connections between spoken and written language by using a synthetic phonics approach that systematically introduces speech sounds, then syllables and words, and, later, connecting them to the written counterparts.

Learning to Read in a Transparent Orthography

Nowadays, it is widely recognized that orthographic transparency has a significant effect on reading. Studies have shown that children learn to read more quickly in a transparent orthography (Seymour, Aro, & Erskine, 2003). In addition, the consistency of the orthography influences the initial adoption of strategies for word recognition. Finnish is one of the most transparent alphabetic languages, with nearly 100% consistent letter–sound correspondence (Aro, 2006; Ziegler et al., 2010). However, as Aro (2006) explained, Finnish words change and their length increases due to their inflections, which increases the decoding burden. The process of transferring written words into spoken words demands rapidly matching a letter or combination of letters to their sounds and recognizing the patterns that make syllables and words (Aro, 2006).

Nearly all Finnish children enter preschool during the year they turn 6 years of age, one year before they start school. Many Finnish children can already read when they enter school (Holopainen, Ahonen, Tolvanen, & Lyytinen, 2000), while the rest normally learn basic decoding within a few months. At the end of first grade, nearly all children can read any words (and pronounceable pseudowords) and sentences in Finnish. From this point on, the most critical requirement is to learn to read words and sentences fluently, which is a phase of reading faced many years later by natives of languages with non-transparent orthography (Aro, 2006; Richardson & Lyytinen, 2014).

The connection between preschool skills and first-grade reading skills is especially visible in transparent languages, and this connection forms the basis for the later phases of fluent reading (Aro, 2006; Seymour et al., 2003; Ziegler et al., 2010). In addition, the connection is likely very sensitive to the timing of the assessment because the letter–sound knowledge skills and decoding skills of regular letter–sound correspondences can develop very rapidly during the first few months of given reading instruction in school, even among the slowest learners (Holopainen, Ahonen, & Lyytinen, 2001).

Scope of the Current Study

Recent results (e.g., Thompson et al., 2015), and earlier studies of orthographically opaque languages (e.g., Carroll & Snowling, 2004; Compton, Fuchs, Fuchs, & Bryant, 2006; de Jong & van der Leij, 2003; Pennington & Lefly, 2001), have shown that, during the kindergarten and preschool phases, two of the most powerful precursors of early reading skills are letter knowledge and phonological awareness. Similar results have been found in studies of Finland's orthographically highly transparent language (Holopainen et al., 2001; Puolakanaho et al., 2008; Silvén, Poskiparta, & Niemi, 2004). In the present study, tasks for assessing letter knowledge and phonological awareness skills were modified and embedded within the GL environment. The aim was to explore whether these measures for preschool-age children offered a reliable tool for predicting their reading skills at the end of first grade. These computerized tasks were compared to a set of standardized, traditional paper-and-pencil letter knowledge and phonological awareness tasks that are commonly used in Finland, along with other assessment instruments, to predict readiness for school entry (Elomäki, Huolila, Poskiparta, & Saranpää, 1999).

The current study was based on data from 57 preschool children (mean age 6.7 years) whose prereading skills were evaluated using both computer-based and traditional instruments. In the current study the children were categorized by the researchers into groups

of slow and normal readers based on their reading skill a year later, at the end of first grade. The main research questions addressed in the present study were

1. What is the predictive accuracy of the traditional paper-and-pencil method and of the computer-based GL assessment method in identifying slow readers?
2. What is the most economical (i.e., the smallest combination of subtests) GL screening method required to predict reading ability after one year at school?

Because earlier studies have shown that computer-based screening methods can be used to predict reading outcomes (Carson et al., 2011; Forster & Souvignier, 2011; Sainsbury & Benton, 2011), we proposed the following hypothesis:

H1: Computer-based screening methods will be as accurate as paper-and-pencil screening methods in predicting reading outcomes.

For screening purposes, it is important to determine the most cost- and time-effective and easy-to-use procedure to predict reading outcomes. Previous studies (Catts, Fey, Zhang, & Tomblin, 2001; Elbro, Bostrom, & Petersen, 1998; Pennington & Lefly, 2001; Puolakanaho et al., 2007; Thompson et al., 2015) have shown that only a few tasks typically are needed to predict reading outcomes. Based on these findings, we also proposed the following hypothesis:

H2: Only a few screening measures of the GL assessment are needed to predict reading outcomes reliably and sensitively.

In the current study, we were also interested in how to make use of the results in everyday life and school day practice. Therefore we also want to show how to determine the pupil's individual risk of reading difficulties. This, in turn, allows a teacher to make plans for classroom teaching and individual reading training for pupils who need special help.

METHOD

Participants

The present data were drawn from the LukiMat project² (Latvala, Koponen, Salmi, & Heikkilä, 2012). The aim of the LukiMat project is to offer professional knowledge and information about various aspects of reading and mathematics to Finnish educators and parents, as well as evaluation and training tools for reading and mathematics skills.

Finnish legislation (Government of Finland, 1998/628) defines that every child must participate in a pre-education program one year before starting school. More than 98% (Kinos & Palonen, 2013) of Finnish children attend formal preschool. Toward the end of the preschool autumn semester (i.e., November and December, 2012), the entire cohort ($N = 83$) of preschool-age children living in a small town in the province of Central Finland was assessed via a standardized paper-and-pencil instrument (Elomäki et al., 1999) to evaluate the children's readiness for school. All seven subtasks from the test were used for screening purposes. The computer-based GL screening tests were administered four months later (in March). The reading outcomes were measured more than a year later, in May, at the end of their first year of schooling.

The data presented in this paper were drawn from 57 participants whose parents gave permission for them to take part in the study and whose full data set was available. The teachers in the participants' elementary school were not encouraged to use the GL learning game with the pupils, although usage was not forbidden. The typical situation in Finnish schools is that some teachers use computer-based means (e.g., GL) in addition to traditional training methods that support children with reading delays (see, e.g., Ise et al., 2011). All participating children were ethnically Finnish, spoke Finnish as their native language, and had no reported mental, physical, or sensory deficiencies. However, three of the participants were children whose school entry had been postponed for one year, five had a history of speech and language delay (specific language impairment), and two were reported to have attention problems. In Finland and internationally, studies show that 5–10% of children have some learning difficulty (Holopainen, 2002; Lyytinen, Ahonen, Korhonen, Korkman, & Riita, 2002), which indicates that the research sample closely resembled the typical Finnish school population. Of course, the incidence of learning difficulties depends on the definition and measures used to assess it, which means an exact percentage of the population is difficult to determine.

Assessment Methods

The predictive measures (assessed in preschool) consisted of the traditional assessment measures presented by Elomäki et al. (1999). This group assessment of school readiness (developed in Turku, Finland) is referred to here as the “Turku battery.” For the digital assessment component of this study (conducted in preschool), we used the Finnish-language version of GL (i.e., Ekapeli). Our main aim was to compare the sensitivity of the reading related tasks (phonological and letter knowledge) using two different methods (Turku Battery and GL), but we also wanted to find out if the other tasks (mathematical, memory and visuo-motoric) in the Turku battery would increase the sensitivity in prediction of reading outcomes. Therefore the sensitivity of the whole Turku battery was analyzed.

We used three outcome (reading) measures to assess reading skills at the end of first grade, and we utilized these measures to categorize the children into groups of slow readers (SR) and normal readers (NR). We also assessed background measures (i.e., vocabulary, performance level, and familial history of reading problems) to investigate whether the categorized groups differed from each other. In the following section, we describe the measures in detail.

Predictive Measures Before School

Traditional Paper-and-Pencil Assessment Tasks

The paper-and-pencil tasks consisted of seven subtasks (Elomäki et al., 1999) and they are prefixed in this study with the initials Tu. Cronbach's alpha for the entire test battery (which we later refer to as *TuPre*) was .80. The subtests of the *TuPre* are presented in following.

Copying from a Model (TuCOP). The children drew a cross, a square, a circle, and a diamond three times according to a given model. The children's performance was estimated based on the standard guidelines outlined in the assessment manual. One point was awarded for each correct shape (maximum score = 12 points).

Memory (TuMEM). Three separate sets of pictures were presented to the children. The teacher named the pictures in each set out loud consecutively. Here is an example of a one set, in which teacher read aloud:³ “Look at the set where there is a *kuppi* [mug], *sieni* [mushroom], *lasi* [glass], *omena* [apple], *kärpänen* [fly], and *kenkä* [shoe].” The teacher then asked the students to draw a line across some of the pictures: “Draw a line through a fly, a glass, an apple, and a shoe. Start now!” The first set included six objects and targeted four to cross out. The second set of pictures presented seven objects and targeted five to cross out and the third and final set presented nine objects, of which five had to be crossed out. One point was given for each correct object crossed out, a point subtracted if an unnamed object had a line through it, and zero points given if a named object was not marked (maximum score = 14).

Mathematical Readiness (TuMAT). This task evaluated mathematical concepts (e.g., as many as, one more, one less, first, fourth, seventh). The tasks were fulfilled using a picture on which children had to draw their answers (e.g., a box of balls was presented with some numbers below, and the child was asked to draw a line across the number that indicated how many balls there were in the box). One point was awarded for each correct answer (maximum score = 18).

Copying Through Dots (TuDRA). The children were asked to draw, with the help of dots, a similar design as in the model picture. One point was given for each correct pair of line-connected dots (maximum score = 10). The task included one item for practice.

Initial Phoneme Matching (TuPHM). Each item included a target picture and comparison pictures that were presented side by side. A line of pictures was first identified aloud by the teacher, and the children were given the test instructions beforehand, in the form of, “Words begin with a sound that can be heard. At the beginning of the Finnish word *risu* [twigs], the [r] can be heard. There are also four other pictures on your paper (teacher points with finger). Here is *auto* [car], *linna* [castle], *ruusu* [rose], and *tyyny* [pillow]. The name of one picture among the four starts with the same sound as *risu*. Is it *auto*, *linna*, *ruusu*, or *tyyny*?” (In this case, the correct answer is *ruusu*.) Participants were asked to draw a line through the picture they selected (maximum score = 10). Three practice items were presented before the test items.

Identifying Rhyming Words (TuRHY). This procedure was similar to the initial phoneme-matching task. However, the children were required to show which two (rhyming) words sounded alike. The teacher would say, “Look at the following pictures in this row; the first picture is *nappi* [button] and next to that are *pappi* [priest], *sika* [pig], and *kaappi* [closet]. Which one sounds like *nappi*? Is it *pappi*, *sika*, or *kaappi*?” (In this case, the correct answer is *pappi*.⁴; maximum score = 10). Two practice items were presented before the test items.

Writing Letters (TuLEW). The children were asked to write on a paper, next to a series of pictures of objects, the requested 19 letters (e.g., “Write *R* beside the picture of the cat”). The letters were presented orally one at a time by the instructor. Correct forms

of uppercase and lowercase letters were accepted. Mirror images, rotated letters, or problems in fine-motor skills were not considered errors (maximum score = 19).

TuPHM, TuRHY, and TuLEW measure prereading skills. The combination of these three measures is called TuRead in the following analysis and Cronbach's alpha for the TuRead portion was .73.

Computer-based Assessment Tasks

The computer-based assessment tasks (*GLRead*), embedded in the GL, consisted of two subtasks and they are prefixed here with the initials GL. The internal consistency of *GLRead*, measured using Cronbach's alpha, was .64. The subtests of *GLRead* are presented here.

Phonological Awareness (GLPhon). *GLPhon* tasks were age-specific modifications of the tasks used earlier in the Jyväskylä Longitudinal Study of Dyslexia project in a computer-animated program called Heps-Kups Land (for a detailed description, see Puolakanaho, Poikkeus, Ahonen, Tolvanen, & Lyytinen, 2003). However, in this study, all of the task instructions and individual test items were presented using the GL program, and the child gave his/her answer by clicking it via the mouse. After giving the answer, the child could see the pictures from that series vanish from the screen, and a new series of pictures would appear. No other feedback on the answer was given.

The *GLPhon* score (maximum score = 20) was based on the following two subtasks:

- a) The first was syllable-level segment identification (10 items), where three pictures of objects were presented on the screen, immediately followed by the name written form of each object (e.g., *kissa* [cat], *koira* [dog], *kukko* [rooster]). The child was asked to identify the sub-word-level units (syllables) within the target (e.g., "In which picture can you hear the sound /koi/?"). If the child was successful in five or more of the items, the program continued to the single- sound-level targets.
- b) Sound identification (10 items). The procedure was the same as for the first task, but the targets were single sounds (e.g., Child hears: *auto* [car], *juna* [train], *vene* [boat] and sees the corresponding pictures; "In which picture you can hear the sound /o/?" The child chooses the picture to which the target sound refers. (In the example, the correct answer is the picture of the car, "*auto*."))

Letter-Sound Knowledge (GLLeSo). Here, the child was asked to match the letter sounds to the letter-appropriate characters (of the 23 presented), written in capital letters and displayed simultaneously on the screen. The sounds of the letters (via recorded natural speech produced by the computer program) were played aloud one at a time, and the child gave an answer by clicking the letter via the mouse. The child could replay the sound by right-clicking the mouse (or by asking the instructor). The placement of the letters on the screen was presented in a fixed order throughout the subtask, and feedback on the answer was not given. (maximum score = 23).

Background Measures

We wanted also to know if the samples in the current study were equal and if the pupils' abilities were among the normal age range. Therefore we evaluated samples using three different background measures; a receptive vocabulary task, a performance-level task, and an evaluation of familial risk of reading related problems.

Vocabulary. The Peabody Picture Vocabulary Test–Revised Form L (PPVT–R; Dunn & Dunn, 1981) was used to obtain a measure of receptive vocabulary. In this test, the child heard a word, and he or she was asked to point out via the mouse which, of the four pictures presented, the word referred to. The pictures and vocabulary items were presented to the children via the computer. The raw sum score of the correct items (for a description of the Finnish shortened version; see Lyytinen & Lyytinen, 2004) was used as a score (maximum score = 75).

Performance Level. Raven's Colored Matrices (Raven & Court, 1998) were used to assess nonverbal IQ, that is, the performance level at preschool age. The matrices were presented to the children via computer. Because the task has not yet been standardized in Finland, the raw sum score of correct items was employed (maximum score = 36).

Familial Risk. Parents were asked to fill out a paper questionnaire designed to evaluate a history of the reading and spelling problems in the children's close relatives (siblings, parents, aunts, uncles, and grandparents). The criterion for the familial risk of reading problems was fulfilled if one of the child's parents or siblings was reported to have a history of persistent reading or spelling problems. For the sake of interest, the reported reading problems of other relatives are also presented in this paper.

According to the nonparametric Shapiro-Wilk test (see Field, 2013), the sample in the Vocabulary and Performance Level tasks was normally distributed. We used nonparametric tests due the small sample size.

Outcome Reading Measures at the End of First Grade

The reading outcomes were evaluated using three different reading related measures described below. These measures were used to classify children into normal and slow readers in the current study. There were no missing data concerning the outcome measures.

Lukilasse. A timed word-list reading test from the Lukilasse test (Häyrynen, Serenius-Sirve, & Korkman, 1999) was used, in which the children read aloud a list of words that gradually became longer and more difficult. The number of correctly read words within the 2-minute time limit was transformed into a standard score according to the guidelines in the test manual (maximum score = 90).

Reading Text. The child's task was to read a short story (*Jännittävät matkat*; 24 words/901 characters) as quickly and accurately as he or she could. The story was presented on paper using lowercase letters. (For clarification, the beginning of the sentences also started with lowercase letters.) The score was calculated by dividing the number of words read by the time spent reading and converted to a final score

of correctly read words per minute. This task was used previously in the Jyväskylä Longitudinal Study of Dyslexia (see Puolakanaho et al., 2007, 2008).

Luksu. The Luksu is a Finnish-modified version of the Woodcock-Johnson reading fluency task (Woodcock, McGrew, & Mather, 2001). The child's task was to read sentences presented in the GL environment and, after each sentence, to indicate if the given statement was true or false by clicking with the mouse. The final scores were calculated by determining how many appropriately true and false statements were correctly identified within 3 minutes (maximum score = 70).

Cronbach's alpha for the three reading measures was .92. The nonparametric Shapiro-Wilk test (see Field, 2013) showed that there was a normally distributed sample in Lukilasse and Luksu.

Categorizing Children into Slow Reader (SR) and Normal Reader (NR) Groups

The three measures of reading (described in the previous subsection) were conducted at the end of the first grade (mean age = 7.9 years, $SD = 0.36$) and used in classifying the participating children as those with and without reading problems. A similar procedure was used earlier in the Jyväskylä Longitudinal Study of Dyslexia (Puolakanaho et al., 2007). In this study, the following procedure led to the classification:

1. A cutoff point was calculated using the score at one standard deviation below the whole group's mean performance for each of the three first-grade outcome measures (i.e., Lukilasse, Reading Text, and Luksu).
2. A child was considered to have deficient skills in each respective task if his or her score fell at or below the cutoff point of the task.
3. To classify a child as a slow reader, the child's skills had to fall at or below the cutoff point for at least two of the three measures.

Using these criteria, 11 children (19.2%) in the study group were classified into the slow reader group. In the following sections, we use the acronym SR for children classified with slow reading skills and the acronym NR (46 children) for those classified with normal reading skills. The groups were compared using nonparametric methods because the sample size was relatively small and some measures were skewed.

Participants' Background Information

The background information relating to the sample is presented in Table 1. The study included 29 girls and 28 boys; however, there were more boys in the SR group than the NR group, proportionately. Gender differences in the predictive and reading-related measures were explored using the Mann-Whitney U-test (see Metsämuuronen, 2017). Girls outperformed boys slightly on the TuRead test battery's TuPHM task (Girls: $M = 7.5$, Boys: $M = 5.9$, Mann-Whitney $U = 278.0$, $p = .038$), the TuLEW task (Girls: $M = 14.7$, Boys: $M = 11.7$, Mann-Whitney $U = 283.0$, $p = .047$) and the TuMAT task (Girls: $M = 16.2$, Boys: $M = 15.2$, Mann-Whitney $U = 282.0$, $p = .038$). The results for both girls and boys are combined in the subsequent analyses.

Table 1. Background of Children in the Sample ($N = 57$).

	NR $n = 46$ (26 girls, 20 boys)		SR $n = 11$ (3 girls, 8 boys)	
	No	Yes	No	Yes
Familial Risk (immediate relatives)*	42	3	8	3
Reported RD Issues in close relatives*	30	15	7	4
* missing information in one case				
	NR		SR	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Vocabulary* ($n = 27 / n = 10$)	18.9	3.0	17.8	3.1
Performance Level* ($n = 25 / n = 11$)	23.0	4.6	20.1	5.1

* missing information in some cases.

Note. NR = normal readers, SR = slow readers, RD = reading disability

immediate relatives = parents & siblings; close relatives = immediate relatives plus aunts, uncles, & grandparents

In this sample, 33% (15 of 46) of the parents whose children were in the NR group, and nearly 36% (4 of 11) of the parents who had children with SR, reported having close relatives with reading or spelling problems. However, the percentage of immediate relatives (at least one among parents or siblings) with reported reading problems was about 7% (3 of 46) in the NR group and 27% (3 of 11) in the SR group. It seems that children whose immediate relatives have reading or spelling problems are more prone to have reading difficulties than children from background with no familial risk. The finding is in line with previous studies of reading problems (Elbro et al., 1998; Pennington & Lefly, 2001; Puolakanaho et al., 2007).

No statistically significant difference was found in vocabulary and performance levels between the SR and NR groups. This result indicates that the groups were equal and further suggests the children's backgrounds did not affect the following results. However, it is notable, that we did not have data of all participants and the interpretation should be taken with caution.

RESULTS

The Connection Between Computer-based and Traditional Measures

In general, the nonparametric correlations (Spearman's rho; see Field, 2013) indicated that the children's various skills were interconnected (Table 2). The traditional and digitally measured letter-sound knowledge tasks' correlation indices showed that they capture a substantial share of the common variance. The various phonological awareness tasks (i.e., TuPHM and TuRHY from the TuRead task battery and GLPhon from the GLRead task battery) have significant connections.

Outcome reading measures had high correlations with each other and with predictive measures in general. However, the Luksu fluency task only correlated with a few (the TuPHM, TuLEW and GLLSo predictive measures, and the Lukilasse outcome reading measure).

Table 2. Correlations (Spearman's rho) Between the Measures in the Whole Sample.

	TuCOP	TuMEM	TuPHM	TuMAT	TuDRA	TuRHY	TuLEW	GLLeSo	GLPhon	Lukilas	Read	Luku
TuCOP	1											
TuMEM	.310*	1										
TuPHM	.270*	.376**	1									
TuMAT	.423**	.392**	.501**	1								
TuDRA	.454**	.392**	.292*	.652**	1							
TuRHY	.368*	.350**	.268*	.364**	.271*	1						
TuLEW	.396**	.440**	.665**	.629**	.364**	.387**	1					
GLLeSo	.505**	.443**	.564**	.618**	.414**	.384**	.739**	1				
GLPhon	.447**	.370**	.551**	.377**	.271*	.374**	.488**	.578**	1			
Lukilas	.370**	.442**	.529**	.540**	.417**	.427**	.592**	.615**	.375**	1		
Read	.294*	.341*	.530**	.413**	.334*	.362**	.545**	.596**	.373**	.948**	1	
Luku	.061	.166	.307*	.239	.223	.176	.355**	.397**	.125	.649**	.787**	1

Note. TuCOP = Copying from Model (Turku Battery), TuMEM = Memory (Turku Battery), TuPHM = Initial Phoneme Matching (Turku Battery), TuMAT = Mathematical Readiness (Turku Battery), TuDRA = Copying through Dots (Turku Battery), TuRHY = Identifying Rhyming Words (Turku Battery), TuLEW = Writing Letters (Turku Battery), GLLeSo = Letter–Sound Knowledge (GraphoLearn), GLPhon = Phonological awareness (GraphoLearn), Lukilas = Lukilasse reading measure, Read = Reading Text “Jännittävät matkat”, Luku = Luku fluency task (computer version),

*** = $p < .001$, ** = $p < .01$, * = $p < .05$

Differences Between SR and NR groups

The descriptive statistics of the predictive and outcome measures in the SR and NR groups are presented in Table 3. No ceiling or floor effects were discovered, although the measures were slightly skewed, indicating that the tasks were well mastered, especially in the NR group. However, because the analysis method used (logistic regression) is not sensitive to the deviation from normality, the measures were accepted in the analyses.

Statistically significant differences were found in the nonparametric Mann-Whitney U-test (between the SR and NR groups in the mean scores of all predictive and outcome measures. The nonparametric effect size values (r ; see Fritz, Morris, & Richler, 2012) indicate that most of the measures have discriminative power. The most powerful predictors are the tasks that measure letter–sound knowledge.

Predictive Accuracy of the Battery of Traditional Tasks

All of the measures from the school readiness battery, that is, the TuPre (i.e., TuCOP, TuMAT, TuDRA, TuPHM, TuRHY, and TuLEW), were included in the logistic regression analyses. Because Performance Level and Vocabulary, which were used as background measures, failed to show differences between the groups, they were omitted from the analyses.

Table 3. Descriptive Statistics of the Preschool Measures and the First-grade Reading Outcomes in the NR and SR Groups.

Measures	Min-Max	NR				SR				Mann-Whitney U	Effect size (r)
		M	SD	<i>n</i> = 46 Ske wne ss	Kurt osis	M	SD	<i>n</i> = 11 Ske wne ss	Kurt osis		
TuCogn											
TuCOP	4-12	11.1	1	-0.1	0.1	8.9	2.3	-0.8	0.3	96.0**	0.44
TuMEM	6-14	11.3	1.5	-0.2	-0.1	9.0	2.1	0.1	-0.3	90.5**	0.44
TuMAT	7-18	16.5	2.5	-1.9	3.2	12.6	3.5	-0.4	-0.7	79.5***	0.49
TuDRA	0-8	5.8	2.7	-1.0	-0.3	3.3	3.0	0.4	0.7	131.0**	0.34
TuRead											
TuPHM	1-10	7.2	2.7	-0.5	-1.0	4.4	1.6	0	-0.8	104.0**	0.41
TuRHY	3-10	9.2	1.2	-1.7	2.3	8.1	2.0	-1.7	3.7	152.0*	0.29
TuLEW	1-19	15.0	4.7	-0.9	-0.7	5.9	2.3	-0.4	1.4	33.5***	0.59
GLRead											
GLPhon	8-20	16.9	3.0	-1.0	0.4	13.6	3.1	-0.1	-0.6	110.0**	0.39
GLLeSo	0-23	18.2	4.1	-0.9	0.0	7.2	3.8	-0.3	-0.2	16.5***	0.64
Reading outcomes											
Lukilasse	0-90	58.0	17.7	0.4	-1.0	20.1	13.7	-0.8	-1.0	7.5***	0.66
Reading Text	9-103	46.7	21.8	0.6	-0.5	11.5	1.8	-0.2	-1.7	0.0***	0.59
Luksu	6-61	33.5	11.7	0.5	-0.7	20.9	14.0	0.2	-2.3	149.0*	0.28

Note. TuCOP = Copying from Model (Turku Battery), TuMEM = Memory (Turku Battery), TuPHM = Initial Phoneme Matching (Turku Battery), TuMAT = Mathematical Readiness (Turku Battery), TuDRA = Copying through Dots (Turku Battery), TuRHY = Identifying Rhyming Words (Turku Battery), TuLEW = Writing Letters (Turku Battery), GLLeSo = Letter-Sound Knowledge (GraphoLearn), GLPhon = Phonological awareness (GraphoLearn),

*** = $p < .001$, ** = $p < .01$, * = $p < .05$, $r = \frac{z}{\sqrt{N}}$ (Fritz, Morris, & Richler, 2012)

We first explored how well the TuPre could predict reading outcomes (i.e., predict that a child would be in either the NR or SR group). The aim of this phase was to answer the first part of the first research question. Table 4 presents the results of the logistic regression analyses.

The regression models for the Turku battery were carried out using the Forced Choice procedure (i.e., enter method; see Field, 2013), and the analyses indicated that all of the predictors contributed to the outcome. The coefficient of determination of the whole TuPre battery was .72 (adjusted R^2 value), indicating the model's good predictive ability. The coefficient of reading-related measurements (TuRead) on the TuPre battery was $R^2 = .64$.

Table 4. The Logistic Regression Analyses of the Turku Battery and GraphoLearn Battery.

Model	Variables in Equation	R^2	Sensitivity %	False pos.	Specificity %	False neg.	Overall %
TuPre measures							
TuPre (enter) cut-off .50	TuCOP TuMEM TuPHM TuMAT TuDRA TuRHY TuLEW	.72	95.7	2/46	81.8	2/11	93.0
TuRead (enter) cut-off .50	TuPHM TuRHY TuLEW	.64	91.3	4/46	72.7	3/11	87.7
GraphoLearn							
GLRead (enter) cut-off .50	GLLeSo GLPhon	.75	95.7	2/46	81.8	2/11	93.0
Economical Model							
GLRead (fcond) cut-off .50	GLLeSo	.75	97.8	1/46	72.7	3/11	93.0
GLRead (fcond) cut-off .35	GLLeSo	.75	95.7	2/46	81.8	2/11	93.0

Note. TuCOP = Copying from Model (Turku Battery), TuMEM = Memory (Turku Battery), TuPHM = Initial Phoneme Matching (Turku Battery), TuMAT = Mathematical Readiness (Turku Battery), TuDRA = Copying through Dots (Turku Battery), TuRHY = Identifying Rhyming Words (Turku Battery), TuLEW = Writing Letters (Turku Battery), GLLeSo = Letter–Sound Knowledge (GraphoLearn), GLPhon = Phonological awareness (GraphoLearn). Two different regression analysis procedures were used i.e., enter = Forced Choice procedure and fcond = Forward Conditional procedure.

Predictive Accuracy of Computer-based Methods

In the second phase of the analysis, to answer the second part of the first research question, a logistic regression procedure was used to examine how the GLRead test battery (i.e., the combined GLPhon and GLLeSo tests) predicted reading outcomes. The results showed that the coefficient of determination (the adjusted R^2 value) for the GLRead test battery was .75, for TuPre was .72, and for TuRead was .64 (see Table 4). It is notable that the predictive accuracy of both the traditional tasks and computer-based tasks were similar.

The Most Economical Predictive GL Reading Readiness Model

The second research question addressed identifying the most economical—that is, the simplest possible—computer-based procedure for predicting reading ability after one year at school. Therefore, the logistic regression analyses were conducted using the Forward Conditional procedure (i.e., fcond; see Field, 2013) for the GLRead (see Table 4). The analyses indicated that just a single measure of GL—letter–sound knowledge (GLLeSo)—was needed (adjusted $R^2 = .75$) to predict whether children would be in the SR or NR group. In logistic regression, it is possible to include more children in the SR group by setting the cutoff criterion lower than .50 (see Elbro et al., 1998). This procedure will recognize more true SR-cases, but at the same time it also increases the number of NR-children falsely recognized as SR-children. From practical point of view, it is more important to try to identify all SR-children, than leave them unrecognized and therefore without support. Decreasing the cutoff criterion of SR from .50 to .35 produced a 93% classification accuracy for the overall model (with a sensitivity score of 95.7% and a specificity score of 81.8%). In our sample, this result meant that 9 of the 11 SR cases were recognized, and two SR cases (i.e., 18% of the total SR cases) could not be predicted using the GLLeSo task. In addition, 2 of the 46 NR cases (i.e., 4.3% of the total SR cases) were misleadingly predicted as having problems with reading at the end of first grade.

Implementation into Practice: Determining the Individual Risk of SR

In the current study, we also were interested in implementing the results into practice to determine the individual risk of reading difficulties. We see that the classification rate of the above-mentioned prediction model (i.e., GLLeSo) is high when compared with other non-Finnish prediction models, particularly those from abroad (i.e., Catts et al., 2001; Elbro et al., 1998; Pennington & Lefly, 2001) but even some from Finland (i.e., Holopainen et al., 2001; Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004). This implies that the model may be clinically useful, and the results could be utilized in school practice, in that the logistic regression model (and the mathematical equations behind it) can be used to predict the individual risk of SR at preschool age (see Elbro et al., 1998). The individual scores for those at risk of SR (based on the most economical model presented above, i.e., GLLeSo) can be calculated from the assessed letter–sound knowledge scores using the following mathematical equation:

$$\text{Individual SR risk score} = \frac{1}{1 + e^{-(6.059 - 0.607 \times [\text{GL Letter-Sound Knowledge score}])}}$$

The index of risk varies between 0 and 1, where values close to zero indicate a minimal risk of SR. The closer the value is to 1, the greater the risk of SR (see Elbro et al., 1998; Puolakanaho et al., 2007; Thompson et al., 2015). We applied the formerly presented results of the logistic regression model and the equation to illustrate the distribution of the individual risk scores, GLLeSo scores, and SR cases in the current study sample (see Table 5).

In Table 5, we present the distribution of SR cases in the present study sample. The table also gives the corresponding GLLeSo scores and individual SR risk ranges of different level-of-risk areas. Of the participants, 66% had a minimal, 18% had a moderate, and 16% had a high risk of SR. Thus, for example, if the assessed preschool child correctly identified 12 letters (based on

Table 5. Distribution of Risk of Being a Slow Reader in the Study Sample.

Level of risk	GLLeSo score at the start of the first grade	Individual SR risk score	Percentage (%) in the current sample	Number of children identified to this group	Number of true positive SR cases	Percentage of the children identified falsely (%): false negative SR/false positive SR
High Risk of SR	0-9	0.644-0.988	16	9	8	27.3 / 11
Moderate Risk of S	10-13	0.137-0.497	18	10	3	0 / 70
Minimal Risk of SR	14-23	0.08 -0.0	66	38	0	0 / 0

Note. SR=Slow Reader; GLLeSo= Letter–Sound Knowledge

their sounds) in GL, he or she would be considered to have a moderate risk of SR, as only 3 out of 10 study participants who scored between 10 and 13 letters correctly were classified accurately as having slow reading learning development one year later in school. We want to emphasize, that this implementation is suggestive and generalization of the results is cautioned due to the small sample size in this study.

DISCUSSION

The first aim of the present study was to compare the predictive accuracy of identifying children at risk of reading problems by a computer-based screening method (GL) versus traditional paper-and-pencil screening methods. The second aim was to determine the most economical model of a GL screening method to predict reading ability after one year of school. This study was conducted with a group of preschool-age children, whose reading performance was measured one year later when they were at the end of first grade. The two most promising preschool predictors of early reading outcomes in languages with a transparent orthography—letter knowledge and phonological awareness—were embedded in the GL learning environment. These GL assessment methods were compared with a standardized battery of paper-and-pencil tasks to predict reading outcomes in young Finnish children.

The current study confirmed the first hypotheses and showed that GL-based screening methods are as accurate as paper-and-pencil screening methods in predicting reading outcomes. The study indicated that the GL-based screening methods offer a reliable and easy-to-use procedure for predicting reading skills. The finding is in accord with other computer-based reading assessment studies (e.g., Carson et al., 2011; Forster & Souvignier, 2011; Sainsbury & Benton, 2011). In addition, we determined that, in the simplest form, only a single computer-based task was needed to predict reading skills in our study, namely letter knowledge assessed using a letter–sound matching activity (the GLLeSo task). Therefore, the study also confirmed the second hypotheses and showed that only a few screening measures are needed to predict reading outcomes reliably and sensitively.

These findings are in line with those of other studies that have indicated that, specifically in writing systems relatively consistent at the letter–sound level, knowledge of letter–sound

correspondence is an important factor, or a preliterate skill, that will further promote reading acquisition skills (Aro, 2006; Georgiou, Torppa, Manolitsis, Lyytinen, & Parrila, 2012; Thompson et al., 2015). Puolakanaho et al. (2008) showed that, starting at 5 years of age, the development of phonological awareness and letter knowledge begin to intertwine with each other in a child's development. From this point onwards, letter knowledge starts to play a more important role than phonological awareness in reading achievement prediction in most orthographic languages (see also the cross-language investigation by Ziegler et al., 2010).

However, these results do not imply that skills such as phonological awareness, memory, or vocabulary are not important during the preschool years. On the contrary, the most accurate prediction model was obtained from the school readiness test battery—if the combination of measures included GL-based reading methods (GLRead and GLPhon) and cognitive measures from the school readiness tests (Turku battery). This combination of screening measures would allow for the evaluation of cognitive, phonological, and other preliterate skills, thus forming the foundation for the development of necessary interventions.

The results of multiple studies indicate that early language, phonological, and cognitive skills form the basis for literacy development. This is shown in both orthographically opaque languages (e.g., Carroll & Snowling, 2004; Compton et al., 2006; de Jong & van der Leij, 2003; Pennington & Lefly, 2001; Snowling, Gallagher, & Frith, 2003) and more transparent writing systems (e.g., Elbro et al., 1998), such as the Finnish language (e.g., Holopainen et al., 2001; Silvén et al., 2004; Puolakanaho et al., 2008). These early measures are also highly predictive of dyslexia, as shown by Torppa et al. (2007), based on the Jyväskylä Longitudinal Study of Dyslexia.

In the present study, preschool letter knowledge predicted reading outcomes in first grade. However, we do not assume that preschool letter knowledge is the only measure that predicts the development of reading skills, particularly reading fluency. Because the Finnish language has one of the most transparent orthographies, children usually acquire reading skills very rapidly whereas reading acquisition takes more time in less transparent orthographies (Aro, 2006). Due to this, the timing of the assessment is crucial when the results are interpreted. Therefore, these results might not be transferable, as such, to orthographically opaque languages.

We recognize several limitations in the study. The present investigation is a pilot study where the sample is considered as representative of the wider population. However, the sample size was small, and therefore the sizes of the groups (NR and SR) were correspondingly small. In addition, the data were drawn from a single town in Central Finland, which might cause some bias. Moreover, we could not control the possible use of additional training methods, such as the GL training game or other methods. Therefore, the present study should be considered a pilot study exploring the reading-level screening possibilities of a computer game-based assessment. Notably, there was a 4-month gap between the Turku battery tests and the GL assessments, and therefore the maturation effects cannot be fully excluded. However, the aim of the study was not to replace the Turku battery for evaluation purposes, but rather to determine if there was an effective computer-based alternative for predicting reading achievement.

The results must also be interpreted with caution because the study was conducted in the context of the Finnish language, which has transparent alphabetic orthography with symmetrically consistent letter–sound (grapheme–phoneme) relationships. In opaque orthographies, our approach might not work as well, or it might work similarly but at a different age and school phase, as Seymour et al. (2003) and Ziegler et al. (2010) have pointed out.

The challenge of future studies is to determine whether GL assessment methods can be used to predict longer-term reading achievements and to explore how the GL method can be used for languages with less consistent orthographic grapheme–phoneme correspondences. Future studies should use larger sample sizes and wider populations (e.g., several towns in Finland, participants with different developmental backgrounds, or other countries with different linguistic orthographies). In this case, it would be important to confirm our results regarding the computer-based assessment task by using a larger variety of GL linguistic environments. Additional studies could follow the reading learning paths from the basic reading acquisition to more advanced fluent reading skills, as well as to reading comprehension skills.

IMPLICATIONS FOR RESEARCH AND APPLICATION

The current study showed that the GraphoLearn (GL) computer-based screening methods, implemented at preschool age, are as accurate as traditional paper-and-pencil screening methods in predicting reading outcomes one year later. Given the transparent orthography of the Finnish-language, only one assessment task, that is, the letter–sound knowledge identified by the GL LeSo task, was required to identify reliably the children with a high risk of SR. The scores from this task will allow Finnish classroom teachers to identify children with a high risk of reading difficulties and therefore facilitate their planning and executing effective teaching activities during the first school year.

The question that arises after identifying individuals at risk of SR is how to support them in the learning process of reading. Many training studies conducted abroad (see the reviews by Bus & van Ijzendoorn, 1999 and Tornéus, Hedström, & Lundberg, 1991) and in Finland (Poskiparta, 2002) have indicated that training in phonological awareness skills with speech processing and letter knowledge has a positive effect on the development of reading skills, especially in the early phases of reading education (e.g., Lundberg, Frost, & Petersen, 1988; Schneider, Roth, & Ennemoser, 2000). In addition, efficient training in letter–sound associations would be useful. These skills are the focus of digital learning games such as GL (see Lyytinen et al., 2009; Saine et al., 2011).

Reading skills are essential for learning other topics in school. Therefore, identification of SR children at an early phase of their school entry and supported start will help SR children not to fall behind their peers in other school subjects. This, in turn, will minimize other school related problems including motivational and behavioral shortcomings that may have notable effects on the pupil's forthcoming learning paths.

ENDNOTES

1. More information about the GraphoLearn learning game can be found at <http://info.GraphoLearn.com>. The GraphoLearn learning game was earlier called the GraphoGame (Ekapeli in Finnish), and these names can be found in the earlier published papers.
2. The LukiMat project aimed at developing knowledge and material for assisting children in learning to read and for mastering mathematics skills. The project was funded by the Finnish Ministry of Education and Culture. More information is available from <http://www.lukimat.fi>

3. For clarification, all the instructions to the children were provided in Finnish. But the teacher's instructions have been translated to English for this report for readers' understanding. The words associated with the tasks have been presented in Finnish (with translations) because the task is based on the Finnish spelling and pronunciation.
4. In the Finnish language, every letter is pronounced, and therefore a double consonant or vowel will affect the rhyming (and therefore *kaappi* is not the correct answer in the given example). Accordingly, the spelling of a word with the same letters, of which some are doubled, changes the meaning of the word. For instance, *tuli* means fire, whereas *tuuli* means wind.

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