Human-Computer Interaction issues in Human Computation

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Abstract This chapter explores the relationship between human computation and human-computer interaction (HCI). HCI is a field concerned with innovating, evaluating and abstracting principles for the design of usable interfaces. Significant work on human computation has taken place within HCI already (see Quinn & Bederson (2011) and, beyond HCI (Jamieson, Grace & Hall, 2012) for reviews of this work) and, as a result of the encounter between HCI and human computation, there are many results concerned with the relevance of interaction design for human computation systems. Rather than attempt to cover this wide range of issues comprehensively, this chapter focuses on providing a broad critique of the nature of the concepts, orientations and assumptions with which human computation systems design is considered within HCI. In particular it addresses two of the five foundational questions for human computation systems suggested by Law and von Ahn: 1) how to guarantee solutions are accurate, efficient and economical; and 2) how to motivate human components in their participation and expertise and interests (Law & von Ahn, 2011). These two key human-related issues lead us to address the ways in which designers conceive of, model and frame *the human element of interactive systems* and how this is relevant in informing our understanding of *the human element of human computation systems*. Building on empirical work in human computation games (e.g., Bell et al. (2008)), this critique seeks to reorient human computation's perspective on human conduct as a fundamentally interpretive and socially organised accomplishment that is negotiated between humans in human computation systems, rather than an *algorithmic* process. Key elements of this reorientation argued in the chapter are: 1) that the human perspective should be considered a *foundational issue* in human computation; 2) that meaning within human computation systems is *situated* (i.e., within a particular context); and 3) that the ways in which human computation systems are experienced by human participants *fundamentally frames* their interaction with it and thus also the *products* of these interactions.

1 What is human-computer interaction and how does it relate to human computation?

Human-computer interaction explores the construction of novel interactive systems (hardware and software), the evaluation and study of interactive systems in use, and the construction of theoretical understandings of those evaluations. Of course, this is a narrow view of HCI and does not fully account for its relationship to other disciplines which have a role within or relationship to it, such as art and design, or software engineering. For the purposes of this chapter, however, it will suffice.

Human computation has become an application domain for HCI, often in the context of crowdsourcing systems. Given that interactions between human and machine form the foundations of human computation, the fit between the two is natural. Most prominent examples of this relationship stem from early work by von Ahn and Dabbish (von Ahn & Dabbish, 2004), which synthesised von Ahn's cryptography research with Dabbish's work on collaborative systems and computer-supported cooperative work (CSCW). Through this, von Ahn and Dabbish produced influential work that brought human computation concerns onto the HCI agenda, particularly through various demonstrations of interactive 'games with a purpose' (von Ahn & Dabbish, 2008). The canonical example within HCI is the 'ESP Game' (von Ahn & Dabbish, 2004), in which paired players attempt to match descriptive tags for images, resulting in the rapid collection of human-constructed annotations for large numbers of images as a 'byproduct' of human-computer interactions. This work has developed into a large literature concerned with developing and evaluating (new and existing) interactivity in human computation systems, ranging from web or desktop-based 'games with a purpose' (such as the ESP Game), to citizen science applications (e.g., Galaxy Zoo[1]), to mobile systems (e.g., Bell et al. (2008)).

1.1 Contributions to HCI

The key contributions of this body of work to HCI is the development of a novel interaction technique, i.e., solving hard computational tasks with human action, as

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[1] http://www.galaxyzoo.org

well as an exploration of various associated HCI issues that inform design. The notion of 'interactive human computation systems' as an interaction technique inverts the more usual and familiar HCI relationship between humans and machines, in which machines are the computational actors. In the inverted technique, *humans are seen as computational nodes* or components within a human-computer assembly, as opposed to a more common HCI perspective which seeks to understand how *machine computational resources* come to feature and be employed within human-human and human-computer interactivity. Thus, within human computation literatures, human activity has been seen as potentially offering vast resources of computation for solving hard computational tasks. Interactivity is a further key part: the knowledge that in theory, interactive computation provides a greater computational power than non-interactive algorithmic systems (Wegner, 1997) supports this notion. The exploration of this unusual configuration of human and machine has necessarily resulted in its particular associated HCI issues being explored. Generally within the human computation literature published at HCI venues this has tended to focus on how to design interactive human computation systems which are correct (i.e., "producing the correct answer in the presence of noise") and efficient (Law & von Ahn, 2011) in terms of 'quality control', or managing issues of 'cheating' or 'gaming the system' through input and output agreement (Law & von Ahn, 2009) systems (e.g., as in the ESP Game's matching of pairs of players (vonAhn & Dabbish, 2004)). This literature has also addressed issues of motivating human 'components' of human computation systems (e.g., Bell et al. (2008); Reeves & Sherwood (2010)), as well as how human and machine contributions can be organised, both in terms of workflows and aggregation strategies (Reeves & Sherwood, 2010; Quinn & Bederson, 2011).

1.2 HCI challenges to human computation

However, as Quinn and Bederson argue, "human computation has a tendency to represent workers as faceless computational resources" (Quinn & Bederson, 2011) (for instance, not considering "issues related to ethics and labor standards"). This is in many ways atavistic towards HCI's strong promotion of user-centred design and focus on user experience as a foundational element of system design. Prior work (e.g., Reeves & Sherwood (2010)) has also critiqued the notion of conceptualising humans as "processing nodes for problems that computers cannot yet solve" (von Ahn &

Dabbish, 2008) or as a "remote server rackspace" of "distributed human brainpower" (Zittrain, 2008).

The tenor of this argument reflects wider historical forces in HCI; the human computation approach within HCI largely reflects what could be seen as a 'traditional' HCI approach, bound by normative forms of design (e.g., there is no sense of participatory design processes where users co-design the system) and evaluation (e.g., formal evaluation techniques such as usability testing). Thus to a great extent, human computation as it features within HCI has remained generally unaffected by the significance of the 'turn to the social' that impacted HCI during the 90s (Button & Dourish, 1996; Bannon, 1991; Grudin, 1990b) and helped bring about a revolution in how we conceptualise 'the user'. Briefly put, this 'turn' in HCI involved a move beyond individualist cognitive formulations of the 'user' to social conception of the 'user' and greater consideration of the importance of coordination and collaboration amongst groups of users.

The rest of this chapter focuses on the implications of this shift for human computation and how it might conceive of these 'processing nodes'. In order to address this we must now turn to consider the 'cognitive turn' as well as the 'social turn' in HCI (section 2) before examining its implications for human computation itself (section 3).

2 Cognitive and social 'turns' in HCI: Conceptualising 'the user'

HCI initially emerged from a convergence between computer science and psychological, cognitive and social psychological models of interaction (Dourish, 2006). Of the cognitive and social 'turns' in HCI, we find their traces most prominently within the evaluative traditions and practices of HCI. There is a significant body of literature within HCI concerned with developing the methods and perspectives with which to conduct evaluation of computer interfaces in use. This ranges widely in purpose, from evaluations concerned with an individual's task efficiency and interface usability (e.g., see 'GOMS' as mentioned below) for work / productivity applications to ethnographic evaluations of user experience of artistic performances (e.g., Reeves (2011)). The range of these various methods and perspectives has increased with the growing spread of digital technologies and their attendant interfaces into ever more aspects of our everyday lives.

Early approaches at the start of the 1980s for evaluating the usability of computer interfaces were derived largely from human factors and cognitive psychology, which considered both the perceptual qualities of interface elements (e.g., ergonomics) as well as the cognitive processes which interface users engage in when interacting with machines. This perspective informed a range of evaluative practices concerned with examining task performance and its relationship to user interface design. Cognitive conceptions such as the human processor model (Card, Moran & Newell, 1983) have provided the basis of task decomposition techniques, such as GOMS (Goals, Operators, Methods, Selection) and its variants (see John (1995)), that offer predictive task performance indicators for expert users engaged in limited tasks, such as data entry and so on.

Key to these early approaches to conceptualising 'the user' in HCI is in constituting the human element as an individual, delimited by the descriptions of cognitive psychology, with individual capabilities described in terms of motor, sensor, memory and computational processing capacities. Models of cognitive faculties explain the possibility of human action in the world by theorising inner conceptual / mental representations constructed by the human to represent systems that exist 'out there' in the world. The human consults these internal representations as a resource when interacting with the world. In this cognitive approach as articulated in HCI, 'the user' has particular goals and subgoals which, so arranged, provide a plan of action to bring about an overall goal such as 'write a letter' or 'send a text message' (e.g., see Card, Moran & Newell (1983)). Through this planning view, the cognitive approach seeks to model and therefore predict the 'human factors' in interactions between human and machine, the reasoning being that through this, designers may themselves be able to systematically explore a design space to find optimal solutions to interface design problems.

However, the advent of a different, socially-oriented approach, drawing particularly on the social sciences, did, towards the end of the 1980s and the start of the 1990s, begin to challenge this dominant individualist cognitive perspective within HCI in a number of ways (Bannon, 1992). Not only was the model of ‘the user’ transformed, but so was understanding of the role of the technological artefact. As Grudin argues, this shift developed into a more holistic view of interaction, exploding the typical HCI definitions of the interface to situate both the technology and ‘the user’ into complex socio-technical constellations, and instead reveal a role for HCI in the design of this itself *as* the interface (Grudin, 1990a). Beyond this, recognition of this growing importance of understanding the social features of interaction were equally found in developments of psychological approaches, such as the emergence of Distributed Cognition theory (Hutchins, 1995) and its application in an HCI context (Rogers, 1994).

2.1 Underlying perspectival shifts in HCI: phenomenology and workplace studies

A key influence in this perspectival shift occurring in HCI was the instrumental effect of a range of workplace ethnographies which unpacked the character of coordination and collaboration with, around and through interactive technologies. Put simply, the individual was no longer a relevant unit of analysis. Instead, as Heath et al. describe, the term ‘collaboration’ provided a useful “gloss to capture a complex configuration of momentary arrangements through which two or more individuals, sequentially or simultaneously participate in particular tasks or activities” (Heath et al., 1995). Many of these ethnographies of workplace technology were driven by an underlying orientation towards sociological phenomenology such as symbolic interactionism, conversation analysis and ethnomethodology (e.g., see Szymanski & Whalen (2011)). In contrast with cognitivist accounts, which derive from a Cartesian perspective of mind-body dualism, the phenomenological perspective gives primacy to ‘subjective’ experience; in phenomenological sociology this matter is transformed into investigation of ‘intersubjectivity’, that is, developing theoretical and empirical understandings of how seemingly incommensurable ‘subjective’ individual experiences are *negotiated* such that individuals may engage in concerted social actions (such as, in Heath et al.’s (1995) case, organising market trades in a dealing room).

Drawing upon this philosophical background, these allied approaches have thus formed part[2] of the reorientation in HCI towards considering the phenomenology of interaction, i.e., the nature of 'user experience' (rather than, say, the 'information processing' capacities of the user). In terms of their contribution to understanding how interactive technologies are experienced in the 'lifeworlds' of users, this body of (mostly) ethnographic work has unpacked the ways in which interaction with and around technologies are fundamentally *socially organised* phenomenon. That is, they detail just how meaning is actively produced, achieved, maintained and repaired by participants in those interactions. This stands in contrast with a traditional cognitive view that would ascribe meaning in terms of input / output to / of an individual's cognitive workings. For instance, Heath et al. (1995) explore how careful verbal and bodily (e.g., gestural) conduct is employed to sensitively produce moments of collaboration in order to make coordinated decisions regarding bidding for stocks within the trading room. In this way the meaning of a given trade does not reside in an individual's mental representation, but is *produced* through a social orientation to ongoing collaborative action.

3 Directions for developing HCI in human computation

Now that the broad outline of the cognitive and social turns in HCI have been discussed, this section explores in more detail how cognitivist ideas have found a natural home in some conceptualisations of human computation systems. As part of this, the following also unpacks what the implications of HCI's 'social turn' might be for human computation.

3.1 Cognitive alignments between HCI and human computation

There is a strong similarity between a cognitive conception of the human in HCI and the standard human computation role of humans. Firstly we begin with the term itself,

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[2] Obviously there are other influences on HCI which have shaped the ascendancy of 'user experience' as a core concern, however these are beyond the scope of this chapter.

i.e., ‘human computation’: it is here that the computation model being applied to human action is initially ascribed. In this sense the term itself configures the field with certain assumptions about the nature of this human action, i.e., that it is readily characterisable in terms of computation. Secondly, the explicit ways in which human elements are described in the literature confirms this view. For instance, humans have been characterised as serving as information processors, or computational nodes (e.g., as before, von Ahn & Dabbish (2008)), as well as definitional forms of “human computation algorithms” being derived from Donald Knuth’s computational ones (Law & von Ahn, 2011). Building upon this perspective, there has been a focus within human computation on game theoretic accounts of human agency, such as in the design of questions or in order to incentivise / motivate users (e.g., (Jain & Parkes, 2009; Law & von Ahn, 2011, p61)). Traditional game theory models rely upon a computational view of human agency (e.g., that human agency involves rational calculation of outcomes), and a transcendent understanding of rational action. This is as opposed to a situated, local view of rational action in which order and meaning is locally produced (Suchman, 1987).

It is no coincidence that the cognitivist approach emerged across a range of disciplines (e.g., psychology, linguistics, computer science, neuroscience, etc.) in parallel with the development of digital computing during the 1950s: the computer was seen as providing a suitable and appropriate metaphor for developing understandings of the human. The broad appeal of this metaphor cannot be underestimated; computational metaphors have been a driving force in the development of theoretical models across a range of disciplines including biology, linguistics, anthropology, physics and art (Cantwell Smith, 2010). Yet metaphors can sometimes prove problematic, in that they may distort the nature of phenomena as well as directing focus away from that nature in favour of the simplifications afforded by the metaphor.

3.2 What HCI’s social turn means for human computation

With the ‘social turn’ in HCI, critiques of this cognitive, computational metaphor view have flourished. A key text here is Suchman’s influential work that argues against a cognitivist, plan-based model of human action, instead transforming the rational plan into a resource which may be drawn upon in the situated, moment-by-moment mundane actions of humans who are ongoingly achieving the construction of social order (Suchman, 1987). While in Suchman's case the analysis was of experts using photocopiers to perform basic tasks, for human computation, this radically changes how we conceive of the 'node' in human computation systems: instead of 'information processors' manipulating data orchestrated by digital computer management we must see humans in these systems as accomplishing social order: developing intersubjective or shared understandings in and through organising their physical and verbal actions moment-by-moment, designing and crafting those interactions so as to be intelligible and meaningful to others, and engaging in ad-hoc but coherent and concerted social actions with one another. In this view the cognitive notions of goals and plans are the construction of the academic imposed onto innate social order rather than an underlying, transcendent theory of human action. Similarly, the utility of analogies between algorithms and "human computation algorithms", considering time complexity, efficiency and correctness (Law & von Ahn, 2011), can potentially obscure considerable design differences (Reeves & Sherwood, 2010).

Some work in human computation has begun dismantling the conception of humans as processing 'nodes' in computation networks by studying the situated ways in which meaning is produced through interactions between users engaging in human computation tasks. For instance, in 'Eyespy', we developed a mobile human computation game in order to produce sets of photos which were useable for navigation tasks as a byproduct of that play (Bell et al., 2008). Like the ESP Game, we relied upon human competencies in order to construct a high quality data set (in our case, of 'good' navigational images, as opposed to 'good' textual tags for images). Players of the game gained points for creating photo tags of landmarks which other players subsequently attempted to locate and visually confirm (based on GPS proximity), in turn gaining points themselves. Successful players oriented their in-game actions towards designing photographs that leveraged local knowledge (of 'good' landmarks), 'findability' and how recognisable they were. These human competencies relied upon commonsense knowledge, i.e., 'what anyone knows' about a given geographic area, and what would constitute a 'good photo' for other players (see von Ahn et al. (2006) for an attempt to collect a generalised set of such commonsense knowledge). It is precisely this notion of how players oriented towards each other, produced their content in ways that were crafted as appropriate to the framing of the game and the imagined recipients of their photos. In short, players' actions are not algorithmic but *interpretive* and *socially organised* within the human computation system, contradicting characterisations of computational nodes or cognitive information processors in which interpretation and social action is part of internal mental processes rather than an accomplished negotiation between humans.

3.3 Human computation system design

This view of human computation developed as part of studies within HCI has three key messages for designers to consider when constructing the next interactive human computation system (Reeves & Sherwood, 2010). They impact two (of five) foundational questions of human computation suggested by Law and von Ahn (2011): firstly, how to guarantee solutions are accurate, efficient and economical; and secondly, how to motivate human components in their participation, expertises and interests.

1. The broadest point is the importance of user experience. HCI's lessons, via a focus on user experience and its 'turn to the social' mean that *the human perspective should be considered a foundational issue* to inform the design and construction of interactive human computation systems. Echoing Quinn & Bederson (2011), once again, this means human issues need to be considered as the initial step rather than something to evaluate post-hoc (e.g., "issues related to ethics and labor standards", also see Irani & Silberman (2013)).
2. *Meaning is situated and locally produced*. This does not mean that human computation systems cannot produce generalised results or reusable products, however it does mean that such things are not readily analogous with machine-based algorithms or necessarily aligned with cognitive descriptions of human agency. Instead, when we consider how (for instance) image tags are designed in the ESP Game, we should view this as the coordinated production of meaning between players rather than input and output transactions.
3. How the human computation system is approached and experienced by its human participants *fundamentally frames their interaction with it*. Therefore the products

of those actions cannot be separated from the social and situated circumstances in which it was produced (see above). This matter of framing is a key design feature, for instance, the way a task delegated to users is introduced and the relationship that is configured between them and designers shapes the way in which that task is carried out (Brown, Reeves & Sherwood, 2009). In other words, human computation tasks do not get performed in isolation. Instead, the seemingly secondary features of interface and task design (e.g., tutorials, what type of task it is communicated as, such as for money (e.g., Mechanical Turk) or scientific progress (e.g., Galaxy Zoo)) can radically change how the human components of computation systems act.

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