2 Approaching Human Computation-Based Citizen Science Analytically

To the best of my knowledge, HC-based CS has not yet been thoroughly analyzed from a cultural or digital anthropological perspective. A few prior investigations were undertaken, such as in the field of crowdworking (Gray and Suri 2019), the interplay of AI technologies and humans in CS (e.g., Ponti et al. 2021; Ponti and Seredko 2022), and the example of Foldit (Curtis 2015; Ponti et al. 2018). Nevertheless, my research builds on existing literature on related fields, such as crowdworking and CS in general, the relationships between play, work, and science in the digital age, and analyses of infrastructures, sociotechnical systems, and human–technology relations (with a focus on digital technologies), especially in the broader field of AI.[1] I mostly draw on research in cultural and digital anthropology, media anthropology, anthropology of technology, and STS. In the first part of this chapter, I give an overview of related work without claiming, or aiming for, completeness. Instead, I present and discuss selected work that is of particular interest to my research endeavor and helps to situate my research in both related fields and existing studies. For my analysis, I refer to and draw on theoretical concepts from the scientific fields mentioned above, in addition to philosophy of ethics and technology and moral anthropological theory. The theoretical concepts that form the overarching foundation upon which this work is built are assemblage theory, human–technology relations, sociotechnical imaginaries, ethical projects, and the care for our hybrid modes of being. In the second part of this chapter, I discuss these concepts in detail, followed by the introduction of the concept of intraversions. I apply this concept to analyze how human–technology relations unfold and continuously develop in HC-based CS.

1 The related work discussed here refers to research on topics and fields that are of overarching importance for my own research. Where necessary throughout this work, I discuss additional literature on subtopics, such as research on trust in Chapter 7.

Crowdsourcing and Crowdworking

According to anthropologist Mary Gray and computer scientist Siddarth Suri, who describe HC as "people working in concert with AIs" (2019, x), "[t]his fusion of code and human smarts is growing fast" (2019, x). Gray and Suri refer here to the context of crowdworking. While I focus on CS as another application of HC in my research, HC generally intersects with phenomena such as crowdworking and crowdsourcing.[2] Most cultural anthropological and related investigations that directly or indirectly address HC are concerned specifically with the latter. I would like to briefly discuss crowdsourcing and crowdworking and selected work in these fields due to the overlap of practices observed in HC-based CS and the concurrency of the phenomena in neoliberal economies and "ludic capitalism" (Dippel 2018, 125).[3]

Tasks in crowdsourcing are outsourced from "traditional human workers" to "members of the public" and do not always rely on humans taking over computational tasks (Quinn and Bederson 2011, 1405). In contrast to crowdsourcing, Quinn and Bederson argue that "human computation replaces computers with humans" (2011, 1405). While HC-based crowdsourcing applications such as reCAPTCHA can be considered a form of "unpaid labor practices" (Scholz 2013, 2), in crowdworking, understood as a form of crowdsourcing, people are paid for their contribution to HC systems. Media and communication scholar Ayhan Aytes argues in his analysis of the crowdworking platform Amazon Mechanical Turk that "[c]rowdsourcing is a hybrid concept that merges the neoliberal outsourcing paradigm with the crowds on the digital networks" (2012, 88). The development of crowdworking is closely linked to the rise of digital platforms (Srnicek 2017). As a "neoliberal reincarnation of the chess-playing automaton" (Aytes 2012, 81) of Wolfgang von Kempelen's eighteenth century "Mechanical Turk," the crowdworking platform's algorithms produce and discipline the workers "into a particular cognitive mode and problem solving that eventually determines the efficiency of their labor and thus their livelihood" (Aytes 2012, 94). In most crowdworking applications involving HC (such as Amazon Mechanical Turk), people perform so-called "microtasks"—including, for example, the categorization of products—that are largely standardized and automated (Felstiner 2011, 150). The repetitive and often only poorly remunerated tasks resemble Taylorist forms of work, which is why cultural studies and political science scholar Moritz Altenried describes crowdworking as "digital Taylorism" in his work on digital factories and their human labor (2020; 2022).

Sociologists Frank Kleemann, Günter G. Voß, and Kerstin Rieder analyzed crowdsourcing and the phenomenon of the "working consumer" (2008) from a theoretical perspective, and sociologist Elisabeth Vogl (2018) has studied organizational models of work

2 On the term crowdsourcing, see Howe (2006). For a broader understanding, see Felstiner (2011, 145) and Vogl (2018, 8). The term HC is sometimes even synonymous with crowdsourcing or crowdworking. The only annual conference specifically focusing on HC is the *AAAI Conference on Human Computation and Crowdsourcing* (HCOMP), and combines HC and crowdsourcing (Association for the Advancement of Artificial Intelligence n.d.).

3 I translated the direct quotes from non-English literature and sources.

on three different crowdsourcing platforms, the latter's impact on society, and the reorganization of work. Political scientist Doris Allhutter (2019) also discusses the important role of human microwork for building the foundations of a semantic infrastructure and related power structures based on ethnographic research on the infrastructuring practices for creating commonsense ontologies in the field of semantic computing. Crowdworking can also go beyond so-called microtasks and include a wide variety of practices, such as design or programming. Anna Oechslen (2020), who argues for a differentiation of crowdworking forms, analyzes crowdworking practices of (graphic) designers from a cultural anthropological perspective. In contrast to microtasks, the designers' practices include designing logos, for example, which can be described as "macro tasks."[4] Platforms often include elements of gamification (Detering et al. 2011; Rackwitz 2015), i.e., game design elements that are introduced into nongame contexts (Detering et al. 2011), to make crowdworking more attractive. One of the first and a remarkable contribution to the analysis of crowdworking was provided by Gray and Suri in *Ghost Work: How to Stop Silicon Valley from Building a New Global Underclass* (2019), in which they investigate the workers behind crowdworking platforms, what drives them to this kind of work, how they creatively try to earn a living with, and, ultimately, what this kind of work means to them (2019, xxvii). At the same time, the study analyzes the business models of such platforms and how ghost work is organized (Gray and Suri 2019, xxvii). Gray and Suri apply the term "ghost work" to show how the work conditions and work performed by humans to drive and enable AI are made invisible by the platforms. Their APIs reduce ghost workers to "a string of letters and numbers instead of a name and a face" (Gray and Suri 2019, 34).

Analyzing how humans are included in such sociotechnical and HC-based work or game platforms, such as the example of CS games, will probably only gain importance in the coming years. A total of 25 million "ghost work" opportunities existed by 2019 and Gray and Suri anticipate this number to increase further (2019, 169). The COVID-19 pandemic probably acted as an additional catalyst for such digital working practices. The field of HC-based CS, and especially projects that focused on research on the coronavirus, saw an increase in participation over the course of the pandemic (Vepřek 2020). Gray and Suri argue that the question to be addressed concerning the increase of crowdworking or ghost work opportunities should be: "If we imagine AI and humans augmenting and supplementing each other, the next issue is not whether humans are necessary. The real question will be: When are they in demand, and for what purpose?" (2019, 192). I aim to contribute with this research to addressing this question regarding HC systems in the field of CS. Unlike crowdworking, however, where human labor is usually exploited for financial compensation, participants in CS are included in scientific knowledge production.

4 On related work on crowdworking in general, see, for example, contributions in Altenried, Dück, and Wallis (2021) and on macro tasks specifically, see Oechslen (2020).

Citizen Science (Games) and the Entanglements of Play, Work, and Science

While crowdworkers are financially compensated for their contribution to AI, HC-based CS systems rely on the voluntary contribution of participants, raising issues such as acknowledgments and forms of engagement, and complex negotiations involving not only designers and developers of such systems but also participants and scientists. Computer scientists and ARTigo creators François Bry and colleagues understand CS as a subfield of HC (Bry, Schefels, and Wieser 2018, 1). The goal of the development of HC-based CS is often finding a solution to a specific scientific problem which cannot be solved with today's computational technologies. While these problems are not always defined as AI problems by the designers, they, nevertheless, are at the edge of AI research and contribute to the advancement of AI in general. Because HC-based CS projects rely on voluntary engagement, they need to be carefully designed and be engaging, entertaining, and rewarding to attract and retain participants.

However, CS generally goes beyond HC, and, according to philosopher of science and cultural ecologist Peter Finke, describes science beyond science (2014, 14), questioning the understanding of science as an expert phenomenon and creating new forms of scientific collaboration. Citizen science generally refers to actively involving members of the public in various scientific research activities (Vohland et al. 2021, 1) which can happen across all stages of the scientific process.[5] CS projects can, for example, take "bottom-up" or "top-down" approaches. While, in the first case, projects are launched by "citizen scientists" themselves or at least built upon the co-construction of research agendas (Hecker et al. 2018, 234), in the latter case, professional scientists invite participants to their research projects. In most cases, volunteer participants contribute to data collection and analysis (Land-Zandstra, Agnello, and Gültekin 2021, 244). The CS projects often arise from professional scientists needing more computing power or human assistance in data analysis steps or data collection (Vepřek 2022b, 31). The goal is to speed up the research progress by out- and crowdsourcing a time-consuming and laborious task that cannot be solved computationally, as in the case of Stall Catchers. In other examples, such as Foldit and ARTigo, CS is based on the assumption that new scientific knowledge can be obtained through novel approaches to scientific problems due the creativity of nonprofessionally trained scientists, their potential for "out of the box thinking," and "wisdom based on life experiences of great crowds" (Görsdorf 2007, 8).

There is a rich body of literature on CS, ranging from the field of ecology (e.g., Irwin 1995; or, as recent publications, Lepczyk, Boyle, and Vargo 2020; Fraisl et al. 2022) and astronomy (e.g., Westphal et al. 2005; Marshall, Lintott, and Fletcher 2015; Lintott 2019), to the history of science and STS research (e.g., Kimura and Kinchy 2016; Burri 2018; Strasser et al. 2018), analyzing, *inter alia*, the motivations of CS participants (e.g., Geoghegan et al. 2016; Land-Zandstra et al. 2016; Larson et al. 2020) and CS games (e.g., Curtis 2015;

5 The term CS, as we know it today, emerged at the end of the twentieth century, and has seen a huge upswing with the spread of the Internet. Nevertheless, it can be considered a phenomenon that has been practiced for several centuries (*cf.* Finke 2014; Hecker et al. 2018). The role of "lay persons" for and even before the constitution of the German-speaking cultural anthropology *Volkskunde* is discussed in Cantauw et al. (2017).

Tinati et al. 2016; 2017). I will discuss participants' motivations as identified in the literature and how these findings align with my empirical observations in Chapter 5. Citizen science has become a subject of cross-national associations, such as the European Citizen Science Association (ECSA) (Verein der Europäischen Bürgerwissenschaften – ECSA e.V, n.d.) or the Association for Advancing Participatory Sciences (Association for Advancing Participatory Sciences, n.d.). As much as it is of interest to scholarly research, there is debate and discussion around issues such as meaningful engagement of participants and power hierarchies and their reproduction (e.g., Cooper, Rasmussen, and Jones 2021),[6] the role of neoliberalization (Kimura and Kinchy 2016), ethical issues in CS, and the need for ethical frameworks (e.g., Resnik, Elliott, and Miller 2015; Rasmussen and Cooper 2019; Cooper, Rasmussen, and Jones 2021; Vohland et al. 2021). However, there still seems to be a gap of research around the question of how CS impacts professional science in concrete ways (*cf.* Wynn 2017). James Wynn (2017) addresses this gap through the lens of rhetoric, focusing on the results of CS projects, on the one hand, and on the interactions between nonprofessional and professional scientists and policymakers, on the other. In my research, I address this gap by focusing on how HC-based CS games create scientific data through human–technology relations with the examples of Stall Catchers, Foldit, and ARTigo, and discuss how the introduction of CS influences and changes the working practices of biomedical researchers in the case of Stall Catchers.

Not only have possibilities to participate in research multiplied with the Internet, but digital technologies, software, and code have also entered the domain of CS, creating new modalities for scientific knowledge production and new human–technology relations. An example is the emergence of "voluntary distributed computing" (VDC), which describes CS in which volunteer participants lend the computational power of their computers to scientific research (Holohan 2013). In fact, as I discuss in Chapter 6, Foldit emerged from such a VDC project. However, while volunteers in VDC simply let their computers contribute to help solve a scientific problem (such as the search for prime numbers), in HC-based CS, they actively perform a specific task themselves. Sociologist Anne Holohan's findings on the transformation of the scientific field, the motivations of VDC volunteers, and observations on "altruistic game-playing," nevertheless, form important references for my work (2013, 27, 71–75).

To the best of my knowledge, there is currently not much research focusing on the interplay of AI and humans in HC-based CS. Two of the few exceptions should be mentioned here. The first is the paper by information scientist Marisa Ponti and colleagues (2021) summarizing the discussion panel "Citizen Scientists Interacting with Algorithms: The Good and the Bad," that was organized by the authors at the *3rd ECSA Conference* in 2020. The aim of this panel was to discuss the collaboration of CS participants with ML algorithms. Using the HC-based CS project and platform Zooniverse as an example, the paper argues that the human–machine combinations can increase the efficiency of data classification.[7] Yet, it also discusses open issues that need to be considered in human–AI collaborations in CS, such as transparency and data ownership

6 On CS as "controversial space," see Jung (2015) and Starzmann (2015).

7 Previous research by AI researcher David Watson and philosopher Luciano Floridi has used the same example of Zooniverse to demonstrate how knowledge on the CS platform is produced in

(Ponti et al. 2021). The second work is Ponti and Alena Seredko's literature review on task distribution between AI technologies and humans in CS (2022). With the aim to close the research gap existing in this field, the authors emphasize that the tasks or "cognitive work," as they call it, "between humans and computational technologies will be shifting, challenging the ontological boundaries between them" (Ponti and Seredko 2022, 11). Therefore, they argue that it is important not to "essentialize the qualities of humans and machines, both of which are constantly evolving, and whose lists of what each is 'good at' (whether relative or absolute) are constantly changing" (Ponti and Seredko 2022, 11). My study aims at contributing to this line of thought by presenting an analysis of how the relations, including the task distribution, between humans and (AI) technologies continuously change in HC-based CS projects.

Projects in the field of HC-based CS are often designed as GWAPs,[8] computer games which, in addition to their core purpose as a game, have the purpose of solving a particular (scientific) problem. The HC-based CS games are also described as "dualpurpose Human Computation systems" (Bogner et al. 2017) and (often) rely on the assumption that people spend much time and energy playing (computer) games, which can be directed incidentally to solving computational or scientific problems as well as training AI algorithms (Von Ahn and Dabbish 2008, 60).[9] Citizen science games have been the subject of different studies, such as interdisciplinary ones in the field of human–computer interaction (HCI; e.g., Iacovides et al. 2013; Tinati et al. 2016; 2017; Díaz et al. 2020), which focus mainly on the participants' perspectives and their motivations. From the examples I study in my research, Foldit has been analyzed regarding, for example, participant motivation (Curtis 2015) or how participants engage with automated scripts (so-called "recipes") in the game and develop a "professional vision" by playing Foldit (Ponti et al. 2018). CS games were also studied by Dippel and Fizek (Fizek 2016; Dippel 2017; Dippel and Fizek 2017a; 2019).

Dippel's investigations of the relations between science and play and CS games as part of the ludic or playful aspects of knowledge production form an informative starting point for my analysis. Based on her ethnographic research in high-energy physics at the European Organization for Nuclear Research (CERN), Dippel analyzes different dimensions of playful aspects of knowledge production in her article "The Big Data game"

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the sociotechnical interplay between human actors and technological components (Watson and Floridi 2018).

8 GWAPs and CS games are sometimes also referred to as "serious games," which are broadly defined as games that are designed "to be more than entertainment" (Ritterfeld, Cody, and Vorderer 2009a, 6), most often with a focus on education (*cf.* Abt 1987; Ritterfeld, Cody, and Vorderer 2009b; Dörner et al. 2016; Söbke et al. 2022). I refer to this term in the following because GWAPs focus more specifically on HC-based projects.

9 Participation in GWAPs might be considered a form of "free labor" (Terranova 2000; 2012), which, according to digital media cultures theorist Tiziana Terranova, is important for the constitution of the Internet and digital economy. However, I focus in my research on how participants perceive and describe their contribution to HC-based SC projects (see Chapter 5). It should, nevertheless, be noted that even if the games studied in my research are developed by nonprofit research institutes and collaborations, they are, nonetheless, influenced by the logic and the "agonal principle of free-market competition [which] has now gained a perfect system of rules" (Dippel 2018, 125).

(2017). Dippel writes that everyone wins in CS games (2017, 511), which are part of the third dimension:

> [W]hile the individual motivation of players participating in *Citizen Science* is characterized by idealistic traits and the desire to participate in a game that has another goal outside of itself, the experts in the *challenges* and the cernies themselves benefit from Big Data because the game in this case brings about a concrete improvement in artificial intelligences. [...] And last but not least, research on general artificial intelligence benefits from this deal in the long run. (Dippel 2017, 511, emphasis in the original [i.o.])

Together with Fizek, Dippel explores CS games as "laborious playgrounds" producing new forms of work-play relations (Dippel and Fizek 2019) and "playbouring cyborgs" (Dippel and Fizek 2017b) that consist of humans and algorithms. They use the term "ludification of culture" to describe "a societal phenomenon that points to an ever-increasing importance of games in everyday life. The concept goes far beyond the use of specific game mechanics that are used to control people's behavior" (Dippel and Fizek 2017a, 368).

Along the same lines, Dippel and Fizek introduce the term "interferences" (Dippel and Fizek 2017a, 377) to describe the mutual overlaps between the different spheres of everyday life. I adopt their term in my research to study how HC-based CS assemblages are formed between science and play and how human–technology relations, or "playbouring cyborgs" evolve and change continuously. Ideas and concepts from play theory that discuss the ambiguity of play (Sutton-Smith 2001; 2008) and how play is permeated with seriousness (Turner 1995) also inform my analysis, which will be discussed in Chapter 5 (Dippel and Fizek 2017a; 2019; Abend et al. 2020; Dippel 2020).[10] Studies from the extensive body of cultural and digital anthropological and cultural and media studies research on games focus on the actors behind games and situate them in broader power and regulatory structures (e.g., Malaby 2012; Cassar 2013).

Other relevant research examines the developer side of software, and particularly of computer games, focusing on their (working) practices and everyday lifeworlds (e.g., Coleman 2013; O'Donnell 2014; Amrute 2016; Bachmann 2018; Plontke 2018; Tischberger 2020). In his research on the Dynamic Medium Group, a San Francisco Bay Area-based research collective, European ethnologist Götz Bachmann investigates the work of engineers on a new digital medium (2018). He shows the importance of including the imaginations of engineers who guide the development of new digital media systems—or, as in my research, HC systems— in order to understand systems in their ongoing emergence and interaction with people and the environment (Bachmann 2018). Social psychologist

10 *Cf.* McGonigal (2012) on the entanglements of work and play. Cultural historian Johan Huizinga's *Homo Ludens* ([1938] 2016) continues to form influential theories of play. In the fields of media and cultural studies as well as philosophy, Valerie Frissen et al. (2015) update Huizinga's theory to apply to digital technologies, which Huizinga had still understood as opposites of play. Emotional practices in (video) games have been studied by cultural and digital anthropologist Christoph Bareither (2020b). On theoretical concepts of play in general see, *inter alia*, Adamowsky (2018), for anthropological approaches to play in general see, e.g., Malaby (2009) and Dippel (2020).

and social anthropologist Sandra Plontke examines design methods and programming practices in game development from the perspective of STS and ANT, focusing on the representation of the player in the code (2018). I begin my analysis of HC-based CS from the perspective of developers and designers of HC-based CS, which has, so far, received less attention in CS literature (Miller et al. 2023). I do this to understand their aims, their imaginations of desirable futures, and of the humans in the loop, and how they materialize these in their everyday development, maintenance, and infrastructuring practices. The humans in the loop imagined in HC-based CS refer to the users or participants.

Studies in STS have focused on how users are imagined and represented in technology and how they, at the same time, shape technology (e.g., Woolgar 1991; Akrich 1995; Grint and Woolgar 1997). The edited volume *How Users Matter* (Oudshoorn and Pinch 2005) discusses how users and technologies are co-constructed and, thus, points to the active role of users in the formation of technology. Emphasizing these forms of co-construction, Malaby suggests defining games as processes: "Games can change as they are played, and this passage points to how this can be done intentionally […]. But games can also change through the unintended consequences of practice, such as when talented individuals or teams find new ways to play the game" (Malaby 2007, 102). How users appropriate games in situated practice in their own ways has also been explored by Internet studies scholar Michele Willson and cultural anthropologist Katharina Kinder-Kurlanda using the concept of "tactics" developed by theologian, historian, cultural theorist, and psychoanalyst Michel de Certeau ([1980] 2013). While Willson and Kinder-Kurlanda focus on tactics that users employ to make themselves less visible to the game platform, I use de Certeau's concept of tactics to analyze participant–technology practices that go beyond the play practices intended by design and enhance, adapt, or work against the game mechanisms. Games, and HC-based CS games in particular in my research, are, thus, "grounded in (and constituted by) human practice and are therefore always in the process of becoming" (Malaby 2007, 103). Therefore, I also include the perspective of participants who play a fundamental role in the everyday becoming of HC-based CS assemblages by bringing their own motivations and creative practices to the projects which do not always align with the developers and researchers' aims. I will return to this perspective when discussing European ethnologist Stefan Beck's relational concept of technology below.

Sociotechnical Systems and the Study of Algorithms, Computer Code, and Artificial Intelligence

While crowdworking, CS, games, or play/work interferences constitute research fields related to HC-based CS, research on sociotechnical systems, algorithms, and AI in general provide helpful insights that I build upon to study sociotechnical HC-based CS assemblages and their human–technology relations.[11]

11 Due to the rapid technological developments in AI and its increasing use in various areas of everyday life, which have attracted increased attention in the humanities and social sciences in re-

In cultural anthropological discourse, digital anthropology has emerged as a new field of research since the 1990s (Fleischhack 2019, 197).[12] Today, it describes an interdisciplinary field that focuses particularly on human–technology relations (Bareither 2022, 29). While different foci can be observed in the research agendas of individual contributing disciplines, the boundaries are blurry, and I concentrate here on research that centers on sociotechnical systems and human–technology relations in everyday life. In German cultural and European anthropology, technology is conceived as a "cross-cutting phenomenon" (Schönberger 2007)[13] and has been analyzed in terms of "culture(s) of technology and the technology(ies) of culture(s)" (Hengartner 2012, 119). Human experience, practice, and constructions of meaning are understood as technologically shaped and mediated (Hengartner 2012, 119). Beck's "complex situational analysis" (1997) of technology in practice is fundamental to my research, specifically from an analytical perspective and its methodological consequences. Beck emphasizes that human experience and practice is not only formed by technology, but vice versa, the social must be situated in technological arrangements and considered a fundamental part of them (2019, 12).

The anthropology of futures and emerging technologies is another productive research area that focuses on how anthropologists can study, engage with, and critically intervene in future-making practices in the field of emerging technologies (e.g., Salazar et al. 2017; Pink 2022; 2023; Lanzeni et al. 2023).

In this section I aim to discuss selected work from the field of digital anthropology, but also from sociology, STS, and related fields. My research here takes particular inspiration from early studies on human–computer relations and the field of AI, of which I would like to discuss five studies in particular.

Sociologist and STS scholar Sherry Turkle conducted a long-term ethnographic study in the late 1970s and 1980s on the computer as an "evocative object for thinking about human identity" (2005b, 3) when computers were mainly regarded as tools, the World Wide Web was not yet born, and mobile computational devices, such as smartphones and smart watches, were far away. In her groundbreaking research, Turkle analyzes how the computer influences human thinking and human nature itself. Her focus on early AI research as one example of computer culture is of particular interest for my research. Turkle aptly shows AI theorists' attempts to create a new philosophy in times when the aim of building AI with superhuman power is still out of reach (Turkle 2005a, 244). What these AI theorists share, Turkle argues, is "an emphasis on a new way of knowing. The new way of knowing asks that you think about everything, especially all aspects of the mind, in computational terms, in terms of program and information processing" (2005a, 225). Understanding this new way of thinking is crucial for Turkle because it shapes how AI theorists think about themselves and human life in general (2005a, 231–232). Turkle's

cent years, the following considerations are sure to be incomplete and refer mainly to selected research that has been published up to March 2023.

12 Cultural anthropologist Julia Fleischhack (2019) summarizes the main positions, methodological approaches, questions, and foci in these discussions. On digital anthropology in general, see, e.g., Boyd (2009); Boellstorff et al. (2012); Horst and Miller (2012); Koch (2015; 2017a); Pink et al. (2016).

13 Cultural and media anthropologist Manfred Faßler had already described information technology as "cross-cutting technology" in 1997 and an evolutionary project in his publication "media interaction" on human–computer interaction (1996, 17).

early analysis of the development of the field of AI is helpful for understanding how HC distances itself from other AI endeavors and is, at the same time, situated in these historical developments.

Furthermore, Suchman's work is instructive in understanding how HC-based CS systems are never fully defined by the designers' imaginations, but are instead *situated* in everyday practice. Around the same time as Turkle's publication of *The Second Self*, Suchman investigated human–machine interactions at Xerox Palo Alto Research Center (PARC) (Suchman 2007b). Suchman's research not only transformed the understanding of HCI in the field of computer science but is also still highly informative today for social and cultural analyses. One of the core contributions of her research is the elaboration of an understanding of "situated actions" that determine human–machine interaction. Against the technical understanding of plans as algorithmic specifications determining action that she observed in her fieldwork, Suchman argues that "given the contingencies of any actual occasion of action, every plan presupposes capacities of cognition and (inter)action that are not, and cannot ever be, fully specified" (2007b, 78). In the expanded 2007 edition, Suchmann, similar to Barad, understands plans as "socialmaterial be-ins" (Barad 1996, 188) that challenge the understanding of autonomously interacting actors and entities.

In reflecting on my own role in the field of HC as an anthropologist (see Chapter 3), Forsythe's extensive and pioneering research on medical informatics and AI is particularly helpful. Forsythe conducted ethnographic fieldwork at different knowledge-based system laboratories in academia and industry in the US in the 1980s and 1990s. Her research, which focuses on software design, presents fascinating insights into AI research culture, one of her central themes being an "attempt to unpack intelligent systems conceptually, from a cultural and disciplinary standpoint" (Forsythe [1996] 2001e, 94). Forsythe showed, for example, how assumptions of AI researchers were inscribed in *intelligent* computational systems that are always "cultural objects as well as technical ones" ([1996] 2001e, 94) and what role users, in her case patients, play.

Like Forsythe, sociologist and STS scholar Susan Leigh Star was one of the first STS scholars to actively engage in the field of AI. Star's work spans various topics, such as infrastructure (see below), classification and standardization of ideas, grounded theory, and distributed AI (Star 2008).[14] Based on the observation that AI relies on social and natural metaphors to fill the void between what computers can currently do and what advanced computer science systems are capable of, and to serve as attempts to make AI intelligible (Star [1988] 2015, 244), Star "argues that the development of distributed artificial intelligence should be based on a social metaphor rather than a psychological one" ([1988] 2015, 243). She suggests using the concept of "boundary objects" (Star and Griesemer 1989; Star 2008; Bowker et al. 2015) as a data structure for the field of distributed AI: "Boundary objects are objects which are both plastic enough to adapt to local needs and

14 Distributed AI is a research subarea of AI. In a nutshell, it is concerned with the development of AI systems that build upon different forms of concurrency, such as parallel computer architecture or multi-agent systems. It can be considered a predecessor of multi-agent systems (Bond and Gasser 1988, 3).

the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer 1989, 393). Ultimately, she argues:

> The more seriously one takes the ecological unit of analysis in such studies, the more central human problem-solving organization becomes to design—not simply at the traditional level of human-computer interface, but at the level of understanding the limits and possibilities of a form of artificial intelligence. (Star 1989; cited in 2015, 249–250)

Consequently, in order to understand human–technology relations and how they form HC-based CS systems, it is necessary to analyze them from multiple perspectives and viewpoints, including the material infrastructures supporting them.

Finally, in the context of early research in German-speaking cultural anthropology, Gertraud Koch's groundbreaking work on the technological processes of becoming of AI (2005) is to be mentioned. Koch investigates practices, policies, and knowledge cultures contributing to the cultural production of technology with the aim of exploring the link between culture and technology. Based on written scientific sources and qualitative interviews, and following Pfaffenberger's concept of the "technological drama" (1992), Koch analyzes the (mainly) German-speaking AI discourse of the late 1970s until 1990s that accompanied the emergence of AI as technology in Germany. She shows how different AI advocates positioned themselves and performed "boundary work" (Gieryn 1983) to legitimize their viewpoints on AI, which is helpful for my analysis of the boundary work performed by HC advocates.

Together, the examples of early ethnographic research on HCI and AI discussed form a fruitful starting point for my research to understand how HC is imagined as being a counter-imaginary to AGI, while, at the same time, sharing common understandings, and how HC-based CS systems are situated in the everyday practice of various actors and human–technology relations. I aim to contribute to this rich ethnographic knowledge by studying a subfield of AI research that has, so far, not been extensively analyzed by ethnographers. My study, furthermore, aims to provide a contribution that shows how HC as a specific branch of research emerged from the fields studied by Turkle, Forsythe, and others, and how the AI research culture has, thus, changed since the research presented.

My research also takes into account previous work that focuses on computer code and algorithms,[15] particularly in the field of AI. I follow the understandings established in cultural anthropological and STS research that algorithms are part of sociocultural networks or entanglements (e.g., Haraway 1991; Mathar 2012, 178) and, thus, on the one hand, have agency (e.g., Kunzelmann 2015; Amelang and Bauer 2019), and, on the other hand, have meanings, values, norms, and (in)equalities inscribed in them. "[A]lgorithm

15 Algorithms are formalized instructions for solving a specific problem that can be expressed differently, for example, as verbal ideas, or implemented using programming languages. When implemented, they can then be executed in computer programs and become part of computer code, which includes all instructions and steps that are machine executable and can, thus, include several (nested) algorithms. On the importance of defining algorithms precisely and as distinct to computer code and programs, see Dourish (2016).

cultures" (Seyfert and Roberge 2017, 18) are always multiple, performative, and never neutral (Plontke 2018). This also corresponds to the understanding that the digital is, in a certain sense, already "coded culture" (Koch 2017a, 11).

Research fields, such as software studies (e.g., Fuller 2008) and critical code studies (CCS; e.g., Marino 2016; 2020), which focus specifically on the analysis of source code have emerged over roughly the last 20 years and provide fundamental insights into the functioning, formative power, and societal meaning of code. Researchers have focused on the agency of code and algorithms, and how they "make the world they work in hang together" (Mackenzie 2005, 13; for selected studies see, e.g., 2006; Kitchin and Dodge 2011; Gillespie 2014; Kitchin 2016; Seaver 2017).[16] In order to understand the agency of algorithms and code and how they operate, they have to be studied in practice, which is where they unfold (Amelang 2017, 359). Cultural anthropologist Katrin Amelang, for example, shows how algorithms are "sensually known and experienced" (2017, 358). She and sociologist Susanne Bauer follow a risk-predicting epidemiological algorithm in its multiple trajectories from development to its validation and use in practice and the infrastructures involved (2019). By adapting the approach of "following the actor" to "following the algorithm," they show how the risk score, predicted by the algorithm, is integrated into accountability practices related to health care and public health (Amelang and Bauer 2019, 495). I take this as inspiration to "follow the data" in Stall Catchers, from *in vivo* microscopic images of mice brains to analyzable video clips in the HC system and beyond (see Chapter 6).

Furthermore, code and algorithms do not simply do things *by themselves* but unfold in dynamic human–machine relations (Lange, Lenglet, and Seyfert 2019) and are embedded in and part of heterogeneous sociomaterial assemblages (Ananny 2017). In fact, code can itself be considered a sociomaterial assemblage (Carlson et al. 2021), though, in this work, I consider it one element of HC-based CS assemblages. Code and algorithms are interwoven with other elements from developers and users (and their practices) to infrastructures, such as servers, APIs, databases, other software libraries, and, ultimately, rely on physical circuits and logic gates that evaluate Boolean functions. Digital media scholar Wendy Hui Kyong Chun argues that "*source code* […] *only becomes source after the fact*" (2008, 307, emphasis i.o.).

Due to their embeddedness in these assemblages, code and algorithms must be analyzed as part of these assemblages in practice (Introna 2016, 20). Furthermore, researcher of technology and ethics Lucas Introna writes, following Barad's (2007b) understanding of intra-relating actions, "[w]hat we see is that the action, the doing, of the code has a *temporal flow*. Every particular 'doing' happening in the present already assumes some *inheritance* from antecedent 'prior-to' actions, and it already anticipates, or *imparts* to, the

16 Algorithms and code, and how they influence, change, and are part of governance, and the exercise of power have been studied in various fields. In addition to the fields already discussed, such as crowdworking and games, research exists on, for example, predictive policing (e.g., Brayne 2017; Egbert 2017; Bennett Moses and Chan 2018; Singelnstein 2018; Egbert and Krasmann 2019), surveillance (Introna and Wood 2002, Introna 2016, Zuboff 2019), and finance (Muniesa 2011), and how they change political protest (Kunzelmann 2021). This list is by no means complete but rather aims at emphasizing the multitude and variety of studies (*cf.* Vepřek et al. 2023).

subsequent 'in-order-to' actions" (Introna 2016, 21, emphasis i.o.). To understand such temporal flows of action (Mousavi Baygi, Introna, and Hultin 2021), I analyze not only the source code of Stall Catchers, or more specifically, the flow of human–code intra-actions in it (see Chapter 3), but also its human–technology relations and both their instantaneous and gradual temporal unfolding (see the section on "Intraversions of Human–Technology Relations" in this chapter). I return to the discussion of code in Chapter 3 when discussing the analysis of computer code in my ethnographic approach.

In this work, I consider AI to be the broad field of research that seeks to build "intelligent" machines. Machine learning, then, is a subset or technique of AI which builds on data to create a decision or prediction model without directly programmed instructions. Deep learning and artificial neural networks, subsequently, are subsets of ML. Other subsets of AI include NLP, computer vision, robotics, and expert systems.

In recent years, more and more research in cultural and digital anthropology, STS, and related fields has discussed and analyzed AI. These include Turkle (2005a), Nilsson (2010), and Engemann and Sudmann (2018), who discuss the historical developments of AI, or media studies researcher Anja Bechman and STS researcher Geoffrey Bowker's analysis of the knowledge production of AI using the framework of classification theory (Bechman and Bowker 2019). Another example is the exploration of the relation between magic and AI by social anthropologist Simon Larsson and cognitive science, psychology and philosophy scholar Martin Viktorelius (2022). Based on the observation that AI advocates use the imagination of AI "as working like magic and glossing over the limitations of technological systems," (Elish and boyd 2018, 74) cultural anthropologist Madeleine Clare Elish and technology and social media scholar danah boyd argue that this hype can lead to poorly constructed models that are understood to be infallible, undermining their power and potential. This also specifically results in "limited space for interrogating how cultural logics get baked into the very practice of machine learning" (Elish and boyd 2018, 74). Therefore, they call for grounding both the rhetoric and practices of AI. History of media, technology, and society scholar Alexander Campolo and media, technology, and AI scholar Kate Crawford use the term "enchanted determinism" to describe how AI discourse is often characterized by references to magic and the inability to create a complete understanding about the generation of results (Campolo and Crawford 2020).[17] In STS research, I would like to highlight the contribution of feminist scholarship, or feminist STS, to the analysis of "sciences of the artificial," as Suchman calls the subfields of science

17 In addition to the literature discussed here, it should be noted that attempts to establish a disciplinary research agenda of AI have also been undertaken in other fields, such as sociology, with a focus on how inequalities are (re)produced by AI technology (Joyce et al. 2021). Furthermore, AI's societal implications are also increasingly becoming the subject of computer and information science literature. To provide one example, the question of how AI affects and changes work has been part of AI discourse from its early days. A recent publication on this topic is the special issue of the *Journal of the Association for Information Science and Technology,* which discusses the "mutual transformations" (Jarrahi et al. 2023, 303) of AI and work and organization. The editors of the special issue argue for the need for practice-focused studies that analyze "the technology at work not in isolation but in conjunction with organizational policies and routines" (Jarrahi et al. 2023, 304).

and technology that include cognitive science, AI, robotics, and related fields in critical adoption of political scientist Herbert Simon (Suchman 2007a).[18]

Sociologist Adrian Mackenzie's "auto-archeological" (2017, xi) study of ML practices and machine learners, which he conceives as referring to both humans and machines, is particularly insightful for this work. Mackenzie aptly describes the diagrammatic practices that form machine learners to show how ML is both a strategy of power and a form of knowledge production (2017, 9). I am particularly interested in his focus on subject positions and the distribution of agency between machines and humans. Drawing on Foucault (1972), Mackenzie asks: "Who is the machine learner subject?" (Mackenzie 2017, 179).

> Oscillating between cognition and infrastructures, between people and machines, neural nets suggest a way of thinking not only about how "long-term knowledge" takes shape today but about subject positions associated with machine learning. As infrastructural reorganization takes place around learning, and around the production of statements by machine learners, both human and nonhuman machine learners are assigned new positions. These positions are sometimes hierarchical and sometimes dispersed. The machine learner subject position is mobile rather than a single localized form of expertise (as we might find in a clinical oncologist, biostatistician, or geologist). Because machine learners vectorize, optimize, probabilize, differentiate, and refer, what counts as agency, skill, action, experience, and learning shifts constantly. (Mackenzie 2017, 186)

Although my focus is more on participant–software and researcher–technology relations in HC-based CS systems and less on programmer-machine relations, Mackenzie's analysis of the "mobile" subject positions and the shifts in, for example, agency and skill, nevertheless, provides rare and valuable points of reference on how subject positions are redistributed and continuously changing in ML processes (2017, 186). Similar to Mackenzie's approach to the machine learner subject, political geographer Louise Amoore, in her book *Cloud Ethics. Algorithms and the Attributes of Ourselves and Others* (2020), defines the "we" of ML as "a composite figure in which humans learn collaboratively with algorithms, and algorithms with other algorithms, so that no meaningful outside to the algorithm, no meaningfully unified locus of control, can be found" (2020, 58). Amoore, therefore, calls for a relational understanding and analysis of the ethicopolitics of ML (e.g., 2020, 7).

Artificial intelligence has also been analyzed from media theoretical perspectives. Andreas Sudmann, for example, whose work is concerned specifically with ML and DL,

18 Among the guiding and common questions driving feminist STS is the "ongoing project of unsettling binary oppositions, through philosophical critique and through historical reconstruction of the practices through which particular divisions emerged as foundational to modern technoscientific definitions of the real" (Suchman 2007a, 140). Even though addressing feminist STS distinctively in the broader field of STS can be important boundary work, I here consider STS to include feminist scholarship. As will become apparent in this chapter and specifically in the second part, where I discuss theoretical conceptualizations, I draw from research and scholars who aim to move beyond dichotomies and binary oppositions.

investigates the role of documentary practices in DL technologies (2015), or media-political dimensions of DL and the company OpenAI's agenda of "democratizing AI" (2018). The volume edited by Christoph Engemann and Andreas Sudmann (2018) provides insights into the development, media, infrastructures, and technologies of AI from the perspective of cultural and media studies and the history of science. However, in these works, HC or HI have received little attention so far.

The development of DL and how it became successful is further studied by Rainer Mühlhoff (2020) from a media-philosophical point of view and social-theoretical critique. He traces the success back not only to the advances in computing power—as is commonly argued—but to "a fundamental structural change in media culture and human–computer interaction (HCI) at societal scale" (Mühlhoff 2020, 1869). He uses the term "Human-Aided AI" to describe a media-cultural dispositive in which different forms of human contributions to DL systems take place and which is based on "socio-economic conditions, technological standards, political discourses, and specific habits, subjectivities and embodiments in the digital world" (Mühlhoff 2020, 1881). Mühlhoff identifies five types of human involvement in hybrid human–AI systems and their corresponding power relations, including gamification as introduced with von Ahn's GWAPs. Together with these forms of human engagement, Mühlhoff argues, comes a shift that leads to a new understanding of intelligence, where human cognitive abilities are integrated into "machine networks" (2020, 1870), changing the role of humans from being simulated by machines and replaced to active embedded cognitive resources. For this understanding of intelligence as relational and distributed across humans and AI, Mühlhoff introduces the term "cybernetic AI" (2020, 1880). His article is an important contribution to the analysis of hybrid human–AI systems from a philosophical and social scientific perspective. While the forms of human participation in AI described by Mühlhoff are helpful for identifying human–AI relations in concrete examples, my research focuses on *how* these relations unfold. The analysis will show that, even though the human–AI (power) relations are indeed initially defined by the creators of such systems, they are, nevertheless, distributed across different actors, who also shape the relations according to their own needs.

In the interdisciplinary volume *The Democratization of Artificial Intelligence. Net Politics in the Era of Learning Algorithms* (Sudmann 2019a),[19] Dippel's contribution *Metaphors We Live By* is especially noteworthy. Building on her study of scientists working with ML and evolutionary algorithms at CERN, Dippel argues for the "paramount importance [… of] investigat[ing] artificial intelligence not only from a specifically technical angle, but in a broader socio-cultural and political context" (2019a, 39). Artificial Intelligence, according to Dippel, should be considered as a "technological alien" (2019a, 39) to be able to think about a different future of the relation between AI and humans than positivist and neoliberal imaginaries propose.

19 The focus here lies on the political dimensions of AI, specifically on discourses and understandings of the *democratization* of AI technologies. Democratization is defined as "the realization of an ethic, aiming at political information, a willingness to critique, social responsibility and activity, as well as of a political culture that is critical of authority, participative, and inclusive in its general orientation" (Sudmann 2019b, 11).

Other work has studied the imaginaries and narratives of (mostly strong) AI (e.g., Cave and Dihal 2019; Cave, Dihal, and Dillon 2020; Fjelland 2020; Bareis and Katzenbach 2022) that fundamentally influence public discourses and AI development. Since the imaginary of HC builds on these narratives to form a counter-imaginary, I will return to this work and discuss it in more detail in Chapter 4.

Finally, sociologist of science, technology and computing Florian Jaton conducted a laboratory study on the constitution of algorithms, regarding how algorithms come into being, at a computer science laboratory for digital image processing (2021). Such constitution, as Jaton shows, is always "open-ended and amendable" (2021, 289). He pays particular attention to the three activities of "ground-truthing, programming, and formulating" (Jaton 2021, 17) that shape algorithms. By following an "enactive conception of cognition" (Ward and Stapleton 2012) which frames cognition "as a local attempt to engage *with* the world" (Jaton 2021, 130, emphasis i.o.) through actions, he situates programming in experience. Jaton's work, therefore, is an insightful contribution to studying "algorithms from within the places in which they are concretely shaped" (2021, 286). In my research and with the Human Computation Institute as an example, I investigate HC-based CS systems, in a similar way, from within the places in which they are formed.

Infrastructures and Infrastructuring

In order to analyze the sociotechnical assemblages and their human–AI or –technology relations in general, it is crucial to include the infrastructures enabling and forming such relations in the first place. As will become clear in the following elaborations, I consider infrastructure both as a subject of study and as an analytical lens. Without neglecting that most of the literature cited above includes an infrastructure perspective, I here want to explicitly point to research on infrastructures and the field of "information infrastructure studies" (Bowker et al. 2009).[20] Anthropologist Brian Larkin defines infrastructures as follows:

> Infrastructures are built networks that facilitate the flow of goods, people, or ideas and allow for their exchange over space. As physical forms they shape the nature of a network, the speed and direction of its movement, its temporalities, and its vulnerability to breakdown. They comprise the architecture for circulation, literally providing the undergirding of modern societies, and they generate the ambient environment of everyday life. (Larkin 2013, 328)

Infrastructures are essential for all areas of social organization of which they form the "backstage" (Koch 2017b, 117). They "mediate between scales, connecting local practices with global systems" (Star and Ruhleder 1996, 114; cited in Hallinan and Gilmore 2021, 6). Despite their importance, they often remain invisible both physically and in discourse

20 Due to the growing interest of social science and humanities researchers in infrastructure in, *inter alia*, Internet studies, media, or urban studies, the trend is referred to as the "infrastructural turn" (e.g., Hesmondhalgh 2021).

(Bowker and Star 2008; Niewöhner 2015). This invisibility is no coincidence but part of the inner workings of power. Bowker and Star showed how working infrastructures go hand in hand with classification and standardization systems and what roles the latter play (2008). Infrastructures in the words of communication scholars Blake Hallinan and James Gilmore, are “agents of power” (2021, 2), and their disappearance contributes to the fiction that they are objective as well as acultural and asocial, and, thus, reliable. If they work smoothly and as intended, the data infrastructures underlying Stall Catchers are not the focus of the researchers’ work or even the subject of laboratory discussions. However, infrastructure becomes visible upon breakdown (Star and Ruhleder 1996, 113; *cf.* Star 1999, 381–382) and,[21] as in the example studied in this work, when they are changed and new aspects are introduced to them. The geographer and scholar of urbanism and the sociology of technology Stephen Graham writes that these moments of disruption, when infrastructures in the background stop working as they should, are the “most powerful way of really penetrating and problematizing those very normalities of flow and circulation to an extent where they can be subjected to critical scrutiny” (Graham 2009, 2).

Susan Leigh Star and computer and information scientist Karen Ruhleder argue, following computer scientist Tom Jewett and social informatics scholar Rob Kling (1991), that the concept of infrastructure is “a fundamentally relational concept, becoming real infrastructure in relation to organized practices” (Star and Ruhleder 1996, 113). They define nine properties of infrastructure, including transparency and embeddedness (Star and Ruhleder 1996, 113; Star 1999). Based on such a relational understanding, social anthropologist Jörg Niewöhner considers infrastructures “as transient embodiments of social, technical, political, economic, and ethical choices that are building up incrementally over time” (2015, 2). With respect to my research field, data infrastructures are, thus, a co-constitutive part of HC-based CS games as sociotechnical assemblages (Niewöhner 2015, 6–7). An analysis of the data infrastructures behind Stall Catchers, therefore, requires not starting with the imaging processes in the biomedical laboratory and stopping at the stage of analyzable data, but rather including the practices of researchers and developers, the game’s code infrastructure, databases, and the social organization and values that flow into and shape the infrastructures, as Bowker and colleagues argue for infrastructures in general (2009, 99). The latter authors also argue that when infrastructure is considered as a concept, it “consists of both static and dynamic elements, each equally important to ensure a functional system” (Bowker et al. 2009, 99).[22] As I will show in this work, infrastructure and their related researcher–technology relations often resist the attempts to be stabilized and cleaned up. They are constantly in the making.

21 Here, breakdown is not considered to be an exceptional state of infrastructure but “a condition of technological existence” (Larkin 2008, 234), as shown by Larkin in his ethnography of media in Nigeria.

22 Bowker argues for performing “infrastructural inversion” (1994; *cf.* Bowker and Star 2008, 34) to analyze infrastructures: “Infrastructural inversion means recognizing the depths of interdependence of technical networks and standards, on the one hand, and the real work of politics and knowledge production on the other. It foregrounds these normally invisible Lilliputian threads and furthermore gives them causal prominence in many areas usually attributed to heroic actors, social movements, or cultural mores” (Bowker and Star 2008, 34).

What constitutes infrastructure, then, depends on perspective. Larkin writes that the "act of defining an infrastructure is a categorizing moment" (2013, 330) that, as I would add, is more an ongoing process than a concrete moment.

This understanding of infrastructures as being always in the making, moreover, shifts the focus to "infrastructuring as a material-semiotic practice" (Niewöhner 2015, 5). Information scientist and STS scholar Claus Bossen and historian and STS researcher Randi Markussen use infrastructuring as a verb to point to, among other things, "the efforts required for their integration, and the ongoing work required to maintain it" (2010, 618; *cf.* Jackson 2014). In my study I consider infrastructuring practices at both the Human Computation Institute and the biomedical laboratory whose Alzheimer's disease research data is analyzed on the Stall Catchers platform. These infrastructuring practices are part of the HC-based CS assemblages and present informative examples of human–technology relations in these sociotechnical systems.

The aim of my research is to understand how HC-based CS assemblages come into being in the interplay of different human and nonhuman actors, and how their human–technology relations change over time and in everyday life. Despite this focus, my research approach is also inspired by the analytical genre of laboratory studies common in STS (Jaton 2021, 19–20). These studies focus on the analysis of how scientific knowledge is produced (famous examples are Lynch 1985; Latour and Woolgar [1979] 1986; Traweek 1992; Knorr-Cetina 1999), or recently, how algorithms are constituted (Jaton 2021). While I mainly conducted participant observation at the Human Computation Institute, my observations at the Schaffer–Nishimura Lab, and the focus on the participant's perspective also played a crucial role in my research (see Chapter 3).

A Theoretical Framework for Analyzing Emerging Hybrid Systems

Alongside the related work I have discussed, my research further builds upon key theoretical concepts which I combine to form a theoretical framework to address the scientific questions central to this study. These theoretical lines, which I discuss separately, consist of, first, the assemblage concept, which is particularly well-suited to adhering to HC-based CS projects' dynamic, procedural, and complex nature and directs the focus onto relations between the humans and nonhumans forming the assemblages. Second, I discuss a relational understanding of technology. Here, I draw specifically from Beck's "complex situational analysis" (1997) and a postphenomenological understanding of human–technology relations, which views human experience as always mediated by technology (e.g., Ihde 1990; Verbeek 2001; 2005; Rosenberger and Verbeek 2015c; Dorrestijn 2017). Third, I discuss moral anthropological and ethics of technology approaches, which form a crosscutting perspective in my research and help analyze how HC-based CS is imagined by designers and developers. This extends to how, for example, participants relate to and cope with their engagement in such systems. From these conceptualizations, I develop the concept of intraversions to capture how human–technology relations in HC-based CS intravert along the dimensions of instantaneity and gradual temporal development.

From Assemblages to Assemblage Thinking

Human computation systems are not static, distinct objects, but continuously becoming in the interplay of and relations between different human and nonhuman actors, themselves shaped and co-constituted as part of the process of becoming. While human–technology relations and, thus, HC systems themselves stabilize over a certain timeframe, they also carry the potential for change. In order to analyze HC-based CS projects, the concept of assemblages offers a helpful theoretical approach to capture such projects in both their temporal consistency and volatility (Welz 2021a, 161).[23] Simply stated, assemblages can be understood as compositions of various heterogeneous elements, including human and nonhuman actors and their relations, which temporally come together in specific configurations (Welz 2021a, 162). The resulting sociotechnical assemblages do not merely constitute the sum of their individual elements; instead, something new emerges, rendering HC systems in their multiplicity unique. As I show in this work, only a highly specific interplay of various sociomaterial relations allows HC-based CS projects to meaningfully contribute to the scientific analysis of a problem.[24]

Assemblage theory recently received considerable attention from across the social sciences (Hansen and Koch 2022, 3). It has also been increasingly well-received in (cultural) anthropology since the turn of the millennium (Welz 2021a, 161). In recent years, European ethnology and digital anthropology employed assemblage theory to analyze "nonlinear processes, unstable states, and unexpected effects" (Welz 2021a, 168).[25] Originally, assemblage theory was developed by Deleuze and Guattari, specifically in their book *A Thousand Plateaus: Capitalism and Schizophrenia* (1980). Here, an assemblage is formed in a multiplicity of heterogeneous elements and "necessarily changes in nature as it expands its connections" (Deleuze and Guattari 2013, 7). Moreover, assemblages act "on semiotic flows, material flows, and social flows simultaneously" (Deleuze and Guattari 2013, 24). In dialogue with the French journalist Claire Parnet, Gilles Deleuze describes assemblage as follows:

> It is a multiplicity which is made up of many heterogeneous terms and which establishes liaisons, relations between them, across ages, sexes and reigns—different natures. Thus, the assemblage's only unity is that of a co-functioning: it is a symbiosis, a 'sympathy'. It is never filiations which are important, but alliances, alloys; these are not successions, lines of descent, but contagions, epidemics, the wind. (Deleuze and Parnet 2007, 69)

23 Citizen science systems have already been analyzed as assemblages by virtuality design scholar Nathan Prestopnik and information science scholar Kevin Crowston (2012). However, the authors did not draw from assemblage theory as discussed in this research and considered CS system assemblages as "a collection of interrelated functional components and social activities" (Prestopnik and Crowston 2012, 1).

24 In fact, in solving a certain problem, new problems emerge (or existing problem definitions change) to be addressed with HC. I will elaborate on this, specifically in Chapter 6.

25 See, for example, the application of assemblage theory to the analysis of AI in museums (Bareither 2023).

These connections between different elements are, in a certain way, random and non-linear. According to Deleuze and Guattari, they are rhizomatic in that they "connect [...] any point to any other point" (2013, 21). The rhizome, in their thinking, lies in opposition to arborescence, a tree-like hierarchical structure that has a beginning and an end. Rhizomes are nonhierarchical, undirected, and heterogeneous, always multiple and can never be broken.[26]

The attempt to fully characterize Deleuze and Guattari's concept of "assemblage" fails due to the various and often inconsistent definitions they offered. Moreover, any attempt to define the concept in English already falls short given the term itself since the English translation "assemblage" does not capture both meanings of the original French "*agencement*" (Phillips 2006, emphasis i.o.). The translation of the term originates from the Canadian philosopher and social theorist Brian Massumi, who first translated *A Thousand Plateaus* and introduced the term "assemblage," adopted by other translators and recipients in subsequent years (Brenner, Madden, and Wachsmuth 2011, 227; cited in Welz 2021a, 163). In its French meaning, the term refers to both the "action of matching or fitting together a set of components (*agencer*) [...], as well as to the result of such an action: an ensemble of parts that mesh together well" (DeLanda 2016, 1, emphasis i.o.). According to sociologist John Law, the English translation does not reflect the uncertainty related to the process (2004, 41).

For Deleuze and Guattari, assemblage was a "provisional analytical tool rather than a system of ideas geared towards an explanation that would make it a theory" (Müller 2015, 28). Nevertheless, various scholars have attempted to explain Deleuze and Guattari's concept or further define it without strictly adhering to their thinking—attempts that others have also criticized, including philosopher and critical and cultural theorist Ian Buchanan (e.g., 2015). My aim in this section, however, is to discuss assemblages in a way that is conducive to my analysis of HC-based CS, admittedly leaving the discussion of different interpretations incomplete. Extensive discussions of the concept of assemblage and its various receptions can be found in, for example, DeLanda (2006; 2016), Müller (2015), Welz (2021a), and Hansen and Koch (2022).

Theorist, artist, and philosopher Manuel DeLanda's work on Deleuze and on Deleuze and Guattari's assemblage concept offers a detailed account of their thinking. DeLanda even advanced Deleuze and Guattari's formulation to a "neo-assemblage theory" or "assemblage theory 2.0" (DeLanda 2006, 4), more tailored towards use as an analytical tool. DeLanda, in fact, introduces a new approach to social ontology based on Deleuze's assemblage theory in *A New Philosophy of Society: Assemblage Theory and Social Complexity* (DeLanda 2006). Assemblages, he argues,

> being wholes whose properties emerge from the interactions between parts can be used to model any of these intermediate entities: interpersonal networks and institutional organizations are assemblages of people; social justice movements are assemblages of several networked communities; central governments are assemblages

26 The latter means that rhizomes do not cease to exist upon rupture but instead change along a different line. Deleuze and Guattari list six defining characteristics of rhizomes in the introductory chapter "Rhizome" (2013). Here, I focus on the assemblage concept.

> of several organizations; cities are assemblages of people, networks, [...]. (DeLanda 2006, 5)

All these intermediate entities can be modeled and analyzed using the concept of assemblages and historical processes. This approach, according to DeLanda (2006, 4), presents a "realist social ontology" that does not need to rely on essentialism to explain the identities of organic, inorganic, or social assemblages by focusing on the processes of production and the maintenance of assemblages "instead of the list of properties characterizing the finished product" (DeLanda 2006, 39). Maintenance, in the form of territorializing processes, is important because deterritorializing (see below) processes continuously destabilize assemblages (DeLanda 2006, 39). Following this thinking, then, DeLanda defines the ontological status of assemblages as individuals and singular (2006, 40). Taking assemblages as starting points helps to follow the processes that form them and those that destabilize them simultaneously.

Assemblage theory is particularly useful for analyses across scales because it understands phenomena as always consisting of various interwoven scales. This allows one to analyze how assemblages come into existence through the interaction of their elements and how they, in turn, influence these individual parts (DeLanda 2016, 34).

Following Deleuze and Guattari, and DeLanda's interpretation, geographer Martin Müller (2015) summarizes five characteristics of assemblages. First, they are "relational," meaning that assemblages come into being through the relations between different elements (Müller 2015, 28): "In a multiplicity, what counts are not the terms or the elements, but what there is 'between', the between, a set of relations which are not separable from each other" (Deleuze and Parnet 2007, viii). These relations are not fixed but temporal (Deleuze and Guattari 2013, 98), and, as DeLanda argues, they are "*relations of exteriority*. These relations imply [...] that a component part of an assemblage may be detached from it and plugged into a different assemblage in which its interactions are different" (DeLanda 2006, 10, emphasis i.o.). This understanding of relations also means that it is not the properties of such components that describe the relations of the assemblage, because the realization of their capacities relies on relations, on references to "the properties of other interacting entities" (DeLanda 2006, 11).

Second, Müller (2015, 29) argues that assemblages create new actors and actions, relations, expressions, and territorial organizations and are, thus, *productive*. As I will show in this work, HC-based CS projects and their intraverting human–technology relations generate new subjectivities, tasks, and purposes. In fact, the purposes of the projects themselves sometimes change.

Third, "[a]ssemblages are *heterogeneous*" (Müller 2015, 29) and, as such, always sociomaterial. "There are no assumptions as to what can be related—humans, animal, things and ideas—nor what is the dominant entity in an assemblage" (Müller 2015, 29, emphasis i.o.).

Moreover, assemblages are formed through the constant processes of deterritorialization and reterritorialization: "the assemblage has both *territorial sides*, or reterritorialized sides, which stabilize it, and *cutting edges of deterritorialization*, which carry it away" (Deleuze and Guattari 2013, 103, emphasis i.o.). Deterritorialization and reterritorialization can be understood as processes that act upon assemblages by disembedding and destabilizing them (deterritorialization), and by restructuring and stabilizing them (reterritorialization). As assemblages, HC-based CS projects are constantly marked by processes of reterritorialization that bring together, align, and stabilize heterogeneous relations and actors, while those of deterritorialization tear them apart, destabilize the assemblage, and increase gaps and frictions between different relations. While such processes play a role in all of the subsequent empirical chapters, Chapter 7 explicitly focuses on the example of building trust as a (re)territorialization process. Despite the continuous work of various processes on the assemblages, they are, nevertheless, not randomly changing and not everything is in motion (Müller 2015, 36). Similar to Beck's observation of the "use potentials" of technology (1997, 223), assemblages are multiple but not arbitrary (see below for more detail).

Finally, and importantly to Deleuze and Guattari, desire is fundamental to fusing the elements of and forming them into an assemblage (Müller 2015, 36). In Deleuze and Guattari's words, "The rationality, the efficiency, of an assemblage does not exist without the passions the assemblage brings into play, without the desires that constitute it as much as it constitutes them" (2013, 465). It follows, then, that assemblages as collections of heterogeneous elements are never neutral but always driven by desire, which can take many different forms of "passion," such as power, pity, cruelty (Deleuze and Guattari 2013, 466), or ethical principles. In this work, I analyze the various passions, the "effectuations of desire" (Deleuze and Guattari 2013, 466) that create HC-based CS assemblages and are created by them.

While DeLanda's work made assemblage theory accessible to the social sciences in general (Welz 2021a, 162), other modes of interpretation have been developed which can be summarized by the term "assemblage thinking" (Anderson et al. 2012; Welz 2021a). These often moved away from the poststructuralist philosophy of Deleuze (Welz 2021a, 164). Here, assemblage thinking encompasses not only ontological but also methodological or empirical approaches (Brenner, Madden, and Wachsmuth 2011, 230), serving as a "descriptive emphasis of how different elements come together" (McFarlane 2011b, 652). The anthropologists Aihwa Ong and Stephen Collier's (2005) edited volume *Global Assemblages. Technology, Politics, and Ethics as Anthropological Problems*, for instance, influenced the cultural anthropological reception of the assemblage concept (Welz 2021a, 165; Hansen and Koch 2022, 5). "Global Assemblages," as the title suggests, focused on questions of globalization at the beginning of the twenty-first century. Here, the term unites the tension in the terms "global", implying a "broadly encompassing, seamless, and mobile" (Ong and Collier 2005, 12) perspective, and "assemblage" as "heterogenous, contingent, unstable, partial, and situated" (Ong and Collier 2005, 12). Contrary to DeLanda, Ong and Collier (2005) do not aim to define the concept further but to make it accessible to empirical research, presenting "assemblage thinking as a heuristic for emerging globalization research in cultural anthropology" (Welz 2021a, 166). They describe assemblages as "ensembles of heterogeneous elements" (Ong and Collier 2005, 4), which are "the product of multiple determinations that are not reducible to a single logic. The temporality of an assemblage is emergent. It does not always involve new forms but forms that are shifting, in formation, or at stake" (Ong and Collier 2005, 12). The latter is especially essential to my research, since the relations within sociomaterial assemblages in HC-based CS intravert such that they, for example, change without necessarily involving new elements or actors. According to cultural anthropologists Lara Hansen and Gertraud Koch, the focus in the current empirical cultural studies of assemblages lies on

> the emergence and unfolding of socio-material fields and the tracing of just such inherent processes of change by the various human and non-human actors. In particular, the randomness of connections and the recognition of the ambiguity of social realities in which the disruption of existing structural categories and dichotomies such as social-material, animate-inanimate, nature-culture, human-non-human, object-subject, micro-macro, or structural-practices is prevalent. The unmasking of these dichotomies as specific, often anthropocentric world views offers fruitful starting points for ethnographic research in the fields of political, educational, environmental or medical anthropology. (Hansen and Koch 2022, 4–5)

I argue for adding digital anthropology and the anthropology of technology to this list of fields of ethnographic research that can benefit from an assemblage approach. Moreover, assemblage thinking and assemblage theory have been of particular interest in urban studies (Farías and Bender 2010; Brenner, Madden, and Wachsmuth 2011; McFarlane 2011a; 2011b; Färber 2014),[27] where the concepts have proven quite useful when employed in combination with ANT (e.g., Farías and Bender 2010; Färber 2014). While my research does not lie within the field of urban studies, the interpretation of assemblage theory from the perspective of ANT, the concepts and perspectives of which serve as important starting points for my research, represents an important trajectory which I will discuss in what follows along with a brief overview of ANT itself.

Actor–network theory, specifically going back to philosopher, anthropologist, and sociologist Bruno Latour ([1988] 1993), sociologist Michel Callon (1984), and John Law (1984; *cf.* Latour 2005, 10), focuses on the analysis of actor networks and their properties (Latour 1996, 369), thereby following a flat ontology (Latour 2005, 16). The focus of ANT lies on overcoming binaries and "does not limit itself to human individual actors, but extends the word actor—or actant—to *non-human, non-individual* entities" (Latour 1996, 369, emphasis i.o.),[28] conceived as "circulating objects" (Latour 1996, 374). These objects are formed through and in actions with other actants and associations. The agenda of ANT, according to Latour, is

> [t]he attribution of human, unhuman, non-human, inhuman characteristics; the distribution of properties among these entities; the connections established between them; the circulation entailed by these attributions, distributions and connections;

27 The concept of assemblage highlights the fundamental "human—non-human multiplicity of relations" (McFarlane 2011b, 651), attending to "why and how multiple bits-and-pieces accrete and align over time to enable particular forms of urbanism over others in ways that cut across these domains, and which can be subject to disassembly and reassembly through unequal relations of power and resource" (McFarlane 2011b, 652). Moreover, it allows researchers to ethnographically analyze cities as interconnected elements in everyday practice without having to determine the nature of their connections *a priori* (Färber 2014, 98).

28 The term "actant" refers to whatever or whoever "acts or to which activity is granted by others. It implies *no* special motivation of *human individual* actors, not of humans in general" (Latour 1996, 373, emphasis i.o.).

> the transformation of those attributions, distributions and connections of the many elements that circulate, and of the few ways through which they are sent. (1996, 373)

According to Star, ANT "opened up a whole new way of analyzing technology" ([1991] 2015, 276) which has much in common with assemblage theory. In fact, Latour, in defining ANT, referred to assemblages and Deleuze's term "rhizome" (e.g., in Latour 1996, 370). Therefore, Müller described ANT as "an empirical sister-in-arms of the more philosophical assemblage thinking" (Müller 2015, 30) developed by Deleuze and Guattari. In contrast to DeLanda, for whom relations of exteriority characterize assemblages, ANT follows a relationalist ontology, according to which relations of interiority form assemblages. For the latter, relations "define the very identity of the terms they relate" (Ball 2018, 242) to. With assemblages, ANT focuses on the becoming of their components (Schwertl 2013, 118),[29] which are conceived as processes of "recursive self-assembling" (Law 2004, 41). Thus, here, the components are co-constructed and shaped in the entanglement with each other and are not preexisting (Law 2004, 42).

Consequently, ANT decenters subjects and artifacts by placing associations, networks, and translations at the center of concern, focusing specifically on processes, changes, and stabilizations (Schwertl 2013, 113). The productive power of relations—especially human–technology relations—plays an important role in understanding how intraversions form.

Additionally, a helpful approach to agency building upon the ANT conception of assemblage is political scientist and philosopher Jane Bennett's notion of "distributive agency" (2010).[30] This understanding decenters agency from being a capacity solely ascribed to humans and sees it, instead, as "distributed across an ontologically heterogeneous field" (Bennett 2010, 23). Following this understanding, assemblages, then, are also not defined and conducted by individual agents but possess their own agency:

> [N]o one materiality or type of material has sufficient competence to determine consistently the trajectory or impact of the group. The effects generated by an assemblage are, rather, emergent properties, emergent in that their ability to make something happen (a newly inflected materialism, a blackout, a hurricane, a war on terror) is distinct from the sum of the vital force of each materiality considered alone. Each member and proto-member of the assemblage has a certain vital force, but there is also an effectivity proper to the grouping as such: an agency *of* the assemblage. And precisely because each member-actant maintains an energetic pulse slightly "off" from that of the assemblage, an assemblage is never a stolid block but an open-ended collective. (Bennett 2010, 24, emphasis i.o.)

29 Within the example of studying science, the concept, according to Law, allows one to "recognise and treat with the fluidities, leakages and entanglements that make up the hinterland of research" (2004, 41).

30 Welz (2021a, 172) also acknowledges the important contribution of feminist STS to assemblage theory, which considers agency as distributed in assemblages across human and nonhumans.

Importantly, while understanding agency as distributed does not directly link agency to a moral subject, it also does not neglect intentionality, albeit consigning it "as less definitive of outcomes" (Bennett 2010, 32; *cf.* Hansen and Koch 2022, 9–10). Thus:

> Agency is, I believe, distributed across a mosaic, but it is also possible to say something about the kind of striving that may be exercised by a human within the assemblage. This exertion is perhaps best understood on the model of riding a bicycle on a gravel road. One can throw one's weight this way or that, inflect the bike in one direction or toward one trajectory of motion. But the rider is but one actant operative in the moving whole. (Bennett 2010, 38)[31]

Despite the parallels between assemblage thinking and ANT, they are also different in several ways. Cultural anthropologist Maria Schwertl (2013), for instance, pointed to the diverging forms of analyzing networks. While ANT is primarily interested in how networks emerge and are stabilized, assemblage theory focuses on its continuous recompositions (Schwertl 2013, 117).[32] Furthermore, ANT focuses on situational development, while assemblage concentrates on pervasive structures and logics (Schwertl 2013, 118).[33]

Focusing on irreversibilities within networks and how they are introduced can be important for analyzing power in the field of sciences (Star [1991] 2015, 275). However, ANT has been criticized for focusing too heavily on the analysis of specific associations and alignments between heterogeneous elements of networks (Beck 1997, 288).[34] According to Beck, this results in an (at least temporarily) stabilized network and the "assignment of specific, stable roles for all human and nonhuman actors" (1997, 288). Additionally, although ANT's contribution to overcoming binaries and boundaries was significant, Star writes:

> [O]ne of the features of the intermingling that occurs may be that of exclusion (technology as barrier) or violence, as well as of extension and empowerment. I think it is both more analytically interesting and more politically just to begin with the question, *cui bono?* than to begin with a celebration of the fact of human/non-human mingling. (Star [1991] 2015, 276–277, emphasis i.o.)

Despite the differences between ANT and assemblage theory discussed here, McFarlane concludes that they "nonetheless exist [...] in similar conceptual terrain attempting to confront the complexity of sociomaterial relationality" (2011b, 655).[35]

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31 This reminds one of Suchman's (2007b) insightful canoeing example, with which she emphasizes the contingencies of action and the necessary incompleteness of plans.

32 Deleuze and Guattari, therefore, call the analysis "nomadology" (2013, 409ff.).

33 For further differences between ANT and assemblage theory, see Müller (2015).

34 It should be noted that writing about "ANT" in fixed terms simplifies its ideas and approaches. Of course, ANT has evolved since its introduction and adaptation (e.g., Law and Hassard 1999; Gad and Jensen 2010). One example is the work of ethnographer and philosopher Annemarie Mol, who demonstrated how phenomena are enacted in multiple versions and through different networks (Mol 2002a; 2002b; *cf.* Gad and Jensen 2010).

35 There are also similarities between the assemblage concept and Foucault's concept of the dispositive (Schwertl 2013, 118). However, since the dynamic nature of assemblages—which does not play

In contrast to ANT's rather unidirectional approach to the stabilization of associations, my research focuses on the continuous changes in role allocations, power distributions, and responsibilities that occur in human–technology relations.

Having discussed assemblage theory or thinking with a focus on DeLanda's and ANT's conceptualizations,[36] I summarize five main points related to how the assemblage concept—which I apply both empirically and analytically (Brenner, Madden, and Wachsmuth 2011, 231), as object and orientation (McFarlane 2011b, 653)—provides a useful theoretical approach to the analysis of HC-based CS projects. First, it allows me to remain open to the complexity of HC-based CS systems (Dietzsch 2022). Indeed, following DeLanda's (2016, 3) interpretation, assemblages are always assemblages of assemblages. To provide an example from my field, biomedical engineering in the laboratory itself can be understood as an assemblage that is part of the Stall Catchers assemblage.[37] I demonstrate in Chapter 6 how it can also be helpful to think of the scientific process in the example of Stall Catchers as an assemblage in and of itself.

Second, the concept of assemblage also directs the focus onto the relations between different human and nonhuman actors, which together form assemblages (Welz 2021a, 164). As a concept, it "highlights the dynamic, the procedural and the inconsistent dimensions of social orders [and sociomaterial practices] rather than their structural dimensions in and beyond societies" (Hansen and Koch 2022, 4). Using the concept of assemblage, then, it is possible to analyze the processes of stabilization (reterritorialization) and destabilization (deterritorialization) simultaneously acting upon Stall Catchers, both forming and changing it.

Third, and related to this latter point, assemblage thinking conceptualizes an assemblage's agency itself in processual terms (*cf.* Hansen and Koch 2022, 9). ANT, as well as its

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an important role in dispositives—is particularly useful for my analysis of HC-based CS, I do not pursue this line of thought further here.

36 I briefly mention Buchanan's critique of both lines of thought, although I focus on how assemblage thinking provides a fruitful starting point for my analysis of HC-based CS systems—or assemblages. Buchanan criticizes ANT's and DeLanda's interpretations of assemblage theory for "cloud[ing] our understanding of Deleuze and Guattari" (Buchanan 2015, 383). Among his greatest points of criticism are the following: On the one hand, and even though ANT's focus on the agency of materialities and nonhuman entities is in line with Deleuze and Guattari's thinking, Buchanan argues it should not form the core of the analysis, and ANT, therefore, misses "what is central to the assemblage" (Buchanan 2015, 385). Furthermore, ANT, according to Buchanan, understands assemblages as indetermined collections and not as purposeful as "the deliberate realization of a distinctive plan (abstract machine)" (2015, 385). On the other hand, DeLanda, from Buchanan's point of view, focuses too much on the becoming of assemblages (2015, 382), and, in that sense, on the "how:" "Worrying about *how* a particular authority structure actually changes forgets that the real question here, at least insofar as assemblage theory is concerned, is *what* is that structure of authority? How is it constituted?" (Buchanan 2015, 388, emphasis i.o.). Deleuze and Guattari, by contrast, were interested more in questions related to the idea of the state itself (Buchanan 2015, 389). As I have stated previously, I do not aim to strictly follow Deleuze and Guattari's formulation of assemblages but, instead, focus on the assemblage concept in a way that is helpful to my analysis, and, thus, pursue a different goal from Buchanan with my discussion of assemblages.

37 It is, thus, important to reveal the cuts I place (Barad 1996, 170–171), the boundaries I draw, and specific regions of the assemblage I focus on in my analysis of HC-based CS projects as assemblages (see Chapter 6).

conceptualization of assemblages, has been criticized for its symmetric relational approach to agency, making it impossible to ascribe accountability to actors.[38] My perspective, therefore, departs from this approach. As I have already briefly mentioned in the introduction, I, instead, follow an asymmetric understanding of human and nonhuman agency, similar to Barad, who, following physicist Niels Bohr, argues as follows:

> (i) [N]ature has agency, but it does not speak itself to the patient, unobtrusive observer listening for its cries—there is an important asymmetry concerning agency: we do the representing, and yet (ii) nature is not a passive blank slate awaiting our inscriptions, and (iii) to privilege the material or the discursive is to forget the inseparability that characterizes phenomena. (Barad 1996, 181)

This understanding is also reflected in the relations, temporalities, and spatialities that form the assemblage, as some actors and processes have a greater influence on structuring, narrating, and forming them than others (McFarlane 2011b, 655). From this, it follows that assemblages are "structured, hierarchised, and narrativised through profoundly unequal relations of power, resource, and knowledge" (McFarlane 2011b, 655).

Fourth, thinking about HC-based CS systems as (sociotechnical) assemblages directs the focus to the different sociotechnical relations in which different human and nonhumans are linked and mutually form each other. Different human–technology relations are interwoven and influence each other productively. Simultaneously, they pull and push against each other, creating frictions while continuously forming and reforming, or reterritorializing and deterritorializing, the assemblage.

Finally, these relations are continuously changing alongside the assemblages, which, as Deleuze and Guattari (2013, 7) have pointed out, change themselves as they extend. I focus on selected human–technology relations and perspectives, elements, and dimensions of HC-based CS assemblages to answer the questions guiding my research.

Using the assemblage concept as a theoretical starting point, I now turn to selected theoretical conceptualizations of human–technology relations, and how these can be analyzed.

Human–Technology Relations

Beck writes that, at least since the era of modern industrial societies, the "relation between self and world is comprehensively technologically mediated and moderated" (1997, 248). Given the dense "texture of the 'technosphere' within which we undertake our daily affairs" (Ihde 1975, 271), technology forms an omnipresent condition of everyday life,[39] which it shapes and, at the same time, is shaped by (Beck 1997, 10). Therefore, the attempt to grasp and understand technology and its role in human life has occupied researchers in various scientific fields. I focus on relational conceptualizations of technology, specifically following Beck's complex situational understanding of technology and

38 As described above, Bennett (2004), therefore, emphasizes intentionality within distributed agency.

39 For these reasons, Hengartner (2012, 120) argues, technology can be understood as culture.

postphenomenological approaches to human–technology relations. Following relational conceptualizations of technology, the focus always lies on the relation between humans and nonhumans, such as humans and technology,[40] and considering both simultaneously. Humans and technology mutually constitute each other within and through their relations. While Beck writes about *user*–technology relations, I refer here to humans in order not to exclude diverse related actors, such as developers, providing specificity whenever necessary. From there, I develop the concept of intraversions, which adds a particular processual and temporal focus to the analysis of the evolution of and continuous changes within human–technology relations along instantaneous and gradual temporal developments in the rapidly advancing fields of HC and HI. I first turn to Beck's work on the use of and engagement with technology (*Umgang mit Technik*).

Beck's *Umgang mit Technik* (1997) has been highly influential in the German-speaking fields of cultural and digital anthropology but to date has not been published in English. In this book, Beck developed the analytical framework of a "complex situational analysis of the use of everyday artefacts," building upon a praxiological perspective on technology in order to take into account the materialities and use of technology in addition to the dimension of meaning, which, thus far, had been the focus in German "*Sachforschung*" (1997, 18, 20). He builds upon concepts from German cultural anthropology and European ethnology and its predecessor *Volkskunde,* as well on philosophical, ethnological, and sociological concepts of technology. Beck develops this framework to analyze the *usage of* what he calls "classical" *technology*, which he contrasts with information and communication technologies, such as the computer (1997, 232–233). Despite this demarcation, Beck's framework constitutes a landmark in the multidimensional and multiperspective sophisticated analysis of technology. Therefore, here I summarize the main elements of Beck's approach relevant to my research.

Beck describes the relationship between users and technology as an interactive process, a "feedback structure" (Zimmerli 1990, 252), in which technology has a formative influence on its possible uses. At the same time, users can render technical artifacts usable for their purposes in creative ways. The relational concept of technology stresses the analysis of *the use* of technology. It, therefore, establishes a "*situational understanding of technology*, which ultimately also opens up the perspective on the *cultural and social contexts of the use act*" (Beck 1997, 224, emphasis i.o.).

In analyzing technology in use and the relations between humans and technology, Beck combines a perspective which focuses on materiality ("*sachtheoretische Perspektive*"), taking technology as a starting point, through a perspective focusing on practice ("*praxistheoretische Perspektive*"), taking actors as its starting point (Bareither 2013, 32).

Focusing on technology itself, Beck builds on a differentiated understanding of context, which he divides into "hard, material con-texts," describing technological object potentials (dimension of practice) and "soft, discursive co-texts" (dimension of meaning), that together lead to the configuration of a user and orient their practice (Beck 1997, 294). Following literary scholar and philosopher Mikhail Bakhtin (1981), Beck stresses the

40 The focus in my study lies on human–technology relations, although these generally also include animals, such as mice, and other nonhuman entities, such as plants, trees, microorganisms, and other formations.

polyphony of co-texts, which can be simultaneously present in one situation and "juxtaposed to one another, mutually supplement one another, contradict one another, and be interrelated dialogically" (Bakhtin 1981, 291–292; cited in Beck 1997, 343). In these situations, different discourses and meanings are negotiated and define acceptable or appropriate practices around technology (and, thus, around HC-based CS projects as well). In Chapter 5, I specifically focus on the multiple meanings present in HC-based CS systems given their situatedness in various fields, such as play and science, and, in the case of Stall Catchers, the powerlessness experienced by some participants toward Alzheimer's disease.

For Beck, con-text refers to the situational practice in which technology's affordances are realized (1997, 342).[41] He reinterprets and expands upon the concept of affordance introduced by psychologist James J. Gibson (1977; 1979),[42] who introduced the term to describe how the physical properties of an object, independent of the user's perception, afford certain behaviors and interactions. Beck criticized Gibson's conceptualization for excluding the social and cultural conditions of technology use (1997, 244), the co-texts in Beck's terms, which restrict these affordances (1997, 304).[43] Furthermore, Beck explains that Gibson's definition did not consider the social context in which user–technology interactions occur or relations unfold. He adds that the same object can provide different opportunities to people depending upon their abilities, intentions, and social contexts. Nevertheless, Beck argues, the concept, if expanded, can be useful for the analysis of the everyday use of technology in two ways:

> First, [Gibson's] hint that perception is directly bound to bodily movement, to the actors' ability to act in space—their kinesthetics; and second, that the relation of user and object is to be regarded as the decisive "unit of analysis", characterized by affordances, by manifold and hardly clearly determinable object potentials. (Beck 1997, 244)

The concept of affordances, thus, focuses on the situated relations between humans and technologies. Beck's emphasis on the manifold and indeterminate object potentials opens up the analysis to human counteractions and creative practices,[44] which de Certeau described as "tactics" ([1980] 2013). These challenge discursive regulations as well as designed and programmed ways of use (Beck 1997, 244–245). The framework of a complex situational analysis, therefore, pays particular attention to resistance and creative

41 Beck further differentiates between *manifest* and *latent* con-texts. While technology offers various latent affordances, these are always constrained by specific co- and con-texts. Therefore, from many possible ways of acting, only a few are considered acceptable and favored (Beck 1997, 348).

42 Gibson's affordance concept has since also been used for and adapted to ethnographic and praxeological research by various authors (e.g., Boyd 2010; Costa 2018; Bareither 2019; 2020a).

43 Beck (1997, 244), for example, shows that the realization of the affordances of a letterbox depend on the knowledge of how a letterbox is embedded in the sociotechnical system of sending a letter.

44 This also relates to sociologist Ian Hutchby's interpretation of the affordance concept. Hutchby added a relational focus to Gibson's functional affordance concept that "draws our attention to the way that the affordances of an object may be different for one species than for another" (2001, 448).

practices and, thus, to the agency of users actively shaping their relations with technology. Beck also suggests moving beyond Gibson's affordance concept, which neglects social and intersubjectivity by including "social configurations" (Elias [1970] 2012) and their influence on how affordances are realized in social interactions (Beck 1997, 246). In accordance with, *inter alia*, psychologist William Noble (1981) and philosopher of science and ecological psychologist Edward Reed (1991), Beck refers to this dependence on social configurations as "socially mediated affordances" (1997, 246). Ultimately, however, the complex relationship should be considered a "*con-figuration* of technological artifacts and society: technological development can, thus, be understood as the result and condition of (not only) modern societies, in that new objects provide new affordances, which in turn enable different kinds of social figurations, from which in turn new objects emerge" (1997, 246, emphasis i.o.).

From a practice-theoretical perspective, it is crucial to focus on how affordances and usage instructions are activated and differently realized in everyday use. In this context, Beck conceives practice as both processual and reflexive, embodied and situated (1997, 298–299), which describes an "active and recognizing mode of being in the everyday life world" (1997, 298–299). He argues that as users realize the co- and con-texts in everyday use, technology as a social and cultural construct is then transformed into a "Tat-Sache" (Beck 1997, 295), a matter (or "thing") of practice. The analysis of technology or human–technology relations, therefore, always requires the analysis of both technology as a "use complex and use configuration" ("*Nutzungskomplex* und *-figuration*") (Beck 1997, 294, emphasis i.o.). This perspective emphasizes users' formative role in creatively constructing these relations and their ability to seize the situated contingency. Building upon the sociological theory of "contingency," Beck then conceptualizes technology as a "materialized *form* of contingency management" (1997, 223, emphasis i.o.). As such, "technology allows *diverse but not arbitrary* use possibilities" (Beck 1997, 223, emphasis i.o.). Beck writes that,

> through the design and functional specification of technical artifacts, options are provided within a spectrum that—in a creative process—must be realized by the users. Additionally, it must be emphasized that, in addition to the materiality of the artifacts, use instructions also discursively stabilize the possible uses. Culturally and socially bound technology can thus be conceptualized as *material and immaterial constraints on the contingency* of technical action—with technology and users being embedded in a sociomaterial feedback structure. (1997, 223, emphasis i.o.)[45]

Considering these different, but not arbitrary, possible uses in the analysis of HC-based CS projects is important for understanding how, for example, user–technology relations change and intravert over time as participants realize the options offered by the design of the platform and software in different ways. In Chapter 5, for instance, I discuss participants' practices, which by design go beyond the intended task contribution, and in Chapter 6 I show how participant–technology relations intravert.

45 Beck differentiates between, "*Gebrauchs- und Nutzungsweisen*" and "*Technik und Technologie,*" which are difficult to adequately translate into English.

Taken together, the multiperspective approach to the different dimensions (the co- and con-texts) and the distinction between technology as a "use and orientation complex" allows for the analysis of the "complex interwoven relations of artifact, culture, and user" (Beck 1997, 247). This analysis takes into account both the perspective of actors and their biographies[46] as well as spatial circumstances and temporal processes that go beyond the actual situation (Beck 1997, 344, 347–348).

Focusing on temporalities to study how human–technology relations unfold and change over time is specifically important to my research. Beck cites anthropologist Arjun Appadurai here, who argues that understanding the meanings of objects, which "are inscribed in their forms, their uses, their trajectories" (Appadurai 1986, 5), requires studying "things in motion" (Appadurai 1986, 5), that is, the "*total* trajectory from production, through exchange/distribution, to consumption" (Appadurai 1986, 13, emphasis i.o.). Different studies in cultural and digital anthropology and STS have already employed such an approach by tracing the different stages of the "biography" (Beck 1997, 291) of technology or objects (e.g., Bijker and Pinch 1984; Bijker and Law 1992; Löfgren 1994). Indeed, I adopt such an approach to things in motion, focusing specifically on selected human–technology relations within HC-based CS assemblages. This focus allows for a microperspective analysis, which considers particular human–technology relations while simultaneously considering how different relations are entangled with and shape each other, together creating assemblages.

Instead of demonstrating how researchers and developers strive to build HC-based CS as *black boxes*, I show how HC-based CS systems specifically rely on staying open to future changes, remaining at the edge of AI and scientific research. Crucially, not only does technology change over time but, along with it, so do the distribution of agency and the subject and object positions of the actors (Beck 1997, 292). I return to this point when introducing the concept of intraversions below.

The question of subjectivities and self-experience regarding human actors in relation to the world mediated by technology, which, according to Beck, must be considered a part of technology as a "use complex" (Beck 1997, 353–354), has been the focus of the philosophical branch of phenomenology. Phenomenology, which, since Edmund Husserl, has focuses on analyzing the world in the everyday (Verbeek 2001, 145),

> seeks to overcome the classical, Cartesian dichotomy between subject and object. Against this dualistic notion, phenomenology holds that subject and object […] cannot be thought independently of each other, but only as always already related. Humans cannot be conceived apart from their relations to the world, and the world cannot be conceived apart from people's relations to it. (Verbeek 2001, 120)

The postphenomenological approach, developed in the philosophy of technology and connected to a broader change in the 1980s in the form of an empirical turn (Achterhuis 2001b), is helpful for my endeavor given its practice-oriented perspective and focus on

46 For example, as becomes clear in Chapter 5, for some participants, their background and relation to Alzheimer's disease play essential roles in their engagement with Stall Catchers and Foldit.

the embeddedness of technology in the everyday.[47] Dorrestijn summarizes this turn with the new theme, "for better or worse, humans have become hybrids with technology" (2017, 316). This understanding of technology as an intrinsic part of culture and human praxis (Ihde 1990, 20) is similar to digital anthropology and the anthropology of technology as described above. Haraway's "cyborg" (1985) and Latour's "hybrids" (1993), or philosopher of science and technology Don Ihde's "human-technology relations" (1975; 1990), serve as examples of this approach to technology (*cf.* Dorrestijn 2017, 316). Ihde's (1975) work on human–technology relations was particularly important for postphenomenology. Specifically, he developed a philosophy of technology, in critical engagement with Heidegger, focusing on technologies or technological artifacts "to reflect [upon] technology as it is concretely present in our daily experience" (Verbeek 2001, 122). Ihde, therefore, places the relation of humans to technologies at the center of his analysis and defines four types of human–technology relations and the world. Among these, the first three— *embodiment*, *hermeneutic*, and *alterity* relations—are "focal" human–technology relations, and the fourth are *background* relations (Ihde 1990, 98).

Embodiment relations ("[Human-technology] → World") describe contexts in which "I take the technologies *into* my experiencing in a particular way by way of perceiving *through* such technologies and through the reflexive transformation of my perceptual and body sense" (Ihde 1990, 72, emphasis i.o.). One of the most apparent examples of such relations are eyeglasses, which mediate the eyeglass wearer's relation to the world in an embodied and perceptual way. The second focal human–technology relations are *hermeneutic* ("Human → [technology-World]"). By referring to the hermeneutics in philosophy as an interpretation, these relations are characterized by "a special interpretive action within the technological context" (Ihde 1990, 80). Users of, for example, a wristwatch, experience the world differently through reading and interpreting the watch's display, explain philosophers Robert Rosenberger and Peter-Paul Verbeek (2015a, 17). In these two relations of mediation (Verbeek 2001, 124), technology forms a "means through which something else is made present" (Ihde 1990, 94). By contrast, in the third relation, the *alterity* relation ("Human → technology-[-World]"), humans have a "relation to technologies as relations *to* or with technologies, to technology-as-other" (Ihde 1990, 98, emphasis i.o.). The AI bots introduced in Stall Catchers represent an example of the latter: participants interact *with* the AI bots, which "emerge as the foreground and focal quasi-other" (Ihde 1990, 107). In contrast to algorithms operating in the background, the AI bots present artificial fellow (or competitive) participants to the human participants.

Finally, the fourth *background* human–technology relation refers to "technologies which ordinarily occupy background or field positions" (Ihde 1990, 108) *designed* and meant to function in or form the environmental context of humans (Rosenberger and

47 While "classical" philosophers of technology, such as Martin Heidegger, focused more on uncovering the essence of technology as an autonomous force determining society (Poel 2020, 500), empirical philosophers of technology understood technology as "fundamentally intertwined with" (Dorrestijn 2017, 316) the human condition. For an overview on the empirical turn, see Achterhuis (2001a) and Dorrestijn (2017, 316), and on different philosophical perspectives on the relation between society and technology, see Van de Poel (2020). For the differences between postphenomenology and "classical" philosophies of technology, see Dorrestijn (2012a).

Verbeek 2015a, 19). Examples mentioned by Ihde include heating or cooling systems but could also refer to infrastructures in general. Despite remaining (if functioning) backstage, "[b]ackground technologies, no less than focal ones, transform the gestalts of human experience and, precisely because they are absent presences, may exert more subtle indirect effects upon the way a world is experienced" (Ihde 1990, 112). Importantly, these different relations form a continuum and sometimes overlap (Ihde 1990, 93, 107) and "stand within the very core of praxis" (Ihde 1990, 108), since, following this postphenomenological perspective, "[t]here is no 'thing-in-itself'" (Ihde 1990, 69).

From Ihde's pioneering work and conceptual framework on human–technology relations, postphenomenology developed into an empirical, philosophical perspective (Rosenberger and Verbeek 2015a, 30). This perspective emerged in various fields, such as STS and the philosophy of technology, to analyze relations between humans and technology to which researchers from diverse disciplines, *inter alia*, sociology, anthropology, and philosophy, contribute (Rosenberger and Verbeek 2015b, 1). Postphenomenology combines the two philosophical traditions: phenomenology and American pragmatism. It does so by critically connecting the understandings of human–world relations from phenomenological scholars such as philosophers Maurice Merleau-Ponty and Martin Heidegger and their approach to *describing* phenomena and human experience "from a closer engagement" (Merleau-Ponty 1962; cited in Rosenberger and Verbeek 2015a, 11), instead of *analyzing* them from afar. At the same time, contrary to analyzing, for example, the alienation of the human experience from the world and from itself by technology, as in the work of Heidegger (1996; Rosenberger and Verbeek 2015a, 10), postphenomenology investigates how technologies "help to shape our relations to the world, rather than merely distancing us from it" (Rosenberger and Verbeek 2015a, 11); thus, how it mediates human experience. As such, following such a theory of technical mediation, "human existence is always, and inescapably, marked and influenced by technology" (Dorrestijn 2017, 312), a perspective that goes beyond both utopian and dystopian perspectives on human–technology relations. Building upon American pragmatism, it follows that the analysis of such relations focuses on the practices of engaging with technology and materiality (Rosenberger and Verbeek 2015a, 12): "It is in practices of interacting with technologies where the phenomenon of technological mediation occurs and can be studied. Human–world relations are practically 'enacted via technologies'" (Rosenberger and Verbeek 2015a, 12). This turn was also particularly important, making it possible for a cultural or digital anthropological analysis to connect to such a postphenomenological understanding of human–technology relations.

In line with ANT, postphenomenology seeks to move beyond the divide between subjects and objects and, following phenomenology's criticism of modernism used to ascribe the source of knowledge to objective facts *or* to subjective ideas, also concentrates on how subjects and objects rely on their interrelations (Rosenberger and Verbeek 2015a, 11). At the same time, postphenomenology focuses on the "fundamentally mediated character" (Rosenberger and Verbeek 2015a, 12) of these relations with technologies as mediators between subject and object. It, thus, does not consider subjects and objects *a priori* but as constituting each other (Verbeek 2005, 112); human subjectivity and objectivity are always shaped in mediation. In contrast to ANT, however, postphenomenology does not adhere to a strict symmetry (Ihde 2015, xv) between humans and objects or nonhuman actors. Instead, it is concerned with the mutual constitution between them and with overcoming their "separation" (Verbeek 2005, 166–168; cited in Rosenberger and Verbeek 2015a, 20):

> In order to see these processes of mutual constitution, and to do justice to human experiences of being subjectively "in" a world, it remains very relevant to make a distinction between humans and things. When we give up this distinction, we also give up the phenomenological possibility to articulate (technologically mediated) experiences "from within." (Rosenberger and Verbeek 2015a, 20)

In this research, I acknowledge how human actors and technology co-constitute each other in their interrelations and how these relations describe more than a connection between two independent entities (which they are not). However, to analyze how the role distributions, responsibilities, and tasks shift over time, I sometimes specifically consider the perspectives of humans and technologies independently and move the focus from one to the other.[48]

Here, Ihde's relations offer helpful starting points to think analytically about the relations between participants and software in HC-based CS projects and how Stall Catchers' contributors experience the world through and with the computational elements. However, in contrast to Ihde and technical mediation, my focus moves between relations. As suggested by Beck, I attempt to consider technology as both a use and orientation complex. Instead of applying Ihde's four types of human–technology relations to HC-based CS, I develop the concept of intraversions to study specifically how these relations change over time and along different temporalities. My focus, therefore, does not remain on the human experience of the world through and with technologies but moves to how the relations of humans and technology unfold and the potential that emerges from them. Nevertheless, a postphenomenological and practice-oriented approach to analyzing technology and human–technology relations in the everyday and concrete contexts of production and use (Beck, Niewöhner, and Sørensen 2012, 41) forms the starting point of my research. Following Beck, Niewöhner, and anthropologist of knowledge, STS, and data Estrid Sørensen (2012), agency and creativity are then studied "at the level of concrete practice and thus as distributed across human and non-human actors" (2012, 41).

Additionally, Beck raises a critical limitation of theoretical approaches building on phenomenology, which must be considered. According to Beck (1997, 312), phenomenology does not sufficiently consider social and intersubjective contexts, and, I would add, the broader embeddedness of human–technology relations in assemblages. Moreover, even if phenomenology does not actively neglect these contexts, it carries an "individualistic bias" (Beck 1997, 312). Beck, therefore, recommends focusing on approaches suggested by American pragmatism and Marxism. While postphenomenology combines phenomenology with American pragmatism to overcome this problem, I, nevertheless, additionally draw from the assemblage concept described above to place human–technology relations within sociotechnical assemblages. I, therefore, pay attention to how

48 For a comparison of the "more complementary than combative" (Ihde 2015, xvi) styles of analyzing technology, see, among others, Ihde (2015).

they are interwoven with other relations, which they form and are formed by, also showing how other human and nonhuman actors influence these relations. Moreover, combining approaches to human–technology relations with assemblage thinking allows me to focus on the continuous process of their formation (Cassirer 1985, 43).

Suchman's (2007b) concept of "situated actions" in human–machine configurations also proves helpful here, since it not only turns away from the idea of human intention as the driving force of action but also, to some extent, questions the understanding of causal sequences of action in linear time. This opens up the perspective to both temporalities and contingencies, also stressed by Beck (see above).

Combining assemblage thinking with human–technology relations as analytical perspectives, thus, helps one to focus on the various nonlinear processes that form, stabilize, and destabilize HC-based CS systems and their human–technology relations. This combination also connects to a "becoming ontology" (Hultin 2019), such as agential realism (Barad 2007a), with the understanding that humans and nonhumans are entangled and continuously formed as intrarelations (Hultin 2019, 92). Sociomaterial studies following a becoming ontology pay particular attention to how "agency emerges, transforms, and enacts as a temporal and performative flow of practices," summarizes economist Lotta Hultin (2019, 93). Specifically, in my research I focus on the temporal becoming of human–technology relations both along instantaneous everyday life and gradual temporal developments, what digital innovation and information systems scholar Reza Mousavi Baygi and colleagues have described as a "flow-oriented genealogical" analysis (Mousavi Baygi, Introna, and Hultin 2021). Hansen and Koch, following anthropologists Paul Rabinow and George Marcus' concept of an "anthropology of the close future" (Rabinow et al. 2008), have pointed to the potential of examining temporality in addition to space in assemblage thinking, bringing together "past, present and anticipated actions" (Hansen and Koch 2022, 6). I hope to contribute a tool for this endeavor with the concept of intraversions. As I argue later in this work, my position is that, here, in bringing together past, present, and the anticipated future, the potential of ethnographic research lies not only in the deconstruction and criticism of studied phenomena, but also in the contribution to shaping HC-based CS assemblages in ways that acknowledge the different interests and perspectives of actors involved and which embraces the contingencies and multiplicities of everyday life.

Before turning to the concept of intraversions, I discuss one final line of theoretical thinking important for my research, one which is concerned with ethics. Such an analytical focus is necessary given that HC-based CS projects (and specifically in the example of the Human Computation Institute's projects) are often imagined and legitimized as the *good* and *right* way to solve specific computational and scientific problems. This naturally leads to the ethical framing of the phenomenon studied. Following anthropologist Michael Lambek, I consider ethics as always representing an "intrinsic dimension of human activity and human lifeworlds" (2015b, 18) and, therefore, investigated in and with the everyday (Lambek et al. 2015, 3; Fassin 2015). Such a moral anthropological perspective directs the focus in ethnographic field research to the question of what is understood and problematized as "good." I discuss in the following section the concept of "ethical projects" (Ege and Moser 2021a), "sociotechnical imaginaries" (Jasanoff and Kim

2009; 2015), and Dorrestijn's "subjectivation and technical mediation" (2012a) in order to do this.

Ethical Projects, Imaginaries, and the Care for Our Hybrid Modes of Being

> Ethics of technology does not entail defending what is genuinely human, but caring for the quality of one's hybrid mode of being. (Dorrestijn 2012b, 234)

The field of moral anthropology has garnered much interest in the last few years (e.g., Faubion 2011; Fassin and Lézé 2014; Fassin 2014; 2015; Lambek et al. 2015; Dürr et al. 2020; Ege and Moser 2021b).[49] In my research, moral anthropology and the ethics of technology form a crosscutting analytical perspective which cannot be clearly separated from other analytical perspectives. For the sake of comprehensibility and to provide an overview, however, I will discuss moral anthropology and the ethics of technology separately in this section.

From a moral anthropological perspective, I aim, first of all, to analyze on an empirical level what is understood and problematized as "good" in the design and development of HC-based CS projects. Specifically, I focus on the Human Computation Institute (see Chapter 4) and why participants contribute to such sociotechnical systems (see Chapter 5). The question is as follows: "[A]ccording to which values, by which means, to what ends, and with what deviations or lapses do people try, and in fact, *do*, make their way?" (Lambek 2015, 9, emphasis i.o.). Here, the analytical concept of "ethical projects" (Ege and Moser 2021a), developed by cultural anthropologists Moritz Ege and Johannes Moser in the context of the interdisciplinary research group "Urban Ethics" (Ludwig-Maximilians-Universität München, n.d.b), which focuses on questions of urban life and its ethical dimensions, is helpful to my analysis. How human actors relate to HC applications alongside how they shape them and are shaped by them can be discussed with reference to

49 It should be noted that a long debate exists on the question of the difference between ethics and morality. In fact, there not only exist different understandings of the terms, but sometimes, they are used interchangeably (Fassin 2012, 6). Foucault, for example, distinguishes between three different forms of morality (1988, 25–26), which Fassin summarizes as "moral code", "moral behavior," and "ethical conduct" (2012, 7). The last form refers to "the manner in which one ought to form oneself as an ethical subject acting in reference to the prescriptive elements that make up the [moral] code" (Foucault 1988, 26). It is this form which Foucault deals with in his work and that has influenced one branch of anthropological approaches to ethics and morality (*cf.* Fassin 2012, 7) as well as Dorrestijn's (2012a; 2012b) ethics of technology, which I discuss later. However, as Fassin emphasized, despite the importance that the distinction between morality and ethics might have from philosophical and conceptual perspectives, in the empirical situations examined by anthropologists, these demarcations blur (2012, 8). Here, I follow Ege and Moser's (2021a) pragmatic approach to this distinction and their understanding of ethics "as the ways in which individuals engage with and relate to moral codes, as socially legitimated and, in that sense, normative 'good' behavior and 'proper' (or 'right') conduct of life. Ethical practice is a form of subjectification or subjectivation, of becoming a type of subject. It is also a form of subjection that relates individuals and groups' regimes of living to broader configurations of power and rule" (Ege and Moser 2021a, 13).

Foucault's analysis of the subject and subjectification (e.g., 1983; 1988), in addition to his reflections on technologies and power. Dorrestijn (2012a), following Foucault, developed a theoretical framework of "subjectivation and technical mediation," which I discuss below. This framework helps in the analysis of how individuals relate to technology and technologies, and how these, in turn, affect actors and predefine certain forms of action.

Considering the perspective of designers and HC developers who strive for "better" human–AI systems with "unprecedented capabilities," HC-based CS projects can be understood as "ethical projects" as defined by Ege and Moser (2021a). In the context of urban anthropology, these are:

> future-oriented undertakings with a certain amount of pre-planning, self-awareness and intentional communication that promise better or more just cities and a better urban life through assemblages of policy, technology, buildings, aesthetics and institutions, and also a ethico-moral sense of "something better." (Ege and Moser 2021a, 7–8)

The aim of such projects, therefore, is not only to improve the quality of urban life but "the ethical character and the ethical valence of urban life" (Ege and Moser 2021a, 7). Applying this concept to the development of HC as new sociotechnical systems allows us to analyze what is understood as ethical or moral by designers and developers of such systems rather than normatively evaluating *if* something is moral or ethical (Lambek 2010; cited in Fassin 2012, 6). Thus, ethical projects are formed by the imagination of a "good life."

The STS scholars Sheila Jasanoff and Sang-Hyun Kim introduced the concept "sociotechnical imaginary" to investigate the relationships between technologies, imagined futures, and society by focusing specifically on how these imaginations are normativized and on the materialities which are part of sociotechnical networks (Jasanoff 2015a, 19). In their first definition, they described sociotechnical imaginaries as "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects" (Jasanoff and Kim 2009, 120). While this understanding focuses on the analysis of national imaginaries, which they developed in their work analyzing nuclear power and South Korean and US responses to it in their later book *Dreamscapes of Modernity* (Jasanoff and Kim 2015), they also broaden the concept "to do justice to the myriad ways in which scientific and technological visions enter into the assemblages of materiality, meaning, and morality that constitute robust forms of social life" (Jasanoff 2015a, 4). The revised definition includes, *inter alia*, social movements, organizations, and professional associations that advocate for their sociotechnical imaginaries, which can also stem from individual visionaries and are often taken up and spread by powerful institutions, including the media or lawmakers (Jasanoff 2015a, 4). Sociotechnical imaginaries are, thus, shared visions of futures that are desirable, and which are both demonstrated in public and "institutionally stabilized" (Jasanoff 2015a, 4). Such imaginaries form through shared ideas of and the belief that progress and developments in science and technology can lead to and support desired forms of social organization and ways of life (Jasanoff 2015a, 4). By considering the "normativity of the imagination with the materiality of networks" (Jasanoff 2015a, 19), the concept forms a bridge for my research between an assemblage analysis focusing on the interplay of human and nonhuman actors and their relations, and a moral anthropological approach investigating the understandings of the "good" in and with HC-based CS.

However, following Jasanoff and Kim's thinking, imaginations in the field of HC might not currently have risen to the status of an imaginary but can be better described by the term "vanguard visions," introduced by STS scholar Stephen Hilgartner (2015). As a relatively new concept and phenomenon, HC is still highly flexible, partly unstable, and under constant development and change. That is, a coherent history has yet to be established. Even if the term used, applied, and referenced today by scientists with varied backgrounds in their work and a growing scientific community identifies itself as HC (or HI) researchers, the visions, shared concepts, and ideas can be traced back to a few individual "sociotechnical vanguards." I return to this concept in Chapter 4.

Bringing together the concepts of sociotechnical imaginaries and ethical projects, then, according to Ege and Moser, ethical practice is both a "form of subjection that relates individuals and groups' regimes of living to broader configurations of power and rule" (2021a, 13) and "a form of subjectification or subjectivation, of becoming a type of subject" (2021a, 13; see also Foucault 1983; 1988). The latter refers to the other important consideration in my research: how other human actors involved in HC-based CS relate to these defining and forming suggestions of ethical projects. As an example, how do participants engage in and relate to HC-based CS (see below)? Ethical projects and sociotechnical imaginaries do not occur in a vacuum. Instead, they are materialized and maintained in everyday life through, for example, the practices of infrastructuring (see Chapter 4) or trust (see Chapter 7). In this everyday enactment of human–technology relations and the becoming of HC-based CS assemblages, different actors contribute to the reterritorializing and deterritorializing processes that form the assemblages and, therefore, bring in their own motivations and goals, which do not always align with the ethical projects and imaginaries but potentially contest them.

How participants relate to the HC applications designed and how they engage with technology in HC-based CS systems, thus, how they shape and are shaped by them, can be researched with reference to Foucault's analysis of the subject and subjectification (e.g., 1983; 1988), as well as his considerations on technologies and power (e.g., 1995; 1998). The approaches of the anthropology of ethics (Faubion 2011) and the postphenomenological approach to the ethics of technology by Dorrestijn, which I build upon in my research, are inspired by Foucault. Dorrestijn (2012a; 2012b) brought together the theory of technical mediation described above with ethical subjectification and technology (or technologies in Foucault's thinking) for an ethics of technology. Dorrestijn's approach to "subjectivation and technical mediation" links the analysis of human–technology relations and the moral anthropological perspective outlined above. In what follows, I briefly outline Dorrestijn's approach, which connects back to the postphenomenological understanding of human–technology relations and technical mediation.

By considering humans as hybrids,[50] the theoretical approach to technical mediation, which Verbeek (e.g., 2005) in particular further developed, "undermines the ethical

50 Even though my focus lies on hybrids of humans and technology, humans are hybrids not only in relation to technology but in multiple ways (e.g., Haraway 1991; Star [1991] 2015).

stakes that inspired much of the philosophy of technology" (Dorrestijn 2012b, 226–227). The problem with this, according to Dorrestijn, is that, if there are no autonomous but instead only hybrid subjects entangled with technology mediating our experiences and relations to the world, the question arises: How then can ethics be considered?[51] To solve this problem, Dorrestijn's ethics of technical mediation follows Foucault's thinking, and approaches human–technology relations by focusing on "*caring for the quality of the interactions and fusions with technology*" (2017, 317, emphasis i.o.). This ethical approach to human–technology hybridization allows one to not commit to either a technology pessimistic/dystopian or optimistic/utopian perspective. Dorrestijn's perspective corresponds to moral anthropology in that it does not seek to normatively evaluate the morality of a given situation but, instead, to understand what values people follow, for what reasons, and how (Lambek 2015, 9), as well as how they "cop[e] with the technical conditions of [their] existence" (Dorrestijn 2017, 317).

Dorrestijn's "technical mediation and subjectivation" framework requires bringing together Foucault's early work on (disciplinary) power and later work on the subject:

> While Foucault's earlier work is rightly seen as a dramatic attack on the autonomous subject presupposed in modern ethics, his later work is concerned with developing an alternative ethical framework wherein "the subject" is not eliminated by revealing its external conditions. Foucault begins to understand ethics as the active engagement of people with governing and fashioning their own way of being in relation to conditioning circumstances. An extension of that framework to the problem of technical mediation opens up a new perspective for ethics in relation to technical mediation. (Dorrestijn 2012b, 227)

Through this interpretation of Foucault's work, "the ethics of technology means an ongoing 'problematization', or a 'critical ontology,' of our technically mediated existence. The aim is finding, or forcing, openings to possible transformations of our way of being" (Dorrestijn 2017, 319). Instead of studying subjectivation in regard to sexuality, as Foucault did, Dorrestijn investigates subjectivation in relation to technology:

> The question is then how people perceive and conceptualize the influence of technology on themselves (and others, human beings in general). […] Articulations of the mediating effects of technology are simultaneously ethical problematizations of how one's own mode of existence is affected by technology. (Dorrestijn 2012b, 234)

Dorrestijn's work, therefore, is of particular importance in analyzing how human–technology relations come into being and how intraversions of human–technology relations "contribute to the coming about of new forms of subjectivity" (2017, 318). Ultimately, this understanding allows us to analyze the practices of actors within such relations in order to cope with changing roles and power distributions. Dorrestijn used design and engineering pilots and usability tests as examples regarding where the approach to the ethics of technical mediation can provide interesting insights:

51 Latour's (1992) answer to the question of morality regarding sociotechnical or hybrid human–nonhuman entanglements is that morality is (partly) delegated to nonhumans.

> Tests are normally performed to examine the technical functioning of new products. These moments also offer a privileged possibility to observe technologies in use for the first time. However, from the perspective of subjectivation, it should be stressed that testing must not be seen as a last check moment, which marks the transfer of a product from its design phase to its use phase. Instead, pilots and tests offer the possibility to see how the accommodation of technology by users takes place, in an experimental setting, and with the possibility of making adjustments to the technology. (Dorrestijn 2012b, 237)

In these testing environments, it can be observed how users relate to the technology under examination, how they are "conditioned by their environment [, and] how people transform themselves, [to] become subjects in an environment" (Dorrestijn 2012a, 119). According to Foucault's and Dorrestijn's understandings of ethics, "freedom," then, is precisely such a "'practice' of conducting oneself by actively coping with external power" (Dorrestijn 2012b, 238).

In Chapter 6, I discuss how Stall Catchers participants relate to the introduction of AI bots as new participants on the platform as an example from my research. As I will show, from the perspectives of participants—and not specifically in line with how human–AI bot teams were envisioned by the Stall Catchers team—AI bots become the other (Ihde 1990, 98). In relation to technical mediation, the human is only "knowable and recognizable" (Rhee 2018, 3) in technology. By linking these elements, we can ultimately ask how actors perceive the functioning of technologies and their own role within them. This allows us to examine the values motivating participants, developers, and researchers, to which actors orient themselves in relation to technologies (Dorrestijn 2012b, 221–222). Dorrestijn argues that this can lead to the design of an "ethics of technology," whereby one cares "for the quality of one's hybrid mode of being" (2012b, 234).

In this chapter, I have discussed three different theoretical approaches: assemblage thinking, human–technology relations, and moral anthropological and ethical concepts, which together form the analytical foundation of my research and support the development of the *intraversions* concept. In what follows, I introduce intraversions as a concept, which attends to the evolution of and continuous changes occurring within human–technology relations in HC-based CS systems.

Intraversions in Human–Technology Relations

Once HC-based CS assemblages are formed—despite continuous processes of deterritorialization and reterritorialization changing the assemblage—they also (re)configure their elements and formative relations in everyday life. Human–technology relations in HC-based CS, therefore, also do not converge to any specific pattern that is stable and remains the same. Actors and materialities do not always engage with relations and sociotechnical systems in the same way. For instance, materialities and infrastructures, such as servers, break down from time to time requiring human interventions, the life cycles of mice can diverge from research agendas, and human actors can intentionally act differently by finding new ways to engage with a game interface and software.

In addition, the *raison d'être* of HC systems, as I will show in the chapter on HC's imaginaries (Chapter 4), requires that they remain at the edge of technological/AI capabilities and—in the field of CS—of scientific research. This edge is continually moving given the last mile of automation, which Gray and Suri call the "*gap between what a person can do and what a computer can do*" (2019, xxii, emphasis i.o.).

Therefore, HC system's human–technology relations must remain open for future tweaking and change. This results in additional forces (primarily, but not entirely, coming from HC developers) acting on and changing human–technology relations, specifically the distribution of agency and the role assignments of subjects and objects, tasks, and responsibilities within these relations over time.

Using the concept of *intraversions,* I attempt to describe processual forward movements and shifts within relations between humans and technology. These movements result from the introduction of new computational capabilities or through new potentials arising from existing relations, which form directly from human actors' practices or algorithmic and material affordances. Along these processual forward movements, various forms of reconfigurations occur. These include 1) shifts in the role assignments of subjects and objects—or, more precisely, in the distributed agency across the different actors—, which can never be fully attributed to one side or the other; or 2) redistributions of tasks or practices, which result in reconfigurations of power dynamics. Intraversions can, thus, be understood as oscillations or weighted shifts appearing within these relations and which I chart along both everyday instantaneity and gradual development. I combine these two temporal dimensions in the analysis of evolving human–technology relations in HC-based CS in order to analyze their intraactions beyond specific moments.

Merely focusing on singular moments and situations has been criticized by European ethnologist Jens Wietschorke, who argues against ANT's emergence-theoretical approach:

> Social actors constantly negotiate meanings, and they do so within conflictual networks of relationships. They negotiate their affairs also within the framework of networks involving nonhuman actors and actants, forming chains of action that converge in concrete situations. But that is only one side. The social is not always newly constituted in the moment, but is embedded in discursive formations and structures of history and society that remain indispensable heuristic categories for social and cultural analysis. (Wietschorke 2021, 64)

Following Wietschorke, if the moment forms the sole focus of analysis, it fails to include historical developments and discursive formations forming and acting upon relations in those specific moments (such as through path dependencies leading to certain configurations of humans and nonhumans) even if these forces remain intangible in the moment itself (2021, 57).

As an analytical tool, the concept of intraversions aims to contribute to the digital anthropological and STS analysis of human–technology relations in HC-based CS. Evolving from my analysis of human–technology relations in this field, the concept of intraversions serves as a magnifier of the forward circular movements within relations between humans and technology, combining the theoretical concept of assemblages, and relational and processual approaches to technology described above, alongside the concept of distributed cognition put forth by Hutchins (1995a) discussed below.

Various terms, such as "transformation" or "change" in general, describe movement and development. However, the concept of intraversions differs from these terms in important ways. While the concept of transformation in general describes an unspecific, not necessarily goal-oriented reshaping or transformation of something, intraversions are more specific, capturing forward-pushing transformative processes that take place within relations. I derive the term intraversion primarily from inversion, which describes the reversal of what existed before, creating the exact opposite or turning something upside down. The Latin prefix "intra" (meaning "within") is invoked in reference to how changes and shifts in human–technology relations do not necessarily lead to the exact opposite of what previously existed but instead identifies movements *inside* and *across* relations in which humans and technology become interwoven. Thus, intraversions focus on inner changes, the partly unpredictable emergent oscillations appearing in various dimensions of human–technology relations unfolding within HC systems. The term also draws upon Karen Barad's term "intra-actions" (1996), since it concentrates on relations between human and nonhuman actors, who and which dissolve and are formed through the relations in which they engage. Humans and technology are, therefore, not independent of each other but form within their specific intraactions with one another. Instead of referring to interactions between fixed and independent entities, Barad uses the notion of intraactions to move beyond such dichotomies (1996, 179). Thus, the concept of intraversions also connects to Karen Barad's described asymmetry regarding human and technological agency.

My definition of intraversions can be further specified using five characteristics which I discuss below. These characteristics cannot be completely separated from each other but are discussed individually here for better comprehensibility.

First, intraversions are not static or fixed entities but processes. In these processes, human–technology relations temporarily stabilize. I take inspiration here from Latour and sociologist Steven Woolgar's discussions in *Laboratory Life: The Construction of Scientific Facts* ([1979] 1986). Specifically in their book, Latour and Woolgar focus on how statements stabilize, analyzing how scientific facts are constructed in the everyday activities of scientists in a laboratory. These processes lead to temporarily stabilized relations (such as algorithmic tools assisting humans in folding protein structures or humans assisting computational models in analyzing data). Yet, at the same time, human–technology relations always remain open for future intraversions. Various actors, such as developers and participants in HC-based CS projects, also contribute to this by intentionally pushing for new developments or action potentials. In my own work, I discuss, for example, how participants in Foldit's predecessor Rosetta@Home demanded the possibility to intervene or how Stall Catchers participants explored new ways of engaging with the platform (Chapters 5 and 6). In this sense, intraversions continuously evolve as modifications of existing relations.

Second, intraverting relations reconfigure actors' tasks, practices, forms of engagement, and even subjectivities within sociotechnical systems. This characteristic builds upon Hutchins' observation of the development of distributed cognition,[52] which he made when studying naval navigation (Hutchins 1995a) and airplane cockpits (Hutchins 1995b). Hutchins' work contributes to understanding cognition as well as human–technology relations.[53] In *Cognition in the Wild,* he aims to contextualize cognitive activity within a sociocultural and material world, "where context is not a fixed set of surrounding conditions but a wider dynamic process of which the cognition of an individual is only a part" (Hutchins 1995a, xiii). Distributed cognition resembles assemblage thinking in that it shows how "various elements [are brought] into coordination with each other" (Hutchins 1995a, 123). Hutchins speaks about a "cognitive ecology," where different tools and humans relate to and mutually support each other in different tasks (Hutchins 1995a, 114). Tools here are also understood as mediating technologies (Hutchins 1995a, 154). Hutchins vividly demonstrates, through the example of solving distance–rate–time problems in naval navigation, how a task that needs solving changes depending upon how a problem is presented as well as how the introduction of new tools changes the task for human problem-solvers (1995a, 147–55).[54] This example demonstrates that the

52 Hutchins' goal is to replace both mentalist and behaviorist approaches to cognition using distributed cognition (1995a, 129). In this way, the concept of distributed cognition can also be understood as a critique of the cognitive approach to AI and HC systems, which considers intelligence as information processing. I return to this aspect when discussing HC imaginaries in Chapter 4. Hutchins moves from a "classical cognitive science approach" (1995b, 266), whose research object is an individual human, to an analysis of sociotechnical systems. It should be noted that Hutchins referred to cognitive science at the end of the twentieth century, which might not reflect the state of the art in cognitive science today. Taking cognitive science's guiding metaphor of cognition as computation as the starting point but applying it to sociotechnical systems, he analyzes the representations internal to sociotechnical systems (Hutchins 1995b, 266). "For our purposes, 'computation' will be taken, in a broad sense, to refer to the propagation of representational state across representational media. This definition encompasses what we think of as prototypical computations (such as arithmetic operations), as well as a range of other phenomena which I contend are fundamentally computational but which are not covered by a narrow view of computation" (Hutchins 1995a, 118). While the internal processes of humans remain hidden in observational studies (Hutchins 1995a, 49), based on Hutchins' approach, "internal" can refer not only to tools and technologies but also to human action, for example. To Hutchins' definition, I would add transformation, not only propagation, "of representational state across representational media." Through this understanding of computation, cognition can then be analyzed in the various interactions between humans and nonhumans.

53 This could also be included in the discussion of human–technology relations in the previous section, but here I discuss it separately to directly connect a specific element of Hutchins' theory to intraversions.

54 He depicts different ways of solving such distance–rate–time problems. A task performer, for example, could rely on their algebraic knowledge and pencil and paper or, instead of paper and pencil, a pocket calculator, or they could have either a three-scale nomogram or a nautical slide rule as tools at their disposal. With algebraic knowledge, solving individual arithmetic operations is no problem. However, the difficult part in the first two scenarios is the coordination of these operations with each other. While the calculator makes it easier for the task performers to solve the individual arithmetic operations, coordinating them remains tricky. In the third scenario, the coordination of the operations is already built into the tools and algebraic knowledge is not required: "The nomogram and the slide rule transform the task from one of computational planning (figuring out what to divide by what) to one simple manipulation of external devices" (Hutchins 1995a,

task or problem that a task performer has to solve is presented to them differently, depending on the individual tools, requiring "a different set of cognitive abilities or a different organization of the same set of abilities" (Hutchins 1995a, 154). Through the introduction of new technologies or tools to a cognitive ecology—and solving problems such as the distance–rate–time problem should never be considered separately but always within cognitive ecologies—the tasks themselves change. Based on this understanding, I demonstrate how in HC-based CS, tasks, practices, and subject–object position assignments change within the human–technology relations, such as through the introduction of new automated tools in Foldit or the introduction of AI bots in Stall Catchers. Regarding the relations studied in HC-based CS, these changes result from the introduction of new computational capabilities and through new potentials arising from relations themselves when, for example, participants actively use the timing of a particular moment to their advantage (Mousavi Baygi, Introna, and Hultin 2021), as well as through algorithmic and material affordances. I then demonstrate how, in relation to the data pipeline, participants in HC-based CS games and researchers also adapt to changes in their subject positions (Beck 1997, 292) and how they reposition themselves and relate to technologies (Dorrestijn 2012a) because of intraversions. In fact, the tasks and purposes of the sociotechnical assemblages themselves continue shifting. This understanding connects back to Deleuze and Guattari's understanding of assemblages as "chang[ing] in nature" (2013, 7) with new and spreading connections, as I specifically show through the examples of Foldit and ARTigo in this study.[55]

Third, intraversions refers to how power dynamics, responsibilities, and agency are redistributed across relations through their reconfigurations. Power is not understood here as belonging to one party or actor. Instead, I adopt Foucault's concept of power as something that is distributed. "Power is everywhere," Foucault wrote (1998, 93), in the first volume of *The History of Sexuality*. Power, then, "must be understood in the first instance as the multiplicity of force relations immanent in the sphere in which they operate and which constitute their own organization" (Foucault 1998, 92). Understood as force relations, power is dynamic, not static. Key to this dynamic understanding of power is that it includes resistance (Foucault 1998, 95). Importantly, Foucault describes these power relations as "both intentional and nonsubjective" (1998, 94). Thus, individuals are not mere passive objects of power, but also exercise power.[56] Power relations "are imbued, through and through, with calculation: there is no power that is exercised without a series of aims or objectives" (Foucault 1998, 95). While power is intentional, the outcome of these intentions remains uncertain and depends upon interactions with other

150). The tools, here, both "constrain the organization of action of the task performer" (Hutchins 1995a, 151) and "they are representational media in which the computation is achieved by the propagation of representational state" (Hutchins 1995a, 154). The tools, then, transform the task for the task performer.

55 If assemblages change as a whole and are flexible, uncertain structures are debated and questioned by, for example, Buchanan as a misinterpretation of Deleuze and Guattari (Hansen and Koch 2022, 8). Since I do not strictly follow one interpretation of the assemblage theory but refer to the concept in ways that help me better understand and analyze HC-based CS and human–technology relations, I acknowledge these discussions but do not go into more detail here.

56 See Heller (1996) for more on power and intentionality in Foucault's work.

power relations. While the developer's intention to create teams of humans and AI bots by introducing bots into Stall Catchers without including the participants in all development steps leads to new user–AI bot relations, these can sometimes unfold in unintended ways. In Chapter 6, I demonstrate how participants do not necessarily engage with AI bots as team partners but also as competitors. Along similar lines, agency in intraverting human–technology relations is understood as distributed and continuously redistributed. As discussed above, Bennett (2010) defines agency in way consistent with Foucault's understanding of power as distributed. However, this does not exclude intentionality or "striving that may be exercised by a human within the assemblage" (Bennett 2010, 38). Following these definitions of power and agency, such dynamic changes within human–technology relations can be grasped through the concept of intraversions. Anthropologist Tim Ingold's notions of the weaving and knotting of relations (2007) also come close to delineating these changes, although intraversions describe the circular forward movements and their related oscillations within relations. They are nearly circular because they evolve and are pushed into new, imagined-to-be better relations between humans and technology in HC-based CS systems.

Fourth, and moving on to the next characteristic, intraversions are not only imagined but are also material, situational, and contingent. Referring to the third characteristic, it follows that intraversions are always situated and materialized in specific configurations of humans and technology (Suchman 2007b). At the same time, they are, to a certain degree, contingent and unpredictable due to the multiplicity of relations interacting with one another and due to different actors' intentions. This also extends to "serendipitous discover[ies]" (Schaffer in Human Computation Institute 2018, 00:33) and instant breakdowns in some entities, such as servers.[57] Therefore, new action potentials can emerge from existing human–technology relations. In addition, however, intraversions do not merely occur via the relations' own momentum but are also differently imagined by various actors. In Chapter 4, I focus on how HC advocates and developers imagine HC systems and their user–technology relations in developing HI, and how these imaginations themselves are always emergent and rendered material.[58] Intraversions are, thus, led by both constant attempts at structuring by different actors according to their imaginaries alongside situational and incidental failings—that is, their contingency.

Finally, intraverting relations are multiples. Anthropologist and philosopher Annemarie Mol (2002b) studies how atherosclerosis disease is enacted and practiced in multiple ways and forms in her book *The Body Multiple: Ontology in Medical Practice*. Instead of defining atherosclerosis disease as a singular object, she studies it through multiplicities of practices. Human–technology relations in HC-based CS are similarly enacted through different assembling practices. User–technology relations in Stall Catchers, for example, can be enacted along the lines of the game and HC system design. However, they can also be enacted through new participant engagements, which circumvent the patterns designed. At the same time, such relations can carry various meanings for different actors and from different perspectives (see Chapters 5 and 6).

57 This holds not only for HC-based CS systems but for sociotechnical systems in general.

58 I will also discuss how intraversions of researcher–technology relations are, for example, imagined by researchers with the aim of someday fully automating the data pipeline.

Although intraverting relations are multiples (Mol 2002b), despite their diversity—as Beck pointed out for use possibilities of technology—, they are not arbitrary (Beck 1997, 223). Similarly, intraversions are not arbitrary, and, in analyzing them, attention must be paid to the processes, discursive elements, specific materialities, and contingencies forming them.

To summarize, the concept of intraversions allows us to investigate from within, showing how human–technology relations continually evolve. As a concept and tool, it attends to the continuous development of these relations both along everyday instantaneity and gradual development. This concept facilitates analyses regarding how previous relations and power dynamics shape sociotechnical assemblages and how they form and influence current and future relations. In this way, intraversions as a concept analyzes sociotechnical systems and their human–technology relations across the past, present, and anticipated future. Notably, given the nature of human–technology relations in HC-based CS as always unfinished and open, their intraversions cannot be explored in their entirety—that is, they are always excerpts of continuous motion.

Following the theoretical approaches and conceptualizations of assemblages and human–technology relations discussed in this chapter, I investigate the continuous formation and reformation of HC-based CS assemblages through the intraactions of their various elements. My investigation includes a focus on intraverting human–technology relations guided by the imaginations of how hybrid systems should be built in the future. Bringing these different lines of theoretical thinking together, my discussion and the argument brought to the fore in this chapter demonstrate the usefulness of such a "flexible" (Heimerdinger and Tauschek 2020, 16) engagement with theoretical concepts for analyzing and better understanding HC-based CS systems.