5 Multiple Meanings and Everyday Negotiations: Play/Science Entanglements

From the imagination, design, and infrastructuring of HC systems, I now turn to how HC-based CS systems unfold in everyday life. In this chapter, I will explore how HC assemblages emerge in the everyday practices, the participants' interests and backgrounds, the entanglement of science and play, and how the visions and imaginations of HC themselves are influenced and reconfigured alongside the becoming of HC-based CS projects. Following Beck, I turn to the contingencies of HC-based CS sociotechnical systems as "use complexes" (1997, 350). I discuss how different motivations, interests, aims that drive participants, as well as the software's affordances (Gibson 1979; Bareither 2020a) and action potentials emerging from the human–technology relation relate to and sometimes challenge the systems imagined and designed by developers. I analyze how participants realize the object potentials of Stall Catchers in relation to algorithms (Beck 1997), including the shared meanings and values that constitute appropriate practices and modes of engagement. Here, the interferences (Dippel and Fizek 2017a; 2019) of play and science play an important role and create a productive space. It is within this space, including the object potentials and different motivations, that human–technology relations in HC-based CS unfold and constantly change, since human–technology relations in HC-based CS are always situated and embedded in the sociotechnical assemblages they simultaneously create.

The chapter is structured as follows: to briefly familiarize the reader with the two examples, Stall Catchers and Foldit, two short notes provide introductory snapshots of the examples from the participants' perspective.[1] For a condensed description, I combine the perspectives of different participants in a given project into one. In doing so, I create a fictive, ideal-typical description that is inspired by "ethnographic portraits" (Gutekunst and Rau 2017) and "cultural figures" (Wietschorke and Ege 2023). I then approach the interferences, starting with the observation that, in the case of Stall Catchers, some participants do not even accept the categorization of the CS project they are contributing to as a game

1 ARTigo will be discussed and described in more detail in Chapter 6.

in the first place.[2] I next analyze how participants ascribe meaning to the systems in their own ways and how they are included in the participants' everyday lives, which may not always align with the imagination of the human in the loop described in the previous chapter.[3] Although some participants reject the description of the projects as games, it is precisely the entanglement of science and play that opens up the space for Stall Catchers and Foldit to emerge, in which these adoption and meaning-making processes take place. This space is not without friction but contested due to different understandings and logics of science and play which create tensions that can only be partly resolved and impact the formation of HC-based CS projects. Understanding how play and science interfere is also crucial because it is in this space that human–technology relations unfold and continuously intravert (see Chapter 6). Adoption, meaning-making, and the changing relations depend not only on the intentions, motivations, and values of participants or other human actors but just as much on the materialities and nonhuman entities with which they engage and the coincidental and "timely moments" (Mousavi Baygi, Introna, and Hultin 2021, 431) that can be seized. Furthermore, new potentials for practices are opened up by the assemblage and its relations and their embeddedness in the context of science and play. In the last part of this chapter, I provide and discuss examples of such play practices that go beyond those intended by the system's design.

A Snapshot of Foldit

A rendering of a protein structure and a brief explanation of the project welcomes users to Foldit's website: "Foldit is a revolutionary crowdsourcing computer game enabling you to contribute to scientific research." (Center for Game Science [University of Washington] et al., n.d.a) The "About Foldit" section gives more details on its aim and how it works:

> Foldit is a one-of-a-kind **protein folding computer game** developed by university scientists. By playing Foldit, you can contribute to advanced research on human health, cutting-edge bioengineering, and the inner workings of biology. Foldit is **free to play** and not-for-profit. Discoveries made in the game are published in peer-reviewed research journals, and Foldit players are always credited for their contributions. Every week, Foldit scientists post new puzzles focused on the latest

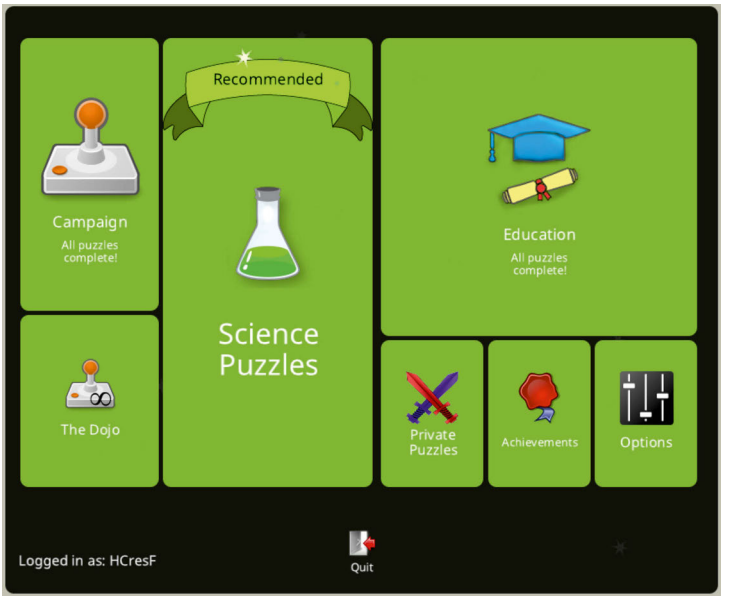
2 This seems to differentiate the example from other games, where in most situations, players or gamers at least initially decided to play a game, and they mostly do so in their leisure time in contrast to their working time—if we exclude professional gaming activities where players make their living from playing and promoting games, for example. The point is that in the majority, it is accepted that something *is* a game.

3 It should be noted that the participants' perspective in this chapter is not shared by all participants but serves as an example of how such systems can be adopted in different ways. In the case of Stall Catchers, for example, even though I focus here on participants who do not call it a game, other participants actively identify as "players" or "gamers," as the following quote from Elisabeth when describing the main idea of Stall Catchers shows: "I'm a gamer … but contributing to a valuable purpose" (May 9, 2020). The arguments are, thus, situated and partial (Haraway 1988).

> problems in protein folding. Read on to learn about ongoing research in **protein design** to treat diseases like influenza and COVID-19, **small molecule design** to invent new drug compounds, and **protein structure solving** to map the molecules that drive biology. (Center for Game Science [University of Washington] et al., n.d.b, emphasis i.o.)

While the first version of Foldit, launched in 2008, focused only on protein structure prediction and design, in 2023, participants can also work on small molecule design and protein structure solving problems. Especially when their gameplay leads to significant discoveries, Foldit participants are actively recognized as scientific contributors by the researchers who use their output. By February 2023, nine scientific papers had been published with Foldit players listed as authors (Cooper, Khatib, et al. 2010; Cooper, Treuille, et al. 2010; Cooper et al. 2011; Foldit Contenders Group et al. 2011; Khatib et al. 2011; Eiben et al. 2012; Khoury et al. 2014; Horowitz et al. 2016; Koepnick et al. 2019).

Figure 3: Foldit overview UI after login



Source: Screenshot taken by LHV on Feb. 2, 2023 (Foldit game)

In order to access and play the game, users must first download and install the software on their computer and create a user account. After logging in (or playing "offline," without an official user account but with limited play experience) and starting the game, the main interface (see Figure 3) appears with different options. New participants can learn how to contribute to Foldit by completing the 34, as of March 2023, tutorial puzzles

in the "Campaign" mode, which introduces different tools and essential aspects of the game.[4]

Once the tutorials have been completed, or once participants feel comfortable enough to start working on the actual "Science Puzzles," they can choose the puzzle they want to contribute to from a list of currently active puzzles of varying difficulty. This list always includes puzzles specifically designed for Foldit beginners and a "Revisiting Puzzle," i.e., a puzzle that has already been solved in Foldit but can be completed again (Foldit Wiki 2019). Additionally, there are different puzzles, such as "Design Puzzles" or "De-Novo Puzzles,"[5] which run for a limited time, usually a week. Participants can earn points and compete by working on these puzzles.

The fictional participants Muhammed and Taylor have been contributing to Foldit daily for the past five years. Before starting a new puzzle, Muhammed carefully reads its description, type, and objective, as his play approach varies depending on the problem type presented. Today, he wants to try out the new design puzzle. After clicking on a new puzzle, the main game interface for the puzzle appears (see Figure 4).

Figure 4: Foldit main game UI

Source: Screenshot taken by LHV on Feb. 21, 2023 (Foldit game)

The initial 3D protein structure is displayed in the center of the screen and can be rotated by clicking and dragging the mouse. At the bottom are several small buttons for different tools. Some are manual tools, such as "cut" or "delete," while others are programmed and perform some automated operations on the protein structure. Examples of the latter are "wiggle" and "shake," which automatically search for better positions of

4 "Education" mode was created for use in the classroom; it includes different introductory puzzles with more biochemical information than the introductory puzzles in "Campaign" mode.

5 De-novo puzzles are characterized by the fact that only the primary structure (the amino acids sequence) is given at the beginning (Foldit Wiki 2017e).

the backbone, the protein's main structural framework,[6] and sidechains[7] (wiggle) or the sidechains only (shake) (Foldit Wiki 2017c; 2017d).

Two leaderboards, one for team-based competition and one for individual participants, are in the top right corner. Muhammed's score for his current puzzle is displayed in the center above the protein structure. In addition, a menu on the left side of the screen contains a help menu and, importantly, the "cookbook." The cookbook includes so-called recipes, which are scripts that automate certain tasks. Muhammed first inspects the protein structure from different angles to find out which structure could meet the puzzle objectives provided[8] before he starts "hand folding" the secondary structure, i.e., making manual changes to the protein structure by, for instance, placing cuts or dragging parts. He decides, for example, how many helices and sheets he can add, and how many segments they should have. He then proceeds by changing the structure provided according to his design choices. Once he likes the shape, he uses the "mutate" tool, which changes the amino acids of mutable segments that are mutable (Foldit Wiki 2017a); this can be followed by another round of rebuilding and correcting sections that did not score[9] well. After that, and if the protein structure seems stable enough to him, he starts using recipes to increase his score and further optimize the protein. In this late game stage, he mostly observes what the automated script does, but sometimes, manual intervention is required to locally optimize a particular section.[10]

While Muhammed prefers to solve puzzles as an individual player, Taylor enjoys playing together with others, which is why he joined a group. They share their designs and approaches, help each other out when they get stuck, and sometimes just chat in the in-game chat while they play. Writing new recipes or improving others' is Taylor's favorite activity in Foldit. Contributions to Foldit can, thus, vary and include folding proteins manually (also called "hand folding"), applying automated scripts, or writing them. Compared to this variability, the "official" task in Stall Catchers is more straightforward.

A Snapshot of Stall Catchers

Visitors of *stallcatchers.com* are first presented with a short video clip introducing Stall Catchers as a CS game (Human Computation Institute 2017). The video shows a child and (presumably) their father sitting on a couch together playing Stall Catchers on a tablet

6 The backbone is the chain of amino acids which is linked together via peptide bonds (Foldit Wiki 2018a).

7 Sidechains are the chemical groups or shapes that are attached to the backbone of the protein (Foldit Wiki 2020a).

8 Objectives are guidelines for folding protein structures in Foldit. If a design generally meets the puzzle objectives provided, participants receive extra points increasing their score (Foldit Wiki 2022).

9 The scoring function in Foldit is based on the Rosetta software for protein modeling and generally indicates how well the protein is folded (Foldit Wiki 2018b).

10 This simplified and general description illustrates how participants engage in Foldit for this research and does not necessarily reflect it in its full complexity. More details on Foldit gameplay and how participants, together with automated tools, solve protein puzzles are provided in Chapter 6.

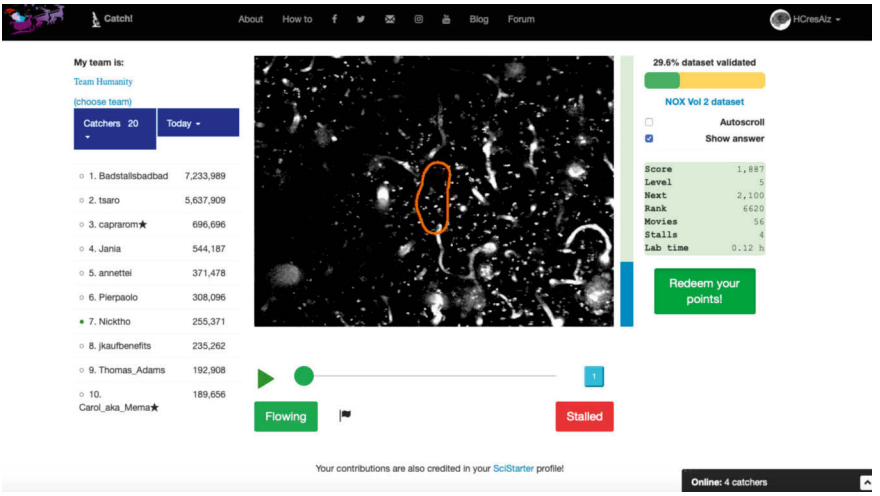
computer, followed by shots of seniors walking and dancing. A voice-over narrates the scene and captions summarize the key points: "We are fighting Alzheimer's, a disease affecting ~44 M people worldwide" (Human Computation Institute 2017, 00:03–00:08) A world map appears with pictures of people all over the world. "Catchers worldwide are analyzing real data, telling apart flowing & stalled vessels in the brains of mice to speed up Alzheimer's research at Cornell University," the caption says (Human Computation Institute 2017, 00:09–00:19). The video shows images of the vascular network of a mouse's brain, mice in a cage, and researchers working in the laboratory. Before viewers are invited to join the Stall Catchers community, the director of the Human Computation Institute, Michelucci explains, "As a global community, we will work together to find a cure for Alzheimer's disease" (Human Computation Institute 2017, 00:20–00:25). An orange "Join now!" button on the right side of the video frame invites visitors to join the ~50,000 "catchers" (as of February 2023) who are already registered with the game. As visitors scroll down the website, they learn more about Alzheimer's disease and how Stall Catchers is helping to speed up research. After registering, participants are directed to the main UI of Stall Catchers. A tutorial guides them through the interface, also called a "virtual microscope" (see Figure 5). Once the tutorial is complete, catching can begin.

The fictional participants Luis and Fiona both contribute regularly to the project. While Fiona often plays on her tablet, Luis prefers his desktop computer. After accessing stallcatchers.com and logging in, Luis immediately jumps into the flow of "catching stalls." The "virtual microscope" includes a video frame in the center of the interface where participants analyze short blood flow videos, resembling a look through a microscope (the research data presented has, in fact, been cleaned and transformed in several steps to make it easier to analyze). Inside the frame, the videos are actually augmented in the form of a small orange circle that indicates the specific area to be annotated. Below the frame is a slider allowing Luis to manually scroll through the video at his own pace. There is also a play/pause button next to the slider and an option to enable autoplay, which lets the video loop indefinitely. However, when using the slider manually, Luis sometimes stops at a specific time point and moves the slider back and forth to examine a dark spot more closely. The vessels, shown as white lines on a black background, move[11] or rather fade in and out of the video frames. To determine whether the vessel is stalled, he must closely follow the white pixels flowing through the encircled area, searching for black pixels that do not appear to be moving, which can indicate "stuck" blood cells and, therefore, a potentially stalled vessel. If he identifies the vessel as stalled, Luis clicks on the red "stalled" button below the slider on the right side. He is then prompted to indicate the exact location of the stall in the circled area by clicking on the position in the video frame. If the vessel is flowing, he clicks the green button below the slider on the left. After submitting his answer, he receives automated feedback. In the case of so-called "calibration movies" that test the participants' skill level, the feedback indicates whether he was right or wrong. In the case of an actual research video of the current dataset, the feedback message asks Luis to redeem points later after a crowd answer has been calculated. Luis pays close attention to the blue bar on the right side of the video frame which indicates

11 The vessels "move" depth-wise, i.e., either toward or away from the screen, rather than off toward any one side of the frame.

his skill level. A horizontal bar in the top right corner indicates the progress of the crowd analysis of the active dataset. Luis is fully focused on the repetitive task of analyzing the short videos lasting several seconds. In doing so, he inadvertently ignores some aspects of the game, such as the leaderboard on the left, with the usernames and scores of the top ten participants or the in-game chat in the bottom right corner.

Figure 5: Stall Catchers' main UI with the "virtual microscope"



Source: Screenshot taken by LHV on Dec. 20, 2019 (https://stallcatchers.com/virtualMicroscope)

Fiona, by contrast, particularly enjoys the company of her fellow participants and loves to chat with them while playing Stall Catchers. She is also eager to climb the leaderboard and compete with others. Therefore, Fiona often participates in special events, such as Catchathons, because they add a little variety to catching stalls every day. For example, if there is a "double points" hour during the night in her time zone, she sets her alarm to get up and collect extra points. Fiona participates in Stall Catchers primarily for fun and to unwind after a long day at work. She also likes the project because she can do something good and valuable in her spare time. Compared to conventional mobile or mini games, such as Candycrush,[12] playing Stall Catchers is still meaningful in that she is helping to advance research while having a good time.

Contributing to Cope With Everyday Life

The two snapshots of Stall Catchers and Foldit, even if they serve primarily as introductory illustrations, show how both systems, intentionally designed as games, invite different modes of contribution, such as focusing on the "task at hand" of folding proteins

12 Candycrush was commonly referred to as a counterfoil to Stall Catchers by participants and team members.

or classifying vessels, or concentrating on the social and competitive game aspects.[13] In the previous chapter, I discussed why these projects were designed as GWAPs in the first place. On the one hand, in the case of Foldit, protein folding in science was thought of as a competitive and game-like endeavor.[14] On the other hand, it was assumed that people would be more motivated to contribute to something that was fun and that they enjoyed. Designed as a "casual game," participants could play Stall Catchers for a few minutes at a time and, thus, using what would otherwise be idle time, such as waiting for the bus or standing in line somewhere, to do something valuable and fun. The representations of users as "gamers" and "people in the workforce" were, therefore, initially "inscribed" in the project's design (Akrich 1995; Fischer, Östlund, and Peine 2020).

When I started interviewing Stall Catchers participants in the Spring of 2020 and asked them about Stall Catchers as a "game," I was initially surprised by reactions such as the following, which I encountered from several participants: "I still don't get the game aspect, I don't even want … I don't, I don't need that, no. That's not got any relationship to why I play it," explained Akin (May 11, 2020). Even though Stall Catchers was designed as a game, some participants rejected this notion. Although to a lesser extent, I noticed similar attitudes in the case of Foldit. For both projects, in written responses to my questions, some participants (Gordon, Jul. 14, 2020; Aram, Feb. 28, 2021; Ada, Mar. 1, 2021) used quotation marks when talking about the "game" or "playing" or emphasized the term when talking about it, adding "the game, if you will" (Alyssa, May 14, 2020; see also David, Mar. 4, 2021 discussed below). Participant Asher explained in our conversation that its design as a game was not a motivating factor for them to contribute to Stall Catchers: "It is technically a game. I don't view it as a game. […] I guess. I'm not doing it for the gaming aspect. [LHV: How would you describe what you're doing?] [I'm] just contributing. Just contributing towards knowledge." (May 20, 2020)

Asher did not "necessarily categorize it in [their] head as a game" (May 20, 2020), and similar to others (i.e., William, May 7, 2020; Elle, May 13, 2020; Noemi, May 14, 2020), the points and scores did not "matter to" (Asher, May 20, 2020) them. Julia mentioned she did not even "understand the point system," and that she had not "really looked into that" (May 11, 2020). So, I was initially surprised that the system's design as a game was not a given for some participants but a contested term. Such statements sparked my interest in understanding how these participants understood their participation, why they contributed, and what meanings they ascribed to Stall Catchers, especially those that did not align with the inscribed meanings and, hence, the visions, values, and norms that the designers and developers implemented in the system's design. In the following, I, first, stay with the example of Stall Catchers to better understand why some participants rejected the classification of the project as a game. To do so, I focus on their personal motivations,

13 In a post on the Stall Catchers forum from September 2020, replying to a new participant's question about the idea of Stall Catchers, Michelucci explained the reason for calling Stall Catchers a game and acknowledged that it was enjoyed by some participants while being ignored by others: "We call it a game because we have added game elements – like a score and leaderboards, and we sometimes run competitive events. Some 'catchers' (Stall Catchers players) really enjoy competing for spots on the leaderboard, and some catchers completely ignore it" (Michelucci 2020).

14 See Chapter 4, footnote 10.

and, in particular, the meaning of Stall Catchers for those who participated because of a personal connection to Alzheimer's disease.

Personal Connections

As discussed in Chapter 2, there is a rich body of literature on participant motivation in CS projects and CS games. Although the literature points to the heterogeneity and dynamic nature of motivations, which also depend on the participants' professional as well as sociocultural and economic background, the most commonly identified reasons include an interest in contributing to "real scientific research or to an important cause such as the environment or health" (Land-Zandstra, van Beusekom, and Koppeschaar 2016, 3), an interest in the research topic of a project, enjoyment, the chance to learn about a particular research area and community, and social reasons, such as connecting with others who share similar interests (Land-Zandstra, van Beusekom, and Koppeschaar 2016, 3). More specifically, research has shown that the primary motivations in CS *games*, although play and fun may be motivating factors, are not in the game itself but rather in the scientific contribution involved in participating (e.g., Curtis 2015; Miller et al. 2019). The results of my research generally confirmed these findings. However, the motivations listed only capture some of the motivations I encountered during my fieldwork on Foldit and Stall Catchers. Specifically for Stall Catchers, more than ten of my interview partners named another key motivating factor: a personal connection to Alzheimer's disease, either because of close friends or family members who suffered or had suffered from the disease or because they were caregivers or feared developing the disease themselves.[15] Even though there may be some selection bias at play, in that participants who chose to share their perspectives in an interview or otherwise contribute to my research, are likely to be among the more active or deeply motivated participants. That is, the participants interviewed are not necessarily a perfectly representative cross-section of the large Stall Catchers participant base. However, written entries in the "dedication" section of the project website indicate that this motivation seems to apply to a significant number of participants in addition to those who actively participated in my research. On the "dedication" page, participants can publicly dedicate their contribution to someone or something (Human Computation Institute, n.d.a). In fact, most of the around 300 entries are dedicated to a close person or family member who was currently suffering from Alzheimer's disease or whom they had lost to the illness or another form of dementia. For those participants and interview partners who have a personal connection to the disease, the motivations and meanings of Stall Catchers go beyond those commonly cited in the literature.

One of my first conversations with Stall Catchers participants was with Elle, who joined Stall Catchers shortly after its launch and was brought to the project because of her father's Alzheimer's disease. She described that,

15 I did not directly ask interview partners about a personal connection to Alzheimer's disease. In the cases mentioned, it was brought up by the participants themselves. It is, therefore, possible that even more of the Stall Catchers participants who contributed to my research have a personal connection to Alzheimer's disease but chose not to share it with me.

> I guess as soon as I heard about it, it gave me a sense of […] it's too late for dad, but […] it might, […] if I can do this and maybe feel a little bit less helpless […], I could perhaps, by participating, I might help […] to find a cure or prevention […] that might prevent other people from suffering […] the way dad has […]. [M]y initial motivation was, here is something practical I can do to help with research. […] Basically, the whole motivation really stems from my personal connection that […] I'm seeing and still living, 'cause my father is still alive and watching him deteriorate and yeah just […] going through what we're going through with his illness and just wanting to help. (Elle, May 13, 2020)

Although Elle was not able to contribute "as much as I wish I could" due to her daily schedule and life being "a bit overwhelming," contributing to Stall Catchers helped her feel "a little bit less helpless" in her everyday life, of which Alzheimer's disease formed a permanent part (May 13, 2020). Similarly, in an interview with the Human Computation Institute published on the institute's blog, Michael Landau, one of Stall Catchers' most active participants, who is deeply invested in promoting Stall Catchers, explained, "I like to play the game because it makes me feel less powerless as I sit and watch my mother's mind slowly being wiped out" (Landau 2018). While contributing to Stall Catchers helped Elle and Michael Landau feel less helpless or powerless, other participants engaged in the project out of fear of one day suffering from the disease themselves after family members had been affected by it. This fear or risk was often shared by the entire family, as in Olav's case:

> On my mom's side of the family, my grandfather and grandmother […] both have—or my grandmother passed away a few years ago, but they both have Alzheimer's. […] [A]nd so […] certainly my mom—because both her parents had it—[…] my mom has never gotten any test to figure out for sure if she has the genetic […] marker that means she's likely to get it but, […] certainly, […] there's that concern. And so, she does everything she can, but obviously, Alzheimer's research […] for those reasons […] is very important to all of us […], and even, I guess, me, frankly 'cause I'm obviously related. (May 21, 2020)

Comparable motivations were shared by some of the participants of Foldit, which addresses Alzheimer's disease amongst other diseases such as cancer or HIV/AIDS (Center for Game Science [University of Washington] et al., n.d.c):

> Like many others, I started playing Foldit while having primary caretaking responsibilities for my parents. One died from Alzheimer's, the second later from Lewy body dementia and Parkinsonism. Even if Foldit is working on different problems at any given time, it helps that there is hope it will address some of the many medical problems at some point. I discovered many "team mates" and Folders from other teams were also providing caretaking for family members. (Ada, Mar. 1, 2021)

During her time caring for her parents, "it was nice" for Ada "to be able to unwind with Foldit around spending time with them" (Mar. 1, 2021). The hope of finding a cure for

dementia to save his mother was the main motivation for David to contribute to Foldit, which he discovered while researching medications.

> [B]ecause my mother had dementia. And then I started looking for medicines, I couldn't find them on the Internet, and then I arrived at Foldit, and I thought it would be a very good idea to participate. To try and find a drug for dementia myself. So, the connection is important […] also intrinsic motivation. (David, Mar. 4, 2021)

Despite the vast differences in design, development, and functionality between Foldit and Stall Catchers, the personal connection to Alzheimer's disease was a primary motivation for participants of both projects.

In his 2008 essay "Play Theory," play theorist Brian Sutton-Smith describes play as a form of protection: "play as we know it is primarily a fortification against the disabilities of life" (2008, 118). He refers to how play goes beyond "life's distresses and boredoms and, in general, allows the individual or the group to substitute their own enjoyable, fun-filled, theatrics for other representations of reality in a tacit attempt to feel that life is worth living" (Sutton-Smith 2008, 118). While Sutton-Smith may not have had GWAPs and CS in mind when writing these lines, and though participants contested the classification of Stall Catchers or Foldit as games, I argue that it is, in fact, *because* the projects move between science and play that they can become so meaningful to participants. Stall Catchers and Foldit can have a "healing function" for participants who contribute because of their personal connection to Alzheimer's disease, corresponding, perhaps explicitly but at least incidentally, to what Sutton-Smith describes for games: "[p]lay was always intended to serve a healing function" (Sutton-Smith 2008, 124). However, the healing function in the examples studied goes beyond the "healing function" that Sutton-Smith ascribes to all games because the fact that Stall Catchers and Foldit address the very disease that affects the participants is crucial to them. This understanding of the healing function goes hand in hand with anthropologist Veena Das' conception of "the everyday as a way of inhabiting the very space of devastation yet again" (2020, 58). Das applies this understanding of the everyday to "think of a politics of the ordinary as a stitching together of action and expression in the work of bringing about a different everyday—I call this the birthing of the eventual everyday from the actual everyday" (2020, 58). Although Das' analysis emerges from her fieldwork in India, where she studied low-income urban families, this understanding can be very informative in analyzing the role of these HC-based CS projects for caregivers or close family members of people with Alzheimer's disease. For Das, the everyday is restored and wounds are healed through and in the everyday itself. What cannot be said, for example, because it is too painful, becomes expressible again in the everyday. Individuals caring for a family member with Alzheimer's disease and who feel powerless over the disease can contribute to research and empower themselves with Stall Catchers.

They also find themselves in an understanding and empathetic "community," as Stall Catchers participant Alyssa explained to me (May 14, 2020). Challenging experiences, such as the loss of a loved one to a disease like Alzheimer's, or the powerlessness others experience in the face of the disease, are part of the everyday. It is precisely the ordinariness of Stall Catchers and Foldit, their situatedness in the everyday, and the possibility to

contribute whenever and for as long as they want that helps participants deal with these challenges and feel less powerless. The games can be easily integrated into daily routines. To quote Stall Catchers participant Akin: "[I]t's always there. It's there at 3 AM, it's there whatever time I have available, it's there" (May 11, 2020).

The projects give participants the feeling that they can do something about Alzheimer's disease while dealing with it. For these participants, unlike others, it is not about contributing to just any scientific study but specifically to Alzheimer's disease research. While it remains unclear if and how their participation in Stall Catchers will lead to a treatment or cure for Alzheimer's disease, the project opens a "horizon"[16] for the participants where their current situation and the state of medicine does not. Stall Catchers, in this sense, can be seen as providing a horizon in the face of a currently incurable and deadly disease in two ways: On the one hand, Stall Catchers introduced a new way of analyzing research data that would not have been possible or feasible otherwise. On the other hand, it can be understood as a form of "horizoning" (Petryna 2022) for participants to cope with everyday life which is marked by a deadly disease. Contributing to HC-based CS is a moral practice with which they participate in the ethical projects. For them, the ethics of the project is not in optimizing HC. It is in fulfilling their perceived responsibility to do something about Alzheimer's disease.

Because of their connection to the disease and the meaning of Stall Catchers as a way of coping with the everyday, the project, like Foldit, is not just fun and not just a game to pass time to them but a serious endeavor.[17] Foldit participant David, therefore, suggested simply calling the project "citizen science" or "gamification of science" because they both contain the word "science:" if the word "is included, then it's already an improvement compared to 'game.' Because by 'game' a lot of people also think of shooting games […] for example, just games you play to kill time" (Mar. 4, 2021). Similarly, long-term Stall Catchers participant Alyssa would prefer for Stall Catchers to be thought of as research, which is how she describes what she does to family and friends:

> I started in […] 2017, and I think by … maybe Spring of 2018 I started calling it "I do research for Cornell University," and that's how I have described it: "I do research for Cornell University," and [people would answer] "Really?! What do you do?" And then I describe the game. The game. And I tell them that it's a game but that in essence, it's doing research for Cornell University for Alzheimer's. (Alyssa, May 14, 2020)

Not only participants with a personal connection to Alzheimer's disease used quotation marks to refer to the projects as "games". When I encountered the use of quotation marks

16 Anthropologist Adriana Petryna (2022) thinks about horizons regarding climate change, where "'horizon work,' allows experts and the public to find other meaningful points of reference from which to imagine how to organize a response to the current crises before we lose the capacity to respond" (2022, 3). Petryna introduces the term "horizoning" as a "conceptual device for thinking about and responding to complex futures" (2022, 5).

17 In her book on VDC, Holohan describes similar reasons for contributing for Folding@Home participants, who are "motivated by the personal helplessness of watching loved ones die of diseases for which the cure is still being sought" (Holohan 2013, 20).

in a written response about Foldit, I asked Aram why he had used quotation marks to refer to the game.

> For me, Foldit is not really a game but a simulation tool. And the players are rather creative researchers than gamers. Many Foldit users don't play for points, but they use Foldit for protein modeling and to implement their own ideas. I think this application goes far beyond a game. In essence, this is why I had put the "". Foldit is more than a game. (Feb. 28, 2021)

For John and Gordon, Stall Catchers was not a game but rather work (John, May 7, 2020; Gordon Jul. 14, 2020). Gordon argued that the "game" is more of a cover for the work previously done by paid scientists, which is why he wanted to be paid for his contribution to Stall Catchers:

> Also, I wish there was some way I could make some money playing the game. I know that it's just supposed to be a volunteer game, but I do think that people put a lot of work into it, and it is really work and not a game, so people should be compensated for their time. Why should people work for free? The researchers don't work for free, so why should the players be expected to work for no pay? It's not a game. It's work made to look like a game, and everyone knows that that's the case, so why pretend otherwise? I'm not saying that it doesn't have value. I fully understand the value of the "game." But I don't think it's fair to call it a game when at some point, I'm sure people were paid money to complete the same task. Just because they have created a facade to make it look like a game, that doesn't mean that it's really a game. (Jul. 14, 2020)

Gordon began contributing to Stall Catchers on a daily basis about six months after it was launched but recently stopped participating because he "got bored with it" (Jul. 14, 2020). Digital media cultures theorist Tiziana Terranova has argued that such forms of "free labor" are inherent to the Internet and the digital economy (2012). While play/work interferences can be considered inherent to games, the relation of CS to or as work, and whether CS participants should be paid for their contributions, have been the subject of scholarly and public debate (e.g., Liboiron 2019; Robinson 2019). However, Gordon's wish to be paid was unique among the examples in my empirical material. This does not mean, of course, that there are no other participants who would appreciate financial compensation, but it was not actively brought up in conversations by participants. For them, in addition to the ethical motivations and coping strategies discussed, it was more important that their contributions were meaningful.

Meaningful Contributions

It was of utmost importance to the participants to feel that their contribution was worthwhile and meaningful. This became particularly apparent in situations where something did not work as needed, such as server outages that made the platform inaccessible, when research data would not load properly, or when the data they were asked to annotate was of poor quality and, therefore, difficult or impossible to interpret correctly. Stall Catch-

ers participant Ellen explained that "if you get the bad quality pictures all the time, you lose interest because it's, you don't feel that you are doing something valuable" (May 19, 2020). She added that "because it's, you just fear that your work is meaningless" (Ellen, May 19, 2020). Kamon shared this perception, since one was forced to simply guess the answer if images were too grainy, "[b]ut that is not so fun […] because, then you end up asking yourself: What am I really going to contribute in this dataset […] if every player makes a guess?" (May 15, 2020). These moments were described as the most frustrating, as the purpose of their participation was not clear to them. It is not unique to HC-based CS games that gamers become frustrated when their game does not work as intended. However, an important difference seems to be that while glitches in other video games are merely disruptive because they interrupt the flow and prevent players from being immersed in the game, in CS, this "immersion" is tied to the perceived real-world purpose.

The understanding of CS games as a way of coping with everyday life can also be applied to other overwhelming situations and experiences in which people feel helpless, such as in the context of the COVID-19 pandemic. Although the meaning of contributing to CS as a form of coping is not necessarily generalizable to all different kinds of CS or individual experiences, comparable forms of engagement in CS projects could be observed during the onset of the COVID-19 pandemic in Spring 2020, when CS projects dedicated to advancing research on the coronavirus or a drug and vaccine against it experienced a considerable increase in participants. In order to better understand this increase, I conducted an exploratory study in which I contacted people via the snowball principle who had started contributing to the Folding@home project (The Folding@Home Consortium (FAHC), n.d.), a distributed computing project for simulating protein dynamics (Vepřek 2020). Participants could contribute to coronavirus research by donating their computing power to the project through downloading and running the software. Six contributors participated in my study by completing a written questionnaire. Here, contributing to such a project was, for instance, described as a way of "doing something" about the crisis. "I felt that I was currently not doing anything to help with the current crisis, and this felt like an easy way to help" (Francis, Mar. 27, 2020), one participant explained in writing. In times of lockdown and social distancing structuring the daily lives of many people not working in jobs of "systemic importance," participating in CS projects such as Folding@Home or Foldit allowed them to feel like they were really "doing something" to contribute to the fight against the pandemic in a meaningful way. Framing contributions to CS as *forms of coping* enriches our understanding of participants' motivations and goals. This perspective goes deeper than the science-focused perspective of doing good or simply enjoying a game. Focusing on the participants' meaning-making processes reveals how they renegotiate and extend the inscriptions and design of the systems.

With regard to GWAPs, participants contribute to science or some form of data analysis and collection "as a side effect of playing the game" (Von Ahn and Dabbish 2008, 60). However, this analysis of the participants' perspectives shows that for many participants it was the other way around. From their point of view, they contributed to science and knowledge production, and the gameplay was the side-effect: "[Y]ou can make games out of it too. But the main thing is to hopefully advance the research," explained long-time Stall Catchers participant Caitlin (May 5, 2020). To Noemi, "it's not important […] to compete except that I do want to contribute, and that's […] my personal goal" (May 14,

2020; see also Jeshua, May 8, 2020; William, May 27, 2020). Based on the analysis of my empirical data, I argue that, in this case, a more suitable description for these *games with a purpose* would be *purpose with a game*. Contributing to "real" science gives participants a sense of purpose, and their understanding of "games" or "playing" refers to a "field" (Bourdieu 1985) of the everyday that does not include seriousness and purpose in this sense. At the same time, the fact that the projects are designed as games is crucial here, as it is the interplay of science and play that forms the basis and opens up the space that allows different forms of meaning-making and adoption.

The "game" is the basis here. It enables participation in scientific research with a low entry threshold and allows participants to actively do something. As Stall Catchers team member Paul aptly describes, "there may or may not be a […] result […] that will help you, but you're still doing something to move things forward in fighting this disease, and [that] just gives people the […] drive to keep going and […] not give up, 'cause otherwise there's nothing else you can do." (Oct. 14, 2020)

The points, the game score, and the leaderboards—even if participants do not participate to compete—help to experience the feeling of progress: "anything that can help measure and feel like there's progress" (Maya, May 13, 2020). In the following, I turn to the specific entanglements of game design and science in HC-based CS, which, as I will show, create object potentials and affordances that open up the possibilities for new relations between participants and software to emerge, and, hence, for intraversions to occur.

A Phenomenon Between Play and Science

Designed as GWAPs, HC-based CS games should, from the designers' perspectives, not only serve the means of the game itself but also contribute to the solution of a particular computational or scientific problem, or to the training of an AI model (Von Ahn and Dabbish 2008, 60). However, as I have shown above with a focus on participants who care about Alzheimer's disease, participants assign varying meanings to their involvement in HC-based CS in their daily lives. Based on these meanings, which can range from a leisure activity to a meaningful contribution to science, work, or even a moral obligation, they position themselves differently. As a result, they stabilize and destabilize the assemblages in different ways.

Game and play theories have long shown that games and play are not merely fields of fun and enjoyment but can involve demanding and complex activities that are more akin to "work," or that games can include repetitive tasks that can make a game tedious and unpleasant at times (*cf.*, e.g., Stevens 1980; Sutton-Smith 2001). There are always interferences between play and work. Terms like "playbour" (Kücklich 2005; Lund 2015) and "laborious play" (2019; *cf.* Abend et al. 2020), along with "playful work" (Abend et al. 2020), have been introduced to describe this phenomenon, emphasizing play "as an act of drawing or blurring boundaries. It is not a given, but an active achievement of all actors involved, including non-human actors like interiors, or hard- and software" (Abend, Fizek, and Wenz 2020, 8). Dippel and Fizek, in their pioneering work on the field of CS, where "science" is an additional pillar in play/work interferences, state that: "[c]itizen sci-

ence games may be perceived as laborious playgrounds, placed between the two poles of *ludus* and *labora*, oscillating between qualities associated previously with leisure or pastime and with productive or useful time" (2019, 256, emphasis i.o.). Playful and productive aspects are interrelated in GWAPs (Turner 1995, 56; *cf.* Abend, Fizek, and Wenz 2020). According to Fizek, the success of CS games lies precisely in "[t]he immediate leverage of a playful and pleasant activity with a socially productive outcome, the element of competition in a large collaborative environment, and the feeling of belonging to a community with a common goal." (Fizek 2016)

My aim is not to further define play, work, and science but to use the terms "play," "science," and "work" as discussed in the field by my research partners. In this sense, the purpose of this work is not to directly contribute to or give a new definition of play, work, or science. Rather, the purpose is to gain a better insight into how different understandings of play, work, and science and their inscriptions in HC-based CS are interwoven and how this opens up the space for intraversions of human–technology relations. In addition, I focus on play and science as the main fields. In the field of HC-based CS, "work" and "science" are blurred. While data analysis had been part of the working routines in the laboratory for which researchers were paid or which were considered part of the study program, it was framed as "citizen science" in the context of the game platform Stall Catchers. Here, from the beginning, participants contributed for reasons other than financial reward (as discussed above). In this sense, contributing to Stall Catchers was not considered "wage labor" or *paid* work even though the task itself was sometimes framed as "work," as I will discuss below. Nevertheless, the overarching reference points in the field were "play" and "science" and, thus, form the focus of my analysis. I consider these terms as tools for the boundary work performed by different actors.

As Sutton-Smith puts it, "[s]omething about the nature of play itself frustrates fixed meaning" (2008, 80). Just as researchers do boundary work by defining what "scientific" knowledge production should look like, understandings of what play is and what it should look like on a digital platform inform the individual perspectives, producing boundaries and resistance. In both examples, Stall Catchers and Foldit, the playful approach was not part of the professional scientist's daily working practices but was delegated to volunteer participants, creating a boundary between the tasks performed by professional scientists in the laboratory and the tasks performed by volunteer participants. Play is, thus, differentiated from professional, scientific practice;[18] the playful approach is understood, or intended, to be incidentally helpful. In Chapter 6, I illustrate this further with the example of biomedical engineering researchers who considered inviting Stall Catchers participants to help with data preparation. The researchers felt that such a contribution to data preparation should not be gamified, unlike the task on the Stall Catchers platform. This was because it would involve the participants in the scientific process of data curation (fieldnote, Oct. 21, 2023).

These entanglements of play and science, and the different expectations, visions, and meanings of various actors, form a productive space that is not frictionless but contested

18 In fact, as shown in Miller et al. (2023), CS games often face the problem that game design is not directly funded by scientific grants, leading to missing resources.

due to different understandings and logics of the fields of science and play, creating tensions that can only be partly resolved, and that affect the everyday formation of their sociotechnical assemblages. The HC-based CS projects, like the intraverting human–technology relations, must, therefore, be considered multiples (Mol 2002b). Referring to Annemarie Mol's research on how atherosclerosis is enacted (2002b), Mol and Law write that "[i]n practice, if a body hangs together, this is not because its coherence precedes the knowledge generated about it but because the various coordination strategies involved succeed in reassembling multiple versions of reality" (2002, 10). Just as a coherent body is the result of different coordination strategies, HC-based CS form a 'coherent' project through the diverse and continuous attempts of all actors involved to assemble the project. These attempts do not always create the desired "seamless space"[19] (Vertesi 2014). Instead, different and divergent modes, logics, and interests converge and coexist in both productive and tense ways. As Mol and Law observe:

> *Often it is not so much a matter of living in a single mode of ordering or of "choosing" between them. Rather it is that we find ourselves at places where these modes join together. Somewhere in the interferences, something crucial happens, for although a single simplification reduces complexity, at the places where different simplifications meet, complexity is created, emerging where various modes of ordering (styles, logics) come together and add up comfortably or in tension, or both.* (2002, 11, emphasis i.o.)

The interferences of play and science are essential to the creation of the HC-based CS assemblage and the participants' experience in the first place, even though some participants may object to calling Stall Catchers or Foldit games. Play and science combine comfortably and in tension at the same time. In what follows, I aim to provide concrete examples of how these play/science interdependencies create the spaces in which participant–technology intraversions unfold. With respect to the mutually supportive or productive science/play entanglements that I turn to first, I focus on the following examples, which mainly, but not exclusively, concern the Stall Catchers project: 1) new approaches to scientific findings with "out-of-the-box thinking" as part of play, 2) making a "boring" analytical task bearable, and using competition and points as motivators and short-term rewards along a lengthy scientific process, and 3) legitimizing play with scientific purpose and making games meaningful.

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19 Sociologist of science and technology Janet Vertesi (2014) borrows the term "seam" from critical studies in Ubiquitous Computing. To approach heterogeneity and complexity, she suggests adopting this vocabulary of seams to "consider the constraining nature of infrastructures at the same time as it observes how actors skillfully produce moments of alignment between and across systems: not fitting distinct pieces together into a stable whole but *producing fleeting moments of alignment suited to particular tasks with materials ready-to-hand*. Rather than moving to the macro view of a meta-infrastructural analysis, [the vocabulary] must hold our focus steady on the micro: actors' observable, reportable activities as they wrestle with many infrastructures' limitations and possibilities to bring them into moments of alignment." (2014, 268, emphasis i.o.) The concept allows one to focus on the (micro)practices and efforts of different actors to align various elements, since "seamlessness cannot be assumed" (Vertesi 2014, 274). Instead, it is continuously created and maintained.

Mutual Supportive Science/Play Entanglements

Out-Of-The-Box Thinking

As a novel mode of biomedical or biochemical practice, for example, CS games open new horizons in knowledge production through the "level of creativity in games" (Dippel 2019b, 248), especially when current technology and established practices fail to meet prior expectations. Their playful encapsulation of scientific problems allows participants without any prior specific domain knowledge "to contribute to […] science through a side door," as Foldit participant David put it in our interview (Mar. 4, 2021). Using the metaphor of a side door, David referred to the fact that CS participants might not rely on established scientific approaches to solve a scientific problem which is presented to them. In the Foldit example, the team saw "out-of-the-box thinking" as particularly promising and could be stimulated in a playful environment:

> [W]hen people are maybe in a playful […] mindset they are more willing to try things that they wouldn't try and look at things creatively and not be as afraid of failure and that kind of thing and so, those would all be good things, I think, for people who are playing Foldit or other citizen science games to try new things, to have fun. Cause in a way, that's kind of […] one of the core motivations for doing things in any case's way is they have to come up with new things that maybe someone who is a biochemist might not have, try out something new. Maybe a little bit unusual, look at a problem in a different way. (Gidon, Jan. 31, 2020)

Games invite creative approaches that can allow CS participants to come up with new ideas that have not yet been tried in the conventional settings of academic or professional biochemistry.[20] Following Dippel, "[t]he old modes of production may still be reflected in the way many games 'work,' and old 'traditions' may still be at work in many video games. However, new worlds, envisioning other ideas of society, are in the making" (2019b, 248). For Foldit participants like Aram, its design as a game necessarily abstracts away the scientific content to a certain extent and allows participants to keep a distance from the serious scientific background:

> I consider the puzzle rather as a separate optimization task. […] Nevertheless, I follow the context (blog, newsletter, etc.) regularly to stay up to date. But I understand many details only to a certain extent since I focus more on the optimization task than on the context. This helps me to keep a certain distance which I consider positive. I also think it's good that Foldit offers this option, because it's not mandatory to have mastered biochemistry to be able to keep up well enough in Foldit. Foldit is abstracted enough for that (by being presented as a game with bonuses, scores, […] which I consider as positive. (Aram, Feb. 28, 2021)

20 It should be stressed that regarding the case studies investigated, this specifically refers to Foldit and not so much to Stall Catchers or ARTigo where the task to be performed by participants is rather straightforward. However, Stall Catchers participants still find creative ways to engage with the platform, as discussed in the subchapter "Adaptations and practices beyond design."

Viewing protein folding as an optimization problem rather than a biochemical one also opens the door to unconventional approaches in current scientific work. This perspective on protein folding was also shared by Foldit researcher José: "[E]ven just thinking about it, when you learn about it in biochemistry class, it kind of feels like a game where you just have to […] find the lowest energy fold" (Jan. 22, 2020). This makes the task in Foldit interesting for participants with various interests, ranging from playing games and solving puzzles in general to computer science, mathematics, or biochemistry. Compared to Foldit, the task in Stall Catchers is more straightforward. This made the science and play entanglements important for other reasons.

Making a "Boring" Task Enjoyable and Keeping the Motivation Up

The interferences of play and science were not only considered to support new creative approaches to scientific problem-solving and out-of-the-box thinking but, especially in the case of Stall Catchers, were essential to making a repetitive task bearable and enjoyable. Participant Ellen explained that the task of

> Stall Catchers itself is tedious. So, it's not really fun but what makes it fun is the way they did it, the way how they [are] getting this rating. Not just the rating is important because it […] keeps you on your toes. [Laughs] So you are not getting lax because […] somebody is catching you if you're not [keeping up]. (May 19, 2020)

It was the game design and the competition[21] that made the task enjoyable in the first place: "I thought they did a really good job of keeping it like a fun, lighthearted competitive energy in the face of a *really* boring job" (Maya, May 13, 2020). To make the task more interesting, the merging of the playful setting with the scientific background of Stall Catchers was crucial. The playful setting creates the conditions for participants to keep going and differentiates Stall Catchers from a mere image analysis task.[22] Participant Maya explained further: "[T]he human nature is you want to, you wanna get the right answer. Like you want to be right and then when you're not right you're like ooch … and they did a good job of not being like '*No! That's wrong!*' [laughs] So I thought they did a very good job of having it be playful." (May 13, 2020)

This sentiment was also expressed by participants who did not see their contributions as play, explaining that they did not care about the points but only focused on the analysis. Olav, who contributed to Stall Catchers mainly to do something about his own risk of developing Alzheimer's disease in the future, explained that "if there was less of a game aspect to it, I think it would be for more people and probably me too, […] a little bit harder to […] stay motivated […]. [B]ut it is kind of fun, and that's what […] continues to bring me back, I think" (May 21, 2020). As a game, Stall Catchers was so engaging that it even risked becoming addictive to Olav: "It's slightly like good games, […] It's a bit […] of a

21 For participant Caitlin, "competition" in Stall Catchers did not refer to plain competing against each other but to a "friendly competition" (May 5, 2020), where it is okay to pass each other on the leaderboard because they are all working toward the same goal of advancing Alzheimer's disease research, as participants reminded each other in the in-game chat.

22 This is not to say that some participants did not take an active interest in the task itself, which was fun and sometimes challenging for them (e.g., Elle, May 13, 2020; Noemi, May 14, 2020).

challenge which you can then become slightly, […] not in a bad way addicted to like, oh, just get one more level. Something like that. Those are what make video games, board games, et cetera, fun" (Olav, May 21, 2020). Being addicted to Stall Catchers, however, is not a bad thing for Olav, as it is still for a good cause. Similarly, Foldit participant David sees addiction as part of any "good game:"

> Part of a good game is also the … in a sense addicting the user to the game. And I think they succeeded with Foldit in this regard because there are often players who say, oh, well I don't need it anymore, I don't do anything anymore. And after a while they come back because they miss it. And I've had that myself sometimes that I thought, okay, I'm having an off-day today and I don't really feel like doing it anymore, so I pull the plug and I don't do it anymore, and then someone comes along with a story about a family member with dementia and I think, yeah, that's why I did it! And the next day I'm back modeling again. (Mar. 4, 2021)

Stall Catchers participant Kamon, who joined the project in 2019, also contributes daily, filling up most of his evenings. With a smile, he admitted in our conversation that Stall Catchers was indeed addictive to him. Sometimes, he said, his partner would remind him of their presence when they felt Kamon was spending more time with Stall Catchers than with them (Kamon, May 15, 2020). "[B]ut I still try to succeed, I'm ranked […], and I still try to keep that […] place. So, if I've gone on vacation for a while and I see I've dropped, I still do a few extra hours to keep that [laughs]" (Kamon, May 15, 2020). The competitive aspect keeps participants coming back to improve or maintain their ranking list position.[23] In the case of Foldit, the daily competition and score also kept long-term participant Lucas motivated to keep contributing, given that the scientific rewards were not common: "The scientific rewards take a very long time to come and they're few and far between. Hearing that we've actually made a contribution to science is a very rare reward and so having a reward that you can go after every time you sit down, I think is important" (Mar. 17, 2022). In addition to their purpose as a short-term reward, points allow participants to contribute without understanding the scientific problem's full complexity or the sociomaterial entanglements behind the projects. In Foldit, some participants focused only on optimizing their game score without knowing, for example, how it was calculated or what biochemical processes were involved in protein design. Similarly, in Stall Catchers, participants do not need to know how crowd answers are calculated, and contributions are evaluated and weighted to contribute. The points they receive for analyzing a video indicate their performance. Hence, the game mechanics play a crucial role in breaking down and hiding the scientific and algorithmic complexity. In fact, any reference to the notion of HC itself was remarkably absent in most of the interviews I conducted with participants.

In the example of Stall Catchers, however, the game features described were mainly seen as the only aspects of Stall Catchers that would make the task playful: "yeah [, it's]

23 An educator who used Stall Catchers in class and contributed to my research declared the scoring aspect and leaderboard to be particularly important for children participating in Stall Catchers as part of their classes (Ren, May 18, 2020).

not very playful unless you look at the score aspect of it and I think that can get people on board and be like 'uh, neat!'," summarized participant John (May 7, 2020).

Caitlin enjoyed "playing my way back up the skill bar. […] [T]he first few times I got up there, of course, I didn't stay there very long and, so when I would make a mistake or two and drop back down on the skill, I much enjoyed that process of climbing my way back up to the top" (Caitlin, May 5, 2020). However, after contributing to Stall Catchers for several years, Caitlin's skill bar was almost always at the top, which is why she did not "really have the fun of climbing my way back up the way I used to" (May 5, 2020).

> I'm always there, right? Yeah, and if I do miss, you don't drop very far cause the longer you're at the top when you eventually do miss, it doesn't drop very much for the first miss. If you miss twice, then it's gonna plummet, but the first time you miss, you merely drop, […] and after a couple of calibrations you're back up at the top again. (Caitlin, May 5, 2020)

While Caitlin and other participants, came up with new play practices that went beyond the coded game features (see below), other participants expressed that they found the game less attractive over time (Gordon, Jul. 14, 2020). Most participants agreed that Stall Catchers was only "medium fun" (Elisabeth, May 9, 2020) compared to other "dumb games" (Elisabeth, May 9, 2020); playing Stall Catchers for a longer period of time exhausts the game's features. Special events, such as the Catchathons mentioned above, were, therefore, essential for keeping participants engaged over a long time and bringing new participants on board. They interrupted the regular game flows and brought the online game into the physical presence (in pre-COVID-19 times) in the form of live meetups in libraries, schools, or even pubs, as explained in a blog post on the institute's website (Egle [Seplute] 2021a). Participants were invited to join the challenge of analyzing as much research data as possible in a given time frame.[24] In particular, the final hours of such events tended to be well attended due to the "double points" that could be earned. In April 2021, I attended the final hour and the related online "hangout" of one such event, where participants could meet the team and complete the challenge together. These meetings would allow participants to pose questions about Stall Catchers and the Alzheimer's disease research behind it. Researchers from the Schaffer–Nishimura Lab often joined the hangouts, as did representatives from the BrightFocus Foundation (BrightFocus Foundation n.d.), one of the longtime funders of Stall Catchers and the CS platform SciStarter (Scistarter.org, n.d.). The hangouts typically ended with the team reading out the challenge's statistics and leaderboards and announcing the winners. The statistics included the number of videos annotated, and how that related to the number of laboratory workdays saved. For example, Michelucci explained in the live hangout on May 1, 2020, that in the *cabinfever challenge*, over the 30-day challenge, 214,000 videos were annotated, of which 156,000 were actual videos from the current dataset, resulting in approximately 205 days of laboratory work (fieldnote, May 1, 2020). Mapping the

24 These time frames spanned from 24 hours, as in the example described in the introduction, or a few days, to an entire month, such as in the case of the "cabinfever challenge" that took place in 2020 during the COVID-19 pandemic (Egle [Seplute] 2020a).

analyzed data back to comparable laboratory time was proof of the scientific purpose and legitimization of the playful contribution. In the interviews with participants, these special events were described as having a "motivating" (Kamon, May 15, 2020) effect on participants. To Ebby, it was motivating that "everybody is catching stalls" (May 8, 2020), and to Elle, special events, "where they're really trying to encourage participation that usually gives [her] a little bit of a kick" to continue participating on a more regular level (May 13, 2020). Some competitions even offered prizes for participation. For a long time, this was Gordon's motivation:

> I started playing Stall Catchers about six months after the program started. I used to play about an hour a day, and then sometimes up to three hours during competitions, but recently, I haven't played it all. I'm kind of embarrassed to admit it, but I got bored with it. It was really difficult for me to stay motivated. They used to have competitions where you could win prizes, and that really kept me motivated. In competitions, I won a trophy, a T-shirt, and a mug. […] Once they stopped giving out prizes, it was very hard for me to stay motivated. […] I need to have some goal to work toward. At one point, I was one of the best players, but just racking up points was not very motivating for me. Also, they allowed the two top players to accumulate so many points that it became absolutely impossible to catch them even if I worked all day and all night, so I realized it would be almost impossible to advance to number one. (Gordon, Jul. 14, 2020)

While points and competition can incentivize players to engage during a specific timeframe, special events also help reinvigorate interest and engagement among participants who might have forgotten about Stall Catchers, inviting them to come back, as in the case of Sophia (Apr. 28, 2020).

As mentioned above, the "double points" hours that occurred during the last hours of the challenges were important to participants (e.g., Elisabeth, May 9, 2020). When bonus points and "hangouts" occurred at the same time, Elisabeth preferred to focus on annotating videos: "Although I was interested in participating in the recent 'live hangout' events, I did not participate because they were held while bonus points were offered. I was motivated more to earn points than to interact" (Elisabeth, May 9, 2020). For some, accumulating points even faster with double points increased their motivation and the perceived value of their research contribution. Stall Catchers participant Alexandra explained:

> During the recent cabinfever challenge I was especially motivated during the double points day on Fridays as I wanted to see how much I could compete against myself in getting the points and number of videos watched up. It made me feel like I was doing something and making a difference when suddenly the numbers went up. I could see the results of watching thousands of videos. I was thinking *wow*. (Alexandra, May 9, 2020)

The importance of double points, challenges, daily scoring, and leaderboard features for the playfulness of Stall Catchers and as motivators for contribution shows how different meanings and understandings of Stall Catchers are interwoven. For some participants,

who rejected Stall Catchers' game design but relied on it for their daily contributions, this led to sometimes conflicting attitudes, as in Daan's example:

> I like the point system in that it gives me an idea of how I'm doing. It does cause me, […] when I get one incorrect where the expert has also reviewed it, and I think it's stalled and the expert says, no, it's flowing. And I look at that and it's like, oh, I just missed all those points. But deep down, it's also […] I didn't get that one right. So, I didn't really contribute that time as well as I should have. […] Whenever I'm doing a job, I try to do the best I can and darn it, I got that wrong. But that sensation doesn't last for too long […]. I don't care about the points, but it is a nice way to keep track of how you're doing. So yeah, I'll look at the points now and then, and I'll laugh, and I'll go, meaning let's put [it as] fun, and I'll just continue trying to amass them, but really, it's did I get this one right? Did I get that one right? And when I'm just participating in adding to the crowd's evaluation of it, I feel like, okay, good. Some of the people agreed with me. Some of them didn't; I'm adding my voice to it. Overall, when you put all of us together, we'll nail it. One way or another, we'll get it right. (Daan, May 26, 2020)

Even though Daan did not actively care about the points, they allowed him to understand "how [he was] doing" in terms of the goal of contributing to the scientific purpose of the project, and he experienced disappointment when he missed them. However, what really mattered to Daan was not the points he missed but that he did not "contribute […] as well as I should have" (Daan, May 26, 2020). Together, the aspects described create a playful experience of a serious situation, as Stall Catchers advocate and founder of the Memory Café Directory[25] initiative Dave Wiederrich put it in a blog post on the project: "Make no mistake. Calling this a game IS NOT trivializing the important work taking place inside this 'game' wrapper" (2019). Participants used the gamification elements to motivate themselves to engage in ethical practices and to position themselves as ethical subjects.

Legitimizing Play

At the same time, the scientific background and "real-world" impact of Stall Catchers are just as important as the game features in motivating participants to continue playing. In addition to the personal motivations described above that ascribe meaning to the project, participants need to know that they are contributing to "real" science, that the data is "real," and that the results could have a "real-world" impact. Learning about the developments in the science behind Stall Catchers is a key motivator for Elisabeth, who has been participating in Stall Catchers since 2016: "It is important to me because feedback continues to fuel my purpose and motivation to participate. The game administrators do a good job providing this information via ongoing website updates" (May 9, 2020). This perspective is shared by many other Stall Catchers participants who contributed to my research. In the example of Foldit, for some participants like James, the

25 Memory Café Directory is a platform that provides resources for individuals with Alzheimer's disease or dementias and their caregivers but primarily informs about "memory cafés," spaces to meet, share information, and learn about resources for support (Memory Cafe Directory n.d.).

scientific purpose of the game also helps to legitimize their play and the time they spend playing:

> It is usual to have a rationale because in my family […] they have the impression that I am crazy about this game, I'm busy with it every day. And I then need to have a reason, and I say, "Yes, but it is still useful!" Right? So, for example, now I say to everyone "Yes we are working on the coronavirus." […] But it is usually to justify that […] we do it because we enjoy it and then you have to justify it to others because it's a game […]. Usually the kids, they are grown up now but they say "Come on, you're occupied with the video and we were not allowed more than an hour […]." So, they laugh, and I say, "Yes, but it's useful." (Feb. 11, 2021)

Contributing to Foldit is useful and valuable because of its scientific purpose, which distinguishes the project from other games and social networks. Participants also described gaining recognition from their families and friends for their contributions to and successes with Foldit and Stall Catchers. Alyssa described her "friends and family cheering [her] on" when contributing to Stall Catchers (May 14, 2020). For David, co-authoring Foldit-related publications was rewarding and an important recognition, which he also used as proof to show that he was doing something "meaningful" when contributing to Foldit:

> [T]he family is really proud that I contributed to that and that we published those papers, that is an important reward for me, that it is recognized somehow, that there is a result and I also like it when my name is on the paper, like, okay, here is proof, I can also use it for my work, that I am doing something meaningful. Other than saying, you're playing games. (David, Mar. 4, 2021)

The scientific purpose is essential to enjoyable gameplay, making it meaningful. At the same time, it serves to legitimize participant's hours of play in front of their friends and family.

Play/Science Frictions

Despite the productive power of the play/science entanglements to create a space in which Stall Catchers and Foldit thrive, it is not an uncontested and frictionless space. Rather, different tensions emerge between play and science, which the actors involved have to deal with, try to work around, or accept. In the following, I will discuss five examples of such tensions between play and science, which were recurrent in the empirical material. While some apply to CS in general, others are specific to HC-based CS games, which help to better understand how these systems form in everyday life. These tensions can be observed at different levels, from the source code level to the discursive level. The examples are: 1) the "balancing act" between software design for scientific accuracy and efficiency versus games, 2) the goals of science versus the goals of games, 3) the uncertainty of science versus the rigidity of games, 4) the hierarchies between play and science, and 5) the different meanings of "success" for science and games.

A "Balancing Act"

At the level of the software, i.e., the source code, of Stall Catchers, the tension between play and science unfolds indirectly as a question or "balancing act," as Michelucci described it in one of our meetings in October 2022 (fieldnote Oct. 12, 2022), of optimizing for efficiency of the analysis vs. optimizing for playfulness. This balancing act needs to be reevaluated and sometimes enacted, for example, when algorithmic changes need to be made to improve system performance for an upcoming Catchathon, as in April 2021. Although, organizationally, it was routine for the Human Computation Institute to organize special events in the form of Catchathons, from the technical side, extra testing—particularly performance testing of the platform—had to be done to ensure a smooth event (see also Thanner and Vepřek 2023). The institute expected a large number of participants in the Catchathon and wanted to ensure that the platform could handle this large crowd annotating data simultaneously. Contributing to these testing efforts as part of my collaboration with the Human Computation Institute during this period allowed me to go beyond my focused code analysis and gain insight into the "balancing act" between play, scientific quality, and efficiency at the software level.

Designed as a game, Stall Catchers was implemented in a way that made the experience enjoyable for participants. This implied that the implementation would not prioritize optimizing the efficiency of the data analysis process over optimizations that made the overall system more satisfying for participants. To illustrate this, it is instructive to consider a simplified process of how data analysis in Stall Catchers could be implemented most efficiently in terms of the individual steps that need to be performed. For example, if a dataset consisted of 500 videos, they could be organized into a simple task queue from which one video at a time could be selected and presented to a participant. Once the participant has annotated the video, it could be removed from the queue so that it shrinks until no video remains to be analyzed. At that point the system's intended annotation task would be complete. This would also mean that the game would end for the participant(s) at that point, at least until a new set of data is uploaded. A cascade of many such queues could be used to gather multiple annotations for each video. However, even then, not every participant would be required to annotate every video, since only a certain number of answers are needed to calculate the final crowd answer per video.

Even though this process would meet the main requirements of Stall Catchers' core data analysis, avoid redundancies, and be relatively easy to implement, the actual data analysis process followed in Stall Catchers is implemented quite differently. This is largely because Stall Catchers participants are not supposed to experience periods where there are no videos to analyze, for example, because all the videos in the current dataset have been annotated. Instead, once a participant has answered all research videos, the video selection algorithm begins to randomly reselect videos from the current dataset. Accordingly, some videos are analyzed more often than necessary to calculate the crowd answer. The purpose of this is not analytical but to keep participants engaged and the game going. Interestingly, and although not addressed by the Human Computation Institute's team, this example of keeping participants engaged seems to be in tension with the institute's normative principle or Hippocratic oath described in the last chapter. According to this principle, humans should not be involved in a task if not necessary. But they also need to be kept busy.

However, a progress bar on the right side and at the top of the video frame indicated the actual progress of the analysis of the current dataset, so when the analysis was officially complete, participants often began asking for new data via the Stall Catchers chat. Annotating videos after the science was complete was considered less meaningful by participants. Participant Akin described these times of waiting for new datasets to arrive as annoying:

> [Whenever the participants are] all way through with this [data]set, you gonna have to wait a while to get another set loaded up, I felt a curious sense of loss [laughs] […] and yeah a down feeling that then began feeling a little aggravated as I checked back a couple of more times and still no Stall Catchers, just a minor prickle of annoyance, but then it came back so. (May 11, 2020)

Another example of the trade-offs at the source code level that I observed was the routine for selecting the next video to be presented to a participant, along with the possibility for the participant to redeem points. The corresponding algorithm for selecting the next videos was quite complex, mainly due to its game-related features and the aim of allowing researchers to get an early look at the data trend. It had to consider, for example, how many other participants had already annotated a research video in order to generate crowd answers for individual videos in a more data-efficient manner, i.e., to avoid collecting redundant answers. The earlier crowd answers existed for videos; the earlier researchers could observe whether there was a trend toward more or fewer stalls in the data before the dataset was fully analyzed (fieldnote Oct. 12, 2022). However, they had also implemented the "redeem points" feature. Participants received a reduced number of points at the time of submitting an answer for annotating a research video, i.e., a video for which an expert answer did not yet exist. They were prompted with an automated message to "redeem later!" Once enough participants had annotated the same video, a crowd answer could be calculated. At this point, the "Redeem your points" button turned green for all participants who had annotated that particular video, allowing them to receive the actual amount of points the system allocated to them for the annotated video (the specific amount depended on whether or not their answer matched the other participants' answers). Depending on how many participants were actively analyzing data during a certain period of time, the crowd answers could sometimes be calculated within a few seconds. However, as Michelucci explained, the points redemption mechanisms were slowed down by design to increase the amount of time people spent playing Stall Catchers. If it took about half an hour to redeem, he argued, participants might be more motivated to keep playing until they could redeem their points (Michelucci, fieldnote Oct. 12, 2022). Michelucci described how they tried to be transparent about this game mechanic to the participants. At the same time, however, it was important to prioritize videos with a few annotations to give researchers an early glimpse of the data trend. These two requirements conflicted, necessitating a balancing act. As a result, the complexity of the algorithm for selecting the next video increased to accommodate the ensuing requirements and to implement a "happy medium" between "depth-first and breadth-first" searches over the dataset (Michelucci, fieldnote Oct. 12, 2022). Together, these constraints resulted in a longer runtime of the required database queries

due to lower efficiency at the algorithmic level. This reduced performance was not necessarily noticeable to individual participants but could become a problem at scale, i.e., if too many participants requested new videos at the same time.

Finally, to ensure that the data quality met the scientific requirements, the crowd answer calculation took into account the individual skill level of each participant in order to weight their answers in the calculation of the crowd answers to which they contributed. As I describe in Chapter 6, the participant's skill level was continuously evaluated with so-called "calibration movies" for which the correct answer was already known. These videos were regularly included and presented to participants between research videos, with the frequency also depending on the individual skill level of the participant. The lower a participant's computed skill level, the more often they had to answer calibration videos, with the side effect of slowing down the main analysis of the current research dataset for scientific data quality. As noted above, these source code and algorithmic/system design trade-offs did not necessarily result in a worse game experience. However, they show how different requirements of play and science influence the implementation of HC-based CS projects and demand continuous balancing acts.[26] Finally, although transparency about these implementation considerations was considered important by the team, trade-offs regarding transparency about the game mechanics and crowd-answer calculations were necessary *because* Stall Catchers was designed as a game.

Goals of Science versus Goals of Game

> The way the score is set up, it encourages you to try to get every little fraction of a point that you can to get higher on the leaderboards. Whereas in practice it's better for us [the researchers behind Foldit] to just have the general shape that you can come up with and then we can optimize it on our own later. We can run those computations so the players are kind of, I wouldn't say wasting time, but they are putting a lot of time into what they call the late game, right? They are putting a lot of time into that refinement process, whereas we are more interested in the early and mid-game of them just coming up with the general shape and trying out a lot of different solutions. (Daniel, Jan. 24, 2020)

As this quote by Foldit team member Daniel illustrates, similar to Stall Catchers, the goals of the scientific research behind Foldit are not perfectly aligned with the goals of the game's mechanics. While Foldit's scoring function motivates participants to collect as many points as possible and optimize their specific protein designs to maximize the score, the scientists working with the resulting protein designs are more interested in the "general shape" and discovering a wider variety of approaches to protein design. Many of the participants I spoke with, especially frequent players like James, were well aware of this fact:

> I [know about] it, but […] we're still competitors so …. we like the competition too […]. [W]e remain in competition and also a motivation for many of us. It's being at the top, staying at the top also. That's why you're still playing and always playing because

26 Similar balancing acts could be observed regarding the data distribution of stalled and flowing vessels on the Stall Catchers platform.

> when you stop playing for a month, you're out again. It's a kind of [a] reputation to keep or something like that. But yes, and we also know that the last three days [of a puzzle] maybe are no longer useful for science, but we do that just to be the first, to be well placed […] They [the Foldit team] have tried systems […] to force us, to make some designs. But that attempt didn't work out well. (Feb. 11, 2021)

The tension between the game's scoring and its underlying scientific value was well-known. Nevertheless, the game mechanics' affordances and their own scores remained important motivators for participants. Similarly, the design and implementation of Stall Catchers as a game affords different practices—such as the accumulation of points—than, for example, "dry" analysis tasks or experiments, where playful practices such as tinkering or even modding[27] would not be afforded in the same way.

During the period in 2020 when I interviewed the Foldit developers, they were trying to find a new approach to the game's design that would be less in conflict with the scientific value of the contributions. Team member Daniel explained:

> [T]he game doesn't do a lot to motivate playfulness. In fact, sometimes the game mechanics we have in place work against playfulness. For example, we have a score system to motivate players to try to get the best score and that is still the best way that we have of telling players "this is good, this is bad," because that score is derived from actual like chemical energy formulas. So, this score is a measure of how likely is it that it would actually fold this way in nature. With the caveat that sometimes that's not true. There are certain edge cases where you can be getting a higher score, and your shape is just unrealistic for nature. And so, when the scientists are looking at player's solutions, they will glance at it and even if it's a good score they might throw it out if it is unrealistic. And so, one thing that we're doing is trying to find ways to adjust the score function to make sure that we are meeting those edge cases. (Jan. 24, 2020)

Their concerns about the scoring system related not only to the fact that the late-game score did not always accurately reflect the scientific value of a solution but also to the difference in gameplay when participants focused primarily on scoring. Such a focus negatively impacted players' "playfulness," i.e., the degree to which they would "play […] around" (Daniel, Jan. 24, 2020) with the protein structures, as participants would think less creatively. But this out-of-the-box thinking, which bypasses the "deterministic" (Charlotte, Feb. 5, 2020) approach of computational solutions and established scientific approaches, was seen by the team as the greatest value of human contributions to Foldit: "Foldit players are very good at exploring outside of the box and exploring ideas that we wouldn't probably think about" (José, Jan. 22, 2020). According to long-time participant

27 Practices of modifying computer games are also termed "modding" and are generally considered "an important part of gaming culture as well as an increasingly important source of value for the games industry" (Kücklich 2005). On different practices common in gameplay that go beyond the game practices intended by design, see Carlson and Corliss (2007). I return to such practices in the examples studied below.

David, when players focus on scoring, their creativity is directed toward accumulating points rather than finding novel solutions:

> And I think the disadvantage of playing for points is that people become very creative to increase their score by consulting sources where there is an example. There are examples of this, even in puzzle comments where people say: Oh, but in PDB [Protein Data Bank] you can see that model and you can download it and […] then you have all those distances and then you can put all those distances, you can put in the length of bands, and you can put that in a script and then you have a very good copy of the original and then you have scored high on the puzzle but that, it completely ignores the point of Foldit. (Mar. 3, 2021)

David lamented that some participants, instead of using their own creativity to come up with a protein structure, would visit the Protein Data Bank (Worldwide Protein Data Bank (wwPDB), n.d.), a database that contains 3D structural data of proteins, and copy characteristics of protein structures into Foldit to get a high score.

The goals of Foldit and Stall Catchers go beyond the objectives of their 'games' and sometimes even conflict with them. However, the games also afford practices that undermine the idea of the overall projects, practices that could be understood in terms of conventional gaming as either skillful play or perhaps even cheating. In the example of Stall Catchers, some participants adapted their behavior according to the temporal flows of the game's algorithms to maximize their rewards at maximum speed (see below). These practices challenge the possibilities of the system that are typical of gameplay and become possible in the intra-actions between participants and software, but they do not necessarily align with the designed or intended play-flows of the game. When the Stall Catchers team became aware of such new practices, their first reaction was to evaluate how these play behaviors affected the scientific accuracy and data quality to determine if such behaviors could harm the system's purpose. If the practice was found not to impact the science negatively, it was accepted and sometimes even supported by the team, as it would speed up data analysis.

Similarly, Foldit participants tried to maximize their score in accordance with the scoring algorithms in ways that were not always helpful to the scientific problem. Here, as team member Daniel described in our interview, the developers and designers tried to respond to this practice by limiting the player's options and improving the scientific precision of the software (Jan. 24, 2020). However, there remains a gap between the software's understanding of proteins, and what proteins look like in the "real lab," as put in one of the monthly Foldit newsletters (Dev Josh 2021b). In the weekly Foldit newsletter of August 27, 2021, for example, Foldit's game designer explained that while "Foldit likes it when the strands on the edges of your sheets are blue hydrophilics […] [,] in the real lab, those edges are too floppy without some sticky oranges to pull the edges into the core of the protein" (Dev Josh 2021b).

These examples show how the goals of the game can diverge from the scientific goals, requiring additional effort from the HC-based CS teams to ensure that the scientific goals of the games are met.

Uncertainty and Unpredictability of Science versus the Rigidity of Game

Scientific processes in (biomedical) laboratories are characterized by uncertainty, unpredictability, and contingencies at various levels, from the results of experiments to failing materialities, and the life cycles of mice. Sometimes, experiments do not go as planned and must be repeated, and things often fail. This understanding of science is widely shared, not only by STS researchers (Law and Lin 2020, 1) but also by the biomedical researchers in the laboratory: "[b]ecause it is science, you […] don't just expect it works [the] first time" (Jada, Oct. 27, 2021). In the laboratory, research was practiced around and with uncertainties and failures. The Human Computation Institute also communicated this uncertainty to participants, such as in the example of a "dreamathon" event (for another CS game run by the Institute), where the director reminded participants in a blog post about the dreamathon's results:

> Before we dig into our initial findings, let me start with the usual reminder that all research is uncertain! At this point we are just taking an initial look at how much your labels agree with the experts on the training images (the ones where you got a "correct" or "incorrect" answer). So while you read the below, please keep in mind that these results are not final, they are based only on the training images and can actually change substantially after we look at the entire dataset. (Michelucci 2019c)

Despite these efforts to communicate the uncertainty of science and to manage expectations accordingly, laboratory members described at least some degree of conflict or "disconnect" between Stall Catchers and the laboratory's research. This was primarily due to the need for Stall Catchers to be "functioning" at all times, which was perceived to be in contrast to scientific work:

> [I]t doesn't go very smoothly at times. […] Like research in general. Yeah, I think that's also part of it. […] cause in research in general, […] things fail […] more often than they work. […] So, I think when you try to put something more rigid on top of research, like Stall Catchers—it's not rigid, but it's something that's established, functioning, working really well. And then you have it trying to support it with research, which is like, oh [laughs], so it kind of there's … I don't know if it's a disconnect or different expectations. I think it's similar to like in the corporate world, things kind of tend to run more smoothly than in research where you're trying things that are probably not going to work. And you will constantly run into problems. So then when you're trying to build a program or a game of something that's constantly running into problems […], it's hard for it to run as smoothly as you'd hope. (Leander, Sept. 22, 2021)

When there were no technical problems, Stall Catchers was always available, usable, and accessible, and, as mentioned above, there was always data to analyze, even if it was only an already-completed dataset. From Leander's perspective, this contrasted with the scientific research behind it, which was subject to different "expectations" and "constantly running into problems." The different temporalities of scientific research, which does not unfold in a steady or predictable rhythm, did not always align with the temporalities of the game, which is expected to function in a predictable and stable way at all times. But these temporalities were also interdependent, since long gaps in which no new datasets

were available would cause some participants to lose interest in analyzing videos, or even to contribute on a smaller basis. The frustration of data gaps was also shared by team member Paul from the Human Computation Institute, who expressed: "[F]or me and for the users, it's really important that they don't waste their time so there's constant flow of data, but the scientists, they have their own stuff going on, and things get delayed and they start too late and then there used to be really huge data gaps, and that was really frustrating" (Oct. 14, 2020).

On December 16, 2020, Michelucci sent a message on an internal Slack channel, addressing an ongoing data gap within Stall Catchers: "most of our active catchers have dropped off because we completed the last dataset, and seem to be checking daily to see when the new data arrives." Data gaps changed the game's flow and temporalities. At the same time, some laboratory members, such as Leander (Sept. 22, 2021), found the requests for new data from Stall Catchers to be stressful. This was because they had to shift their focus to preparing new data for Stall Catchers, regardless of whether there was an immediate need for analysis.The laboratory's PI Schaffer described this as "an unanticipated thing for us" (Dec. 07, 2021). Stall Catchers had not always been faster in analyzing data than the laboratory could provide. In contrast, Schaffer, explained,

> early on when we first started Stall Catchers up and going, we were desperate for more throughput from Stall Catchers because we were generating data and had this huge backlog. We were generating data at a faster rate than they could analyze and had a huge backlog of data. But as the number of players has grown and as Pietro [Michelucci] has developed more sophisticated methods of agglomerating answers, the capacity has grown quite a bit. (Schaffer, Dec. 07, 2021)

When the dynamic reversed from the laboratory waiting for their data to be analyzed to Stall Catchers being too fast for the laboratory to keep up with data provision, "the cart was in front of the horse." (Schaffer, Dec. 07, 2021)

> [T]here was some sense in the lab of […] like it's our job to get data to Stall Catchers. And I never thought about it like that. And we're honest, we would tell people […] there isn't new data to analyze right now. So, the game is just not going right now, and Pietro [Michelucci] was always much more concerned about that. I think from a player management or participant management kind of perspective […]. I didn't mind there being a little bit of a tension there, but I did want to shift the perspective of the lab to Stall Catchers as a very valuable tool that we use. And we treat it with respect, just like we do every other tool. But it's not like this thing that we have to feed with data. And I think we're over that now. (Schaffer, Dec. 07, 2021)

Although, according to the PI, this period had already passed by the time of our interview in late 2021, some laboratory members still expressed the pressure they experienced in my interviews with them. It becomes clear from the quote above that the laboratory and the Human Computation Institute sometimes had different priorities. For the biomedical laboratory, Stall Catchers was a "tool" for their research and not the primary focus of their efforts. In analyzing the researchers' perspective, I noticed a hierarchy between the

work Stall Catchers does and the work done in the laboratory, which I will elaborate on below.

Another expectation that some researchers found stressful and felt was directed toward them was the pressure to continually generate new research questions for each dataset submitted to Stall Catchers for analysis. According to researcher Jada, this was particularly experienced at the beginning of the collaboration with Stall Catchers:

> And at that time, the pressure was also up for everyone much more that kind of each dataset would have—it's still a little bit the case, which I don't like, but I do understand that sometimes it feels like each dataset has to be kind of a new question that we are answering in a way, but this is typically not how science works. It's typically, you run the same thing again and again […] and change something and see what turns out to be the best, and that was a little bit frustrating at the beginning because you need to get players on the one hand, you need to keep them going. So, you kind of make those questions, but in reality, what you need is running the same data several times with different parameters. (Jada, Oct. 27, 2021)

To motivate participants to continue contributing to Stall Catchers and to attract new participants, Jada felt a pressure to deviate from the way "science works," which requires running experiments repeatedly with small, controlled changes in their design. It was impossible to predict when a research question would be answered and how many experiments and changes in experimental conditions would be needed to arrive at an answer. For Jada, however, the CS game context required predictable processes and progress that were at odds with their scientific practice.

Hierarchies Between Play and Science

> Because we are all members of more than one community of practice and thus of many networks, at the moment of action we draw together repertoires mixed from different worlds. Among other things, we create metaphors—bridges between those different worlds. Power is about *whose* metaphor brings worlds together, and holds them there. (Star [1991] 2015, 284, emphasis i.o.)

In both case studies, I could observe a clear hierarchy between what was considered "play" and "science." This hierarchy was introduced and represented by different actors. It is, for example, generally inscribed in the funding logic of scientific research that endeavors related to game design or improving the play-related user experience are not typically considered legitimate uses of grant money, which poses challenges for online CS game designers and developers (Miller et al. 2023). In the words of Foldit team member José during our interview:

> One of the other challenges is that our financial resources are driven by academic grants. So, we don't have money to make cool new backgrounds or add a story or something like that if we can't justify it with a scientific paper. So, everything that we work on in the game has to be directly connected to some scientific advance, which makes my job very hard because that basically cuts out all of our budget for game design. There isn't a budget for making the game feel better, making the UI nicer. Because that isn't some scientific advance. (Jan. 24, 2020)

Good game design and an enjoyable player experience are important for the success of any online game, including online CS games, which presents developers with a difficult problem to solve. However, the Foldit team also exercised control over which scientific tasks could be delegated to nonprofessional volunteers and which required professional training and expertise and, thus, could not be handed over to volunteer participants. Sometimes, they were approached by motivated participants wanting to help improve the design or fix bugs, specifically to help make up for the missing resources due to the funding problems described above. However, when team member Hugo told me about such offers in our conversation, he argued that even though they appreciated "those calls" (Jan. 28, 2020),

> [w]e can't always take people up on it from a perspective of security and knowing how to conduct research and all those things. We have to make sure that we only parcel out certain parts of the game to players in those contexts where the player volunteers. I don't even know within the player community if it's known that other players […] do this sort of thing and […] when I say other players, I think we had a few volunteers, we only ever had one person actually doing anything after some very stringent screening. But I know we continue to get on and off those sorts of volunteers. (Hugo, Jan. 28, 2020)

The tasks to be performed by untrained participants were carefully selected and distinguished from other scientific practices that required training, specialized knowledge, or even security measures (see Chapter 6).

The hierarchy between science and play in Stall Catchers manifested in the game design and in the diverging temporalities. The top priority for the biomedical researchers with respect to Stall Catchers participants was simply that the scientific requirements be met to the same degree and standard as their previously established research process. Therefore, the goals of improving player experience and ensuring accuracy in scientific research were not always aligned. For example, the Human Computation Institute and the laboratory initially had the idea of letting Stall Catchers participants "see their progress if they finished a mouse or something like that. We talked about that [it] would have been really cool if you could see, OK, mouse, Fred and […] Molly, and then we finish those things" (Nishimura, Dec. 7, 2021). This game feature, however, could potentially interfere with the scientific requirement of a "blinded" analysis in which participants would not know which mouse certain data belonged to. The PIs were concerned that "people would figure out that there was a trend in the data. So, in the end, we ended up doing it […] the right way, but […] we sacrificed […] a little bit on the user experience where the whole dataset is blinded, which is, I think, the right way to do it" (Nishimura, Dec. 7,

2021). The "right" way to design the HC-based CS game in this example diverged from the most enjoyable way for participants. Here, from the perspective of the researchers (and, in this case, also from the perspective of the developers at the Human Computation Institute), the formula "play follows science" guided the development of Stall Catchers.

Similarly, regarding the different temporalities between the scientific research behind the game and the game itself, researcher Jada explained the importance of research setting the pace (fieldnote Oct. 28, 2022). When we discussed my observation that some researchers had expressed that they sometimes felt stressed by Stall Catchers' data requests, she argued that providing Stall Catchers with data always had to be justified. You could not "kill 20 mice" just to produce data, she said. Producing data had "real consequences" (Jada, Oct. 28, 2022). Therefore, Jada considered it important to prioritize scientific goals over user experience. This hierarchy between play experience and science was shared by virtually all participants who contributed because they wanted to help scientific research or had a personal connection to Alzheimer's disease. Most of the participants interviewed also valued the game/play and science parts differently, as in the words of Caitlin: "[S]o you can make games out of it too. But the main thing is to hopefully advance the research" (Caitlin, May 5, 2020). The hierarchies between play and science described here were, thus, not simply enforced by the scientists and developers on the participants but shared by most of the actors involved. They drove the formation of HC-based CS assemblages.

"Success" Has Different Meanings for Game and Science

Finally, as a last example of friction or misalignment between science and play in HC-based CS projects, I would like to discuss the different perceptions of the project's success, using Stall Catchers as an example. As an online CS project, Stall Catchers was perceived as very successful by all members of the laboratory I spoke with, and they were all very enthusiastic about it. Researcher Jada, for example, explained to me:

> [A]s a project, I think it's extremely successful […]. I think it has been extremely successful to engage the people [and] has been successful especially also on the human computation side, from the institute, it really gets the people in and doing all this work. And also on how this whole thing has been growing. (Oct. 10, 2021)

The success of Stall Catchers and the importance of the participants' contributions were publicly acknowledged in blog posts and at live events. Participant contributions were also measured in "lab hours" to communicate how much time the participants saved the researchers by contributing to Stall Catchers. Prior to my field research visit to Ithaca, I had the impression that the project's success story was widely and unquestionably shared by all actors involved. However, when I spoke with researchers in the laboratory who had been working with Stall Catchers and asked them about the "success" of Stall Catchers without further defining the term, they distinguished between "success" in terms of the project in general and in terms of its scientific value: "[I]n terms of popularity obviously, it's doing really well. […] I think it has the potential to be very successful," explained Leander (Sept. 22, 2021). When I asked why he was referring to the potential for success, he clarified further:

> I mean it's obviously successful as a game, it's growing, people are interested, so there's definitely something there. On our end, but I don't know if that's so much a flaw of Stall Catchers is like—what I was talking about earlier—where we didn't have the infrastructure in place to support it being successful. So, if it's successful, we need to figure out how to do that. So, I think it's […] almost there in terms of being successful from our end. (Leander, Sept. 22, 2021)

During my research at the laboratory, the challenge from the researchers' perspective was that the data results they received from Stall Catchers were unreliable due to problems in the data pipeline. The next chapter on researcher–technology relations will discuss the pipeline and its problems in detail. For now, it should suffice to note that because of the infrastructure problems, working with Stall Catchers was, at times, even more time-consuming for the researchers than manually analyzing the data themselves.

Similar to Leander, researcher Emily explained to me during a coffee break that the project's limited success on the laboratory side was not the participants' fault but rather a problem on their end. She also said that she sometimes preferred to analyze the data herself rather than sending it to Stall Catchers because of the problems they were facing with the data pipeline (fieldnote, Sept. 15, 2021). Despite the perception of Stall Catchers not being successful in terms of advancing and supporting the research as they had hoped, Leander believed that they were "almost there" (see above) because of the infrastructuring they had been focusing on over the last few months. Jada agreed that while the scientific side "was lagging behind […] I think it got way better by now. It's just tricky, that's all I'm saying, and it took many years. But I think it's—now looking back of course—, it was all worth it and it was really good" (Oct. 27, 2021). The hope was that the infrastructure, i.e., the data pipeline, would eventually solve the problem once it was "functioning."

Despite the frustrations, the researchers agreed that Stall Catchers was a successful game. As PI Schaffer argued, the "value of Stall Catchers" (Dec. 07, 2021) could not be reduced to scientific value. By "value," he was referring to "understanding culture and process and the fact that it's people who do science rather than any particular scientific fact" (Schaffer, Dec. 07, 2021).

> I think the other value of Stall Catchers […] is not just the quality of the data analysis or the data analysis that we get, but it's the opportunity to engage people who haven't been trained as professional scientists in the act of doing science. So, I do talk about the idea that […] it is authentic science that people are engaged with. Not every experiment works. Things go wrong. We're public about that. We try to—as much as possible as you can with this sort of amorphous cloud thing—but try to make this an opportunity for people who are interested to get a peek behind the curtain at how scientific decisions are made and how priorities are set and how it is slow and why it's slow and things like that. (Schaffer, Dec. 07, 2021)

While this value was important to and supported by the PIs, I, nevertheless observed some tension, or at least an inherent imbalance, between different perceptions in the laboratory. There remained frustrations with the project for the researchers working with the Stall Catchers data, to which I return to in Chapters 6 and 7.

Closely related to this aspect of divergent meanings of "success" is the balancing act that the researchers and the team of the Human Computation Institute had to perform to communicate the value and success of Stall Catchers, as well as its scientific goals and progress. The politics of communication, or the balancing act, was to motivate and encourage participants to contribute and to translate the scientific concepts and processes to the general public while, at the same time, not overpromising results or creating too much hope for rapid development of a treatment for Alzheimer's disease. Researcher Oliver Bracko expressed his concerns about this fine line of communication in an interview with *The Scientistt Podcast*:

> [As scientists] we really have […] to watch our language because these people, they really play because they usually have a family member that had […] died or has Alzheimer's disease or another form of dementia and I mean we as researchers often state or overstate our results and I think we really have, I learned my lesson to have to be much more cautious because things are really slow in science and the players […] had to understand it and so did we that we cannot say it's basically this is the path to a new drug or this is the path and it is a path, there's a possibility that is a path to a new drug, but it's slow, and it's at least ten years from now. (Scientistt 2020, 5:46–6:27)

The researchers had to be very careful not to overpromise the results of their research, Bracko said. It was for this reason that the original name of Stall Catchers' umbrella project, "WeCureAlz" (Ramanauskaite 2016), was changed to "EyesOnAlz." In one of our conversations, Michelucci explained that while the idea behind the brand name "WeCureAlz" was to convey that they were "all in it together" to work toward the goal of curing Alzheimer's disease, they still changed the name so as not to mislead participants (fieldnote, Nov. 2, 2022).

The tensions described in this chapter, from the unpredictability of science and the need for rigidity and reliability of Stall Catchers' infrastructure to the hierarchies of science and play and the associated understandings of success in terms of the game and science, exist alongside the productive entanglements of play and science discussed above, requiring researchers, participants, and developers to find ways to accept and work around these tensions through trade-offs or to align their different interests actively. An example of such alignment practices is discussed in Chapter 7. However, these entanglements between science and play also led to the emergence of new play practices, to which I turn in the following.

Adaptations and Practices Beyond Design

In analyzing HC-based CS games as multiples (Mol 2002b) and assemblages of different human–technology relations, various participant–technology practices come to the fore that go beyond the play practices intended by design. The affordances of Stall Catchers and Foldit as games, for example, and the participants' active engagement with the platforms invited practices that went beyond the task of analyzing research data (in the case of Stall Catchers) and designing proteins (in Foldit). In the following, I present several

examples of such practices initiated by participants in relation to technologies. While the next chapter focuses more on the nature of the relations from a processual perspective, I focus here on the practices that emerge within and from these relations. While this order of discussion seems to suggest that these practices precede the intraverting relations, neither this nor the reverse is fully the case. Instead, these practices are fundamental parts of the participant–technology relations and vice versa, as the evolution of the relations and the practices are interdependent.

These practices span a wide range of different activities. They include adapting the projects in ways that enhance participant–technological performance and interpreting the data presented in ways that go beyond protein folding or data from the brain vasculature of mice. They also involve building new games into the existing ones. Some practices even attack the designed functionality of the projects and their purposes. All of these practices reflect the creativity in HC-based CS games. This creativity arises from the system's affordances, existing relations, and intentional actions. It also stems from the ways in which participant–technology relations shape the projects alongside designers and developers. However, they are too often overlooked in existing definitions of HC.

Ameliorating the Participant-Technological Performance

While the intended workflow for data analysis in Stall Catchers is well-aligned with the platform's goal and is followed by most participants, especially by new and occasional users, some long-term and frequent participants have developed their own practices to improve their play and speed of analysis. Some participants, for instance, as they shared in the in-game chat in September 2022, have written scripts for their browser that allow them to use hotkeys that reduce the number of clicks required to annotate videos.[28] Others started using multiple browser tabs to avoid the long load times that sometimes slowed down their play. While Foldit explicitly allowed and supported participants to write their own scripts to automate protein folding steps, some participants went further, such as Aram, who additionally created "an environment in Autohotkey that allows me to monitor multiple Foldit clients and run them in parallel" (Feb. 28, 2021). Participants also often used multiple Foldit clients to work on several puzzles at the same time or to run different recipes. "Some do multiples on a single puzzle, on multiple designs they have," explained participant Brandon (Mar. 4, 2021). The "minimal" way to play Foldit is with one client running and one UI, on which one manually designs or folds a protein,

> but you can also use a recipe, like a script, that continues working on it. You can go eat or something, it will do it automatically. But you can also open a second window [so that] one is automatized, and you are working on the other. […] So, this can also be done with another computer. I have old computers on which I have put Linux. (James, Feb. 11, 2021)

Participant Cleo described their daily routine of starting Foldit as follows: "I open up three Foldit clients for the three current puzzles. Then for each one I set a suitable recipe from my cookbook in motion" (Apr. 22, 2021.) Some participants kept multiple clients

28 Gray and Suri have observed similar tactics in their study on ghost workers (2019, 12).

running in the background 24 hours a day, seven days a week (Arthur, Feb. 12, 2021). Participant David even set up his Foldit infrastructure and environment so that he could

> access them from basically anywhere in the world via a secure connection. So, they are always, basically, they are always on, or on standby, if I don't need them right away, then I can also put them in sleep mode. But I've been on vacation […], for example, and you're in the middle of nowhere, and then you can still connect to the servers via cell phone, and you can still do puzzles. (Mar. 4, 2021)

In this way, David enhanced his play and detached it from the need to be in physical proximity to the computers on which he was running Foldit to contribute. Taken together, these play practices in Foldit provide examples of how participants improve their play or contribution in a way that still takes place within the practices inscribed by design.

Similarly, in Stall Catchers, participant Alyson discovered a new way to interact with the flow of the platform's computer algorithms by testing different key combinations at a specific moment in the data analysis, which allowed her to move more quickly to the next video to annotate. In an email to the institute, Alyson explained:

> It required my hitting the refresh button before the [Next] button had a chance to come up. My mousing is too erratic to do that repeatedly, so I switched to playing with my left little finger on the keyboard [anonymized key] button and the index finger posed over the [anonymized key] so I could refresh immediately after annotating. I was amazed. I played that way for several minutes (over 100K points worth) and it seemed significantly faster.[29]

By seizing a timely moment (Mousavi Baygi, Introna, and Hultin 2021: 431), this tactic, as understand by de Certeau ([1980] 2013), altered the flow of play and created a new path for analyzing data in Stall Catchers.[30] With tactics such as those described above, participants creatively adopt the HC-based CS projects that go beyond what the developers or designers had in mind when implementing them. This nicely demonstrates the first principle Latour defined in the context of studying science in action: "the fate of facts and machines is in the hands of later users" (2014, 131).[31]

Reading Data Differently and Playing Games in Games

Another practice I observed in the Stall Catchers example was the visual reinterpretation of the research data displayed. This practice was occasionally discussed by participants in the in-game chat. Rather than simply treating the videos as scientific data, participants sometimes interpreted them as, for instance, images of the universe, supernovas, black holes (in-game chat, Feb. 2019), caterpillars or artworks by famous painters (in-

29 Quote from an email exchange with the Human Computation Institute on Apr. 16, 2021, with Alyson's permission to publish.

30 I describe this example in detail in Thanner and Vepřek (2023).

31 Of course, the practices presented here probably represent only a moderate sample of participant–technology tactics that users have discovered and developed. There might be many more that did not come to my knowledge in my ethnographic research.

game chat, Oct. 2019), sparking discussions among participants in the chat as they analyzed the videos. While this particular practice largely grew out of the Stall Catcher's community, the Foldit team actually initiated a somewhat similar practice. During their "Snowflake Challenge" in 2020, they invited participants to submit snowflake-shaped protein designs, of which the developers and team then rated the most beautiful creations (joshmiller 2021).

Despite Stall Catchers' game features described above, which are designed to make the repetitive task of analyzing black-and-white video sequences more fun, some participants came up with even more ways to stay entertained. Participant Caitlin, who had been contributing to Stall Catchers from its beginning, and as I quoted above, described in our interview that, in the early days, she had "much enjoyed [the] process of climbing [her] way back up to the top" (May 5, 2020) when her skill bar had dropped. But since she had now become one of the top players, her skill bar no longer dropped low, and she missed "the fun of climbing my way back up the way I used to" (Caitlin, May 5, 2020). To make Stall Catchers more enjoyable and fun again, she started playing "leapfrog" with other participants. In this in-game game, they played Stall Catchers by taking turns passing each other on the leaderboard. "I'll get one, then [they]'ll get one, and then I'll get one, and we will do this all the way up the board, and we'll banter back and forth in the chatbox" (Alyssa, May 14, 2020), described one of the leapfrog players. Sometimes, participants tried to match someone else's exact high score on the leaderboard (Caitlin, May 5, 2020). This practice of trying to match or beat another participants score was also used by a teacher to keep the students motivated:

> They do see, when I participate, […] They see the teacher, they see my name: If I'm above them, just above them, then they want to pass me and then so we can motivate each other a bit. If I also usually, I nowadays collect quite a lot of points because my progress bar is quite high then, but I usually stop when I am just above them so they can catch up with me because otherwise, they go like, he is already much too far above me, I can't catch up, then they are demotivated. But if I'm just above them, then they can beat the teacher like, "hey, I'm above the teacher" and all that. (Ren, May 18, 2020)

While these examples did not undermine the official task of Stall Catchers but rather motivated participants to continue contributing and completing the task, in Foldit, some participants developed in-game games that created a parallel game space to the actual Foldit task. Building on the scripting feature allowing participants to write their recipes for automating the folding of the protein, different games were implemented using repurposed Foldit controls to, for instance, change the direction in the new in-game game (Friedrich, Mar. 9, 2021). One example of such a game is "The Game of Go minigame," developed by Foldit user z03xiaJonWeinberg, an adapted version of the famous board game Go (2021a). Like other player-developed games in Foldit,[32] the game was shared with the

32 See, for example, the "action realtime minigame" and recipe "rate1star output anime Minecraft13pub.lua" (z03xiaJonWeinberg 2021b).

Foldit public so that all other participants could download the recipe and play the game in their Foldit client.

Exploring Boundaries

"People may likely push on the edges of a mimetic world as part of exploration or even in an effort to hack it," notes computer scientist and video game designer Brenda Laurel in *Computers as Theatre* (2014, 131). Laurel defines players' attempts to try to find the limits and boundaries of a game as part of every game. As the following example shows, this also applies to HC-based CS games. In addition to the playful modifications of the engagement in Stall Catchers described above, which enhance the experience and introduce a new play mode without disrupting the game, there have also been attempts to hack, spam, or troll Stall Catchers.

Up until a certain point, for example, Stall Catchers participants could change their usernames. Eventually, this feature was exploited, as Michelucci recounted in one of our conversations. A small group of participants were playing Stall Catchers "all night long […] and then pretty soon, they were the top three. They had the top three positions on the leaderboard. And then they coordinated their behavior, and they all switched their usernames to put it to create a three-line political message at the top of the leaderboard" (Michelucci, Jan. 14, 2021). Although this did not interfere with the core task in Stall Catchers, these users repurposed the Stall Catchers platform as a political bulletin board. As a result, the team had to "apologize to the community and sort of say we didn't intend for this to happen, we're […] doing something about it" (Michelucci, Jan. 14, 2021). Fortunately, Michelucci explained, it was not "a very harmful thing that had happened" (Jan. 14, 2021) in terms of the scientific purpose and functionality of Stall Catchers. Moreover, in order to repurpose Stall Catchers, the participants who "hacked" Stall Catchers first had to make valuable contributions to the project—valuable in the sense of data analysis. Michelucci contacted the participants, and

> the first thing I did is I thanked them for all the research contributions they had made because by getting to the top of the leaderboard, they had annotated a lot of stalls. I looked carefully to see if they were using a bot to do it, and […] it looked like they were actually doing it themselves. So, they were making a research contribution. There was value. I looked at their sensitivity. So, it was truly a research contribution. (Jan. 14, 2021)

After this incident, the team updated the platform to prevent participants from changing their usernames in the future. However, during my time at the institute in November 2021, due to an undetected and (re)introduced bug, some students participating in Stall Catchers discovered the possibility of changing their usernames again. The following excerpt from my fieldnote, written one day after the event, shows how this new incident unfolded:

> At around 4:40 pm yesterday, I noticed some strange chat behavior in the slack channel that forwards all chat messages sent on Stall Catchers. Some users were spamming the chat. I immediately went to Stall Catchers to see what was going on—ap-

> parently, some schoolchildren had taken over the chat; some had copied the usernames of the supercatchers and had included a black star into their username, which, in Stall Catchers, stands for "supercatcher." They were also insulting users, not personally but by username. Some catchers had already asked them to stop spamming as they wanted to focus on analyzing research data.
> I posted a message in the chat reminding everybody of the fact that spamming was not allowed in the chat.
> I sent a message in the slack channel to report bugs. [Developer Samuel] had also noticed the spamming. Pietro [Michelucci] quickly jumped in and tried to stop the spamming.
> He blocked some of the users from the chat ([Samuel] had identified the user IDs). Pietro [Michelucci] also renamed some of the users who had copied existing usernames, but shortly after that, some of them managed to change their names again. This should not be possible—there must have been some recent update to the code that overwrote the feature of not being able to change the username.
> Pietro [Michelucci] also messaged the chat, and after that, a few students mentioned how great the game was, etc.
> However, spamming did not really stop. At one point, a student wrote in the chat that a teacher had called the students off. After a while, the conversation (if you can call it a conversation) slowed down. (Nov. 17, 2021)

After the situation had calmed down, Michelucci apologized to the chat and to some of the participants who had been personally insulted, and developer Samuel deployed a new feature to prevent users from changing their usernames. This short note from my field diary shows how participants, in this case, schoolchildren, search for the game's boundaries and adopt the platform for their own purposes, which do not always align with the purpose intended by design. Situations like the one depicted require immediate attention from the team, regardless of what they are currently working on, because the spammers' messages also disrupted other Stall Catchers participants' game flow through the chat window, expanding with each new message and, thus, affecting the project's working in general. This incident exemplifies how the HC-based CS game Stall Catchers is continuously being negotiated by different actors and human–technology relations (in this case, participant–platform and researcher–code relations) in everyday life.

Emerging Spaces in Play/Science Entanglements and Frictions

These examples of different practices presented here show how gaming the projects is part of every game, as Laurel wrote, and how participants find new ways of engaging with the platform and software. By tinkering with it or modding, they adopt the platforms differently. At the same time, new possibilities for human–technology relations emerge beyond the designers' intentions and expectations. Here, the software's affordances or object potentials and the game frame (the "con-text" in Beck's terminology [1997, 342]) invited such different practices.

However, despite participants' rejection of the classification of the project or their contributions as play, I argue that the entanglement of play and science directly influ-

ences how the sociomaterial assemblage and its human–technology relations form. "Play" and "science" here refer to attributions I encountered in the field and were used to explain why, for example, Stall Catchers ran smoothly in contrast to the scientific research conducted in the laboratory, or why something did not work, and why different perspectives did or did not come together. Different goals and motivations unfold in parallel and in tension rather than together and in unison. It is in these interferences of play and science that the space for the HC-based CS games emerges in which participant–technology relations unfold and continuously intravert. In Deleuze and Guattari's words, these productive and tense entanglements can be understood as "movements of deterritorialization and processes of reterritorialization" that are "always connected, caught up in one another" (2013, 9).

While communication, game, and design scholar Mia Consalvo writes, following cultural historian Johan Huizinga, that play "occupies a time apart from normal life" (Huizinga [1938] 2016; cited in Consalvo 2007, 6), this chapter also illustrated the importance of the very embeddedness of GWAPs in the participants' everyday lives and the personal connection to the advancement of scientific research. In the case of Stall Catchers, Alzheimer's disease has always been part of the game, which is permeated with seriousness and leads some participants to refuse to call it a game. This was discussed in the first part of the chapter, which concentrated on the co-texts of the HC-based CS games studied with a focus on Stall Catchers. As I showed, most participants contributed because of a connection to Alzheimer's disease and not, as the team had initially imagined, to fill spare time while waiting in line, for example. Alzheimer's disease formed the overarching system of meaning "with which specific representations and perspectives, evaluations, and normative orientations of technical artifacts are established" (Beck 1997, 351). In this setting, calling Stall Catchers a game was perceived by some participants as devaluing their contribution, as they felt it did not accurately represent the seriousness of their endeavor.

From these play/science interferences in Foldit and Stall Catchers, specific values and normative claims were shared by participants, creating understandings of the *right* way to play and specific ethical subject positions. Participants with a connection to Alzheimer's disease, for example, positioned themselves as *assistants* or *helpers* to the researchers (e.g., Louise, May 07, 2020; Quinn, May 07, 2020; Jeshua, May 8, 2020; Elle, May 13, 2020) rather than as *gamers*.[33] Moreover, playing these games was considered more meaningful than playing other games. Foldit participant Aram explained that he had stopped playing other games partly because of time constraints but mainly because he would not "see much sense in it anymore because there is simply no real application behind it" (Feb. 28, 2021). This perspective of doing something meaningful was also part of Stall Catchers' designed narrative and was shared by participants. Using computer hackers as an example, anthropologist Gabriella Coleman describes such processes as

33 However, other participants stated that the actual motivation of participants to contribute did not matter because every contribution was meaningful. Stall Catchers participant Noemi, for example, explained that "every person participating […] taking that step to assist is important whether they are just doing it to play a game or whether they are doing it because of personal reasons or just 'hey, yo,' it's all important" (May 14, 2020).

"ethical enculturation" (2013, 124). In such enculturation, the actors involved learn about "the tacit and explicit knowledge (including technical, moral, or procedural knowledge) needed to effectively interact with other project members as well as acquiring trust, learning appropriate social behavior, and establishing best practices" (Coleman 2013, 124). These values emerged in the relations between the programmed and intended play practices based on the assumptions, values, and visions of developers, designers, and researchers, as well as the participants' particular forms of engagement that fill Stall Catchers with multiple meanings. However, as should have become clear, the HC-based CS assemblages shaped by the interferences of play and science are never neutral but fragile and contain processes of deterritorialization. Similar to the social space described by Bourdieu (1985), they are contested and permeated by power relations, different interests, and, as I have shown in this chapter, different logics of play and science inscribed in them.

In the next chapter, I will shift my focus to concrete human–technology relations in HC-based CS projects. With the example of participant–software and researcher–technology relations, I analyze how they unfold in the setting described here and how they evolve and change, or intravert, over time.