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# Towards Post-Interaction Computing: Addressing Immediacy, (un)Intentionality, Instability and Interaction Effects

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## ABSTRACT

The changes that have come about through the increased speed, ubiquity, and scale of computational systems require a reconceptualisation of how we think about and study the relationship between humans and computers. Driven by the increased production of data in interaction and the transfer of value from interaction to data, we argue that computing that fundamentally impacts human-computer relations is no longer happening only *in* interaction but also *without* and *outside* interaction. While recent arguments have highlighted interaction as a problematic concept for HCI — challenging what constitute users, use, the human, and the computer in interaction — we propose post-interaction computing as one means to conceptualise a fourth wave of HCI. We propose four concepts — immediacy, (un)intentionality, interaction effects, and instability — that can help us in identifying and slicing our objects of analysis in new ways that better match the challenges that HCI is now faced with.

## CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI); HCI theory, concepts and models;**

## KEYWORDS

post-interaction, HCI, interaction, immediacy, intentionality, instability, interaction effects

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## 1 INTRODUCTION

While the ‘third wave’ of Human-Computer Interaction echoed changes in how and where people interacted with computers, it was also reflective of an underlying shift in what and how computers helped us to know, and conversely, through approaches such as affective and experiential design, how we should conceive of computing [11]. As much as the third wave was defined by the shift of computing into the spheres of the home, leisure, and arts,

it was transformed through the epistemologies of phenomenology and the ontological realm of, *inter alia*, emotions, values, identity, and culture. To us, what defines the shift from one wave to the next, then, is a change in how we can think about what computing technologies are, rather than a shift in domains of study.

Over the past years, a number of researchers have begun to articulate and address an apparent crisis of Human-Computer Interaction, through the guise of one of the founding concepts in the field — ‘interaction’ [55, 65, 68]. At stake has been the ability of HCI to generate knowledge, through a shared understanding of interaction and through a limited scoping of ‘interaction’ precluding consideration of its impacts. We continue this conversation and suggest that this crisis of interaction is indicative of the presence of a ‘fourth wave’ in HCI. We argue that this ‘wave’ can be characterised by any number of shifts in how we interact with computers — the scale, speed, and ubiquity of computing, alongside its seeming increasing visibility in public life and invisibility in our daily lives — but that the most significant shift is one we don’t observe or interact with directly. Where the third wave moved computing into the forefront of our lives, this fourth wave has set those third wave interactions as only one part of the complex computational landscape of current human-computer interaction. That is, while the third wave sought to design computing systems for interaction, the fourth wave is more concerned with designing interaction for and with computing — data mining, analytics, advertising, and so on. The computational aggregation of human-computer interactions in the fourth wave has an increased focus on not only the implications of interaction for individuals, but the political and social justice implications of HCI on a broader level.

In this paper, we characterise the fourth wave as *Post-Interaction Computing*. In what follows, we define what we understand as the necessity of a post-interaction framing of HCI, what constitutes such a framing, and how we might take this approach. While many new topics, technologies and application areas define contemporary HCI, we believe that the fourth wave is defined by a change in the epistemological and ontological tools necessary to understand how we are interacting with computers, more or less directly, sometimes to the point where interaction risks failing to make sense as the organising concept. Akin to Susanne Bødker’s [11] articulation of the third wave, the aim of this paper is to articulate the challenges and opportunities that we consider central for the community to tackle. We offer four concepts — immediacy, (un)intentionality, interaction effects, and instability — that we believe can help in identifying and slicing our objects of analysis in new ways that better match the research challenges we are faced with.

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## 2 TOWARDS POST-INTERACTION COMPUTING

In this section, we want to briefly outline our motivation for, on the one hand, thinking of our current state of HCI and computing as being in a fourth wave and, on the other hand, being in a wave that we want to call *post-interaction computing*. Before we do that, it is worth noting that the fourth wave of HCI as we see it is not altogether different from the third in that both touch upon many sites of interaction: we interact with computing systems in our homes, on the move, at our leisure, and while at work. We do not propose the death of ‘interaction’, much like the emergence of the third wave did not make second wave concerns obsolete, but a move which attempts to re-situate interaction. Articulating an understanding of what interaction now does in computing, we argue that the proposed fourth wave is different from the third in the characteristics of its computational footprint in three regards:

First, fourth wave computing is driven by the increased production and value of data in interaction with computing systems. The data that we produce when interacting with systems is now a significant economic and political resource. The scale and ubiquity of data collection has led to transnational legislation to return rights to the producers of data, and the value of the data-driven economy is estimated anywhere from hundreds of billions (estimates for the current value of the data economy in the EU are at EUR300 billion, growing to EUR739 billion or 4% of overall GDP [48], while estimates have suggested a figure closer to 2% in the US [51]) to over USD20 trillion or close to 90% of the stock market value of the most valuable companies [16]. Aside from the economic value of data derived from interaction and the potential this opens for exploiting those producing content through interaction [23], an issue closer to traditional HCI concerns is that this data is itself being used to change interaction. As such, interaction serves only one purpose of a fourth wave of human-computer interaction — it produces the data necessary for computing [14]. That interaction always produced data (inputs and outputs) is uncontested, though with the fourth wave of computing, computing is happening ‘without’ interaction and ‘out with’ interaction. Through sensors and algorithms we no longer need to interact with computers directly, while at the same time, our interactions feed computing that takes place outside of our interaction. To understand why a post-interaction computing framing in HCI is needed, let us consider the example of high-frequency trading. In their 2013 paper, Neil Johnson and colleagues [38] examine the occurrence of what they call Ultrafast Extreme Events (UEEs) in the financial markets. High-frequency trading is motivated by the desire to make profits by responding to information faster than anyone or anything else [40]. UEEs, where a significant change in the market occurs and is reversed within a few microseconds, are driven by computational and algorithmic decision making that happens at speeds that outpace human perception, cognition, and action. This has led to an argument for a new theory of economics which de-centers human agency and capability [38]. Evidently, computational systems that outpace humans are a challenge not only for economics but also for the field of Human-Computer Interaction. Computation is happening faster than we can interact with it, and it is more complex than we can make sense of.

Second, in parallel with the rising diversity and complexity of the systems at play, HCI seems to — once again — expand its concerns, placing a stronger emphasis on the economic, political, and other societal implications of the systems it envisions, builds, and studies (cf. [3, 19, 36, 59, 62, 63, 67]). Calls for critical consideration of where HCI stands when it comes to social justice issues and its implications to the well-being of individuals, social relationships, and entire societies are not new, but they seem to have become louder and more urgent. The scale of computing’s footprint in our individual and collective lives is huge and growing — computing saturates society. At these scales, ‘interaction’ loses focus [65].

Finally, the changes in Human-Computer relations that have come about through the increased speed, ubiquity, and scale of computational systems in human life, require a reconceptualisation of the relationship between humans and computing. Not only are the ‘loops’ of human-computer interaction often too small to ‘fit’ a human (as in the case of UEEs), but they are also too long and complex, as in the case of environmental sustainability [42, 53], for their effects to be known or knowable to the human actant. These scales (temporal, geographical, aggregation across populations) also interfere with readings of where and how the human is in-the-loop, to the extent that we argue that human agency, and with it intentionality, are no longer the only perspective from which we should consider sense-making. Again, the extent to which these computational timespans, long and short, are interwoven with our own human, but also sub-perceptual and conversely geological, timescales, sets this apart from previous waves of HCI. While in these timespans it might be tempting to ascribe agency directly to computational and algorithmic systems, as we will discuss, we should be cautious of not recognising the intentionality in the design of systems and the question of scale in understanding human-computer interaction [60].

## 3 RECONSIDERING CENTRAL APPROACHES

Given these changes in computing in society, we review how other authors have begun to unravel the crisis of ‘interaction’. Following concerns for the current state of interaction (see [65, 68]), a number of authors have attempted to either rein in interaction as a concept, or to dissect the constituent elements of interaction, including ‘interaction’ [34], the ‘user’ [6], the ‘human’ or human-exceptionalism [46], alongside recounting the human work of ‘computing’ [1, 56, 70]. We map out key developments in recent literature that have been influential to our formulation of Post-Interaction Computing: First, we will review research that reflects on interaction as a foundational yet ambiguous concept in HCI. Second, we will consider ongoing discussions regarding reconfiguring the user and *post-userism* — a conversation that calls into question how we approach the human in HCI. Third, getting closer to the computer in HCI, we discuss work that troubles the notion of the interface.

### 3.1 Interaction

Interaction as a foundational concept in HCI has come under renewed scrutiny, largely due to the arguably “incoherent” definitions of interaction in use in the field [34, 55], despite contrary articulations of the productivity of epistemological plurality [31]. These

discussions range from making order of interaction [34], to rethinking interaction [65], to arguments that, in fact, interaction as the focus of HCI design and study, is misplaced [68]. In their CHI 2017 essay on interaction, Kasper Hornbæk and Antti Oulasvirta [34] argue that there have been scarce efforts to define what interaction is, despite the term’s field-defining role in HCI. They describe how interaction is variously viewed in HCI literature as dialogue, transmission, optimal behavior, embodiment, and tool use. Unsurprisingly, given the supposed crisis of interaction, they point out that the concepts have different scopes and ways of construing causal relationships between the human and the computer. The authors answer the question of what interaction is in part in the negative: *“Interaction is not the idea promoted and repeated in folk notions that a computer and a human are engaged in some interplay.”* More interestingly for our purposes in this essay, the authors, following Mario Bunge [15], state that interaction concerns two entities that determine each other’s behavior over time. They point out that the mutual determination of humans and computers can be of many types, including statistical, mechanical, and structural. Yet, despite the multi-determination supposed by this, Hornbæk and Oulasvirta [34] tie the characterisation of interaction back to human intention: *“Users, with their goals and pursuits, are the ultimate metric of interaction.”*

### 3.2 User

The concept of the ‘user’ has been pervasive in HCI, partly as a boundary around which the discipline has been built [17] and, as the concept has evolved — from ‘user’ to ‘person’ and beyond (cf. [4]) — as a means to demarcate the ethical space of who the user is and, more importantly, is not, as in the traditions of cooperative and participatory design [12, 50] and with renewed interest in socially just design [19, 63]. While already the foundational work by Steve Woolgar [70] showed how developers try to use technology to configure users to fit into a certain mold, HCI research has opened up questions on how ‘users’ go beyond these categories, both practically, for instance when individuals use systems to help someone else [6, 58], and as a resistance to normative expectations on use [7] and users [29, 41, 45, 62]. Rena Bivens and Oliver Haimson [9] demonstrate how, even when the user-facing system can appear without such categories, interconnected systems such as those for advertising, reinforce normative categories of who or what a ‘user’ should be.

Eric Baumer [4] has used the term ‘usee’ to refer to cases where the ‘user’ is designated not by their use but by their being used by a computational system. Studies of computational labour where ‘cheap’ human labour ‘fills in’ for algorithmic systems [61] are explicit examples of this, pushing against the seamless vision of automation. The consequence of such a framing can be clearly seen in the broader arguments on social injustices [22] — people are embroiled in interactions with digital society often without knowing it, without control over it, with or without intention to engage, and even with the intention to disengage or actively resist use. In this sense also, interactions with different kinds of systems have consequences for those who have no direct contact with them. One drastic example of consequences that interactions may have to those whose intentionality is not part of them is the case of

how data gathered with satellites to monitor atrocities occurring in Sudan during conflict were apparently being used to commit further atrocities [66]. In a relatively more prosaic situation, the consequences of transactions in, for instance, Airbnb may affect the neighbours of those who rent out apartments [43]. In the short-term, guests may be noisy, but the consequences may also act on a broader scale, for instance by driving up rental prices in certain areas and thus making them unattainable for some groups of people [44].

While we do not wish to claim that the user is not important, it is obvious, as others have already shown [5, 7], that if we do not challenge this category and look beyond it, we risk creating an atomistic picture of information technology’s role in the world.

### 3.3 Interface

Perhaps the most developed argumentation, and implementation, of what we might start to consider as post-interaction is the notion of computers without interfaces. Since Mark Weiser and John Seely Brown [69] articulated the dream of a less intrusive and arguably more natural or organic interface to computers, HCI research has pursued the capture of human action through sensors, the sense making of sensed data through algorithms, and the conceptual language and tools for dealing with such implicit interaction [39]. In these configurations, the ‘interface’ is understood as the site of interaction, but it is also one that can be foregrounded or, importantly, backgrounded. This backgrounding of the interface, and thereby the computer, is intended to allow for seamless action on behalf of the user without explicit interaction per se. The faceless interface [37] is one that does not present itself for use, but that through various sensed inputs corresponds to the user.

Conceptually, this maintains many of the notions of interaction, though the intentionality of interaction is less well articulated. While an automatic door opener should respond to a potential user’s approach, such faceless interaction is prone to errors, such as reacting to non-users who are just passing by. Alex Taylor [65] has argued that this pulling back of interaction has consequences beyond the system itself, consequences that are ultimately political and societal. With his example drawn from London’s bicycle hire scheme, he shows how the interface to the system is both distributed and often invisible to the cyclist. More worryingly, so too are the impacts of the inequality presented by the availability of the bikes as an interface to the city. As Lucy Suchman [64] has suggested, Weiser’s ubicomp dream and the techno-utopian version of post-interaction where computers are not in the way, but just part of a nice continuity of human activity that they facilitate without humans needing to think about them, propagate a problematic vision of computing, not as interface but as infrastructure. The post-interaction computing concern here is that, while increased computational sophistication can help to background our interactions with computers to the extent that we no longer ‘see’ or ‘experience’ interaction with them, our reliance on invisible and inscrutable systems leads to questions of responsibility and accountability for the actions and decisions being made.

## 4 RESLICING THE UNITS OF ANALYSIS

In the previous sections, we have attempted to outline some of the current challenges in dealing with interaction. From here, we propose that these challenges point to a need to rethink what interaction is doing. To be clear, this is not about taking interaction out or somehow removing it from our analyses. Instead, the challenge here is to go beyond it in our conceptualisations of who and what are the subjects and objects of computational processes, making interaction just one of those subject/objects. We are talking about computing because we are talking about interactions with technologies but also about how data is processed, how we use computers for computational tasks, and how our use of computers ends up contributing to computational processes that we may not have intended to take part in — and the broader implications of those processes.

Where Hornbæk and Oulasvirta [34] have shown that intentionality is central to the dominant conceptualisations of interaction in HCI, we call for a post-interaction orientation that grapples with shifts in immediacy, (un)intentionality, interaction effects, and instability in order to revisit the unit of analysis we work with and the methodologies necessary for conducting our research. We offer these concepts as an invitation for the community to consider together how we might slice our objects of analysis differently and focus on different slices and how they intra-act [2]. Our aim here is to articulate issues we are faced with in transitioning to meet the challenges of fourth wave HCI. How to best resolve those issues is an open and interesting question.

### 4.1 Immediacy

As evidenced by the example of ultrafast extreme events, computational speeds far exceed human perception and cognition, and that speed is being used to create events, make decisions, and change the human-world, in ways which we can no longer fully account. This computational speed is allowing longer distance interactions, with instantaneous quantum communication achieved between Earth and an orbiting satellite. Simultaneously, as Don Ihde's [35] proposition in postphenomenology of background relations and embodiment relations suggest, technology is both 'out of sight', taking examples such as smart thermostats and email servers, and is literally 'all seeing' to take his examples of eyeglasses. In this way, technology is both immediate in its direct mediation of the world and immediate in its inescapable ubiquity. These alterations of the human perceptible space-time of computing begins the change we intend in suggesting post-interaction. We make three contentions: First, feedback loops have become too small to 'fit' a human. Second, feedback loops have become too long to be meaningfully human alterable. Third, feedback loops have become spatio-temporally distributed making them effectively non-cohesive and, consequently, non-interactive.

Our contentions about the space-time of computing prompt us to trouble and expand the metaphor of human-in-the-loop: When does it make sense to talk of a human in the loop? Where in the loop is the human involved and in what ways? This is different from moves that try to displace humans from the loop altogether, in pursuit of full automation. Rather than pushing humans out of the picture entirely, we need ways to think of where and in what

ways they are involved. As Nick Seaver [60] advises, we might do well to take narratives of computational systems working without a human in the loop with a grain of salt: "*If you cannot see a human in the loop, you just need to look for a bigger loop.*" Here, he points at the steady accumulation of feedback loops where there are people everywhere "*making little stitches, tacking software to the social world*".

In addition to looking more broadly for *where* in the loop the humans are, we can take guidance from David Mindell's [49] orienting questions in his book on robotics and the myths of autonomy and consider *when* they are involved: "*Where are the people? Which people are they? What are they doing? When are they doing it?*" As an example, he discusses how when flying a traditional airplane, the human inputs come as the events are happening and have immediate results, where as in a spaceflight scenario, the vehicle might be on Mars and it might take twenty minutes for it to receive a command and another twenty minutes for the operator to get feedback. As a further complication, planes that land 'automatically' can be thought of as controlled by those who specified their functioning, sometimes months or years earlier.

However, while some of this involvement can still meaningfully be placed under the umbrella of interaction, and while thinking with the notion of loops can be generative (for instance, through the parallels of craft and computing [56]), we propose that we would benefit from new metaphors for making sense of human-machine relationships where interaction may not be the most appropriate or productive concept. Foregrounding issues of time seems like a particularly productive direction to explore, and certainly an area where HCI scholars are already making headway [27, 47]. Following an epistemological stance, we might consider how time is made and made sense of in interaction. Madhu Reddy's [54] study on medical work suggests ideas of, for instance, human-computer *rhythms*. Drawing from ontological studies of time, we must ask what types of time do we even consider in our design and study of computing systems. We can already see that computational ontologies of time are problematic in terms of scale, density, and the tensions of linear and periodic timescales [21]. The challenge we see here is that in sync with the broadening concerns about the implication of HCI, it is becoming clear that it is not enough to be thinking about human time and computer time, but that we need to account for bigger scales, too, all the way up to geological time [42, 46]. We must consider how different immediacies, in and outside of interaction, are mutually constituted.

### 4.2 (Un)Intentionality

At the heart of theories of HCI is the notion of 'intentionality' [20, 34]. According to Hornbæk and Oulasvirta, this pervasive consideration — that human-computer interaction is always, in some way, goal-directed — is also one of the limitations. There is little conceptual work done to talk about how intentions are formed, nor how they are influenced by interaction. Hornbæk and Oulasvirta suggest that all models of interaction are seen "*as channeling and realization of human intentions through a computer, furthermore assuming that these intentions are outside the realm of interaction itself.*" Here, rather than contest the argument that intentionality should be better conceptualised in interaction, we want to demonstrate

how the pervasive nature of intentionality is itself a limitation of the thinking on interaction within the field of HCI.

First, let us start with a mundane example. Every morning, when I (Rob) open my phone and check my email for the first time, my interactions communicate with a number of services. My intended interaction is with my institution’s email server. However, in the process I interact with a number of other services, including those on my phone, my router, my ISP, and so on. We can think of these as perhaps not ‘unintentional’ (since they are in the ‘path’ of my intention), but ‘consequential’. When I check the morning news I engage with a similar series of servers and services, some of which, such as advertising, are explicitly outside of my goal directed actions – they make it slower for me to do my ‘task’. Here, ‘intentionality’ might still serve as a useful concept – how quickly can I achieve what I intended – and the result being that advertising is ‘bad’ design for my interaction. Yet, these interactions are further used to profile my behaviour, to target me for advertising, and ultimately to try to shape my interactions. These actions are ‘intended’ by advertisers and system developers, but are not my intention when interacting. I am not intending to get better ads by doing better interaction. A further unintended consequence comes in the fact that, when, in this case Airi’s sister opens her phone in the morning when staying with the parents, the phone automatically turns on the printer downstairs in their family home. This alerts her father to the fact that she is awake. That these interactions might also be habitual and routine without meaningful intentionality, or in some cases designed to exploit lapses in our intentions [25], and that we might enact impacts without or against our intentions such as time and energy cost (cf. [53]), adds a further complication to intentionality’s centrality in human-computer interaction.

In looking at intentionality we can see that social practice theory provides a starting point to reconcile individual actions/interactions, their cultural and normative reproduction, and the possibilities for unintended outcomes. Examining how food is wasted, Eva Ganglbauer and colleagues [24] highlight the seemingly unintended food waste that comes from well-intended practices of shopping, cooking, and so on. This is conceptualised as a split between integrated and dispersed practices. While we recognise the practice of ‘shopping’ or ‘buying food’, we do not ever notice that at the same time we are ‘wasting food’ by, for instance, overpurchasing. Shopping here is an intentional and recognisable, integrated practice, while wasting food is, in this case, a dispersed practice. Similarly, with the use of music listening and sharing services, we can observe some integrated practices, such as listening to music and recommending music to a friend. We do not so easily recognise the practices of automated profiling of our musical taste, the automated recommending of music to others, and so on. In these cases, the interaction might be intentional, but the data and outcomes are not always so, where we produce data that has some meaning for an algorithm or computer, but not for us. As Eli Blevis has demonstrated with regards to environmental and social sustainability in design [10], the choices we make in designing systems are distributed to individuals, people, and places far beyond our intentions. This is not to say we don’t know that those other practices are happening, but that we are focused (or intended) on one integrated practice.

We suggest that a post-interaction computing perspective would be to begin to unravel the connected practices of interaction and

computing. As with the relationships between use and non-use, we must not always assume intentionality in interaction as the norm, but investigate it. Unintentionality then gives us a frame from which we can understand what is left out of and left over from our interactions, particularly where those things that are left out are the intentions of others. Accounting for the residuals or even the unnoticed, might better support us in understanding when and where things are noticed, integrated, and intended.

### 4.3 Interaction effects

As computing systems have proliferated, the consequences of interaction with one system now often influence or even propagate to another. Beyond the questions of (un)intentionality discussed already, these effects – we call them ‘interaction effects’ – have profound impacts on people, across populations and in aggregate.

At the individual level, the most mundane instances of interaction effects is the ever present ‘personalisation’, or the recursive case where interacting interacts with interaction [14]. This can be immensely beneficial for users, even when it goes beyond the assumption that my interaction is improving my interaction to include the interaction of others. Yet, it can also be highly problematic – singling out users or ‘leaking’ data to another system or user [32]. The house of cards of interaction effects is also not robust and it is embedded in itself. We can’t ‘delete’ data without losing structure, meaning or ‘experience’, nor can we escape the bubbles of personalisation. Moreover, our experiences and interactions with one system cannot be removed from interaction with others [9].

This is not only an issue of use, but also non-use. As I (Rob) am not a Facebook user, when I had to use Facebook’s Messenger application for work purposes, the company’s algorithm was unable to connect me with meaningful social contacts in its recommended contacts. In other cases, what data exactly is collected and how it is used can affect how services are built and personalised for different users. While online news outlets may use clicks as a metric to decide what kind of content to produce or suggest to readers, it is also possible to measure other things, such as reading time [26], to make these decisions. From the user’s perspective, the interaction would be more or less the same, but it could lead to different kinds of outcomes. As a consequence, and in their design, interaction effects are difficult to observe through user-centred approaches – they are, by design, aggregated and normalised.

For populations, these interaction effects have become part and parcel of a narrative, and increasing reality, of the automation of decision-making which reinforces existing biases in technological and social systems [22, 52, 57]. These effects are likely to increase in scale and scope as the use of algorithmic inference increases and in spite of legislative attempts to diminish practices such as data profiling.

The point we want to make here is that a shift from the third wave occurs where computing is designed around interaction effects. Systems rely on sending data across platforms, services, and applications – the ubiquity of APIs demonstrates some of this thinking and engineering. However, this has also led to a challenge for HCI researchers. To do such design work, to build systems around interaction effects, needs rich and wide data [14]. This scale of data – or of ‘interaction’ – is beyond what most prototypes or research

systems can generate [13]. When we design relying on the idea of data and interaction effects, things fail when the data is not there.

#### 4.4 Instability

Personalisation, A/B testing and the online nature of modern services mean that the systems we interact with are not the same to everyone, nor do they stay the same over time [14]. We encounter a slightly different Facebook everyday, and our Facebook differs from those around us. Also, if we look back, many services that we have incorporated to our lives have changed drastically: for example, in addition to the plethora of other changes that have been made to the service, Youtube now hosts longer videos than when it first appeared online. As ‘interaction effects’ play out, for instance, our geographical location affects what advertisements we see, and as we grow older we move between target segments which changes the kind of material companies want to market to us. This instability means that making sense of services is always tied to specific moments and contexts— both for the users and for the researchers — as the systems we encounter will not stay the same [8].

Following from such instability, and given the instabilities already described in relation to the ‘user’, ‘interface’, and so on, it seems clear that in a fourth wave, HCI will struggle to study and describe interaction without an extensively limiting depiction in the *only* here and now [36]. These challenges are already known from the third wave, epitomised in the concerns for the embodied and situated nature of interaction [20, 64] and the desire to challenge the biases of naive generalisation [36]. Yet, while the third wave sought to make sense of the particular from the general, a post-interaction perspective echoes the vast mechanisms of computational aggregation to ask what is general in the particular. Again, Alex Taylor’s [65] example of the London bicycle hire scheme highlights how, although the ‘interaction’ with a bicycle might seem the same for any rider, the aggregated use of the bicycles, represented through visualisation, shows systematic exclusion of certain geographies. While any ‘one’ can use the system, there are many who generally cannot. Don Ihde’s [35] notion of ‘multistability’ provides a means to make sense of patterns of interaction — although objects are never fully known [30], they are in some perceptual ways persistent. Understanding such stabilities, when we can articulate them from our own standpoint [31], allows us to extend to those normativities and normalisations [7], and to go as far as troubling them [28, 31]. This also serves to acknowledge the power and persistence of norms and expectations in use, both productively, where in design we might want to design for certain experiences, and progressively, where we can identify, acknowledge, and hopefully rectify, the exclusion of particular stabilities and perspectives.

## 5 CONCLUSION

In this paper, we have made a move towards what we think post-interaction computing as a fourth wave of HCI might entail, emphasising in part how it is driven by the increased production and value of data in interaction with computing systems. We have discussed immediacy, (un)intentionality, interaction effects, and instability as four concepts that pinpoint challenges the field of HCI is faced with, while offering some initial thoughts on how we might work

on each. We are neither the first to discuss these issues, nor do we have the answers at the ready. Yet as we move between ‘waves’, we believe that there is value in identifying and articulating the shift we are going through so that we can move the conversation forward.

In shifting attention away from more straightforward interaction that we can observe in user studies and individual experiences that participants can to some degree account for in interviews, we are faced with tremendous methodological challenges. These range from how to slice our units of analysis to locating and scoping our sites of study, to gathering and analysing the kinds of materials that could help us make sense of the complex consequences and implications at play. One central concern here are issues of scale [13] — how can HCI create big enough data sets or run big enough trials to create knowledge on par with the large technology companies that are currently dominating the landscape? If we cannot (and do not want to) replicate these settings, then how do we keep up and stay relevant?

Our emphasis has been to look at the multiple interactions, users, and interfaces to see intra-actions and those multistable patterns, perceptions, interactions, and effects [33] that are produced in the relational spaces between immediacies, (un)intentions, interaction effects, and instabilities. Design, in among these knots of ‘interacting’, might be understood as a means to shake the web, to push back, trouble, and reveal the (in)stabilities [18, 28]. As we move forward, we will be asking ourselves: How do we connect immediacies and timespans? How are interactions stabilised currently (and in the future)? Who are our unintended users? What are the points of collapse of interaction effects, and what is produced in these points and moments of collapse? How are multiple intentionalities, including unintentionality, performed and accounted for? How are normativities of intention accounted for in system design and use(s)? We will also turn our questions on themselves and ask: What are our (un)intended immediacies, stabilisations, and interaction effects? How do we stabilise our immediacies? How are our immediacies stacked against each other, producing interaction effects?

More practically, we hope this paper will be an early turn in a broader conversation of what post-interaction studies could look like and how we might engage in interaction design with post-interaction sensitivities.

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