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A Survey of the Trajectories Conceptual Framework: Investigating Theory Use in HCI

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ABSTRACT
We present a case study of how Human-Computer Interaction (HCI) theory is reused within the field. We analyze the HCI literature in order to reveal the impact of one particular theory, the *trajectories framework* that has been cited as an example of both contemporary HCI theory and a strong concept that sits between theory and design practice. Our analysis of 60 papers that seriously engaged with trajectories reveals the purposes that the framework served and which parts of it they used. We compare our findings to the originally stated goals of trajectories and to subsequent claims of its status as both theory and strong concept. The results shed new light on what we mean by theory in HCI, including its relationship to practice and to other disciplines.

Author Keywords
HCI; Theory; Trajectories; Strong concepts;

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H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – Theory and Methods;

INTRODUCTION

The nature of theory is a longstanding topic of debate in HCI. While even undergraduate and postgraduate HCI textbooks [4, 6, 9, 21, 22] routinely offer accounts *of* different examples of HCI theory, the research community remains engaged in protracted discussions as to its nature, status and utility. This debate has ranged across histories of HCI theory [12], ways to identify different types of HCI theory [3], analyses of trends in theory development [20] and the relationship of theory to practice [63].

Of particular interest here are two recent threads of discussion. First, are attempts to broadly characterize the nature of HCI theory, most notably Bederson and Shneiderman's 2003 classification of HCI theory [3] and Rogers' subsequent 2012 extension of this to address "contemporary" HCI theory [20]. Second, are recent attempts to bridge between theory and application, most notably Höök and Löwgren's "strong concepts" [63].

We offer a case study to further illuminate this discussion. Specifically, we chart the life of a potential theory from its first exposition to its uptake and use by others. The particular theory we follow is the trajectories conceptual framework (henceforth called *trajectories* or *trajectories framework*), a suite of related concepts intended to express the nature of user journeys through hybrid physical-digital experiences. We have chosen this example because it has been cited both by Rogers as an example of contemporary HCI theory [20] and by Höök and Löwgren as a strong concept [63], but also because its expression as a rich vocabulary makes it particularly well suited to tracking its use in literature. As something that is evidently of interest to those who themselves are interested in theory, and also something that appears to sit somewhere between theory and 'not-quite-theory', trajectories offer a prima facie case for shedding light on what we mean when we talk of theory in HCI.

Our method involves a systematic review and coding of 60 papers that seriously engaged with trajectories in order to understand both the *purpose* the framework served and which of its constituent *concepts* were of use. The results paint a complex picture of the life of a theory; one that in part affirms, but that also challenges, contemporary notions of theory in HCI.

Our main contributions are therefore (a) to provide a method to survey and analyze the use of HCI theoretical constructs and (b) to participate in the global conversation on theory in HCI. Another secondary contribution is the guidance our work may provide for people specifically interested in *trajectories*.

WHY IS THEORY SO CHALLENGING FOR HCI?

We begin by considering why defining the nature and utility of theory appears to be such a challenge for HCI in the first place. We suggest that many theory tensions arise from two fundamental characteristics of HCI research.

The first is its breadth. Since its birth, HCI research is often described in terms of passing through several 'paradigms' or 'waves' during which the field has turned to different disciplines – including psychology, sociology and design – in search of inspiration for ideas, methods and theoretical foundations [20]. These disciplines embody very different epistemologies, from the scientific foundations of psychology, to the grounding of design in the traditions of

the humanities. It is perhaps then no surprise that HCI often appears to be somewhat confused about the underlying nature of theory. In response, researchers such as Bederson and Shneiderman have attempted to answer the question: "what is HCI theory?", classifying its diverse forms as being descriptive, generative, explanatory, prescriptive and predictive [3]. Reflection on successive waves of HCI, has led Rogers to extend their classification to account for "contemporary" HCI theory as also being informative, ethnographic, critical, formative and conceptual [20].

The second fundamental characteristic of work in HCI research communities that affects an understanding of theory is its applied nature. Much of HCI is concerned with designing new experiences or enabling technologies, which inevitably raises the question: "what is HCI theory for?" Or often more specifically, how does it inform design of one kind or another? Many researchers have wrestled with this thorny issue. Gaver, for example, argues that, in contrast to theories grounded in a scientific epistemology, design-oriented theory in HCI is inherently provisional, contingent and aspirational [11]. Of particular interest here, Höök and Löwgren argue for "strong concepts" that bridge between theory and design practice, are generative of ideas, address interactive behavior, and embody potential design solutions that can be appropriated by designers and researchers.

By presenting a detailed case study of a conceptual framework that has been claimed as both contemporary HCI theory by Rogers and as a strong concept by Höök and Löwgren, we seek to explore the core questions of "what is HCI theory" and "what is HCI theory for", shedding new light on the tension between theory and practice. At the same time, in doing this case study we can enrich the *trajectories framework* itself, suggesting an empirically-driven form of practical theory development for HCI.

METHOD

Our approach is to undertake an analytic literature review. There are, of course, numerous examples of HCI research based on literature review, for example looking at the production of theory [20], adoption of methods such as ethnography [8] and human computation [17], or summarizing progress in specific areas such as Mobile HCI [13, 14] to name just a few. There are also examples of using bibliometric analysis to explore issues such as the nature of publications from different countries and organizations and the merit or otherwise of CHI Best Paper awards [2], conducting co-word analysis to establish a broad thematic mapping of the field [15], and even applying bibliometrics to rank individual scholars [16].

Our approach sits somewhere between the two. We have been inspired by Boehner et al.'s study of the impact of cultural probes on HCI methodology in which they traced and analyzed literature that cited the spread of probes, revealing how the original notion of a cultural probe was reinterpreted to inform many variants [5]. Our approach also echoes how Kjeldskov and Paay [13] coded their review of mobile HCI literature along two dimensions (purpose and methods), although we're less interested in the global purpose and contents of papers but rather focus on the use of one specific conceptual framework, which may be a more or less central feature of each paper.

We began by identifying three works—two papers and a book—that constitute the original academic sources of the *trajectories framework*. We then looked at bibliographical databases to identify works that cited any of these. Starting from over 250 distinct works, we narrowed the list down to 60, selecting only those papers that we considered to be actively engaging with the *trajectories framework*. We then analyzed the resulting corpus, carefully reading the papers and developing a coding scheme to classify them according to (i) the purpose behind using *trajectories* and (ii) which particular trajectory concepts they employed.

We then use this analysis to ground our discussion on whether uses of *trajectories* correspond to three claims that have been made about them: (1) their authors' claim about how they should be used, (2) Rogers's review of theory in HCI and (3) that they are a "strong concept". We note that this transition from analysis to discussion has required a certain amount of interpretation, but we believe this interpretative effort by us as authors mirrors the interpretative achievements of the users of trajectories.

THE SOURCE TRAJECTORY LITERATURE

We begin by introducing the three source publications [27, 29, 28] that, according to the originators of *trajectories*, constitute the authoritative source of the framework. We introduce the main concepts and vocabulary of the framework so that we can refer to it in later discussions. We introduce the three sources chronologically, beginning with *temporal trajectories* [8], a subset of the more general *interactional trajectories* framework [10], that was then expanded in the book *Performing Mixed Reality* [9]. We use the term *original trajectories* to refer to all three.

Temporal Trajectories in Shared Interactive Narratives

The *temporal trajectories* framework [27] is based on the description of temporal structures in Day of the Figurines, a mixed-reality game by artist collective Blast Theory [10]. *Temporal trajectories* are defined the expression of a mapping between *story time* (as the game involves events unfolding over 24 hours in a fictional world) and *clock time* (the actual time in which the story is accessed). Three types of *trajectories* are introduced:

- *Canonical trajectories*, i.e. temporal mappings as envisioned by experience authors.
- *Participant trajectories*, represent temporal mappings as actually experienced by participants. The gap between these two types of trajectories arises from the level of control participants have over their own trajectory.
- *Historic trajectories*, which are retellings of past trajectories, synthesized from recorded data.

From Temporal to Interactional Trajectories

The notion of *interactional trajectories* was introduced a year later [29], informed by the description of three more experiences: two mixed reality performances and an augmented fairground ride. This significantly expanded the concepts in the framework to include:

- A *trajectory* itself is defined as a coherent journey through a user experience.
- The *hybrid structure of experiences* defines a set of complex dimensions that the journey traverses. These dimensions are *time* (the subject of temporal trajectories), but also *space*, *roles* and *interfaces*.
- Transitions describe points in the trajectory where continuity is at risk. This includes a number of specific transitions, such as *beginnings*, *endings, transitions between episodes* or *seams in the infrastructure*.
- *Managing trajectories*, in order to balance the tension between *participant* and *canonical trajectories* as they diverge due to *interaction* and ensuring they converge back again through *orchestration.*
- *Interleaved trajectories* describe the social and collaborative aspects of trajectories.

These five groups of concepts are introduced in five sections of the article, followed by a one-column summary providing a concise expression of "a conceptual framework for trajectories" [29 p. 716]. We note that the paper doesn't include the previous concept of *historic trajectories*.

This paper also proposes intended uses of the framework, as well as classes of experiences to which it may be applied. These are defined in the paper as "cultural experiences" and include museum tours, artistic performances and games [29 p. 709], but extensions beyond these are also suggested, most notably towards learning [29 p. 716]. Below we list the framework's four "possible uses" which we return to later to reevaluate in light of our analysis:

1. A *sensitizing concept* to inform future studies.
2. A *vehicle for compiling craft knowledge*, which describes the process that embeds the practical knowledge of experience creators into a conceptual framework. The originators suggest it is an ongoing process. How this knowledge informs the design of experiences is left open, though guidelines and design patterns are mentioned.
3. *Identifying requirements for future technologies*. This calls for building technologies that specifically support trajectories or elements of the framework.
4. *Enabling a dramaturgy of interactive user experiences*, which includes acting as a bridge between the fields of HCI and Performance Studies.

Performing Mixed Reality

The last source for trajectories is a 2011 book [28]. The framework itself is expressed in the last chapter [28 pp. 229-268] whose structure mirrors that of [29], but with expanded descriptions of the elements of the framework, the return of *historic trajectories*, and the extensive use of trajectory diagrams. The book also includes in-depth reflection on the artistic experiences that fed into the framework, as well as interviews with practitioners and researchers, potentially offering another way of accessing the craft knowledge embedded in trajectories. Compared with the two papers above, it shows a stronger Performance Studies perspective, being written with both HCI and Performance communities in mind. We also note that, unlike the earlier two papers, *Performing Mixed Reality* explicitly labels trajectories as being a theory [28 p. 263].

60 USES OF TRAJECTORIES IN THE HCI LITERATURE

We now present the process through which we built our corpus of publications that cite and engage with trajectories.

The broader corpus

We started by looking at a selection of bibliographical databases to identify publications citing the three *original trajectories* works. We surveyed four different bibliographical databases: the Association for Computing Machinery's Digital Library (ACM DL), Google Scholar, Scopus and Web of Science. Table 1 shows the numbers of papers discovered for each source paper and each database.

Citing	ACM DL	Google Scholar	Scopus	Web of Science
Temporal Trajectories [30]	26	54	6	4
Interactional Trajectories [29]	58	150	26	16
Performing Mixed Reality [28]	37	139	Not found	Not found

Table 1. Result counts in databases (August 20th, 2016)

We first look at the whole result set and at overlaps between databases (all but 2 publications, which we identified through Scopus are covered by Google Scholar). Doing so, we grouped duplicates (either wrongly split by the database, or multiple chapters of a book by a single author) and removed references for which we could not find any information beyond the title and author. That process yielded 263 references.

Table 2 lists the most frequent types of publications and venues. Types not listed include conference adjunct proceedings (such as workshops), magazines, project reports, patents and papers whose status is less easy to determine. They include texts found on authors' own websites, which may comprise rejected papers or internal presentations. As expected given the book's ambitions, citations of *Performing Mixed Reality* include a broader number of arts-oriented journals, such as Digital Creativity or the International Journal of Performance Arts and Digital Media. We also looked at the presence of the framework's originators, who are co-authors for 38 of the 263 references.

Publication Type	2008 paper [30]	2009 paper [29]	2011 book [28]	Total
Conference papers (main proceedings)	20	58	26	**92**
ACM CHI	*6*	*10*	*5*	***18***
ACM DIS	*1*	*5*	*2*	*7*
Journal papers	9	28	33	**63**
Digital Creativity	—	*1*	*8*	***8***
ACM ToCHI	*3*	*4*	*3*	*7*
Books or chapters	2	23	22	**41**
Theses, Dissertations	8	20	17	**37**
Other publications	7	12	14	**30**
Total	**46**	**141**	**111**	**263**

Table 2. Publications found by type and source cited

The narrower corpus

We then narrowed down this corpus to papers that we judged to be relevant to our study of the use of *trajectories*. We weeded out papers where *trajectories* aren't mentioned (e.g., when cited only to mention Blast Theory works, or as a proxy to access other concepts imported from other works, such as seamful design [7] which itself is incorporated in the trajectories framework). We also excluded papers where there was no evident purpose or depth to their engagement with trajectories.

We thus reduced the corpus to 60 papers, including 14 co-authored by an originator of the three sources of *trajectories* (numbered 30-43 and in *red italics* hereafter). The publications in this narrowed corpus fall on a continuum between classic HCI venues such as CHI, design-oriented venues such as the DIS or the Interaction Design and Architecture (IxD&A) journal, and finally humanities-oriented venues such as Digital Creativity or the Nordic Digital Excellence in Museums (NODEM) conference. Our narrowed corpus leans more heavily towards the HCI end, with 10 CHI and 6 DIS papers.

FINDINGS: HOW ARE TRAJECTORIES USED?

We now present our findings, based on the two dimensions of coding we applied to this set: what **purpose** *trajectories* serve in a paper and which of its **concepts** are employed. For each of these, we performed a non-exclusive classification of our 60 papers. The categories and descriptions we use relate to how authors have accounted for their research in their writing, and may not correspond to how the research itself was conducted.

The PURPOSE of using trajectories

We identified four main purposes for using trajectories, which we describe in the following sub-sections, including generally situating one's work, analyzing user behaviors and/or designs, generating designs and finally a conceptual use, where they help build or critique concepts.

Purpose 1: Situating the work

The first purpose we identified was to include trajectories as part of a literature review. This is generally easily identifiable from the presence of trajectories in sections titled "Introduction" or "Related work". 31 papers in our corpus share this purpose, 6 with a trajectories originator as author. Two papers [56, 59] specifically mention trajectories' role as a bridge between HCI and performance, echoing the framework's fourth "possible use". Interestingly, one of these [59] uses their review to identify a gap in literature, suggesting the lack of bridges between networked music performance and trajectories and similar work. We identified one paper where trajectories served no other purpose in our coding [69], with a review of mixed reality performances mentioning the 2009 paper mainly to cover Blast Theory's works, but also quickly describing trajectories as the outcome of these studies.

Purpose 2: Analyzing and describing an experience

28 in our selection of papers use *trajectories* to analyze or describe experiences *as* trajectories in a variety of ways. The depth of this description varies widely, along a spectrum that runs from simply labeling experiences as trajectories with relatively little analysis [e.g. 79, 80], to engaging with a number of concepts in the trajectories framework (as we'll discuss in the next subsection).

A common way of presenting the analysis of *trajectories* is to draw diagrams showing how an experience unfolds, found in 7 papers. In most cases, *trajectories* are plotted along a horizontal axis showing time [*34, 38, 39*, 55, 77, 86, 87], but there are examples of them being shown as an overlay on the map of a space [74, 87]. Plotting *trajectories* is also an activity that researchers have asked participants to do to probe their experience [75].

One paper reported on using a systematic method for analyzing participant's experiences that takes into account *trajectories*, elaborating a coding scheme for interview data, based in part on concepts from the framework [66]. In this category, we also include a paper that suggests *trajectories* could be used "as a metric for evaluating […] experiences" [47] and five [*30, 43,* 73, 79, 83] who map *trajectories* to descriptions that are grounded in hypothetical accounts of experiences than user studies.

Purpose 3: For designing experiences

We divide the 24 papers for which we identified a design purpose into two sub-categories: actual (9) and prospective designs (15), which we describe in more detail below, focusing in particular on how design is accounted for.

Purpose 3a: For actual designs

Although only 9 papers show trajectories as explicitly used for designing experiences, there may be more: two papers analyze or describe *trajectories* before a design activity, but don't show whether these *trajectories* had an impact on

design [75, 83]. In two other cases [76, 88], the structure of the paper, where authors include *trajectories* in a review of related work, then present an experience they've designed themselves and finally analyze the experience using *trajectories*, suggesting that the framework may either have been used early on in the research project to support design or later when looking for analytical tools.

There are different degrees with which these 9 papers account for how *trajectories* are incorporated into designs, ranging from only stating that authors have taken *trajectories* into account [e.g. 74] to systematically using a number of framework elements [e.g. *38*]. We found a few indications of how *trajectories* have been part of design methods and processes, although the description of "how" is far less systematic than of "what". Processes include first authoring a script, then considering supporting resources [74], speculating about how an element (an animated character in [85]) would entice participants into a trajectory, and an iterative design process in which detecting dropouts in early versions led to a refined experience [89].

Other accounts of design processes in this subset of our corpus tend to focus on external requirements, such as site-specific constraints [*42*], or coordinating with stakeholders (e.g. a sound designer [*38*], museum staff [84]). In 6 of these 9 papers, the evaluation of the experience connects back with *trajectories* (counted in the sub-section above).

Purpose 3b: For prospective designs

15 papers suggest that using, or at least taking into account, *trajectories* helped with the design of future experiences. Rather than suggesting iterative improvements to systems presented by the authors, in most cases (13), *trajectories* raised novel design requirements for a class of experiences. In the remaining case [82], *trajectories* helped assemble currently distinct experiences. These suggestions are offered in the late stages of papers, generally in the "discussion" section, and follow either user-centered studies (10 papers [*34, 41, 43*, 54, 55, 57, 60, 79, 82, 86]), surveys of existing systems [*40*] or theoretical works [*30*, 49, 67, 73]. Arguments leading to such suggestions include:

- Analyzing or labeling an experience as a *trajectory* and suggesting that these trajectory aspects should be supported in future designs [55, 60, *41*, 79, 86].
- Proposing specific design strategies that include, but are not limited to, *trajectories* [*40*].
- Reflecting on how aspects of an experience could hypothetically be mapped with *trajectories* [*43,* 73].
- Drawing requirements (e.g. balancing elements of an overall experience [57] or accounting for changes in the context of use [67]), then suggesting *trajectories* may address these requirements.
- Expanding the scope of *trajectories* by describing how they fit one class of experiences and how this knowledge could inform others ([*30*] suggests transpositions from theatrical to musical performances, and [*34*] from miniature wargaming to the Internet of Things).

Purpose 4: Discussing and building concepts

The most frequent purpose we have identified is to call on trajectories during discussions of other HCI concepts, which accounts for 38 papers in our corpus. In this subsection, we provide a non-exhaustive list of different ways in which *trajectories* have led to building concepts, including comparing and borrowing concepts, as well as building implicit and explicit extensions to the framework.

Purpose 4a: Comparing with existing concepts

Several works review trajectory concepts early in the paper. This use tends to overlap with the "situating" purpose listed above. For example:

- Cerratto-Pargman et al. [56] compare different analytical frameworks before setting out on their analysis of a theatrical performance (finally ruling *trajectories* out).
- Although they don't consolidate it into a conceptual framework, Calori et al. [55] draw together a number of sources, including *trajectories* and concepts from education research to establish a taxonomy that they use as a frame of reference when analyzing an experience.

Purpose 4b: Comparing with resulting concepts

Another way papers employ *trajectories* is by first building their own concepts independently and then comparing them with either the full framework or its components:

- Benyon's blended spaces [48, 49, 50, 51] that resonate with *trajectories' hybrid spaces*.
- Bowser et al.'s [53] Prototyping for Location, Activities, and Collective Experience (PLACE) framework, with aspects close to the four *hybrid dimensions of experience*.
- Hansen et al. [62] map a number of the aspects of their Alternative Reality Game (ARG) Reusability Framework to concepts in *temporal trajectories*.
- Höök and Löwgren's [63] suggestion that *trajectories* share qualities with *social navigation* and *seamfulness* that make them "strong concepts".
- In contrast, Rossitto et al. [80] see *trajectories* as being antithetical to their recommendation of "loose coupling between narrative and places".

Purpose 4c: Borrowing trajectory concepts

Other authors develop concepts that directly borrow elements from *trajectories*:

- Barba [46] combines *trajectories* with cognitive models and design theory to build "a theory of meaning for mixed reality walking tours".
- Barba and McIntyre [47] map a level of their *scale model of mixed reality* with the *hybrid spaces* in *trajectories*.
- Benyon and Mival [50] propose a framework for designing collaboration including *transitions*.
- Bonsignore et al. [52] see *trajectories* as occupying the close-ended end of her ARG design continuum.

- Lindinger et al. [70] integrate the balance between *canonical* and *participant trajectories* and *orchestration* into their principles for participatory performances.
- Lundgren et al. [72] see *trajectories* as an inspiration for their "mobile collocated interaction framework", and import concepts such as *synchronization* and *pacing*.
- The different components of Wouters et al.'s [87] "honeypot model" are connected through *trajectories*.
- Yule et al. [88] use the *dimensions of experience* to map out the role of docents as guides through experiences.

Purpose 4d: Explicitly extending trajectory concepts

Although two papers listed above explicitly state their contribution as being to extend *trajectories*, these propose frameworks that differ widely in structure and contents from *trajectories*. We thus restrict the list below to works that offer additions to existing trajectory concepts in ways that fit the current structure of the framework. We identified the following extensions, mostly from the originators:

- Considering *trajectories* on multiple scales [*33*].
- "Trajectories of things", which drive a new type of transition in terms of change of ownership [*34*].
- Considering "group trajectories" as well as feedback between *canonical* and *participant trajectories* [*36*].
- Two-scale (global and local) *trajectories* and a specific structure for the *local trajectory*, as well applying them to cultural interpretation [*37*].
- A fifth *dimension of experience*, knowledge that generates "parallel trajectories" and *transitions* at "setups" and "reveals" in magic performances [*39*].
- *Trajectories* may apply to "less structured" experiences, i.e. ones without an extended narrative connecting multiple episodes of interaction [85].

Purpose 4e: Implicitly extending trajectories

We look at works that echo the types of extensions listed above and draw lessons that in our view could have been labeled as extensions. In contrast with the above, only one of these [*35*] involves *trajectory* authors. They include:

- Showing engagement with *trajectories* as progressive, through an active process of "gearing in" [*35*].
- Exploring *role transitions* and suggesting ways of addressing them [60].
- Proposing a mechanism for managing multiple *participant trajectories* that does not rely on top-down *orchestration* but on voluntary synchronization [66].
- Suggesting a typology of *participant trajectories*, which can be "dropout trajectories" or "activation loops" [87].
- Seeing *historic trajectories* as either reflections on *participant trajectories*, extensions of them or self-contained *trajectories* [77].

In the latter case, the authors have not employed the term "*historic trajectories*" themselves as they are referring to the paper that doesn't include them. In all these cases, the extensions stay implicit because the authors structure their discussion around eliciting a number of themes and establishing a main contribution, which do not necessarily align with the goal of extending *trajectories*. In the examples above, authors are primarily concerned with establishing design guidelines for a specific purpose (increasing participation in performances [60] or engagement with arts institutions [77]), exploring a design space (theme park visiting in [*35*]), building their own framework [87] or understanding a phenomenon (behavior change with an app [66]).

Purpose 4f: Critiques of trajectories.

Seven papers in our corpus draw the conclusion that *trajectories* are not suited to certain classes of experiences. All of these critiques argue that trajectories are too structured [65, 71, 80], too close-ended [52, 62], or involve too much authorial control and too little agency for participants [*37*, 52, 64]. Some of these critiques are justified by explicitly stating what characteristics of experiences fall outside the remit of *trajectories* (e.g. 'everyday interactive artifacts […] do not possess any explicit "stories" [71]'). On the other hand, some critiques resonate with themes that are present in our corpus, with a number of works exploring whether *trajectories* can extend to open-ended, user-created [68] or less structured experiences [85], or proposing intermediate levels where *trajectories* "scaffold" the experience [*37*, 85] rather than directing it. This critique resonates particularly with the types of experiences described in *original trajectories*, i.e. artist-led, mostly scripted experiences that require suspension of disbelief from participants.

Which trajectory CONCEPTS were used

Having dealt with the various purposes for which *trajectories* are used, we now turn to the various **concepts** in the framework. Again, we identified four categories, from the most general to the most particular: (1) *trajectories* as an example framework, (2) the global idea of *trajectories* as a user journey, (3) mentioning specific components of the framework, and (4) detailed instantiations of components.

Concepts 1: Trajectories as an example framework

32 of the papers we listed describe trajectories as being an example of a theory, a concept and/or a framework. Other papers do not describe the nature of *trajectories* at all, for example referring to them as generic "works" or identifying *trajectories* with Blast Theory's performances. In most cases, engaging with the theoretical nature of *trajectories* goes little beyond labeling. Exceptions are:

- Benford et al.'s [*31*] description of the method of "performance-led research in the wild", which provides a detailed account of the development of *trajectories*.
- Höök and Löwgren [63]'s suggestion of *trajectories* as a candidate for being "strong concepts".

A number of authors provide accounts of the nature of *trajectories* as a theory. It is often seen as a framework that "describes", "characterizes" or "expresses" experiences [*36*, *39*, 46, 47, 52, 71, 89] or that helps understand them [60, 66]. It's also seen as directed at designers and artists, with a more or less prescriptive phrasing ("urging" [53] or

"encouraging" [34] them or simply suggesting their use to "create" [72] or "frame" [85] experiences).

Concepts 2: Trajectories as a global user journey

A majority of this corpus (45 papers) label *trajectories* in a form or another as being a global journey through an experience. Three papers seem to have a differing global definition of *trajectories*. One refers specifically to "interpretative trajectories" [80], building on Fosh [38]'s extensions of the framework. The other two draw additional concepts into their definition of *trajectories*: one [55] calls upon the concept of *learning trajectories* from educational research [23] and the other [87] on interactive artists' description of interactions as journeys [24]. These "composite" characterizations of *trajectories* are introduced early and are used throughout these papers.

Concepts 3: Mentioning specific trajectory components

A majority of papers (48) mention one or more of the components of the framework we have described. We now look at how broadly and how deeply authors have engaged with these components. We first looked at how many of the five main components of *interactional trajectories* (*types of trajectories*, *dimensions of experiences*, *transitions*, *managing trajectories and interweaving trajectories*) were mentioned in each paper. Most papers use narrow sets of concepts, with 23 borrowing from only one category, 8 from two, 7 from 3 categories, 6 from 4 and finally 5 papers only covering the full extent of the framework.

We then look at the depth of engagement with concepts by looking at which papers go beyond a mention or a quick description of the elements of the framework. This is the case of 31 papers. Engaging in depth with all categories of concepts is limited to four papers, all co-authored by one of the originators of *trajectories*, one which suggests the application of *trajectories* to another fields [30], two that use *trajectories* to analyze existing experiences designed by artists [33, 36] and one to design and evaluate a new experience [38].

Some concepts are more frequently cited, such as *hybrid dimensions of experience* (25 papers), *transitions* (25) or *canonical trajectories* (22), while *interleaving trajectories* (15) and *historic trajectories* (10) enjoy less success, the latter being only used 4 times in works that don't involve a trajectory author. 14 of the works that engage with the framework at the level of its components do not describe what a trajectory is at the global level. One of these [66] does not even mention the word "trajectories" at all, the paper looking at *trajectory* elements as being characteristics of "hybrid experience".

Concepts 4: Worked instances of trajectory concepts

In the fourth approach, papers engage with *trajectories* by providing more detailed examples, seen in 24 works. In most cases, these instances are grounded in analyses of experiences, with a strong overlap (21 papers) with the analytical purpose from the previous subsection. Other sources for these examples come from descriptions of designs [38, 42, 61, 77, 85, 84] or from fleshing out examples in literature [88]. Examples of how *trajectories* are instantiated include:

- [33, 38, 42] show step-by-step examples of *canonical trajectories* in existing experiences or their own designs.
- [33, 36, 38, 41, 83, 85, 87] provide instances of *role transitions*; [38, 76] of *seams* (GPS inaccuracy); [33, 77, 85, 86] of *beginnings* and *endings*, including premature endings or "dropouts" [87, 89]; and [33, 23] of *orchestration* by teachers and facilitators respectively.
- *Participant trajectories* are represented as diagrams, which may also map other concepts (*transitions* and *hybrid dimensions of experience* for [86], *roles* for [87], *orchestration* for [55]).

We also include in that section intermediate-level descriptions, which are slightly more abstract than ones extracted from a specific instantiation of trajectories, but are applied to a class of experiences. Often, this backs up claims that trajectories could potentially address new types of experiences [30, 43, 79]. For example, [7] suggests a potential use in musical performances of each concept.

DISCUSSION

Our analysis reveals a complex picture of multiple ways in which *trajectories* has been used in HCI research, both in terms of purpose and of the choice of particular concepts within the framework. It appears that *trajectories* is used to situate other work, analyze existing experience, sometimes (but perhaps less so) to justify the design of new ones, and often to discuss or help build further concepts. Citations suggest that the most common use by the original authors is as a sensitizing concept to analyze studies of cultural experiences while the most common use by others appears to be to relate *trajectories* in some way to other concepts. Not all *trajectory* concepts are equally popular. Rather, it seems that many researchers are happy to pick and choose concepts from within the overall framework, often treating them superficially, but sometimes in depth, but with only a few papers attempting to apply it in its entirety. This may not seem surprising given how *trajectories* are highly open to interpretation rather than prescribing a specific use and that, whether or not we consider them to be theory, HCI as a discipline doesn't seem to have developed a consensus on what a theory is or how it should be used.

So how can we make further sense of this complexity and what does it tell us about HCI theory? To answer this question, we consider our findings from three angles:

1. How they stack up against the originators' own claims for the *trajectories framework's* utility in HCI?
2. How they compare to Rogers' claims that *trajectories* are an example of contemporary theory in HCI?
3. How they compare to Höök and Löwgren's claim that *trajectories* are a strong concept in HCI?

Comparing trajectories with the originators' claims

Here we return to the "possible uses" of *trajectories* that were suggested by the originators. Our findings paint a mixed picture, with evidence of three out of four of these being met to some extent, while also revealing an unanticipated use in the form of building further theory. Here we review all five:

(i) As a sensitizing concept – we found numerous examples of studies that have employed *trajectories* in the analysis and write-up process. This has arguably been the easiest use to identify, perhaps because some form of grounded analysis of studies is a popular kind of published output within HCI.

(ii) As a vehicle for compiling craft knowledge – the case here is less compelling. We found evidence of the use of *trajectories* in design reported in nine papers, although accountability was often lacking, both in terms of the extent and rigor with which the concepts had been embedded in the designs and/or supporting methods. It may be that the presentation of design-oriented research remains difficult in HCI as noted by Wolf et al. [25] who see "communications within the CHI research community" as "contrary to the nature of design", and also by Gaver in his proposal for *annotated portfolios* as an outcome of research through design [11].

(iii) Identifying requirements for new technologies – for this third ambition, we have not identified any examples of papers describing a technology that explicitly addresses a specific concept or set of concepts from the framework. Perhaps this particular framework is not implementable? Or maybe there is an even larger disconnect between theory and technology development in HCI than there is between theory and design?

(iv) Enabling dramaturgies – writing as HCI researchers, evaluating the outcome of *trajectories* in terms of new "dramaturgies" may be beyond our competence, but we have identified a number of papers that engage with *trajectories* to describe performances within performance studies and digital arts publications and relate them to theories from theatre and drama. Two of these clearly state their purpose as being to inform dramaturgy [60, 70].

(v) An additional outcome – building new HCI theory – our findings show evidence that trajectories have contributed to the building of other concepts, some of which have been labeled "theories" or "frameworks" by their authors. While we see a number of new concepts being developed, few beyond the originators have complemented or extended the framework with their own findings. Maybe such concepts are "like your toothbrush, fine for you to use but no one else is very interested in using it" [reported by 19]. Perhaps there is a lack of incentives for research teams to complement each other's theories, offering some grounds for concerns about HCI's "theory industry" [20]. Or perhaps, unlike software development, theories are not yet articulated in a way that makes them open and readily extensible.

Trajectories as HCI theory

We now broaden our perspective away from the originators' own claims to examine those of others. As part of a historical survey of theory in HCI research, Rogers listed *trajectories* as a "successful" application of contemporary theory in HCI [20]. In the same book (which also labels *trajectories* as a "conceptual framework"), she introduces a typology of theory, drawing both upon a previous review by herself [19] and existing categories proposed by Bederson and Shneiderman [3]. As Rogers does not explicitly specify where *trajectories* fit within these, we now review this typology. We compare, on one hand, both the original *trajectory* literature and the corpus we've analyzed, and on the other hand descriptions of theory types to identify which of these may best describe *trajectories*. First, we evaluate Bederson and Shneiderman's original types, which they consider as being non-exclusive:

- *Trajectories* are **descriptive**, as they "clarify terminology […], identify key concepts [and] guide further enquiry", and are frequently characterized as such in literature.
- Papers that use *trajectories* to support design give evidence of them being **generative** as they "enable practitioners to invent or discover something new", although *how* designs should be generated isn't explicated by either the framework's originators or its users.
- *Trajectories* match their definition of **explanatory** theory as they help find "combinations that fail or succeed". Other authors identify them as such [60, 66].
- *Trajectories* may be **prescriptive** according to their definition, as they "convey guidance for […] design by recording […] known dangers", although they are not phrased as prescriptive guidelines. One endeavor to use trajectories in a systematic way [*38*] and one characterization of the framework [53] in particular connect to this prescriptive nature.
- Whether trajectories are **predictive** may be open to interpretation depending on one's expectations of the type and strength of predictions theory should make. Even though *participant trajectories* have been described as made of "unpredictable choices" [87], labeling transitions as "moments at which […] continuity is at risk" [29] may constitute such a prediction about user performance.

We now turn to Rogers's [20] extensions:

- *Trajectories* are **informative**, as they seek to examine "knowledge and generalizations from another field" (i.e., performance, arts, etc.) and "couch understandings and designs" using a particular language.
- Although trajectories are described in subsequent work as grounded in **ethnographic** studies [31], they don't provide detailed descriptions of the experience of either authors or participants in interactional journeys.
- Both the original intentions and uses of *trajectories* fit the description **conceptual theory**, i.e. to offer "high-level frameworks and dimensions for informing and articulating

design and evaluation". However, *trajectories* do not tell researchers *how* design and evaluation should be done.

- We note that the 2004 paper by Rogers also describes **formative** theory as "provid[ing] a lingua franca; a set of easy to use concepts for discussing design" – this appears to chime with the intentions of *trajectories*.
- Finally, although *trajectories* are not directly described as **critical** by either their original authors or the rest of the literature we identified, they are derived from "critical analyzes of practice" [28] and, both in their formation and their use, correspond to Bardzell [1]'s description of "critical theory as it applies to interaction". *Trajectories* are an example of "interaction design [that] can develop theory" and they "inform the existing design process". Where trajectories seem to differ from critical theory is by their lack of orientation towards activism.

We offer several observations here. Firstly, we found that applying the typologies of Bederson and Shneiderman, coupled with that of Rogers, is not a straightforward activity. On this note, we could add that none of these authors provide tools to assess theory types or use. Hence, in several instances in the prior section, it is not entirely clear what constitutes, say, the threshold for considering a theory "prescriptive". This is likely because the typology trades on vernacular meanings yet does not provide formal definitions. Secondly, it is possible under both Bederson and Shneiderman and Rogers's schemes for an HCI theory to be several types simultaneously in the typology. Thirdly, it is unclear whether other theories are more or less likely to occupy multiple types e.g. is something that is a "critical theory" *less* likely to have more type affiliations? Fourthly, we note that the character of Rogers's extensions to Bederson and Shneiderman differ from their original types. The latter describe theory types in terms of *adjectival* qualities, whereas Rogers's combines this with intellectual traditions (e.g., critical), and methods (e.g., ethnographic).

These challenges aside, it is possible to make a case to fit *trajectories* under a number of these headings. In this sense, *trajectories* might indeed be considered to be a valid HCI theory. However, *trajectories* do not fit some of the noted criteria that one would associate with theories from either a broad scientific tradition (e.g. being predictive) or that of the humanities (e.g. being critical). Indeed, the *trajectories framework* doesn't appear to be grounded in any recognizable or established "big theory" of the kind that was imported into HCI in its early days, for example cognitive theories from psychology [19]. Perhaps, as a formative theory, it does, as Rogers proposes, represent a *new* form of contemporary HCI theory. Perhaps this kind of theory is grounded in and emerges from HCI itself rather than being imported? It may even be the case that this theory is now trying to reach back towards other fields, for example towards the arts and humanities as a new dramaturgy. Or perhaps, less grandly, *trajectories* are not theory at all but rather something else as we now consider.

Trajectories as a strong concept

Höök and Löwgren [63] set up a vertical relationship between "instances" and "theory", identifying *trajectories* as being a "strong concept", i.e., something that is more abstracted than particular instances, yet does not aspire to the generality of a theory, although does retain a distinctive relationship to it. *Trajectories* seems to sit comfortably "above" particular instances, but it is harder to evaluate whether it is "below" theory. The originators of *trajectories* do not help greatly here as the original 2008 and 2009 papers do not claim trajectories to be a theory, but the *Performing Mixed Reality* book clearly does. If trajectories do indeed sit below theory, then below which theories do they sit? The only explicit "vertical grounding" trajectory authors claim may be the connection between *canonical trajectories* and plot time in narrative theory, but it does not seem to extend to other trajectory concepts. That said, previous characterizations of critical theory [1] in HCI show that theory itself may be developed from interaction design and not only in existing bodies of theory.

Trajectories do appear to fit more comfortably with other features of *strong concepts*, such as being "generative", concerning "interactive behavior rather than static appearance", and comprising "elements of potential design solutions, that can be appropriated by designers and researchers" all of which appear to fit the original formulation of *trajectories* and are evidenced to some extent by our findings. It is, however, hard to argue that trajectories are "potential parts of artifacts".

Assessing whether *trajectories* "work" as a strong concept is therefore also tricky. First, our classification showing which *trajectory* concepts were used seems to map with multiple levels across Höök and Löwgren's description of intermediate-level knowledge as a continuum between *instances* and *theory*. *Trajectories* therefore seem to sit at multiple locations in between, from the very top to the very bottom, depending on how they're used.

If we do consider the framework to be a strong concept, then it is worth consider whether and how it operates as a bridge between theory and design. First, *trajectories* doesn't appear to work as a *single* strong concept, but rather as a *flexible set* of concepts whose "strength" depends both on where they sit within the framework and the lenses through which they're engaged with. As we saw earlier, researchers seem happy to pick and choose concepts rather than systematically buying into the whole framework.

Also, many of the papers that we reviewed appear to use trajectories to develop other concepts. While some papers certainly do explore the vertical relationship downwards into design, and maybe a few look back upwards towards theory (dramaturgy), many of the uses that we see operate "horizontally", with other concepts justifying themselves in terms of *trajectories*, borrowing from them, critiquing them and implicitly or explicitly extending them. It seems that there may be a great deal of "churn" in Höök and Löwgren's

"intermediate-level knowledge space". Figure 1 revisits and extends Höök and Löwgren's original diagram that positioned *strong concepts* alongside other concepts and methods in the gap between theory and instances. Here we suggest how strong concepts may be both structured frameworks and singular, that they may *often* engage with one another and with the other inhabitants of the gaps in various ways while also connecting to instances and theory.

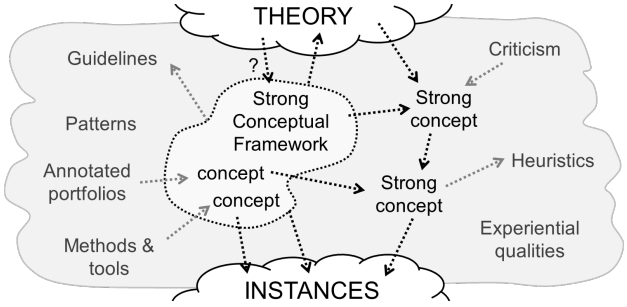

Figure 1: The churn in intermediate-level knowledge space

Bridging theory and practice

Our description of horizontal relationships in the "strong concept space" shouldn't led us to ignore the importance of vertical relationships. Bridging between layers is clearly important and often difficult. While we have seen some evidence from the literature of *trajectories* bridging downwards, it is perhaps difficult to make this assessment without examining practice itself. This may be complicated by the need to find new ways to put trajectories into practice. We acknowledge that might also be because literature review is not the best place to look for such evidence—after all, HCI theory itself is strongly wedded to the discursive activities of reading and writing academic papers so our analysis pertains to an explication of *those* practices rather than those of design practitioners. We question whether designers outside HCI research (e.g. in industry) would report their work in the academic literature and if they did would they cite evidence of trajectories? Intriguingly, we recently encountered a professional Information Architect who had adopted trajectories and adapted them for the User Experience community, producing a pamphlet [18], a series of blog posts and speaking at UX conferences. It is notable that (1) this work did not show up in any sources used to build our bibliography and (2) even though this professional has identified value for trajectories in their line of work, their writings don't describe any evidence of actual use in practice. "Visibility" is thus a key issue here for any future studies of HCI theory in practice.

Future work that intends to bridge the gap between theory and practice may therefore involve reaching out to professional practitioners, e.g. by attending and publishing into industry-led UX conferences or by popularizing trajectories within organizations. Research through Design may also provide a way of understanding how theory can best be appropriated. We may though want to diverge from Gaver's suggestion that artefacts should be annotated to give particular examples of theory in practice [11] (the outcome may be similar to Benford et al.'s mapping of *trajectories* to a description of Day of the Figurines [33]), and rather annotate the process of designing to understand how appropriation of theory happens.

CONCLUSION

Discussions about forms of knowledge in HCI (such as *theory*, or *strong concepts*) form an important part of our research communities. But more often than not—and perhaps understandably—these discussions lack an empirical contribution. In presenting a systematic, analytic review of the trajectories framework, we hope to offer both a contribution to help better understand HCI theory and at the same time, provide a way forwards for enriching the discussions around how HCI research treats theory. We draw three general conclusions from our analysis:

First, conceptual frameworks such as *trajectories* could be justified as examples of theory under some contemporary definitions. However, they are not obviously like, or indeed grounded in, the kinds of theories that were previously imported into HCI in its earlier waves, one characteristic being the diversity of approaches through which they may be used. Are they instead a kind of "native" theory that is emanating from HCI? If so, might they eventually push back into other disciplines?

Second, *trajectories* may also match the definition of a *strong concept*. If so, our analysis reveals that, beyond their construction as explored by Höök and Löwgren, the lifecycle of *strong concepts* involves complex structures and relationships within "knowledge space" through which concepts are brought together, and perhaps from which theories may emerge and eventually push upwards?

Third, the method of literature analysis appears to be a useful way of charting the development and impact of such theories (as it was previously with the method of probes). We note that the approach might be easier to apply if some of the purposes and relationships we identified above were subsequently embedded into keywords or other publication metadata. Perhaps this would even make theories and strong concepts more open to reuse and recombination.

While this is beyond the remit of the current paper, we finally note that one additional contribution of this method could be to consolidate existing additions to *trajectories* into an extended framework. For example, critiques about the closed-ended aspect of *trajectories*, combined with suggestions that *trajectories* may also serve open-ended [85] or "scaffolded" experiences [37], could lead to a typology of control ranging from designer-led to participant-led.

DATA ACCESS STATEMENT

Articles reviewed and their coding can be obtained at http://dx.doi.org/10.6084/m9.figshare.4524617

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