Reviewing Reflection: On the Use of Reflection in Interactive System Design

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ABSTRACT

Designers have demonstrated an increased interest in designing for reflection. However, that work currently occurs under a variety of diverse auspices. To help organize and investigate this literature, this paper present a review of research on systems designed to support reflection. Key findings include that most work in this area does not actually define the concept of reflection. We also find that most evaluations do not focus on reflection *per se* rather but on some other outcome arguably linked to reflection. Our review also describes the relationship between reflection and persuasion evidenced implicitly by both rhetorical motivations for and implementation details of system design. After discussing the significance of our findings, we conclude with a series of recommendations for improving research on and design for reflection.

Author Keywords

Reflection; review; reflective HCI.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Interaction design originally focused largely on workplace and task-based settings [32] where productivity was the primary goal. Later work developed from "human factors to human actors" [3], considering the human not as a portion of a larger cognitive mechanism but rather acknowledging and incorporating many of the psychosocial dimensions of technology use. Third-wave HCI [11,35] then argued for considering how other aspects of human experience—emotion [82], domestic life [89], sexuality [46], culture [41], religion [7,101]—might factor into technology design.

During this third wave shift, the theme of designing for

reflection has emerged. That is, designers have become interested in the ways that technology might be able to support human reflection on experience [23,75]. While reflective thought has arguably existed as a locus of interaction design for years [cf. 20], explicit focus on supporting reflection is relatively nascent, though with an already emerging body of literature [23,75]. For work in this area to move forward and mature into a developed subfield, it would be valuable to consider how such work approaches reflection. How is reflection defined? Where is reflection expected to be most helpful, and in what ways? What techniques and design strategies are used to encourage and support reflection? When do we know that reflection has occurred, i.e., how is reflection evaluated?

This paper reviews literature in the emerging area of designing for reflection. First we describe the process of our literature review, resembling in many ways that of [21]. The subsequent section presents a number of trends, patterns, and themes we identified in our analysis, followed by an interpretation of these findings and their implications, as well as suggested directions for future work on designing for reflection.

We find that little work actually explicitly defines what reflection is, and even less grounds the definition in a conceptual or theoretical framework. The rareness of a clear definition leads to a majority of work using colloquial or implicit definitions of reflection and as a result presenting the concept as fairly limited in its scope. Similarly, relatively few evaluations focus on reflection per se, instead assessing outcomes supposedly resulting from reflection. Finally, while reflection is purported as a benefit in a variety of areas—from education to design to personal informatics—almost no work considers potential downsides of reflecting.

Reflection is considered central to many fields including healthcare, education, and design. If interactive systems design is to contribute meaningfully to supporting reflection in these and other areas, it will be essential to have a more nuanced understanding of reflection itself, means of assessing it, and strategies to support it.

OUR PROCESS

Before beginning our literature review, we sought to achieve at least partial consensus among the authors about

what constituted reflection. The goal was not to articulate a highly specific definition, but rather to provide some set of criteria for whether a paper should or should not be included in our review. Drawing on ideas from Dewey [20], Schön [76], Moon [67], and others, we see reflection as reviewing a series of previous experiences, events, stories, etc., and putting them together in such a way as to come to a better understanding or to gain some sort of insight. This broad, general conceptualization was intentional, as this review is meant to be inclusive rather than exclusive. These basic ideas were used to guide our literature search.

Building the Corpus
Due to our specific interest in how reflection has been conceptualized and deployed in interactive system design, we used a search of the ACM Digital Library to collect papers. Specifically, we collected all papers published under the H.5 ACM classification (Information Interfaces and Presentation) that used "reflect," "reflecting," or "reflection" as a keyword. We chose not to use the keyword "reflective" as such papers often focused more on designers', researchers', and practitioners' reflection on their own work (discussed further below). We used the H.5 designation to capture as much relevant literature as possible (noting that the template for many human-computer interaction venues uses H.5.m as the default classification). This keyword-based approach could omit some papers that arguably pertain to reflection as defined above. However, our goal was not to find every paper that fit this definition but to identify those papers that the authors viewed as being *about* reflection. These were the papers that we wanted to include in the review, those that explicitly purported to engage with the concept.

This initial search generated 100 results. Of those, we sought papers that involved studies of some person or persons (often users though not always) who were reflecting. We excluded papers where the keyword "reflection" was used to refer to the optical phenomenon, e.g., "frustrated total internal reflection" as a technique in touch-based interfaces. We also excluded papers that were reflections on the field of HCI where the authors were the primary people doing the reflecting. This process resulted in 76 papers being included in our review.

Reading and Analysis
We began our analysis by developing a series of questions intended to provide a sense for how reflection was conceptualized and deployed.

1. What definition of reflection does the paper offer?
2. To what application domain does the paper pertain?
3. Who are the people doing the reflecting (e.g., system users, designers, students, the elderly)?
4. Is reflection the desired result of an intervention described in the paper (as opposed to, say, a paper studying reflection in some specific context)?
5. If the paper describes an interactive system, what design features or strategies are used to support reflection?
6. What are the stated benefits of reflection?

These questions were not meant to be restrictive, i.e., these were not the only aspects of these papers in which we were interested. Rather, they were meant to provide generative guidance—what patterns, trends, or themes might be noted by attending to these questions? After formulating our list of questions, the papers were evenly divided among the authors. Each author read her or his papers, both answering our list of questions and noting other trends. The authors also met periodically throughout the reading process to discuss both observations and questions.

After reading all the papers in our corpus, we conducted an analysis based on a grounded theory approach [27]. Combining our answers to the above questions with other notes and observations, we developed a list of salient themes emerging from our discussions of the papers. These themes became the basis for a series of memos, with each memo both describing one theme or pattern and indicating the reason for its interest or significance. The memos were then circulated among the authors, who discussed them further, refined them, and considered relationships among them. These memos, and the themes they describe, form the basis for the following sections.

RESULTS – THEMES AND PATTERNS
In total, our corpus included 76 papers, all published between 2000 and 2013. The average publication year was 2010 and the median 2011. A plurality of papers come from the ACM SIGCHI conference, either the full proceedings (13 papers) or the extended abstracts (16). The later include a mix of workshop descriptions, works in progress, posters, etc. The next largest contingent appears in the Creativity & Cognition conference (8). The remainder occurred in such venues as Designing Interactive Systems (3), Artificial Intelligence and Education (3), iConference (2), Tangible and Embedded Computing (2), and other similar venues. The papers themselves describe a variety of endeavors, including interactive systems to support reflection [e.g., 12], methods intended to incorporate reflection into design processes [e.g., 19], techniques for user studies [e.g., 39,40], empirical studies of reflective practitioners [e.g., 73,68], and others.

This section describes a number of trends and patterns observed in the corpus during our analysis. The subsequent section turns to the interpretation of these patterns, their significance, and their implications for future work.

Reflection and its Definition
As described above, this review sought to explore the definitions of reflection used in the HCI literature. However, the papers we reviewed rarely actually defined reflection. Of the 76 papers, only 30 included an explicit definition. Often, this definition consisted of a brief,

surface-level description without grounding in extant theory, e.g.: "conscious, purposeful thought that is directed at a problem in order to understand it and form integrated conceptual structures" [79:49]; "inform the users about their own behavior" [62:322]; a process "in which people recapture their experience, think about it mull it over and evaluate it" [6:1786]; or "looking at lists of collected personal information or exploring or interacting with information visualizations" [55:562].Of those 30 with a definition, only 22 papers provided a citation on which their definition was based. Interestingly, six more papers referenced such a citation but did not include a clear definition of reflection, presumably expecting the reader either to be familiar with the concept or to reference the citation. Of those 28 papers that did cite a reference for reflection, a large majority (20) drew on Schön's [76] concept of reflection-in-action. The remainder cite work from a variety of areas, such as creativity [100].

Reflection and its Evaluation

We also examined how evaluations of reflection were conducted. The overwhelming majority of papers we reviewed treated reflection as the means to an end, such as improved education [30,48,78], better design [66,83], a greater understanding of one's illness or cognitive abilities [25,52], etc.

As such, quantitative assessments in these studies rarely measured reflection *per se*. Instead, either they measured other outcome variables, suggesting that an improvement in those outcomes indicated increased levels of reflection, or the evaluation was less concerned with whether reflection happened, using it primarily as a justification rather than an outcome [30,62]. In several studies, individuals were considered to have reflected on their behaviors or patterns after being presented with their data, but little evidence is provided to suggest that these people engaged in some kind of reflective thought [cf. 67,76] beyond simply looking at the data [56,94].

Qualitative assessments of reflection often occurred in the context of interview studies [53,90]. This approach, however, encounters similar difficulties noted above, namely, lacking a clear definition of reflection and not asking directly about reflection. For instance, Leijen et al.'s [53] interviews dealt with self-assessment and use of video recordings in dance instruction. While reflection comprised a part of that dialogue, the interview questions appear less directly focused on reflection, instead focusing on "the streaming video usage in the course: video editing and viewing to support the describing of experiences, use of video, evaluation questions and criteria for online self-assessment, and online peer feedback activities for learning from multiple perspectives" [53:172].

A few exceptions to this trend either explored reflection for its own sake or measured reflection as a contribution to another outcome. For example, Isaacs et al. [42] asked study participants to revisit old entries posted in a journaling system and re-rate their feelings about the event in question. Doing so not only made the reflection visible and thus enabled direct analysis thereof, but it also allowed investigation of the effects of that reflection on overall wellbeing. Indeed, Isaacs et al. [42] provide one of the more methodologically rigorous evaluations in our corpus.

In light of the above noted vagueness with which reflection is often defined, this trend of not measuring or exploring reflection directly might be expected. Indeed, the lack of clarity resulting from using either no definition or a colloquial definition of reflection would likely make direct assessment challenging at best. Thus, many studies instead investigated outcomes or aspects of experiences that purportedly would benefit from increased reflection. The following sections detail three specific types of benefits these papers suggest reflection can or should provide.

Reflection and Education

First, of the papers we reviewed, 15 dealt with education in some way [14,15,16,17,30,43,48,50,51,53,70,77,78,79,90, 93,98]. Specific foci ranged from reflection as a means of educating working professionals [16] to music [14,43] or dance [53] instruction, to teaching programming [90].

This prevalence does not come as entirely surprising. Dewey's [20] philosophical investigations on the value of reflective thought links it explicitly with education, and others have similarly argued for the value and importance of reflection in education [e.g. 67]. Indeed, some form of learning (through reflection) occurred in many papers, both those that deal with formal education and those that do not. Furthermore, Schön's [76] work on the reflective practitioner is often cited in professional education. Indeed, of the five education-oriented papers that cited a definition of reflection, three [14,51,90] cite Schön [76] and two [53,90] cite Dewey [20], while others [79] cite Moon [53] and Norman [71].

In contrast to the general trend described above, many of the papers on reflection in education focused their evaluations specifically on reflection. Lamberty and Kolodner [51] describe how camera talk—having students speak directly to a camera when describing their work—enabled a variety of activities labeled as reflective, particularly those in which the student was explaining aspects of their mathematical understanding. Leijen et al.'s [53] use of video to support dance education was evaluated in terms of how the processes and experiences it afforded resembled reflection, particularly the ability to draw on multiple perspectives from peers. Tchetagni et al. [90] go so far as to develop an analytic scheme based on Dewey's [20] stages of reflection that they used to assess the degree of reflectiveness evidenced among students using their system. Rather than focusing solely on outcomes, this work dealing with reflection in education generally tended to include more consideration of process in addition to product.

Reflection and Design

Second, 17 of the papers we reviewed related to reflection in and on the design process [2,19,28,29,33,34,37,61, 66,69,80,83,84,86,92,95,102]. These papers focused overwhelmingly on designers working alone or in groups (13) and secondarily designers and users reflecting together a la co-design or participatory design (4). About half of the papers focus on reflection that takes place during the design process, spanning from problem formulation [95], to reflecting on design outputs [33], to comparing multiple design solutions [86]. In the works that cover reflection on the design process focus generally on improving design ability by reflecting on prior design processes "to extract lessons and insights that can be applied to future design situations" [84:84].

Most of these papers do not provide such an explicit definition of reflection, but many make reference to Schön's [76] concepts of reflection-in-action and reflection-on-action. This prevalence is perhaps not surprising, considering Schön's description of design as a reflective conversation with materials and process. In these papers, reflection is overwhelmingly considered a positive activity that can lead to better design, including both improved design outputs [19,34,61,69,86] and an improved design process or creative process [37,66,84,102].

These studies suggest a range of specific benefits. Reflection can create a deeper understanding of the design space [92] or deeper insight into the problem at hand [95]. Reflection leads to improved or increased communication, such as the sharing of viewpoints or understanding between designers, or between designers and stakeholders [2,95]. Reflection itself leads to increased creativity [28,29], or the more effective communication and coordination that reflection enables can improve creativity [33].

Yoo et al. [102], however, consider that in some cases reflection might inhibit creative thinking and explore how to "prompt stakeholders to reflect on action without undermining exploration and creative thinking" [102:420]. This was one of the few examples in our corpus where the authors acknowledged that reflection might not provide universal benefit or value.

Reflection and Self Knowledge

Third, reflection is often described as providing increased self knowledge, a benefit cited in 15 of the papers we reviewed [1,13,25,26,31,52,55,56,57,58,59,63,72,97,103]. Such knowledge is often cited as motivation for work in both health and, moreover, in personal informatics. The latter involves collection of data about the self followed by presentation of that data back to the self. Closely linked with the quantified self movement [56,58], the value of knowledge gained by this data-driven introspection comes from a long-standing tradition in Western thought. Li et al. [55] open their paper with a narrative of how ancient Greeks, who would pilgrimage to the Temple of Apollo at

Delphi to find answers, were there greeted with the inscription "Gnothi seauton" or "Know thyself." Knowing thyself, this literature suggests, is non-trivial. We "often have incomplete knowledge of ourselves, we cannot monitor our behaviors all the time, and we cannot easily find patterns in our behaviors" [57:4490]. Personal informatics systems fill this gap, thereby "fostering insight, increasing self-control, and promoting positive behaviors" [57:4490]. Reflection, in this model, consists of the process of examining one's own data.

While this rhetorical positioning comes across clearly in personal informatics, many papers in our review that were not identified by the authors under that umbrella still cited similar motivations. For example, Mathur and Karahalios describe a visualization system based on bookmarks in a web browser wherein "the user is able to notice things about oneself that he or she did not notice before" [65:4657].

Interestingly, although reflection plays a prominent role in personal informatics and related work, the final stage of Li et al.'s [55] model, and the goal of much similar work, is *action*. Their line of reasoning suggests that showing users data about themselves will lead them to *do* something, presumably something different from and better than what they are already doing. For example, showing diabetics blood sugar levels will increase their ability to manage their condition [25]; showing frequency of shortcut key usage will increase their usage [62]; showing mouse accuracy will reduce exaggerated movements and improve future performance [44]. Indeed, the idea of inciting behavioral change occurred implicitly in much of the papers reviewed here. However, these papers also varied in the degree of prescribing exactly of what that behavioral change should consist, raising comparisons with persuasion.

Reflection and Persuasion

As indicated above, sometimes the goal of reflection is not only to increase self knowledge but to take action based on this increased awareness. Systems of reflection vary as to the extent that they support taking such action. Some suggest specific actions that users should take, such as using hotkeys more often [62], and others leave the decision making up to the user. Li et al. [55] refer to these properties as system-driven and user-driven in personal informatics systems, respectively. They found that one barrier during the action stage was a lack of specific, actionable suggestions of what to do next to help the user apply the outcome of their reflection to action.

Similarly, the vast majority of systems we reviewed did not recommend particular actions after reflection. Fifty-five of the papers in this review described some type of intervention to support reflection, whether it be a mobile or desktop system [e.g., 29,31] or public installation [36,94]. Of these 55, only 3 (5%) of the interventions suggested specific action [9,62,91]. This is not to say that designers of

the remaining 52 did not have particular goals in mind for users of the interventions, just that the resulting systems did not command users to take specific actions to achieve them. For example, Frost and Smith's intervention seeks "to help diabetics develop better understanding of how daily activities impact fluctuations in their blood sugar" [25:2] so that they can better learn how to control their disease. However the specific actions that users take based on this understanding are not prescribed through the system.

On the other end of the spectrum, a few papers in our review explicitly, both in the paper and through their design, sought to be open-ended about the upshots of reflection. For example, A Diary Built for Two [13] used selectively shared digital diaries among romantic couples to emphasize "re-storying," i.e., developing alternative understandings of shared experiences, but without specific prompts directing the kinds of diary entries users should make or share. Similarly, the designers of GoSlow aim to "promote discourse on one's actions and values in one's every pursuits" but without prescribing "how and to what extent they should cut back, slow down, and reflect" [18:431].

Even in situations where designerly intent is made expressly clear, reflection may not always take the form or have the results intended. For example, experienced patients using the MAHI [64] system employed it less as a problem-solving tool, instead leveraging a commenting feature to craft stories that allowed them to construct their identity as diabetics [63]. Similarly, a visualization of email and phone activity intended to support reflection on long term, higher level patterns was consistently used instead to reminisce about specific events [103]. While these systems can end up reappropriated in ways not necessarily accounted for by designerly intent, such alternative uses may still constitute some manner of reflection.

Ultimately, we do not pass judgment on whether prescribing specific action in systems of reflection is good, bad, practical, necessary, or desirable. We instead note that these systems of reflection exist on a spectrum when it comes to prescribing action, creating a nuanced relationship with persuasive technology [24]. Some systems, such as the 3 interventions noted above, are very prescriptive in the action their users should take, and these would fall into the persuasive class defined by Fogg [24]. Others still have general outcome goals for their users but do less to guide them toward a specific action [e.g., 25]. Finally, some systems support the process of reflection itself without any pre-conceived goal for action or behavior change [e.g., 36].

DISCUSSION

This section turns from describing what we found during our literature review to considering the implications of these patterns, as well as what they suggest as valuable directions for future work in this area.

The Definition(s) of Reflection

As mentioned above, few papers in our survey included an explicit definition of reflection, and of those that did many cited Schön [76]. This finding raises three important points. First, it might be seen as somewhat disconcerting that over half of the papers using reflection as a keyword never define the concept. One could interpret this absence of a definition as indicating a clear consensus about what reflection is; since everyone knows what reflection means it needs no definition. Alternatively, and we suggest more likely, this lack of definitions indicates relatively little deep consideration of or engagement with the phenomenon of reflection, how it should be defined, what might constitute it, and how best to design for it.

Second, the preponderance of Schön's work in papers that do cite a reference for their definition of reflection might again suggest a sort of consensus, that those who do seek conceptual or theoretical grounding agree to draw on reflection-in-action [76]. However, this Schönian majority might also suggest some limitations or constraints in how HCI approaches reflection. Indeed, a variety of conceptualizations of and definitions for reflection could be used to inform design, from education [e.g., 67] to aesthetics and design [10] to philosophy [20,47]. We suggest that there may be rich possibilities for considering other conceptualizations of reflection or, perhaps, for comparing or synthesizing from among them [cf. 23]. Doing so would, we suggest, help tease apart the relationships among reflection, reminiscence (see further below), reflexivity [REF], and other related concepts.

Third, without a clear explicit definition, many of the papers we reviewed implicitly conflated reflection with feedback. For example, dancers who observe video recordings of their performances are said to be reflecting [53]. In personal informatics, "looking at lists of collected personal information" [55:562] constitutes the reflection stage. Both the content and repercussions of these implicit definitions about what constitutes reflection can be seen more clearly by examining details of the techniques used in interventions intended to support reflection.

The Constitution of Reflection

Many of the papers in this review described interventions designed to support or encourage reflection in some way. However, the lack of definition or deeper engagement with the concept of reflection poses challenges for design. For example, what does it take to reflect? How can interventions provide spaces that are conducive to reflection? As mentioned above, the Personal Informatics model described reflection as "looking at lists of collected personal information or exploring or interacting with information visualizations," [55:562]. This definition carries an implicit assumption that by providing access to data that has been "prepared, combined, and transformed" [55:561] for the purpose of reflection, reflection will occur. The majority of the interventions in our review held similar

assumptions [e.g., 94]. In these papers, reflection was implicitly defined as something that would happen by providing the user with some type of information about a particular situation, and as a result the user would have a newfound awareness in the intervention's domain of interest.

Prior work has made certain recommendations for supporting reflection through designed interventions, such as providing encouragement and allowing time for reflection to occur [23,60]. Li et al.'s [55] model also presents barriers to reflection that should be addressed in systems, including lack of time and effective visualization of personal data. However, we believe that as designers there is much to be gained from being explicit in what we mean by reflection and engaging with it as an important part of a larger set of processes and practices, and not just as a natural consequence or byproduct of presenting information to users. By making the reflective process of our systems the focus of inquiry, we can better learn what it takes to reflect and how to support both reflective processes and other system goals in our designs.

The Evaluation of Reflection

Perhaps as a consequence of the lack of a clear definition of reflection, the majority of the papers do not provide a direct assessment or evaluation of reflection *per se*. It is difficult to observe what you cannot define. However, such indirect evaluation may also arise from a focus on the utility of reflection, i.e., reflection as a means to an end. A greater shift toward viewing reflection itself as a meaningful activity may lead to more focused evaluations of the process thereof.

A few evaluations in the papers we reviewed did focus specifically on reflection. As mentioned above, Isaacs et al. [42] directly analyzed participants' reflections by asking them to add notes to already recorded journal entries and re-rate their feelings about the event on a Likert scale. Similarly, a Diary Built For Two [13] focuses on the reflection and "re-storying" that can occur by romantic couples selectively sharing diary entries with one another. In another example [described in 23], teachers and their mentors used SenseCam, a lifelogging technology, to enable reviews by mentors and to help facilitate social reflection [22], to which we return below.

This is not meant as a blanket methodological critique of evaluative approaches taken in the papers we reviewed. Reflection is a complex, potentially nebulous concept [cf. 20,76], making evaluation thereof that much more difficult. Indeed, some in education have suggested that meaningful direct assessment of reflection can become intractably difficult [88]. We suggest that this gap presents an opportunity for future research to consider how, if at all, evaluations might directly focus on reflection itself.

The Sociality of Reflection

Most of the papers we reviewed described reflection as an individual, largely mental or cognitive activity, e.g., reflecting on one's performance as a given task [44,62] or observing data about one's self [25,55,56].

A few papers did acknowledge the possibility of reflection as a social activity. For example, Prilla et al. [73] describe both a study of and a system to support hospital workers in collectively reflecting on their conversations with patients' family members. Also, by focusing on collaborative co-design [e.g., 2,9] or political engagement [49,74], a number of the papers oriented similarly towards group reflection.

We suggest this gap represents an opportunity in at least two ways. First, the area is ripe for work on both understanding and designing to support reflection not only as an individual, cognitive activity but also as a social process. Second, examining situations of social reflection may help address some of the difficulties noted above in evaluating reflection *per se*. We see this benefit as similar to that provided by distributed cognition's [38] analytic orientation. Generally, cognition is seen as an internal process that, as such, is not readily visible to researchers and, thus, is not readily accessible for analysis. By focusing on the ways that cognition is distributed among multiple people, devices, and artifacts, distributed cognition makes more visible, and thus more accessible for analysis, cognitive processes. We argue a similar approach might provide benefits in terms of studying reflection. Situations of social reflection require externalization [cf. 96], i.e., that individuals explicate their thinking and engage with that of others. While activities such as camera talk [51] and responding to reflective prompts [93] could provide opportunities for externalization, we suggest that the dialogical aspects of externalization in social situations likely may them an even more interesting case. Studying such situations may provide a beneficial means of understanding a phenomenon otherwise difficult to observe directly [cf. 13,22,42].

The Dark Side of Reflection

With rare exception [42,102], the papers we reviewed treated reflection as almost universally beneficial. Whether for behavior change [91], increased self-awareness [56], improved design processes [83], or better educational outcomes [17], reflection was nearly always positioned as wholly good. However, some research has suggested that such reflectiveness may bring with it associated, sometimes unintended, costs.

First, related literature on reminiscence [8,45] and privacy [4] has at times described the value of forgetting. Human memory naturally and selectively fades over time, in contrast with the eternally perfect recall [cf. 55] provided by many computational systems. Such perfect recall, though, can have negative repercussions. For example, one of the functions of reminiscing is *bitterness revival*, or

continually focusing on negative life events and using them to justify current behavior [99].While the pieces we reviewed that discussed reminiscence at times seemed to conflated it with reflection [e.g., 42,97], the authors of this paper suggest the two as distinct processes. Reminiscence focuses on the recall of a specific event or events in one's past. Reflection, on the other hand, involves synthesizing across events to arrive at some greater understanding. While the two are almost certainly related, it might be beneficial for research on reminiscence to discuss explicitly the perceived relationship with reflection.

Second, computational systems by their nature focus on things they can observe and tend to omit (intentionally or unintentionally) those things not easily observable or measurable. A system might have access to, say, your accuracy with a mouse pointer [44] but not your frustration at the time with having to use a technology you may already dislike [cf. 60]. Similarly, as described above, a system can track a diabetic's blood sugar levels [25] but has a difficult time representing how changes in use of the system may enact changes in performed identity or self presentation [63]. We do not suggest that such "missing factors" should be included and tracked in the design of reflective systems. Rather, we want to draw attention to the potential commodification of experience [cf. 85] embedded in a focus on automatically observable, quantifiable metrics. Such a focus can not only unnecessarily constrain the kinds of reflective activities a system affords, as [87] found when asking people to reflect on their friendships using their Facebook "See Friendship" pages, but it also may have significant ramifications on the impacts that reflection might have.

At the risk meta-discussion, it might be valuable for designers of reflective systems to explicate the supposed value of reflection. Such an endeavor likely resembles reflective design [81], critical design [5], or other approaches that involve a designer interrogating her or his own assumptions. Potential considerations include not only the good of reflection but also the kinds of sociocultural practices in which reflection is embedded, as well as who is presumed to be in a position privileged enough to reflect and, conversely, who is not.

CONCLUSION

While the literature on reflection and reflective thought is decades old [e.g., 20], reflection has only recently come to focus in HCI. While the oldest paper in our corpus was published in 2000, most papers in the review presented here were published in the years since 2009. We suggest this recency as evidence of increasing interest in designing for reflection. Indeed, an increased interest in reflection aligns closely with many concerns concomitant with third wave HCI [11,35]. As research progresses in this area, we believe that the directions described in our discussion section will be helpful in shaping research trajectory. Specifically, we reiterate three main implications here.

First, relatively few papers clearly define the concept of reflection. We present this finding less as a critique and more as an opportunity. Rather than prescribing one or another framework, we suggest that work in interactive systems design would benefit from engaging with the rich, diverse theoretical literature on reflection [e.g., 10,20,47,67]. Doing so may help clarify some of the current "fuzziness" [23] in our discourse around reflection and related concepts [cf. *54*]. Engagement with these definitions may also move reflective systems beyond simply presenting the user with data to develop other techniques for supporting reflection.

Second, of those papers that involved an evaluation, very few focused specifically on reflection itself. Given the vague or at times nonexistent definitions of reflection provided, this finding should perhaps not come as a surprise. Again, though, we offer this less as a critique and more as an opportunity for future work to engage with how (if at all) [88] we might best assess or evaluate reflection.

Finally, we identified three main types of benefits reflection was described to provide: better education, improved design processes, and increased self knowledge. Future work could make valuable contributions by exploring situations in which reflection may be detrimental or even harmful. Furthermore, the techniques used to encourage reflection across these and other areas evidence implicit assumptions, particularly that feedback constitutes reflection. To reiterate, we suggest that engaging with the conceptual and theoretical literature may provide valuable grounding and inspiration for more sophisticated, subtle, or nuanced designs for reflection.

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