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Revisiting Reflection in HCI: Four Design Resources for Technologies that Support Reflection

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Reflection is a commonly addressed design goal in commercial systems and in Human-Computer Interaction (HCI) research. Yet, it is still unclear what tools are at the disposal of designers who want to build systems that support reflection. Understanding the design space of reflection support systems and the interaction techniques that can foster reflection is necessary to enable building technologies that contribute to the users' well-being. In order to gain additional insight into how interactive artefacts foster reflection, we investigated past research prototypes and reflection-supporting smartphone applications (apps). Through a structured literature review and an analysis of app reviews, we constructed four design resources for reflection: temporal perspective, conversation, comparison and discovery. We also identified design patterns in past digital artefacts that implement the resources. Our work constitutes intermediate-level knowledge that is intended to inspire future technologies that better support reflection.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**.

Additional Key Words and Phrases: artefacts,, technology-supported reflection,, systematic review

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1 INTRODUCTION

As an increasing number of systems around us aim to improve our health and well-being, reflection is a concept that gains more and more relevance. Reflection is regarded as beneficial and desired [10, 77], as it can (1) offer more self-insight [10], (2) motivate behavior change [67, 85], and (3) support life changes [102]. Consequently, reflection is a recurring theme in HCI research. The field's interest in this area spans from inquiries into design practice to a more recent focus on reflecting on personal data in the field of personal informatics [67]. As a consequence, a significant amount of work was invested in building models that feature reflection [35, 67], conceptualising reflection [11, 99] or reviewing past papers to extract overarching concepts [39]. This body of

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work suggests that there is consensus that fostering reflection is a desirable design goal for interactive systems. While the literature agrees that reflection should be pursued, it is less clear what tools and techniques can be used to implement the goal of supporting the user in reflection.

At the same time, an increasing number of systems in HCI literature embraced reflection as a key design goal or reported that they helped users reflect. Researchers developed a wide spectrum of artefacts, from living plants enhancing reflection on physical activity [16, 23] through informative art that let users pause and think [36], to conversational agents designed for workplace reflection [63]. Even though these systems try to accomplish the same objective, i.e. enhancing reflection, the fields of application and the techniques used to enhance reflection are diverse. Furthermore, the rise in research prototypes was accompanied by a proliferation of commercial products and smartphone applications that claim to foster reflection. Despite the fact that there is a wide corpus of systems that support reflection, it remains unclear what features of current artefacts and apps contribute to the enhancement of reflection. An overview of the techniques, as well as the interface features that were used to implement these techniques, is currently missing. Consequently, there is a lack of understanding in the field regarding the shared design qualities of reflection artefacts, and it remains unclear what reflection-supporting techniques are likely to be effective in future artefacts.

In order to address this gap, this paper takes stock of past artefacts designed with the goal of supporting reflection. We take a retrospective look at systems that support reflection presented in past HCI literature. We also analyse reviews of current smartphone applications that communicate the intention to support reflection. These two reviews offer a complementary contribution and enable contrasting the developments in HCI research with the solutions for fostering reflection that are currently available to users. Based on our analysis, we contribute a set of design resources that can be used to foster reflection. We then look critically at past developments in the field to identify key challenges for future reflection support system. Our review addresses the following research questions:

- *RQ1: What are the conceptualisations and applications of reflection in HCI research and commercial smartphone applications?*
- *RQ2: What interaction techniques can be used to effectively design interactive technologies which support reflection?*

This paper contributes the following: (1) a systematic review of reflection support systems in HCI literature, which updates an earlier review by Baumer et al. [10]; (2) an analysis of the techniques used for reflection-support in current HCI artefacts, which was not addressed in Baumer et al.'s review [10]; (3) a structured analysis of user reviews for smartphone reflection applications; (4) a taxonomy of design resources and patterns for systems that foster reflection that we propose based on our analysis and (5) challenges and opportunities for future systems for reflection.

2 RELATED WORK

We begin our inquiry by reviewing the applied conceptualisation of reflection in the field of HCI. We then report on various efforts in HCI to develop a comprehensive understanding of reflection that can inform the design of technologies. This is followed by a discussion of artefacts that were designed to support reflection.

2.1 Definitions and Operationalisations of Reflection in HCI

Work in HCI uses a number of definitions and operationalisations of reflection. A first step towards an inventory of reflection-facilitating technology was a systematic review conducted by Baumer et. al [10]. This review looked into how reflection was defined in HCI studies which focused on designing for reflection, as well as the fields in which these systems were applied, the types of users it was designed for, the reported benefits of reflection and how reflection was evaluated. Baumer's primary goal was taking stock of past research and clarifying some of

the conceptual flux around reflection that appeared in HCI. However, such an approach leaves some questions about the design of the artefacts unanswered. What kinds of artefacts were designed to enhance reflection? What reflection techniques were applied in these artefacts? What reported effect did these artefacts have on how users reflect?

Schön's framing of reflection [10, 99] has been prevalent in HCI research, as shown by Baumer et al. [10]. Their review showed that 70% of HCI papers that explicitly defined reflection used Schön's notion of reflection-in-action or reflection-on-action. Reflection-in-action happens while a user is performing a given task [96]. Usually, this requires unexpected events or unpredictable outcomes of actions [78]. Reflection-on-action is a post-hoc act. It is a reconstruction of an experience, based on our memories of it. This type of reflection allows users to reconstruct past memories and draw conclusions based on an analysis of past events [38]. Schön's differentiation between in- and on-action was later on translated to an HCI context in a paper by Ploderer et al. [85]. Their work offers a conceptual framework consisting of five key approaches aimed at behaviour change support systems that focus on social interaction and reflection.

However, Slovak et al. [99] remarked that Schön's framework does not directly address how technology can support reflective processes, and they argue that there is a gap in our understanding of how in-depth reflection can be facilitated through technology. To address this gap, Slovak et al. used Schön's notion of the *reflective practicum* to scaffold the process of reflection in the context of social-emotional learning (SEL) [99]. The purpose of a reflective practicum is to structure a learning process. The practicum can be seen as a kind of virtual world, a safe environment, in which students learn through scaffolded learning experiences. Their work shows that there are three components (explicit, social and personal) that all work together to create the 'right experiences' (i.e. tasks) for students in which reflection can be scaffolded. Slovak et al. try to translate these components from a *social-emotional learning* context to more general guidelines for designing reflection support technology. Past works chart the general directions when designing for reflection and offer key principles underlining possible reflection support systems. Yet, it remains challenging to use these in the practical design of reflection-supporting technology [34].

Recently, scholars in HCI started engaging with the complexity of reflection. For instance, a paper by Eikey et al. [33] highlights a potential risk for reflection enhancing systems. Certain groups of users of personal informatics systems experience negative thoughts and emotion cycles due to self-tracking. The authors use the term rumination for this negative thought cycle, which is a counterpoint to self-reflection and defined in line with Trapnell and Campbell [106]. Eikey et al. [33] discuss that rumination and reflection are related to a broader sense of the self, also known as self-awareness. Rumination can undermine personal informatics systems, yet it currently remains an open question how to balance promoting self-reflection on the one hand, and preventing rumination on the other. Mitigating this risk in a fitness tracking context was addressed by Niess et al. [79]. They inquired how unmet goals can be presented in fitness apps to prevent rumination and facilitate reflection. Their mixed-method study showed that bar graphs offered a significantly better potential for reflection and multicoloured charts triggered significantly more rumination.

2.2 Designing for Reflection: A Meta Perspective

Fleck and Fitzpatrick [39] proposed a systematic structure to categorise the outcomes of reflection. Their work presented a framework of five different levels of reflection, R0 to R4. Each level built on the previous, and corresponded to a deeper understanding. Additionally, the authors offered examples of how technology could offer support for reflection and conclude their work with guidelines for facilitating reflection. These guidelines are comparable to those from Slovak [99] in the sense that they offer a direction for reflection-oriented design.

Reflection is also a prominent term in studies of personal informatics systems [35, 67] and forms a key element of models which shape the current understanding of personal informatics experiences. Personal tracking systems help people collect personally relevant information for the purpose of self-knowledge [67]. Reflection featured

prominently as a process in proposed models of personal informatics experiences. The Stage-Based Model of Personal Informatics Systems [67] consists of five stages that users of these systems iterate through: preparation, collection, integration, reflection and lastly, action. The model has since been expanded and clarified by Li et al. [68]; the reflection stage has been divided into two separate stages: maintenance and discovery [68], in which people ask themselves different types of questions about their personal data. The Lived Informatics Model of Personal Informatics [35] was a further extension of the stage-based model. Several stages have been added, such as deciding to track, selecting tools, tracking and acting as an ongoing process of collection, integration and tracking. Finally, lapsing, i.e. not using a tracker, was added as a stage, since it is a common phenomenon when using personal informatics systems. Later, Niess & Wozniak [80] proposed the Tracker Goal Evolution Model, that explains phenomena of goal-setting and relates them to Epstein et al.'s model [35].

As these models show, personal informatics technologies aim to support the collection of personally relevant data for the purpose of self-reflection and gaining self-knowledge which can then lead to action. However, current personal informatics systems do not offer enough support for reflection [28, 30, 68]. As Baumer notes, prior work carries the implicit assumption that reflection will occur as long as the collected data has been prepared, combined, transformed, and visualised [10]. However, as also mentioned by Slovak [99], this conflicts with prevalent reflection theories which highlight that reflection often does not occur automatically, but needs to be encouraged. Thus, personal informatics models show how personal informatics systems work when they adequately fulfill their role of fostering reflection. Consequently, the way in which users can be supported in reflection should be actively considered in the design process of such systems.

2.3 Artefacts to Foster Reflection

There is a gap in our understanding of how reflection can be facilitated through technology. In HCI multiple systems aiming to facilitate reflection for a variety of different application contexts have been designed. For instance, SleepTight [26] was developed to reduce the capture burden of long-term manual tracking. With the help of Android's widgets it improved information access and supported self-reflection. On another note, DayClo [66] was designed to facilitate reflection on personal schedule data with the means of an everyday object (i.e. an analogue clock). Karyda et al. [57] also utilised everyday objects to trigger reflection. In a *research through design approach* they combined everyday objects with meaningful representations of participant's personal data in a variety of different ways (e.g. one participant received a plectrum combined with their heartbeat data from a day when they were playing a concert). Furthermore, Choe et al. [27] note that longitudinal data feeds from various self-tracking tools offer opportunities for fostering reflection. Yet, most self-tracking tools lack support for integrating, analysing and reflecting on such data. To address this gap, the authors propose a web-based application called Visualized Self, which allows users to integrate personal data from multiple personal informatics systems, explore their data with timeline visualizations, and to perform temporal comparisons. Through the evaluation of Visualized Self the authors discuss lessons learned and offer directions for designing visual data exploration tools for fostering reflection.

Although various HCI artefacts have been designed for enhancing reflection, an overview of these artefacts, the techniques they deploy and how these artefacts affect reflection is missing. This implies that we are not fully aware of what interaction techniques and design resources can be used to effectively support reflection. In other words, while past work has effectively established design principles that guide designing for reflection, contributed effective ways of understanding the reflection experience and designed systems for reflection, it is still unclear which interface design techniques can foster reflection.

Hence, previous work focused on reflection from a meta perspective and designed artefacts with the aim of supporting reflection. In contrast, our work aims to offer intermediate-level knowledge that can serve as a starting point for new, improved systems that foster reflection. To that end, we take a retrospective look at systems that

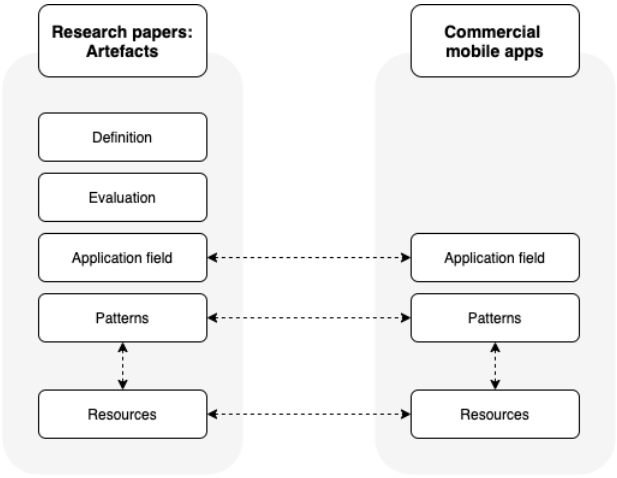


Fig. 1. An overview of the process which we used in reviewing artefacts and commercial smartphone applications. For research artefacts, we explored the definitions, evaluation methods and application fields for reflection, identifying design resources and design patterns. For smartphone apps, we explored the application fields, as well as the resources and patterns they deploy to enhance reflection.

support reflection presented in past HCI literature. Further, we analyse current smartphone applications that communicate the intention to support reflection.

3 METHOD

In order to build a structured understanding of the design techniques used in systems that support reflections, we used a two-step approach, as presented in figure 1. The first step of our approach consisted of a structured literature review of papers that focus on reflection in HCI. This structured review partly consisted of a revisiting of Baumer's [10] findings to investigate if the definitions, evaluation methods and application areas for research on reflection changed in the last seven years. While this context cannot be ignored, rather than scoping the understanding of reflection in HCI, our work aims to understand how systems for reflection were designed and what the tools available to designers are when they want to support reflection. To that end, we identified design resources and design patterns [14] for reflection that artefacts reported in HCI literature.

In parallel, as a second step, we conducted an analysis of commercial smartphone applications which claim to support reflection. We analysed users online reviews to explore the application fields of these smartphone apps, as well as the resources and patterns they deploy to enhance reflection. We then, based on these two data sources, charted the design resources used to support reflection along with design patterns that can be used to implement these resources. This enabled us to identified parallels and differences between the directions in supporting reflection taken by researchers and practitioners.

The remainder of this work is organised as follows. We first describe the process of our literature review and smartphone applications review. We then present the results of the literature review and discuss application fields for research artefacts and smartphone apps. Next, we present our taxonomy of design resources for reflection and accompanying design patterns based on the literature and app review data. Finally, we discuss the findings and highlight ways forward based on our insights.

3.1 Literature Review

Following an approach based on literature reviews previously published in the HCI community [12, 95] we used the ACM Digital Library to determine our corpus. This implies that our review is limited to the works available in that source. We decided to use a keyword-based search to select all papers where the authors made the conscious decision to discuss reflection. This is in line with the approach by Baumer et al. [10] who published an earlier review on reflection in HCI. The reason for using keywords was that we wanted to make sure that our review would include systems that were specifically designed with the declared goal of enhancing reflection. This way, we could identify papers where authors explicitly engaged with the concept. Therefore, all papers published under H.5 [1] in ACM classification (Information Interfaces and Presentation) that used `reflect`, `reflecting`, or `reflection` as a keyword were collected. By adopting this method, we replicated the approach used by Baumer [10]. In doing so we aimed to ascertain how research on reflection within HCI has developed since 2013 (which is when Baumer's review was concluded) and add additional, artefact-centred insights to the Baumer's framework.

Two authors collaborated on conducting the review, constantly comparing results in order to assure consistency. This increased the accuracy of the inclusion/exclusion process as well as minimised the risk of bias. All the papers were processed in a shared spreadsheet, which helped with the accumulation of details and analysis throughout the process and allowed transparency regarding which papers were to be included or excluded.

The selection process was structured by using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram, as depicted by figure 2. We chose PRISMA, because it is likely to improve the reporting quality of a systematic review and provides substantial transparency in the selection process of papers [75].

3.1.1 Inclusion Criteria. We defined the following criteria for the target scope of the publication corpus:

i. The focus of the paper must have been reflection in the meaning of a thought process. Papers which referred to reflection in the context of optical phenomena were not included.
ii. The paper must have been an archival contribution. Thus, posters and workshop proceedings were not included. Shorter contributions were unlikely to deliver rich descriptions of artefacts. This is a key difference from the earlier review by Baumer et al. [10]. As we wanted to investigate how reflection was conceptualised and evaluated in research work, we relied on extensive submissions which were subject to rigorous peer review.
iii. The paper was required to describe an artefact—system, prototype or tool that was designed and evaluated with a clearly declared intention to enhance or provoke reflection among users. Thus, papers which addressed reflection on a conceptual level were not included. This allowed us to focus on the design qualities which provoke reflection rather than conceptualisations of reflection, which was already addressed by Baumer et al. [10].

This initial search generated 369 results (as opposed to 100 results in the 2014 review [10]). We found and removed one duplicate. The remaining 368 papers were equally divided among two researchers and screened for the inclusion criteria.

We reviewed the title and abstract to define if a paper met the first inclusion criterion. While reading the abstracts was enough to decide on inclusion for most papers, we identified a number of edge cases. These papers were then read in full by both researchers and discussed in detail. All papers that referred to reflection in the context of optics were excluded, resulting in an exclusion of 151 papers. The remaining 217 papers were then screened to determine if they were archival, which led to an exclusion of another 92 papers. Lastly, the remaining 125 papers papers were read in full to determine if the paper described an artefact, system, prototype or tool that

[1] https://www.acm.org/publications/computing-classification-system/1998/h.5

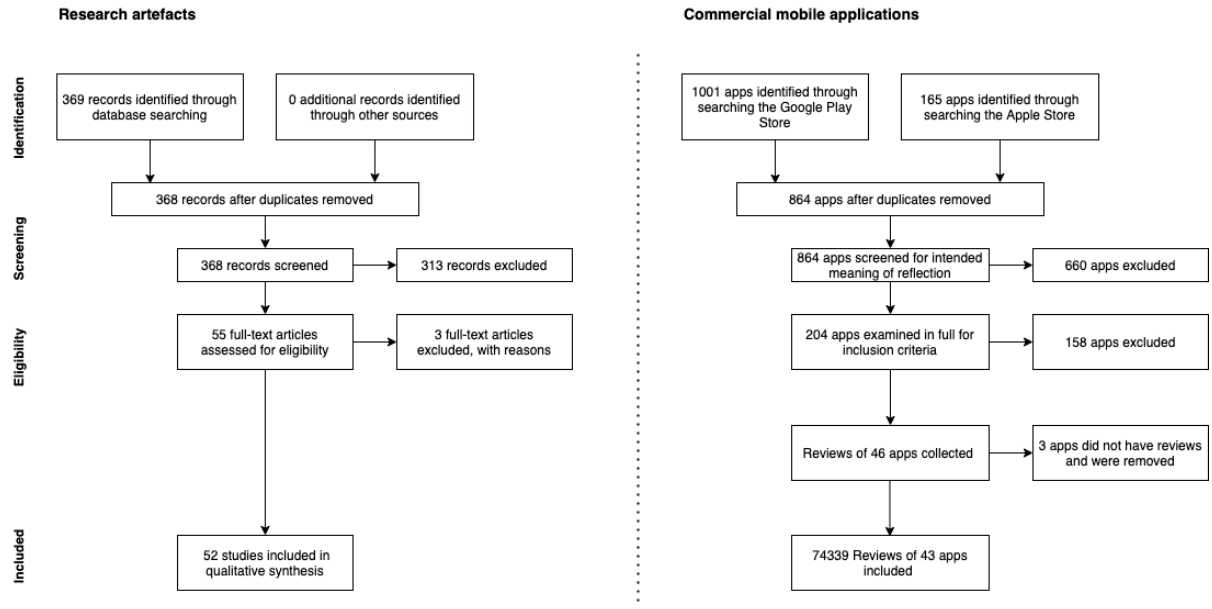


Fig. 2. Overview of the selection process of the research artefacts and commercial smartphone applications with the goal of identifying systems that aim to enhance reflection among users.

was designed with the intention to enhance reflection. After screening for this last criterion, 55 papers remained. Later, three more papers were excluded because they described the same artefact and were therefore considered to be duplicates. This process ended with building a final corpus of 52 papers.

3.1.2 Analysis. Having established the final corpus, we decided on the following analysis lens to understand its contents. We first revisited questions from Baumer et al.'s [10] review on reflection (Q1–Q3). Next, we added an additional, artefact-specific question to investigate the specific qualities of artefacts which support reflection.

(1) Q1: How was reflection defined?
(2) Q2: How was reflection evaluated?
(3) Q3: In which domain was reflection supported?
(4) Q4: What interaction techniques and design qualities were used in reflection support technologies?

As there is no shared systematic understanding of reflection in the HCI field, and the works in the corpus were diverse in many aspects, we adopted a bottom-up qualitative analysis method [15]. This enabled us to build overarching concepts present throughout the corpus based on initial low-level codes. Thus, we used open coding as the main analysis instrument. In line with Blandford [15, p.93], this implies that differences between coders were resolved in discussions rather than measured through inter-rater reliability coefficients.

The papers were open-coded by four researchers for Q1 and Q2, using the Atlas.ti software. For Q3 a spreadsheet was used. In order to answer Q4, we identified the design patterns used by the artefacts in the review through open-coding. For the proposes of our research, we defined design patterns broadly—as practical design choices possible in multiple systems—inspired by Björk and Holopainen. Three coders divided the corpus so that each paper was read by two researchers. In case of disagreement between the initial two codes, a third coder would also analyse the paper and a group discussion would be held. We then used affinity diagramming to identify

patterns with different codes and similar meaning in an iterative discussion. This way, we obtained the final list of design patterns which we used for later analysis.

3.2 Smartphone Application Review

We collected data about commercially available smartphone applications that feature reflection to understand the current user experience of reflection support. This enabled us to identify what interaction techniques were used in commercial apps and discuss the similarities and differences between the approaches used in research and practice.

3.2.1 Data Collection. We collected data about smartphone applications from the Google Play Store and the Apple Store. We chose to do so as these app sources cover 89% of the global market [101] and thus offer a broad perspective on the range of applications used in practice. In July 2020, we queried both app sources with the term `reflection`. The initial search yielded 1001 apps in the Google Play store and 165 apps in the Apple App Store. Next, we removed duplicates and excluded apps that did not address reflection in the intended meaning, e.g. referred to reflecting photos. This process resulted in 204 apps (153 + 51). Next, we examined the app descriptions in more detail and only included apps which supported a reflection experience related to one of the definitions used in HCI research. In an iterative discussion, we defined the following inclusion criteria: (1) the app declared engaging the user in a reflection process in the app description [78, 111] and (2) the app facilitated allowing time for reflection [78]. Two researchers analysed the app descriptions according to the criteria (discrepancies were discussed), resulting in a final app corpus of 46 applications. In the next stage of our process, we downloaded 74339 reviews for the corpus[2]. Three apps did not have reviews and were removed. The resulting reviews were then analysed.

3.2.2 Analysis. We adopted the approach used by Aladwan et al. [1] to analyse the content of the app reviews, which, similarly to the literature review, is a form of bottom-up qualitative analysis. We chose not to directly apply the codes from the literature review as we expected that apps would feature a larger diversity of reflection support than the papers.. Three coders read 10 reviews longer than 35 words chosen at random per app. Based on the initial immersion into the data and an iterative discussion, we built a list of 33 keywords[3] which we then used to identify relevant reviews. This resulted in a final selection of 29 apps which had relevant reviews with a total 3633 reviews. Two researchers then open-coded the reviews to identify application areas and design patterns similarly to the coding process of the literature review. Q2 and Q4 as stated in section 3.1.2 were applied to smartphone application reviews as well as to the research artifacts.

3.3 Design Resources

Having concluded the initial analysis of literature and apps, we analysed the full corpus in another round of open coding. This time, we sought to identify meta constructs which describe how reflection support is enacted in research artefacts an apps. This way, we could create a collection of design resources which can support reflection in interactive systems. Similarly to the other stages of the reviews, we applied a bottom-up analysis, identifying recurrent codes in an iterative discussion. The iterative analysis resulted in two levels of codes: design resources and resource categories.

[2] https://heedzy.com/

[3] aware, clarify, clarity, confidence, deeply, insightful, insights, inspires, knowledge, meaningful, noticed, patterns, personal development, perspective, reflect, reflection, relieve, relive, revelation, routines, self reflect, self reflecting, self reflection, self-reflect, self-reflecting, self-reflection, subconscious, surprise, thought provoking, thoughts, understand, well being, wisdom

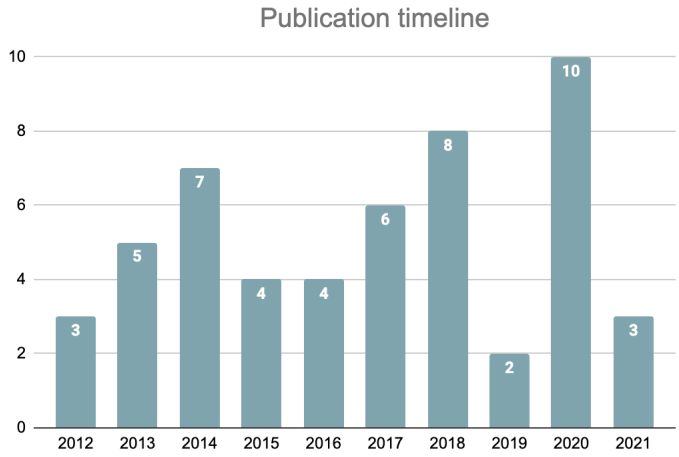


Fig. 3. Timeline of the publication years of the papers in the corpus. The timeline shows an increasing trend in HCI studies that report on artefacts designed to enhance reflection. Concurrently, the timeline demonstrates some fluctuation. For instance, our corpus contains 2 papers for 2019, which is remarkably low when comparing to adjacent years. This is partially due to the exclusion of duplicates. In total, four papers from 2019 met the inclusion criteria. Yet, two of these papers were later on excluded because they described the same artefact and were therefore considered to be duplicates. Note that data for 2021 is partial as this review was concluded in July 2021.

4 FINDINGS

Here, we report on the results of our review in terms of Q1–Q3. We highlight the increasing number of publications about reflection and differences between our reviews and Baumer's et al.'s earlier account [10]. We discuss instances where our results differ from the earlier review. Our findings with respect to Q4 are discussed in the next section 5.

4.1 Publication Dynamics

The final corpus consists of 52 papers. The corpus is published as an open Zotero library[4]. All papers in the corpus were published between 2012 and 2021, see figure 3. There is a steady increase in HCI studies that report on artefacts designed to enhance reflection [10, 76]. Importantly, the majority (44/52) of the papers in our review was published after Baumer et al.'s review [10]. Despite the fact that the earlier review included more (76) papers, the majority (71/76) of the works there were non-archival [25, 50, 108] or theoretical [67]. Most of the works in our corpus appeared in the CHI conference (18 papers), followed by the DIS conference (7 papers), the OzCHI conference (4 papers), and the IMWUT journal (3 papers). Other venues featured no more than two papers.

4.2 Q1: Defining Reflection

To understand if and, possibly, how the concept of reflection in HCI evolved, we repeated Baumer et al.'s work [10] and investigated how reflection was defined in the corpus. The original work showed that only few papers in their corpus defined reflection. Despite the different sample of papers, our findings showed that still many papers do not clearly define reflection, as demonstrated in figure 4a.

[4] https://www.zotero.org/groups/4574553/revisiting_reflection_full_corpus/library

Table 1. Definitions of reflection identified in the corpus. Table 1a demonstrates the variety of definitions that were used by the papers in which reflection was specifically defined. Three papers formulated a working definition for reflection, as shown in table 1b

(a)

Specific definition		
	number of papers	references
Schön [96]	6	[112] [86] [56] [49] [29] [64]
Boud et al. [17]	2	[90] [37]
Sengers et al. [97]	1	[49]
Merleau-Ponty [73]	1	[81]
Fonagy et al. [40]	1	[60]
Dewey [31]	1	[105]
Butler [21]	1	[103]
Bryant et al. [20]	1	[54]

(b)

Working definition	
definition	reference
'Reflection' can refer to an individual mental cognitive activity in examining previous occurrences [that lead to food waste]. But reflection can also be thought of as social activity,"	[41]
Considering and analysing past, present and future experiences in order to reassess our thoughts, beliefs, feelings and actions regarding our everyday life.	[77]
Self-reflection is an important process where people work to gain a clearer understanding of themselves through thoughtful introspection.	[6]

Through open-coding the definitions in the papers, we identified four ways in which reflection was defined: papers that specifically define reflection (14/52 papers), papers that use a working definition which is formulated by the authors (3/52 papers), papers that use what we call a definition by proxy (17/52 papers), and papers that did not define reflection (18/52). The papers which specifically defined reflection demonstrate that a variety of definitions are being used in HCI, as shown in table 1a. The most often used definition comes from Schön [96], which is in line with findings from the earlier review from Baumer et al. [10].

In contrast, three papers use a working definition formulated by the authors. Table 1b demonstrates these definitions. An example of a working definition comes from the work by Mols et al. [77]. Their paper describes different definitions, from both Staudinger [102] and Mezirow [74] which they combine to formulate their working definition:

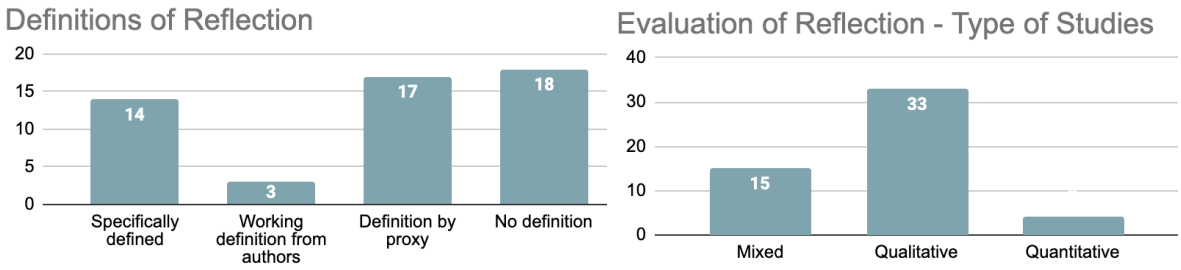
> *Considering and analysing past, present and future experiences in order to reassess our thoughts, beliefs, feelings and actions regarding our everyday life.* [77, p.68]

Further, seventeen papers used a *definition by proxy*, i.e. they mentioned definitions of reflection in an implied or indirect manner. These papers either described a variety of different notions of reflection without specifying which conceptualisation they apply in their work (e.g. [47, 57]), or they listed one or more references of works focused on designing for reflection without engaging with their underlying definitions in more depth (e.g. [82, 94, 103])

As these examples illustrate, and as earlier noted by the review by Baumer et al. [10], there is a lack of conceptual agreement in the field. Currently, a variety of definitions for reflection are in use. While the majority of papers in the corpus do not use a specific definition based on reflection theories, there is an implicit understanding of reflection present throughout the HCI field. For a better understanding of this framing of reflection within the field, we analysed the associated terms that are being used to describe reflection. To this end, three researchers coded all the sentences in the corpus of papers containing the word 'reflect'. We focused on the reflection processes that occurred either before, during or after reflection, as well as mentioned prerequisites for reflection. This resulted in a list of associated constructs, as shown in Table 2. The diversity of the corpus shows that reflection is a broad concept which is constantly (re-)interpreted in HCI work and put to action through designing new artefacts.

4.3 Q2: Evaluating Reflection

As shown in figure 4b, the majority of the studies in the corpus used a qualitative approach (33/52 papers) to evaluate the level of reflection support offered by the artefact. Fifteen studies use mixed methods and four studies



(a) (b)

Fig. 4. Bar charts that show how reflection was defined (figure 4a) by the papers in our corpus, and the type of study that was used to evaluate the artefact's level of reflection support (figure 4b).

Table 2. Constructs associated with reflection in our corpus. We coded all the constructs which were used in the same sentence as the word 'reflect*'. All constructs in the table were mentioned by at least two papers, with a maximum of seventeen times (i.e. awareness).

Construct	Frequency	Construct	Frequency	Construct	Frequency	Construct	Frequency
awareness	17	analysis	3	emotional	2	planning	2
engagement	15	contemplation	3	empathy	2	portrayals of self	2
learning	13	deciscion making	3	empowerment	2	processes	2
behavior change	8	discovery	3	engaging	2	professional development	2
sensemaking	8	encouragement	3	experiences	2	prompt	2
understanding	8	gain insights	3	experiencing	2	re-evaluate	2
interpretation	7	insight	3	explore	2	recall	2
thinking	7	meaning-making	3	expression	2	recording	2
feedback	6	patterns	3	fun	2	reflective activities	2
insights	5	self-improvement	3	gaining insight	2	reinterpret	2
memory	5	thoughts	3	identify	2	relationships	2
attention	4	time	3	internal change	2	remembering	2
discussions	4	change	2	internal states	2	retrospective	2
engage	4	collective reflections	2	learn	2	reviewing	2
introspection	4	communication	2	meaning making	2	revisiting	2
reminiscence	4	considering	2	monitoring	2	self-awareness	2
revisit	4	conversation	2	new insights	2	self-expression	2
self-knowledge	4	curate	2	past experiences	2	sense-making	2
self-understanding	4	discuss	2	personal	2	think	2
ambiguity	3	discussion	2	personal insights	2		

use a quantitative approach. The papers applied a wide variety of methods, as demonstrated in table 4. The most often used method for evaluating reflection are interviews, questionnaires and observations.

The review by Baumer et al. [10] reported that the majority of the papers analysed in their review did not provide a direct assessment or evaluation of reflection per se. Quantitative evaluation approaches often assess the quality of the system as opposed to its effect on reflection [10]. Our review mirrors these findings (cf. table 4). Qualitative evaluations on the other hand encounter other difficulties, such as the lack of a clear definition of reflection and not asking directly about reflection [10]. Our findings are similar, most papers do not evaluate reflection *per se*. For instance, the work by Jung et al. aims to enhance reflective design while building a mechatronic system, through reflective questions asked by an external prototyping agent. Their study evaluates reflection in a quantitative manner through:

Table 3. Methods used to evaluate artefacts designed for reflection, arranged by the type of study (i.e. qualitative, mixed, quantitative.

(a) Qualitative studies

	% of papers	references
analogue diary	3,85%	[107] [89]
diary method	3,85%	[87, 105]
focus groups	1,92%	[104]
group interview	1,92%	[88]
interviews	53,85%	[9] [52] [86] [8] [81] [107] [89] [110] [82] [44] [69] [59] [94] [58] [105] [64] [92] [24] [87] [47] [77] [7] [66] [103] [60] [6] [62] [57] [3]
observations	9,62%	[110] [69] [77] [6] [3]
performance	1,92%	[64]
questionnaire	7,69%	[9][104] [64]
roleplay	1,92%	[6]
think-aloud	3,85%	[52] [6]
usage	7,69%	[86] [89] [110] [64]
workshop	3,85%	[100] [49]

(b) Mixed methods studies

	% of papers	references
app entries	1,92%	[41]
coded emotion imprints	1,92%	[48]
interviews	23,08%	[4] [54] [109] [41] [26] [91] [55] [90] [48] [93] [5] [114]
observations	1,92%	[109]
participation logs	1,92%	[109]
performance	5,77%	[4] [90] [37] [93]
questionnaire	25,00%	[4] [54] [112] [109] [26] [91] [55] [90] [37] [93] [5] [114] [2]
self-reports	1,92%	[112]
usage	5,77%	[41] [55] [2]

(c) Quantitative methods studies

	% of papers	references
performance	3,85%	[72] [29]
questionnaire	7,69%	[72] [56] [29] [83]
self-reports	1,92%	[56]
usage	1,92%	[29]

> *Measures of 1) liking of agent, 2) agent social presence, 3) task stressfulness, 4) electronics prototyping confidence, and 5) prototyping performance* [56, p.30].

Another example comes from a study by Arakawa and Yakura [5]. In this study the Authenticity Scale [113] was used to evaluate the INWARD system, which was designed to realise reflection in the field of executive coaching for professional development. As these examples show, reflection is often measured indirectly. Concurrently, our corpus also shows some novel examples of evaluating reflection.

Baumer et al. reported that one paper [54] provided one of the more methodologically rigorous evaluations in their corpus. This study by Isaacs et al. [54], proposes a framework for evaluating reflection. This framework determines the emotional depth of users' reflections and is somewhat similar to the proposed framework by Fleck and Fitzpatrick [39]. Our corpus shows a similar approach by Prilla and Renner [86], who used a coding scheme consisting of three levels (i.e. provision or description, reflection, learning or change). What distinguishes this scheme from the other examples is an additional operationalisation of these stages. Nine phases, consisting of twelve different codes, were defined to enable a more accurate analysis of reflection. In a later study by Rivera-Pelayo et al. [90], this coding scheme was used again, this time to analyse *The MoodMap App*. Whereas our corpus showed some novel approaches [86, 90] to evaluating reflection, the approaches are still not widely used. There are no metrics or processes that would be a local standard for evaluating artefacts designed for reflection.

4.4 Q3: Fields of Application

To create a more complete overview of the fields of application, both the corpus of scientific papers as well as the smartphone apps were included in the analysis. The fields of application varied widely, but can be divided into seven categories (see figure 5). The apps all fall into two categories: they either aim to let users reflect on

Table 4. Measures that are used by the papers in the corpus for a quantitative evaluation of systems.

Scales	number of papers	references
The Subjective Happiness Scale (SHS) [71]	1	[54]
The Satisfaction with Life Scale (SWLS) [32]	1	[54]
The Psychological General Well-Being Index (PGWBI) [22]	1	[54]
The Mindfulness Attention Awareness Scale (MAAS) [19]	1	[54]
The Achievements Emotion Questionnaire (AEQ) [84]	1	[91]
The System Usability Scale (SUS) [18]	2	[55] [83]
The Game Experience Questionnaire(GEQ) [53]	1	[83]
The Learning Activities Survey (LAS) [61]	1	[83]
The Authenticity Scale [113]	1	[5]

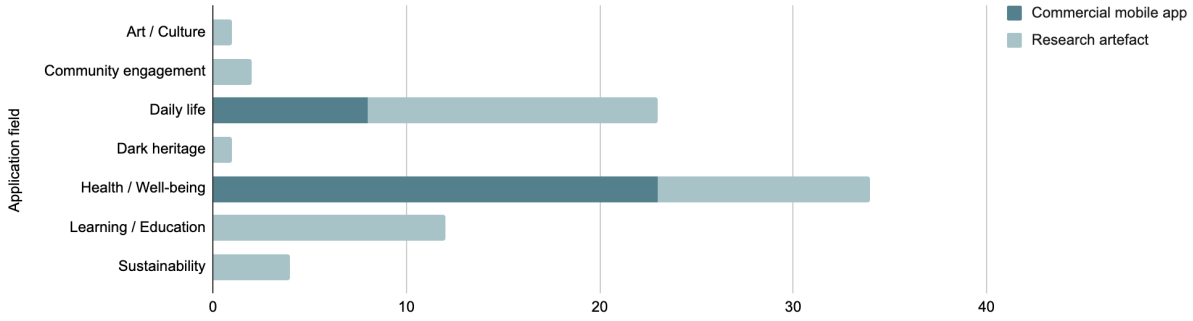


Fig. 5. Fields of application for which artefacts and apps that aim to enhance reflection in our corpus were designed.

their health and wellbeing (e.g. anxiety, mood, mental health), or on their daily life (e.g. reflecting on memories, self-improvement) in general.

The artefacts show more diversity in their fields of application. Most of the artefacts are designed for use in daily life, yet in contrast to the apps, the objectives of these artefacts are divergent. Some of these aim to encourage users to reflect on their social media use [4, 8], smartphone use [51], parenthood [107], solo travel [24] or support open-ended everyday life reflection [77]. Next to daily life, also health and wellbeing is an often mentioned application area in our corpus of artefacts, which is in line with the smartphone apps. Artefacts in this category focused on nutrition [55, 89, 103], physical activity [94], sleep [26] and chronic disease management [7, 87]. Finally, a substantial number of artefacts aim to enhance reflection in education or a work-setting.

The fields of application show some resemblance with those reported by Baumer et al. [10]. In the earlier review, the largest application area was education. We also identified a number of new developments in this area. Yet, in contrast to Baumer's review, the vast majority of artefacts and apps in our corpus are designed for a private setting, focusing on enhancing users' reflection on health, wellbeing and daily life.

5 Q4: RESOURCES FOR DESIGNING SYSTEMS THAT SUPPORT REFLECTION

This section describes the way interaction design was used in our corpus for the design of interactive technologies that support reflection. Through analysis of the artefacts and reviews of apps, we identified the design patterns used by these interactive systems for reflection. Based on this analysis we developed a taxonomy of resources for designing for reflection, which we introduce in this section. The taxonomy is a three-level tree. The taxonomy's goal is to provide a systematic overview of the interaction techniques used in designing for reflection and inspire further exploration. The branches of the tree are resources organised in two levels. The top-level resource categories help group resources into meta-groups. The leaves of the tree represent design patterns that were used

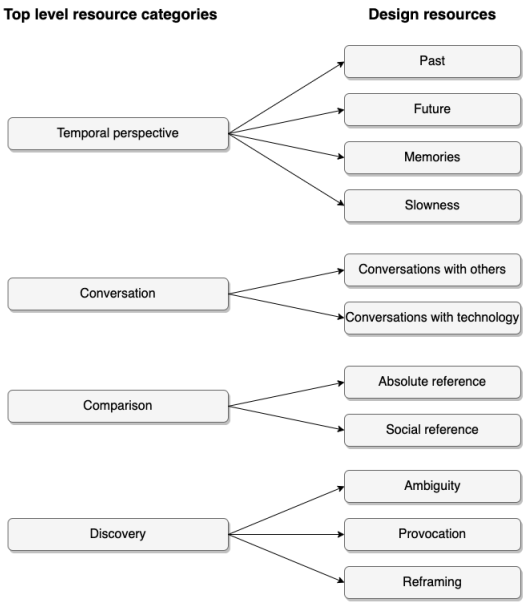


Fig. 6. Taxonomy of resources for designing for reflection. The figure illustrates the top-level resource categories which group the design resources into meta-groups. Each design resource can be implemented by multiple design patterns, see figure 7

in past research artefacts and apps. While the resources represent high-level concepts which, if implemented, were identified as leading to reflection, the design pattern are concrete ways to operationalise the concepts and implement them in a system. Our analysis showed that some of the resources were strongly related. To show this, we also include resource categories (meta-resources) in the taxonomy. Figure 6 shows the design resource part of the tree. The full tree, including the design patterns linked to the resources is available in the auxiliary material. Below, we describe the design resources and provide examples of their use in research and practice. For each of the resources, we provide examples of how design patterns were used for implementing this resource, in SMALL CAPS. A visualisation of the taxonomy including the design patterns is presented in figure 7. This Sankey visualisation illustrates the connections between the design resources and design patterns. It shows the design patterns that were applied in the smartphone apps and the corpus of papers, to implement the design resources. Given the high number of patterns, we recommend using the data in auxiliary material for a full overview. Next, we provide a detailed description of the resource categories and the resources they include.

5.1 Temporal Perspective

Several artefacts and apps use a *temporal perspective* as a resource for reflection. Temporal perspective in this context refers to using time as a means to offer users a new point of view, which, in turn, can lead to reflection. We identified four different resources in this category: past, future, memories and slowness.

5.1.1 Past. Many artefacts and apps make use of the *past* to enhance reflection. These systems generally offer users the possibility to revisit their data, i.e. retrospection, creating a new perspective. An example of an artefact deploying a perspective of the past as a resource for reflection is *Trackly*, designed by Ayobi et. al [7]. Trackly is a smartphone app that helps patients with Multiple Sclerosis. The app lets users manually track their symptoms and then visualises patterns and trends in the user's long-term data to help patients to manage their chronic

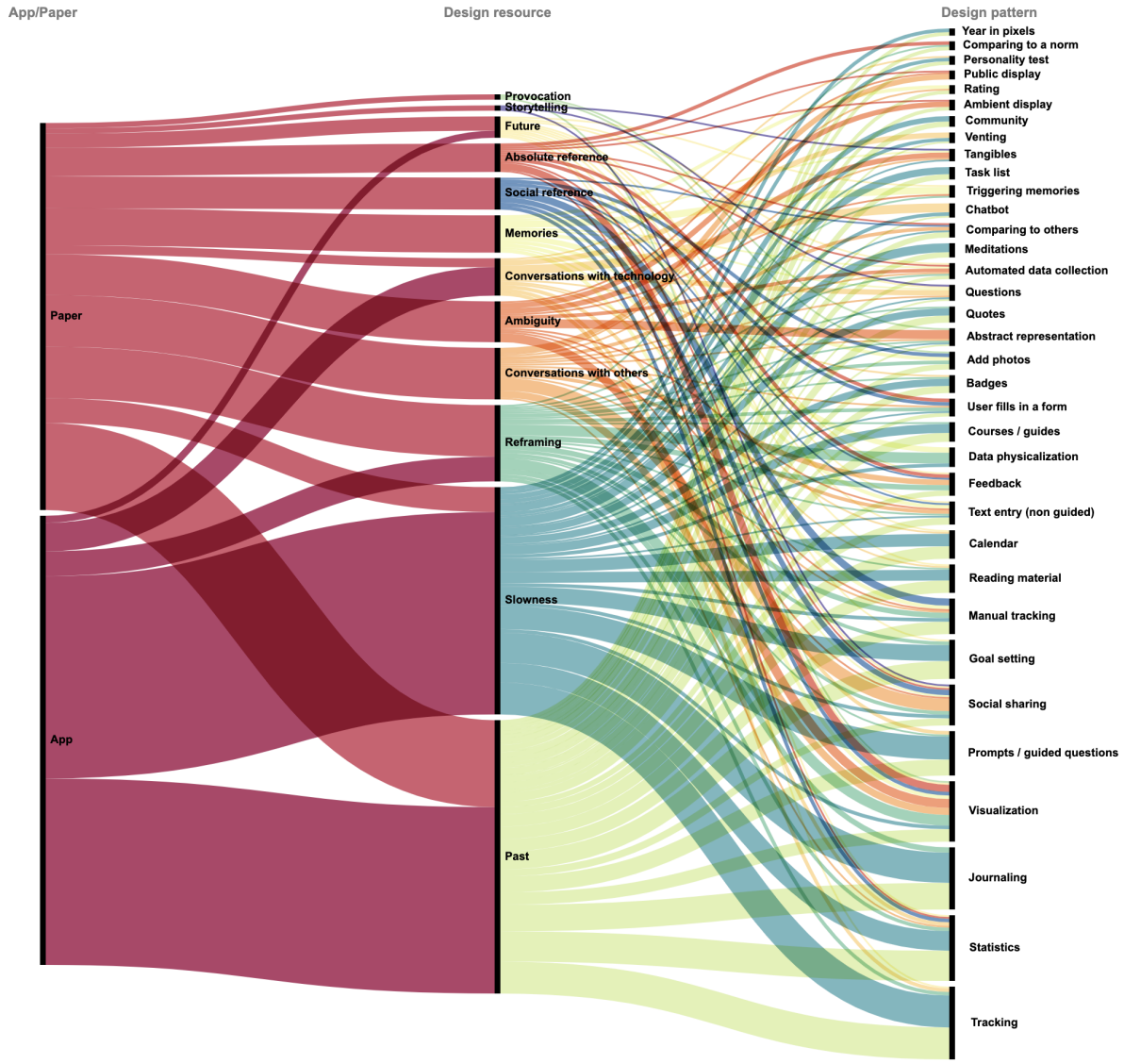


Fig. 7. Sankey visualisation that demonstrates the connection between the design patterns that were used in the smartphone apps and the corpus of papers to implement the design resources. The visualisation only contains the design patterns that occurred at least five times in the data set, and the thickness of the line represents the frequency of occurrence in the data set. The full data set, along with a tool for creating customised versions of this plot, is available in the auxiliary material.

disease. Through visualising past data the app can trigger reflective moments. This technique is also used in other artefacts such as *DReflect*, a smartphone app developed by Raj et. al [87]. DReflect enables diabetes patients to track their symptoms and to discover patterns through data visualisations.

The majority of commercial reflection apps use this resource to enhance reflection. These apps often let users manually track data and offer users through statistics and visualisations to look back in their past. For instance, Daylio [5] lets users manually track their mood and offers visualisations of a user's mood over time, enabling reflection. The same approach is also used by several other apps, such as Moodtracker [6], Moodflow [7] and Youper [8]. Artefacts and apps that used the past to enhance reflection often feature VISUALISATIONS of past data, as well as STATISTICS as design patterns.

5.1.2 Memories. Another design resource in our taxonomy is *memories*. Memories are related to a perspective on the *past*, yet this resource enhances reflection in a different way. The *past* resource tries to offer an objective portrait of the past, whereas artefacts and apps that use memories choose a more subjective approach. As described by Staudinger [102], reflection can be seen as reconstructing life events from memory combined with a further analysis (explanation and evaluation) of these memories. By triggering a user's memory of a certain event these artefacts and apps encourage reflection. For instance, Isaacs et. al [54] designed *Echo*, a smartphone app for recording everyday experiences and reflecting on them later. The app presents old entries to users and lets them re-rate their current happiness regarding the memory. Echo used RATING memories, as well as sending PROMPTS to revisit past memories. Systems such as Echo [54] actively remind users of life events (e.g. trigger memories) as a source for reflection. Another artefact that triggers memories is *ReflectiveDiary*, a smartphone app designed by Rzayev et. al [93]. However, the approach used in this app differs considerably from Echoes. ReflectiveDiary aims to support reflection on previous activities by automatically collecting data about the user (location, calls, messages, etc.). To trigger memories of these activities, the app sends quizzes during the day to let users memorise and reflect on their activities. ReflectiveDiary deploys several design patterns, such as AUTOMATED DATA COLLECTION of user activities and asking QUESTIONS about these activities to trigger memories.

5.1.3 Future. Future is another temporal design resource. Instead of triggering memories, the artefacts and apps that make use of this resource, let a user consider the future to enhance reflection. An artefact in our corpus that uses this resource is *FutureMe*, a website evaluated by Odom [82]. It lets users make time capsules, by sending messages to people to be delivered in the future. People can send letters to themselves, as well as others. This artefact actually uses two resources for reflection. On the one hand it lets a user reflect while typing a message by thinking about the future, on the other hand it encourages reflection on a memory at a later point in time. An app that uses the future as a resource for reflection is Success Life Coach [9]. This app lets users consider their direction in life through offering READING MATERIAL on self-improvement and by supporting users on that path through GOAL SETTING.

5.1.4 Slowness. The last temporal resource is encouraging a user to slow down for reflection. An example of this is *The Ripening Room*, a social networking system designed by Bae et. al [8]. The aim of the system is to raise users' awareness of social media posts by delaying the publishing of such. This allows users to let thoughts sink in, reconsider and refine their posts before posting. Two design patterns that Ripening Room uses are DELAYING MESSAGES and allowing users to REFINE OR REVISIT their previously written posts. Gorichanaz [47] designed a paper journal that guided individuals through reflection on city murals. The aim of the artefact was to promote moral learning in individuals and societies by reflecting on murals in the city. The journal used TEXTUAL PROMPTS and QUESTIONS to encourage participants to slow down and to consider a mural in more detail. An app that

[5] https://play.google.com/store/apps/details?id=net.daylio&hl=en
[6] https://play.google.com/store/apps/details?id=diary.questions.mood.tracker
[7] https://play.google.com/store/apps/details?id=com.moodpixel
[8] https://play.google.com/store/apps/details?id=br.com.youper
[9] https://play.google.com/store/apps/details?id=com.way4app.successwizard

uses slowness as a resource for reflection is 7Mind [10]. This app aims to encourage a user to slow down through MEDITATION sessions. This design pattern is also used by DiveThru[11], an app that combines MEDITATIONS with JOURNALING features to help a user to slow down for daily reflection.

5.2 Conversation

Conversations are a well-known technique for reflection [78]. A study by Mols [76] showed that there is a social dimension to reflection, 85% of their participants stated that they reflect through conversations with for instance a partner, friend or colleague. Our taxonomy contains two resources in this category: conversations with others and conversations with technology.

5.2.1 Conversations with Others. Our corpus shows various examples of artefacts that intend to encourage conversation between users of an artefact [5, 29, 86, 88, 94, 109, 110]. Valkanova et. al [109] designed *Reveal-it!*, an interactive public display that encouraged participants to reflect on their energy consumption to increase social awareness and foster discourse. A user voluntarily entered their energy consumption data in a web-form on a tablet. The data was then visualised as a sunburst representation on a public display. This enabled comparing one's energy consumption with others. The design patterns used by Reveal-it! are VISUALISATIONS on a PUBLIC DISPLAY of energy consumption based on data gathered through the USER FILLING IN A FORM. While *Reveal-it!* used a public setting in which people would chat face-to-face, Prilla and Renner [86] enabled conversations through a computer application. *TalkReflection* was designed to let users share difficult situations at work with their colleagues. This resulted in online dialogues between co-workers leading to collaborative reflection. TalkReflection used EXPERIENCE REPORTING and SOCIAL SHARING as design patterns.

5.2.2 Conversations with Technology. Beside conversations with other users of an artefact, there are also examples in which a user has a conversation with the artefact itself. Three artefacts enhance reflection by creating a conversation between a user and technology. An example of such an artefact is *Chimeria: Grayscale* [83]. Chimeria is a computer application that enables users to critically self-reflect on issues of sexism in the workplace. The application is an interactive narrative that lets users have a dialogue with the system through email (within the application). The application describes situations of sexism and lets users choose between several options as to how they would response to such a situation. Another example comes from Kocielnik et al. [63], who designed *Robota*, a chatbot with voice interaction. Robota aims to stimulate reflection and self-learning in the workplace by asking questions and having a chat with the user of the system. Also, several apps use this resource, for instance the Replika: my AI friend [12] app that lets users have conversations with a chatbot powered by artificial intelligence. This app uses a combination of questions, as well as allowing users to vent as a means of enhancing reflection. An approach that is also used by the Youper [13] and HOLD [14] apps. These examples all use a CHATBOT which asks QUESTIONS to enhance reflection. Replika, Youper and HOLD also use VENTING as a design pattern, by allowing users to vent frustrations or thoughts about challenging experiences the app enhances reflection.

5.3 Comparison

The next category of resources in the corpus is comparison. Artefacts that use this design resource enhance reflection by letting users compare their current status to an 'ideal' status. This comparison is done in two different ways: comparison to an arbitrary norm (absolute reference) or comparison to others (social reference).

[10]https://play.google.com/store/apps/details?id=de.sevenmind.android
[11]https://play.google.com/store/apps/details?id=com.divethru.divethru
[12]https://play.google.com/store/apps/details?id=ai.replika.app
[13]https://play.google.com/store/apps/details?id=br.com.youper
[14]https://play.google.com/store/apps/details?id=com.wingmanalpha.Hold

5.3.1 Absolute Reference. Two research artefacts use an absolute reference as a resource for reflection. The *HotkeySkillometer* is a computer widget designed by Malacria et. al [72] that encourages users to reflect on their performance level in interacting with an interface. This widget specifically focuses on using hotkeys. The widget uses progress bars to give a user feedback on their hotkey-skills, showing progress from 'slowpoke' to 'superstar'. A norm for comparison is also used by Jung et. al [55], in a smartphone app called *FIT* (Food InTake Logger). This app lets users manually track their vegetable consumption and it visualises the number of servings of vegetables the user still needs to eat for that day. These artefacts both enhance reflection by giving FEEDBACK on performance through VISUALISATIONS.

5.3.2 Social Reference. Other artefacts use a social reference as a design resource. For example, the *BinCam* [104] is a garbage bin that has a smartphone attached to the lid. Every time the user throws something in the bin the smartphone takes a picture of the bin's contents and automatically posts the photo to Facebook. The intention of this system is to affect normative social influence, which it aims to achieve by using automated SOCIAL SHARING and a LEADERBOARD which adds a competitive element to the system. Another artefact which used a social reference for comparison is *MoodMap*, designed by Rivera-Pelayo et. al [90]. MoodMap is a personal computer application that lets users track and reflect on their mood at work. In this sense the MoodMap also uses a temporal perspective as a resource for reflection, by allowing users to track their mood and look back onto their past entries. Yet, this system differs in that it also lets users compare their mood to that of colleagues through VISUALISATIONS.

5.4 Discovery

The fourth design resource is *discovery*. This resource aims to enhance reflection through evoking the user to discover something, or have a user see something in a new light. Such discoveries can lead to marvel or 'Aha!' moments, which, in turn, can lead to reflective thoughts. Our taxonomy contains three resources in this category: (1) ambiguity, (2) provocation and (3) reframing.

5.4.1 Ambiguity. The use of abstract representations or *ambiguity* is a known design resource for reflection [42, 43, 70]. An example of an artefact that uses ambiguity as a design resource is *Admixed Portrait* [107], which is a digital photo frame. The artefact extracts and amalgamates faces found in its users' Facebook photos and creates alternative representations of online presence. The aim of the system is to enhance reflections on parenthood in that way. Another example is *Eloquent Robes*, an interactive installation designed by Núñez-Pacheco and Loke [81]. The installation projects physiological data onto a robe, to enable users to reflect on data that normally remains concealed from our everyday awareness. These artefacts both use *abstract representations* as a design pattern for reflection.

5.4.2 Provocation. Besides ambiguity, also *provocation* can be used to enhance reflection. This design resource is deployed by Gulotta et al. [52]. They developed three photo archiving websites named BlackBox, DataFade and BitLogic that provoked participants to consider how their digital legacies might be treated in the future. The design of these systems was inspired by patina of physical objects. Physical objects, such as printed photos show signs of aging, which often contributes to the value of these objects. The three websites aimed to use the same principle in a digital way, provoking reflection through TRANSFORMING UPLOADED PHOTOS leading to DIGITAL DECAY.

5.4.3 Reframing. Several artefacts and apps use *reframing* as a design resource. These systems aim to let a user see something in a new light, which in turn evokes reflection. Reframing is often implemented through the use of DATA PHYSICALISATION as a design pattern. In a study by Thudt et. al [105], participants created physical objects to visualise tacking data. Similarly, in a study by Ryokai et. al [92], participants made physical mementos of laughter to enable people to preserve and revisit these moments. Other examples are data SONIFICATION of

crocheting-skills [100] and using a colour imprint techniques to let children VISUALISE their mood in class [48]. An app that uses reframing as a design resource, is force4change [15]. This app uses text mining to analyse JOURNAL entries and shows the user STATISTICS and VISUALISATIONS of how each person in their social circle influences their emotions. This enables users to see their social life in a new perspective, which can enhance reflection.

6 DISCUSSION

In this section, we reflect on the results of our analysis and discuss potential starting points for future research on systems that support reflection in HCI. In contrast to Baumer et al.'s work [10], our results offer a structured overview of work on reflection. Future designers of technologies which support reflection can use our taxonomy to review what design resources and patterns were used in the past to foster reflection and create a blend of solution specific to their system. Further, they also can identify which resources are less explored and offer potential for improvement.

6.1 Reflection Remains a Relevant, but Largely Undefined Concept in HCI

Our review shows that defining reflection still remains an open question. While we observed a large number of new systems developed with the goal of supporting reflection, roughly a third of them did not provide a definition of reflection. In this aspect, our findings mirror Baumer et al.'s [10] insights. Reflection is a multi-faceted concept. If we do not have a shared understanding of what reflection is, evaluating such systems and extending our knowledge about reflection is challenging. However, we hypothesise that the multi-faceted nature of reflection is one of the aspects why it is such a generative concept to design for. Hence, embracing its multi-faceted nature instead of striving for one, uniform HCI definition could be one way forward. In other words, engaging with the multitude of available definitions of reflection (within and beyond HCI) and clarifying which has been applied in a specific design context combined with applying our taxonomy which offers can improve the shared understanding of reflection in the HCI community. As the taxonomy provides intermediate-level knowledge, it can be used to operationalise reflection, for instance in addition to deciding on a definition or if no pre-defined definition of reflection fits the designated design context.

We observed that HCI research about reflection transitioned from initial explorations to more artefact-driven work which often features empirical studies. The design resources and patterns in our work enable effectively contrasting and comparing artefacts, stimulating more effective discussions. The resources in our paper describe the possible means to an end—reflection. We believe that *the next step for HCI research in reflection should be developing a technology-centric conceptualisation of reflection that can be effectively linked to the resources and aid designers in more precisely defining the goals of their work on reflection.*

6.2 Evaluation Methods for Reflection Technologies Need Further Development

Our review also echoes Baumer et al.'s [10] findings in terms of evaluation. While the majority of the systems we reviewed did involve an evaluation, a very limited number of the works evaluated reflection *per se*. The lack of difference in this aspect is surprising. Baumer et al.'s [10] review included non-archival works, which are often not required to contribute a comprehensive evaluation and our work looked only on full papers. This indicates that despite the growing maturity of reflection as a research topic, there is still an urgent need for understanding how to evaluate if systems support reflection. Our results show that, often, qualities of the system other than supporting reflection were evaluated even when reflection was the stated design goal. This indicates that HCI researchers need a wider toolbox for understanding and assessing reflection in interactive systems. In particular, table 3c summarises the scales that were used for the evaluation of systems in our corpus, demonstrating that different aspects are measured, e.g. usability (SUS) or subjective happiness (SHS). Therefore, HCI researchers

[15] https://fnd.io/#/us/iphone-app/1499167510-force4change-tag-journaling-by-invoodoo-

did not have at their disposal a questionnaire specifically designed to evaluate interactive systems that support reflection. A very recent work by Bentvelzen et al. [13] can support further development in this area. In particular, they propose the Technology-Supported Refection Inventory (TSRI) as a scale that evaluates how effectively a system supports refection.

In combination with measures such as the TSRI, *we suggest using our design resources as intermediate-level concepts for evaluation*, as our analysis shows that the resources are linked to reflection. Thus, if it can be determined that a system effectively uses one of the resources, the results suggests that the system is effectively supporting reflection. For instance, if a system that visualises data for reflection allows the user to effectively revisit historical data (which can be inferred with usage logs), it can be interpreted as using the *Past* resource. A qualitative inquiry can follow to confirm if viewing the past evokes reflective experiences.

6.3 Using the Design Resources and Patterns

This paper contributes the taxonomy of design resources and patterns for reflection with the intention to further stimulate designing systems for reflection and offer a systematic starting point for new inquiries. We suggest using the taxonomy beyond classifying systems (as done in this paper) in two ways.

First, the taxonomy can be used to indicate initial design solutions based on past experiences. When starting a design process for technologies for reflection, the taxonomy offers an overview of the design resources at hand. Here, the designer can think of ways to creatively combine or exclude specific resources depending on the application area and the target user groups. The design patterns linked to the resources represent solutions which worked in other contexts. This reduces the uncertainty in a design process and creates the opportunity for re-imagining the design pattern in the context of a particular system. When designing an interactive artefact which should support reflection, the designer can first decide which strategies they want to employ to foster reflection, by choosing the design resources to use. Our taxonomy then provides tangible ideas on how to implement these strategies through design patterns and links to examples of past systems.

Second, the derived taxonomy is not exhaustive. Hence, we hope that that the things that are *not* in the taxonomy can inspire future researchers and practitioners. In other words, interacting with the taxonomy and using it as a resource for inspiration can help to identify aspects that have not yet been (sufficiently) addressed in previous designs. Our taxonomy provides a summary of the current state of the design efforts in supporting reflection. Defining new resource or design patterns for reflection can be an effective research pursuit. Further identifying how some design patterns can be used to implement resources that were not linked to them before can be a creative challenge. Furthermore, new combinations of resources can be a source of inspiration. It has to be noted that the systems we analysed were designed for reflection. However, as discussed above, the concept of reflection is in conceptual flux. As the derived taxonomy is based on the analysis of systems designed to foster reflection, the taxonomy needs to be treated with care. Nevertheless, some of the identified design strategies are based on theories from Psychology. We recommend authors to engage with the intricacies of applying the taxonomy either in their method section or their discussion. In addition, future work should explore how the taxonomy can guide focused evaluation (i.e. evaluating particular aspects of interactive systems which were designed to foster reflection. Insights from such studies could then support the further development of the taxonomy.

Finally, a challenge for interaction design which emerges from our result, is *effectively using the design resources in personal informatics experiences*. Given the importance which personal informatics work has ascribed to reflection [34], personal informatics systems should empower the user to engage in a reflection process. The resources identified in our work can be employed to effectively help the user enter the reflection phase of a personal informatics experience [35] and meaningfully remain in it. For instance, reframing can be used to trigger an 'a-ha' moment based on one's personal data. This curiosity can later be stimulated through facilitating conversations with others, allowing the user to continually remain in the reflection phase.

6.4 Limitations

While we completed our review with utmost care, we recognise that it is prone to certain limitations. Firstly, we took an informed decision to focus only on artefacts for reflection. While this enabled us to study the properties of those artefacts in detail, it also excluded conceptual work from our review such as the recent work by Eikey et al. [33] or the work by Slovak et al. [98] on understanding technologies and reflection in the education domain. Future work should chart the conceptual developments in HCI for reflection. Along similar lines, a number of reflection papers in literature focus on theoretical exploration, which were excluded from our corpus due to our specific focus on evaluated systems; this resulted in a smaller corpus than e.g. the one in Baumer et al. [10]. Further, while our review covers systems developed for research and smartphone applications, there are also analogue artefacts designed for reflection such as physical pre-printed notebooks. While it would be challenging to systematically review such products, they may have qualities that can impact our understanding of the design resources presented. We also recognise that our review was based on sources indexed in the ACM Digital Library and focused on HCI work. A different, cross-disciplinary review could address how notions of reflection are explored in other fields, e.g. industrial design [45, 46] or philosophy [65]. Similarly, our corpus consists solely of papers that meet the criteria used for the literature search. These criteria are, in turn, based on annotations in the bibliographic database used. This may mean that some relevant papers may have been omitted because of incomplete metadata, e.g. [27].

Further, we recognise that by focusing on apps that promised the users the experience of reflection in their description we might have excluded some apps that use reflection but do not mention it, e.g. data tracking apps. Nevertheless, we made this decision as we were focusing on an software explicitly citing reflection as a design goal and a 'promise' to the user. Finally, we note that focusing solely on academic work may have given us a more systematic overview of the current literature. Yet, we would also risk steering the community away from the everyday experience of reflection support. A review focusing solely on apps would chart the current commercial landscape precisely, yet it would omit the innovative ideas present in the literature. We believe that our method will enable future researchers in and designers of reflection support systems to learn both from the open-ended conceptual explorations in research and the practical aspects of commercial apps to better understand the effective means to design for reflection.

7 CONCLUSION

In this paper, we reviewed research papers and smartphone applications to build a better understanding of what qualities in interactive artefacts can foster reflection. We found that past HCI work which featured systems for reflection was in an epistemological flux. The definition of reflection and how to evaluate systems for reflection are still open issues. In order to provide ways forward, we contributed a taxonomy of design resources and patterns that describe the qualities and interaction techniques used to foster reflection in existing systems. We hope that our taxonomy will inspire new explorations into to how interactive technologies can help in reflection.

REFERENCES

[1] Ahed Aladwan, Ryan M. Kelly, Steven Baker, and Eduardo Velloso. 2019. A Tale of Two Perspectives: A Conceptual Framework of User Expectations and Experiences of Instructional Fitness Apps. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (Glasgow, Scotland Uk) (CHI '19). Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3290605.3300624

[2] Deemah Alqahtani, Caroline Jay, and Markel Vigo. 2020. The Effect of Goal Moderation on the Achievement and Satisfaction of Physical Activity Goals. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 4, 4, Article 116 (Dec. 2020), 18 pages. https://doi.org/10.1145/3432209

[3] Daniela De Angeli, Daniel J. Finnegan, Lee Scott, and Eamonn O'neill. 2021. Unsettling Play: Perceptions of Agonistic Games. J. Comput. Cult. Herit. 14, 2, Article 15 (May 2021), 25 pages. https://doi.org/10.1145/3431925

[4] Mohd Anwar and Philip W.L. Fong. 2012. A visualization tool for evaluating access control policies in facebook-style social network systems. Proceedings of the ACM Symposium on Applied Computing (2012), 1443–1450. https://doi.org/10.1145/2245276.2232007

[5] Riku Arakawa and Hiromu Yakura. 2020. INWARD: A Computer-Supported Tool for Video-Reflection Improves Efficiency and Effectiveness in Executive Coaching. (2020), 1–13. https://doi.org/10.1145/3313831.3376703

[6] Bon Adriel Aseniero, Charles Perin, Wesley Willett, Anthony Tang, and Sheelagh Carpendale. 2020. Activity River: Visualizing Planned and Logged Personal Activities for Reflection. In Proceedings of the International Conference on Advanced Visual Interfaces (Salerno, Italy) (AVI '20). Association for Computing Machinery, New York, NY, USA, Article 4, 9 pages. https://doi.org/10.1145/3399715.3399921

[7] Amid Ayobi, Paul Marshall, and Anna L Cox. 2020. Trackly : A Customisable and Pictorial Self-Tracking App to Support Agency in Multiple Sclerosis Self-Care. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (2020), 1–15.

[8] Jae Eul Bae, Youn Kyung Lim, Jin Bae Bang, and Myung Suk Kim. 2014. Ripening room: Designing social media for self-reflection in self-expression. Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS (2014), 103–112. https://doi.org/10.1145/2598510.2598567

[9] Eric P.S. Baumer, Sherri Jean Katz, Jill E. Freeman, Phil Adams, Amy L. Gonzales, John Pollak, Daniela Retelny, Jeff Niederdeppe, Christine M. Olson, and Geri K. Gay. 2012. Prescriptive persuasion and open-ended social awareness: Expanding the design space of mobile health. Proceedings of the ACM Conference on Computer Supported Cooperative Work, CSCW (2012), 475–484. https://doi.org/10.1145/2145204.2145279

[10] Eric P.S. Baumer, Vera Khovanskaya, Mark Matthews, Lindsay Reynolds, Victoria Schwanda Sosik, and Geri Gay. 2014. Reviewing reflection: On the use of reflection in interactive system design. Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS (2014), 93–102. https://doi.org/10.1145/2598510.2598598

[11] Eric P S Baumer. 2015. Reflective Informatics: Conceptual Dimensions for Designing Technologies of Reflection. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). Association for Computing Machinery, New York, NY, USA, 585–594. https://doi.org/10.1145/2702123.2702234

[12] Mehmet Aydin Baytas, Damla Çay, Yuchong Zhang, Mohammad Obaid, Asim Evren Yantaç, and Morten Fjeld. 2019. The Design of Social Drones: A Review of Studies on Autonomous Flyers in Inhabited Environments. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19). Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300480

[13] Marit Bentvelzen, Jasmin Niess, Mikołaj P Woźniak, and Paweł W Woźniak. 2021. The Development and Validation of the Technology-Supported Reflection Inventory. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. 1–8.

[14] Staffan Björk, Sus Lundgren, and Jussi Holopainen. 2003. Game Design Patterns. In Level Up, Vol. 54. 180–193. https://doi.org/10.1.1.10.4097

[15] Ann Blandford, Dominic Furniss, and Stephann Makri. 2016. Qualitative HCI Research: Going Behind the Scenes. Synthesis Lectures on Human-Centered Informatics 9 (2016), 1–115. https://doi.org/10.2200/S00706ED1V01Y201602HCI034

[16] Fadi Botros, Charles Perin, Bon Adriel Aseniero, and Sheelagh Carpendale. 2016. Go and grow: Mapping personal data to a living plant. Proceedings of the Workshop on Advanced Visual Interfaces AVI 07-10-June (2016), 112–119. https://doi.org/10.1145/2909132.2909267

[17] David Boud, Rosemary Keogh, and David Walker. 1985. Reflection: Turning experience into learning. Routledge.

[18] John Brooke et al. 1996. SUS-A quick and dirty usability scale. Usability evaluation in industry 189, 194 (1996), 4–7.

[19] Kirk W Brown and Richard M Ryan. 2009. The mindfulness attention awareness scale (MAAS). Acceptance and commitment therapy. Measures Package 82 (2009).

[20] Fred B Bryant, Colette M Smart, and Scott P King. 2005. Using the past to enhance the present: Boosting happiness through positive reminiscence. Journal of Happiness Studies 6, 3 (2005), 227–260.

[21] Robert N Butler. 1963. The Life Review: An Interpretation of Reminiscence in the Aged. Psychiatry 26, 1 (1963), 65–76. https://doi.org/10.1080/00332747.1963.11023339

[22] Anna Carotenuto, Angiola M Fasanaro, Ivana Molino, Fabio Sibilio, Andrea Saturnino, Enea Traini, and Francesco Amenta. 2013. The Psychological General Well-Being Index (PGWBI) for assessing stress of seafarers on board merchant ships. International Maritime Health 64, 4 (2013), 215–220.

[23] Robert Cercos, William Goddard, Adam Nash, and Jeremy Yuille. 2016. Coupling Quantified Bodies: affective possibilities of self-quantification beyond the self. Digital Culture & Society 2 (2016), 177–182. https://doi.org/10.14361/dcs-2016-0114

[24] Runyuan Chen, Mania Orand, Shin Young Choi, and Leena Choi. 2018. An empirical exploration of mindfulness design using solo travel domain. Conference on Human Factors in Computing Systems - Proceedings 2018-April (2018), 1–12. https://doi.org/10.1145/3173574.3173671

[25] Justin Cheng, Akshay Bapat, Gregory Thomas, Kevin Tse, Nikhil Nawathe, Jeremy Crockett, and Gilly Leshed. 2011. GoSlow: Designing for Slowness, Reflection and Solitude. In CHI '11 Extended Abstracts on Human Factors in Computing Systems (CHI EA '11). Association for Computing Machinery, New York, NY, USA, 429–438. https://doi.org/10.1145/1979742.1979622

[26] Eun Kyoung Choe, Bongshin Lee, Matthew Kay, Wanda Pratt, and Julie A. Kientz. 2015. SleepTight: Low-burden, self-monitoring technology for capturing and reflecting on sleep behaviors. UbiComp 2015 - Proceedings of the 2015 ACM International Joint

Conference on Pervasive and Ubiquitous Computing (2015), 121–132. https://doi.org/10.1145/2750858.2804266

[27] Eun Kyoung Choe, Bongshin Lee, Haining Zhu, and Nathalie Henry Riche. 2017. Understanding self-reflection: How people reflect on personal data through visual data exploration. In ACM International Conference Proceeding Series (PervasiveHealth '17). Association for Computing Machinery, New York, NY, USA, 173–182. https://doi.org/10.1145/3154862.3154881

[28] Eun Kyoung Choe, Nicole B. Lee, Bongshin Lee, Wanda Pratt, and Julie A. Kientz. 2014. Understanding quantified-selfers' practices in collecting and exploring personal data. Conference on Human Factors in Computing Systems - Proceedings (2014), 1143–1152. https://doi.org/10.1145/2556288.2557372

[29] Andrew John Clayphan, Roberto Martinez-Maldonado, and Judy Kay. 2017. A student-facing dashboard for supporting sensemaking about the brainstorm process at a multi-surface space. ACM International Conference Proceeding Series (2017), 49–58. https://doi.org/10.1145/3152771.3152777

[30] Sunny Consolvo, Predrag Klasnja, David W. McDonald, and James A. Landay. 2012. Designing for healthy lifestyles: Design considerations for mobile technologies to encourage consumer health and wellness. Foundations and Trends in Human-Computer Interaction 6, 3-4 (2012), 167–315. https://doi.org/10.1561/1100000040

[31] John Dewey. 1933. How we think. https://doi.org/10.1037/10903-000

[32] ED Diener, Robert A Emmons, Randy J Larsen, and Sharon Griffin. 1985. The satisfaction with life scale. Journal of personality assessment 49, 1 (1985), 71–75.

[33] Elizabeth Victoria Eikey, Clara Marques Caldeira, Mayara Costa Figueiredo, Yunan Chen, Jessica L Borelli, Melissa Mazmanian, and Kai Zheng. 2021. Beyond self-reflection: introducing the concept of rumination in personal informatics. Personal and Ubiquitous Computing (2021), 1–16.

[34] Daniel A Epstein, Clara Caldeira, Mayara Costa Figueiredo, Xi Lu, Lucas M Silva, Lucretia Williams, Jong Ho Lee, Qingyang Li, Simran Ahuja, Qiuer Chen, Payam Dowlatyari, Craig Hilby, Sazeda Sultana, Elizabeth V Eikey, and Yunan Chen. 2020. Mapping and Taking Stock of the Personal Informatics Literature. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 4, 4 (12 2020). https://doi.org/10.1145/3432231

[35] Daniel A. Epstein, An Ping, James Fogarty, and Sean A. Munson. 2015. A lived informatics model of personal informatics. UbiComp 2015 - Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (2015), 731–742. https://doi.org/10.1145/2750858.2804250

[36] Chloe Fan, Jodi Forlizzi, and Anind K. Dey. 2012. A spark of activity: Exploring informative art as visualization for physical activity. UbiComp'12 - Proceedings of the 2012 ACM Conference on Ubiquitous Computing (2012), 81–84. https://doi.org/10.1145/2370216.2370229

[37] Xiangmin Fan, Wencan Luo, Muhsin Menekse, Diane Litman, and Jingtao Wang. 2017. Scaling Reflection Prompts in Large Classrooms via Mobile Interfaces and Natural Language Processing. (2017), 363–374. https://doi.org/10.1145/3025171.3025204

[38] Sebastiao Ferreira. [n.d.]. Reflecting in and on Action. Technical Report.

[39] Rowanne Fleck and Geraldine Fitzpatrick. 2010. Reflecting on reflection: Framing a design landscape. ACM International Conference Proceeding Series (2010), 216–223. https://doi.org/10.1145/1952222.1952269

[40] Peter Fonagy, Guörgy Gergely, Elliot L Jurist, and Mary Target. 2018. Affect regulation, mentalization, and the development of the self. Routledge.

[41] Eva Ganglbauer, Geraldine Fitzpatrick, and Florian Güldenpfennig. 2015. Why and what did we throw out? Probing on Reflection through the Food Waste Diary. Conference on Human Factors in Computing Systems - Proceedings 2015-April (2015), 1105–1114. https://doi.org/10.1145/2702123.2702284

[42] William Gaver, John Bowers, Andy Boucher, Andy Law, Sarah Pennington, and Nicholas Villar. 2006. The History Tablecloth: Illuminating Domestic Activity. In Proceedings of the 6th Conference on Designing Interactive Systems (DIS '06). Association for Computing Machinery, New York, NY, USA, 199–208. https://doi.org/10.1145/1142405.1142437

[43] William W Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity as a Resource for Design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03). Association for Computing Machinery, New York, NY, USA, 233–240. https://doi.org/10.1145/642611.642653

[44] David B. Gerritsen, Jennifer K. Olsen, Dan Tasse, Tatiana A. Vlahovic, Rebecca Gulotta, William Odom, Jason Wiese, and John Zimmerman. 2016. Mailing archived emails as postcards: Probing the value of virtual collections. Conference on Human Factors in Computing Systems - Proceedings (2016), 1187–1199. https://doi.org/10.1145/2858036.2858541

[45] Maliheh Ghajargar, Alberto De Marco, and Francesca Montagna. 2017. "Wise things": When smart objects stimulate reflection. In Proceedings of the International Conference on Interfaces and Human Computer Interaction 2017 - Part of the Multi Conference on Computer Science and Information Systems 2017. 233–238.

[46] Maliheh Ghajargar, Mikael Wiberg, and Erik Stolterman. 2019. Designing Places for Reflection. In Social Internet of Things, Alessandro Soro, Margot Brereton, and Paul Roe (Eds.). Springer International Publishing, Cham, 107–120. https://doi.org/10.1007/978-3-319-94659-7{_}6

[47] Tim Gorichanaz. 2020. Engaging with Public Art: An Exploration of the Design Space. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (2020), 1–14. https://doi.org/10.1145/3313831.3376640

[48] Pauline Gourlet. 2018. Children's conversation with experience: Making emotional imprints. IDC 2018 - Proceedings of the 2018 ACM Conference on Interaction Design and Children (2018), 313–324. https://doi.org/10.1145/3202185.3202734

[49] Pauline Gourlet, Louis Eveillard, and Ferdinand Dervieux. 2016. The Research Diary, supporting pupils' reflective thinking during design activities. Proceedings of IDC 2016 - The 15th International Conference on Interaction Design and Children (2016), 206–217. https://doi.org/10.1145/2930674.2930702

[50] Sten Govaerts, Katrien Verbert, Erik Duval, and Abelardo Pardo. 2012. The Student Activity Meter for Awareness and Self-Reflection. In CHI '12 Extended Abstracts on Human Factors in Computing Systems (CHI EA '12). Association for Computing Machinery, New York, NY, USA, 869–884. https://doi.org/10.1145/2212776.2212860

[51] Miriam Greis, Tilman DIngler, Albrecht Schmidt, and Chris Schmandt. 2017. Leveraging user-made predictions to help understand personal behavior patterns. Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services, MobileHCI 2017 (2017). https://doi.org/10.1145/3098279.3122147

[52] Rebecca Gulotta, William Odom, Jodi Forlizzi, and Haakon Faste. 2013. Digital Artifacts as Legacy: Exploring the Lifespan and Value of Digital Data. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). Association for Computing Machinery, New York, NY, USA, 1813–1822. https://doi.org/10.1145/2470654.2466240

[53] Wijnand A IJsselsteijn, Yvonne AW de Kort, and Karolien Poels. 2013. The game experience questionnaire. Eindhoven: Technische Universiteit Eindhoven 46, 1 (2013).

[54] Ellen Isaacs, Artie Konrad, Alan Walendowski, Thomas Lennig, Victoria Hollis, and Steve Whittaker. 2013. Echoes from the past: How technology mediated reflection improves well-being. Conference on Human Factors in Computing Systems - Proceedings (2013), 1071–1080. https://doi.org/10.1145/2470654.2466137

[55] Jisu Jung, Monica Nour, Margaret Allman-Farinelli, and Judy Kay. 2017. Harnessing the "ambience" of the mobile-phone lockscreen for ultra-lite logging. ACM International Conference Proceeding Series (2017), 21–30. https://doi.org/10.1145/3152771.3152774

[56] Malte F. Jung, Nik Martelaro, Clifford Nass, and Halsey Hoster. 2014. Participatory materials: Having a reflective conversation with an artifact in the making. Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS (2014), 25–34. https://doi.org/10.1145/2598510.2598591

[57] Maria Karyda, Elisa D Mekler, and Andrés Lucero. 2021. Data Agents: Promoting Reflection through Meaningful Representations of Personal Data in Everyday Life. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3411764.3445112

[58] Ryan Kelly, Daniel Gooch, and Leon Watts. 2018. Designing for reflection on sender effort in close personal communication. ACM International Conference Proceeding Series (2018), 314–325. https://doi.org/10.1145/3292147.3292174

[59] Ahmed Kharrufa, Sally Rix, Timur Osadchiy, Anne Preston, and Patrick Olivier. 2017. Group Spinner: Recognizing and Visualizing Learning in the Classroom for Reflection, Communication, and Planning. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). Association for Computing Machinery, New York, NY, USA, 5556–5567. https://doi.org/10.1145/3025453.3025679

[60] Wonjung Kim, Seungchul Lee, Seonghoon Kim, Sungbin Jo, Chungkuk Yoo, Inseok Hwang, Seungwoo Kang, and Junehwa Song. 2020. Dyadic Mirror: Everyday Second-Person Live-View for Empathetic Reflection upon Parent-Child Interaction. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 4, 3, Article 86 (Sept. 2020), 29 pages. https://doi.org/10.1145/3411815

[61] Kathleen P King. 2009. The handbook of the evolving research of transformative learning: Based on the Learning Activities Survey. IAP.

[62] Tiffany Knearem, Jeongwon Jo, Xiying Wang, and John M. Carroll. 2021. Seek and Reflect: A Mobile Scavenger Hunt to Develop Community Engagement. In C&T '21: Proceedings of the 10th International Conference on Communities amp; Technologies - Wicked Problems in the Age of Tech (Seattle, WA, USA) (C&T '21). Association for Computing Machinery, New York, NY, USA, 212–223. https://doi.org/10.1145/3461564.3461573

[63] Rafal Kocielnik, Daniel Avrahami, Jennifer Marlow, Di Lu, and Gary Hsieh. 2018. Designing for workplace reflection: A chat and voice-based conversational agent. DIS 2018 - Proceedings of the 2018 Designing Interactive Systems Conference (2018), 881–894. https://doi.org/10.1145/3196709.3196784

[64] Rafal Kocielnik, Lillian Xiao, Daniel Avrahami, and Gary Hsieh. 2018. Reflection Companion: A Conversational System for Engaging Users in Reflection on Physical Activity. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 2, 2 (7 2018). https://doi.org/10.1145/3214273

[65] Hilary Kornblith. 2013. On Reflection. 1–192 pages. https://doi.org/10.1093/acprof:oso/9780199563005.001.0001

[66] Kyung-Ryong Lee, Somi Ju, Temirlan Dzhoroev, Geonil Goh, Moon-Hwan Lee, and Young-Woo Park. 2020. DayClo: An Everyday Table Clock Providing Interaction with Personal Schedule Data for Self-Reflection. In Proceedings of the 2020 ACM Designing Interactive Systems Conference. Association for Computing Machinery, New York, NY, USA, 1793–1806. https://doi.org/10.1145/3357236.3395439

[67] Ian Li, Anind Dey, and Jodi Forlizzi. 2010. A Stage-Based Model of Personal Informatics Systems. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10). Association for Computing Machinery, New York, NY, USA, 557–566.

https://doi.org/10.1145/1753326.1753409

[68] Ian Li, Anind K Dey, and Jodi Forlizzi. 2011. Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies. In Proceedings of the 13th International Conference on Ubiquitous Computing (UbiComp '11). Association for Computing Machinery, New York, NY, USA, 405–414. https://doi.org/10.1145/2030112.2030166

[69] Tengfei Liu, Xianghua Ding, Peng Liu, Tun Lu, and Ning Gu. 2016. ArchiExpression: A physical eco-feedback display in an outdoor campus space of China. ACM International Conference Proceeding Series 08-May-201 (2016). https://doi.org/10.1145/2948708.2948711

[70] Kiel Long and John Vines. 2013. Mind Pool: Encouraging Self-Reflection through Ambiguous Bio-Feedback. In CHI '13 Extended Abstracts on Human Factors in Computing Systems (CHI EA '13). Association for Computing Machinery, New York, NY, USA, 2975–2978. https://doi.org/10.1145/2468356.2479588

[71] Sonja Lyubomirsky and Heidi S Lepper. 1999. A Measure of Subjective Happiness: Preliminary Reliability and Construct Validation. Social Indicators Research 46, 2 (1999), 137–155. https://doi.org/10.1023/A:1006824100041

[72] Sylvain Malacria, Joey Scarr, Andy Cockburn, Carl Gutwin, and Tovi Grossman. 2013. Skillometers: Reflective widgets that motivate and help users to improve performance. UIST 2013 - Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology (2013), 321–330. https://doi.org/10.1145/2501988.2501996

[73] M Merleau-Ponty. 1962. Phenomenology of perception (C. Smith, Trans.) London & New York: Routledge Classics. Original work published in (1962).

[74] Jack Mezirow et al. 1990. How critical reflection triggers transformative learning. Fostering critical reflection in adulthood 1, 20 (1990), 1–6.

[75] David Moher, Alessandro Liberati, Jennifer Tetzlaff, Douglas G. Altman, Doug Altman, Gerd Antes, David Atkins, Virginia Barbour, Nick Barrowman, Jesse A. Berlin, Jocalyn Clark, Mike Clarke, Deborah Cook, Roberto D'Amico, Jonathan J. Deeks, P. J. Devereaux, Kay Dickersin, Matthias Egger, Edzard Ernst, Peter C. Gøtzsche, Jeremy Grimshaw, Gordon Guyatt, Julian Higgins, John P.A. Ioannidis, Jos Kleijnen, Tom Lang, Nicola Magrini, David McNamee, Lorenzo Moja, Cynthia Mulrow, Maryann Napoli, Andy Oxman, Bá Pham, Drummond Rennie, Margaret Sampson, Kenneth F. Schulz, Paul G. Shekelle, David Tovey, and Peter Tugwell. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. https://doi.org/10.1371/journal.pmed.1000097

[76] Ine Mols, Elise Van Den Hoven, and Berry Eggen. 2016. Informing design for reflection: An overview of current everyday practices. ACM International Conference Proceeding Series 23-27-Octo (2016). https://doi.org/10.1145/2971485.2971494

[77] Ine Mols, Elise Van Den Hoven, and Berry Eggen. 2020. Everyday life reflection: Exploring media interaction with balance, cogito & dott. TEI 2020 - Proceedings of the 14th International Conference on Tangible, Embedded, and Embodied Interaction (2020), 67–79. https://doi.org/10.1145/3374920.3374928

[78] Jennifer Moon. 1999. Reflection in learning & professional development. RoutledgeFalmer, New York, NY, USA. 229 pages. https://doi.org/10.4324/9780203822296

[79] Jasmin Niess, Kristina Knaving, Alina Kolb, and Paweł W. Woźniak. 2020. Exploring Fitness Tracker Visualisations to Avoid Rumination. In 22nd International Conference on Human-Computer Interaction with Mobile Devices and Services (Oldenburg, Germany) (MobileHCI '20). Association for Computing Machinery, New York, NY, USA, Article 6, 11 pages. https://doi.org/10.1145/3379503.3405662

[80] Jasmin Niess and Paweł W. Woźniak. 2018. Supporting meaningful personal fitness: The tracker goal Evolution Model. Conference on Human Factors in Computing Systems - Proceedings 2018-April (2018), 1–12. https://doi.org/10.1145/3173574.3173745

[81] Claudia Núñez-Pacheco and Lian Loke. 2014. Aesthetic resources for technology-mediated bodily self-reflection: The case of eloquent robes. Proceedings of the 26th Australian Computer-Human Interaction Conference, OzCHI 2014 (2014), 1–10. https://doi.org/10.1145/2686612.2686613

[82] William Odom. 2015. Understanding long-term interactions with a slow technology: An investigation of experiences with futureme. Conference on Human Factors in Computing Systems - Proceedings 2015-April (2015), 575–584. https://doi.org/10.1145/2702123.2702221

[83] Pablo Ortiz and D. Fox Harrell. 2018. Enabling critical self-reflection through roleplay with chimeria:Grayscale. CHI PLAY 2018 - Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play (2018), 365–380. https://doi.org/10.1145/3242671.3242687

[84] Reinhard Pekrun, Thomas Goetz, Anne C Frenzel, Petra Barchfeld, and Raymond P Perry. 2011. Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). Contemporary educational psychology 36, 1 (2011), 36–48.

[85] Bernd Ploderer, Wolfgang Reitberger, Harri Oinas-Kukkonen, and Julia Gemert-Pijnen. 2014. Social Interaction and Reflection for Behaviour Change. Personal Ubiquitous Comput. 18, 7 (10 2014), 1667–1676. https://doi.org/10.1007/s00779-014-0779-y

[86] Michael Prilla and Bettina Renner. 2014. Supporting collaborative reflection at work: A comparative case analysis. Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work (2014), 182–193. https://doi.org/10.1145/2660398.2660400

[87] Shriti Raj, Joyce Lee, Ashley Garrity, and Mark Newman. 2019. Clinical Data in Context: Towards Sensemaking Tools for Interpreting Personal Health Data. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 3, 1 (2019), 1–20.

https://doi.org/10.1145/3314409

[88] Søren Rasmussen, Jeanette Falk Olesen, and Kim Halskov. 2019. Co-Notate: Exploring Real-Time Annotations to Capture Situational Design Knowledge. In Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19). Association for Computing Machinery, New York, NY, USA, 161–172. https://doi.org/10.1145/3322276.3322310

[89] Wolfgang Reitberger, Wolfgang Spreicer, and Geraldine Fitzpatrick. 2014. Nutriflect: Reflecting collective shopping behavior and nutrition. Conference on Human Factors in Computing Systems - Proceedings (2014), 3309–3318. https://doi.org/10.1145/2556288.2557384

[90] Verónica Rivera-Pelayo, Angela Fessl, Lars Müller, and Viktoria Pammer. 2017. Introducing Mood Self-Tracking at Work. ACM Transactions on Computer-Human Interaction 24, 1 (2017), 1–28. https://doi.org/10.1145/3014058

[91] Samara Ruiz, Sven Charleer, Maite Urretavizcaya, Joris Klerkx, Fernández Castro Isabel, and Erik Duval. 2016. Supporting learning by considering emotions: Tracking and visualization. A case study. ACM International Conference Proceeding Series 25-29-Apri (2016), 254–263. https://doi.org/10.1145/2883851.2883888

[92] Kimiko Ryokai, Elena Durán López, Noura Howell, Jon Gillick, and David Bamman. 2018. Capturing, representing, and interacting with laughter. Conference on Human Factors in Computing Systems - Proceedings 2018-April (2018), 1–12. https://doi.org/10.1145/3173574.3173932

[93] Rufat Rzayev, Tilman Dingler, and Niels Henze. 2018. ReflectiveDiary: Fostering Human Memory Through Activity Summaries Created from Implicit Data Collection. Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia (2018), 285–291. https://doi.org/10.1145/3282894.3282907

[94] Herman Saksono and Andrea G. Parker. 2017. Reflective informatics through family storytelling: Self-discovering physical activity predictors. Conference on Human Factors in Computing Systems - Proceedings 2017-May (2017), 5232–5244. https://doi.org/10.1145/3025453.3025651

[95] Ari Schlesinger, W Keith Edwards, and Rebecca E Grinter. 2017. Intersectional HCI: Engaging Identity through Gender, Race, and Class. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery, New York, NY, USA, 5412–5427. https://doi.org/10.1145/3025453.3025766

[96] Donald A. Schön. 1983. The Reflective Practitioner. https://doi.org/10.1542/peds.2005-0209

[97] Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph'Jofish' Kaye. 2005. Reflective design. In Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility. 49–58.

[98] Petr Slovák and Geraldine Fitzpatrick. 2015. Teaching and Developing Social and Emotional Skills with Technology. ACM Trans. Comput.-Hum. Interact. 22, 4, Article 19 (jun 2015), 34 pages. https://doi.org/10.1145/2744195

[99] Petr Slovak, Chris Frauenberger, and Geraldine Fitzpatrick. 2017. Reflective practicum: A framework of sensitising concepts to design for transformative reflection. Conference on Human Factors in Computing Systems - Proceedings 2017-May (2017), 2696–2707. https://doi.org/10.1145/3025453.3025516

[100] Thomas Smith, Simon J. Bowen, Bettina Nissen, Jonathan Hook, Arno Verhoeven, John Bowers, Peter Wright, and Patrick Olivier. 2015. Exploring gesture sonification to support reflective craft practice. Conference on Human Factors in Computing Systems - Proceedings 2015-April (2015), 67–76. https://doi.org/10.1145/2702123.2702497

[101] Statista. 2020. Mobile OS market share 2019. https://www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/

[102] Ursula M Staudinger. 2001. Life Reflection: A Social–Cognitive Analysis of Life Review. Review of General Psychology 5, 2 (2001), 148–160. https://doi.org/10.1037/1089-2680.5.2.148

[103] Zhida Sun, Sitong Wang, Wenjie Yang, Onur Yürüten, Chuhan Shi, and Xiaojuan Ma. 2020. "A Postcard from Your Food Journey in the Past": Promoting Self-Reflection on Social Food Posting. In Proceedings of the 2020 ACM Designing Interactive Systems Conference. Association for Computing Machinery, New York, NY, USA, 1819–1832. https://doi.org/10.1145/3357236.3395475

[104] Anja Thieme, Rob Comber, Julia Miebach, Jack Weeden, Nicole Krämer, Shaun Lawson, and Patrick Olivier. 2012. "we've bin watching you" - Designing for reflection and social persuasion to promote sustainable lifestyles. Conference on Human Factors in Computing Systems - Proceedings (2012), 2337–2346. https://doi.org/10.1145/2207676.2208394

[105] Alice Thudt, Uta Hinrichs, Samuel Huron, and Sheelagh Carpendale. 2018. Self-reflection and personal physicalization construction. Conference on Human Factors in Computing Systems - Proceedings 2018-April (2018), 1–13. https://doi.org/10.1145/3173574.3173728

[106] Paul D Trapnell and Jennifer D Campbell. 1999. Private self-consciousness and the five-factor model of personality: distinguishing rumination from reflection. Journal of personality and social psychology 76, 2 (1999), 284.

[107] Diego Trujillo-Pisanty, Abigail Durrant, Sarah Martindale, Stuart James, and John Collomosse. 2014. Admixed portrait: Refections on being online as a new parent. Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS (2014), 503–512. https://doi.org/10.1145/2598510.2602962

[108] Tiffany Tseng and Coram Bryant. 2013. Design, Reflect, Explore: Encouraging Children's Reflections with Mechanix. In CHI '13 Extended Abstracts on Human Factors in Computing Systems (CHI EA '13). Association for Computing Machinery, New York, NY, USA, 619–624. https://doi.org/10.1145/2468356.2468466

[109] Nina Valkanova, Sergi Jorda, Martin Tomitsch, and Andrew Vande Moere. 2013. Reveal-It! The Impact of a Social Visualization Projection on Public Awareness and Discourse. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). Association for Computing Machinery, New York, NY, USA, 3461–3470. https://doi.org/10.1145/2470654.2466476

[110] Nina Valkanova, Robert Walter, Andrew Vande Moere, and Jörg Müller. 2014. MyPosition: Sparking Civic Discourse by a Public Interactive Poll Visualization. In Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW '14). Association for Computing Machinery, New York, NY, USA, 1323–1332. https://doi.org/10.1145/2531602.2531639

[111] John R. Ward and Suzanne S. McCotter. 2004. Reflection as a visible outcome for preservice teachers. Teaching and Teacher Education 20, 3 (2004), 243–257. https://doi.org/10.1016/j.tate.2004.02.004

[112] Andrew M Webb, Rhema Linder, Andruid Kerne, Nic Lupfer, Yin Qu, Bryant Poffenberger, and Colton Revia. 2013. Promoting Reflection and Interpretation in Education: Curating Rich Bookmarks as Information Composition. In Proceedings of the 9th ACM Conference on Creativity & Cognition (C&C '13). Association for Computing Machinery, New York, NY, USA, 53–62. https://doi.org/10.1145/2466627.2466636

[113] Alex M Wood, P Alex Linley, John Maltby, Michael Baliousis, and Stephen Joseph. 2008. The authentic personality: a theoretical and empirical conceptualization and the development of the authenticity scale. Journal of Counseling Psychology 55, 3 (2008), 385.

[114] Meng Xia, Yuya Asano, Joseph Jay Williams, Huamin Qu, and Xiaojuan Ma. 2020. Using Information Visualization to Promote Students' Reflection on "Gaming the System" in Online Learning. In Proceedings of the Seventh ACM Conference on Learning @ Scale (Virtual Event, USA) (L@S '20). Association for Computing Machinery, New York, NY, USA, 37–49. https://doi.org/10.1145/3386527.3405924