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A Systematic Review

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Technologies Supporting Self-Reflection on Social Interactions: A Systematic Review

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Abstract

As intelligent technology and applications have become an integral part of nearly all aspects of people's daily lives, many intelligent systems have been designed to help people navigate the complex space of social interactions. One prominent strategy for such intelligent support is providing meaningful *Ad Hoc Interventions (ADI)*, e.g., through timely notifications. An alternative is *Technology-Supported Reflection (TSR)*, e.g., by offering information about activities in one's past for personal insights. In contrast to straight-up interventions, the aim of the latter strategy is not to directly augment human skills but instead support learning and personal growth over time. However, while TSR has seen widespread interest in applications in some areas, such as physical fitness and mental health, its use for improving human social interactions has not yet been systematically explored. Concretely, it is currently unclear 1) what forms of self-reflection systems intend to support, 2) how their different technological components (e.g., data collection, information integration) are involved in providing support, and 3) what common limitations and design challenges they face. In this article, we present the results of a systematic literature review focusing on these questions to provide a structured foundation for targeted research. Concretely, we identified and analysed a collection of 23 relevant papers, each describing a system deploying TSR to support humans with elements of social interactions.

We constructed a framework with a set of features to comprehensively describe and analyze the systems that support self-reflection, including their application domains, how they fit into the existing design framework, how they facilitate learning through reflection, how adaptive they are to individual users, and how they were evaluated. Finally, we propose a direction for designing systems that support individual's social interactions through self-reflection in an adaptive manner.

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CCS Concepts

• **Human-centered computing → User centered design**; *HCI design and evaluation methods.*

Keywords

reflection, social interaction, design, human-computer interaction

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1 Introduction

One of the biggest challenges people face in daily life is to navigate the complex space of social environment, where individuals cooperate and interact with each other [5, 56]. Social interactions may involve both 1) making decisions about *what* plans to pursue based on sampling and processing information in a social context (social decision making), and 2) actions of engaging with others in service of these plans (social behaviors) [56]. Social interactions are challenging because of their dynamic nature, where the relationship outcomes are not only influenced by perceptions and interpretation of "external" information from others and the environment but also by one's own "internal" states (e.g., emotions)[56].

As the variety of available technology devices grow increasingly common and become more closely integrated into people's daily lives, a variety of systems have been developed to support social interactions. One prominent strategy that is adopted in existing technology is providing *Ad Hoc Interventions (ADI)* to help people achieve a certain goal in specific, well-defined tasks. Some systems provide ADI through implementing conversational agents [20, 27, 57, 58]. For example, social robots can influence and shape interactions by either being peripheral companions or directly engaging in conversations [20]. These systems with conversational agents can provide support in tasks such as counseling [57], engagement management [58], negotiation [27], etc. Some systems help people choose information overload. For example, recommendation systems can provide social recommendations [44] such as selecting learning peers on online platforms [41]. Other systems are integrated with personal informatics systems to promote effective behavior change or collaboration, e.g., intelligent coaches that facilitate online group meetings by presenting real-time feedback on participation, interruption, volume, and facial emotion [49].

All of the above examples of intelligent systems that provide ADI for social interactions tend to focus on improving behaviors or choices towards specific and well-defined task goals. They also often facilitate this improvement by *nudging or persuading* individuals' decisions and behaviors towards the direction that serves the specified task goal.

Another promising alternative to support social interactions is through post-hoc *Technology-Supported Reflection (TSR)*. Specifically, using an intelligent system that supports learning through *self-reflection*. *Self-reflection* means that an individual can revisit and rethink the past, find new insights and perspectives, and potentially reach a greater understanding or make changes for future behaviors [43]. TSR has received widespread attention in various fields. For example, in the survey by Bentvelzen et al. [9], authors found that artefacts and applications have been designed to enhance self-reflection in fields including art and culture, community engagement, health and well-being, learning and education, sustainability, etc. In addition, some systems have also been designed to provide TSR for workplace learning through *collective*reflective practices, where reflection is done as a group activity [29, 42, 43]. Some technology also uses ambient display systems in the work environment to encourage workers to reflect (and act) upon their stress at the work environment (e.g., [12, 23]).

These examples illustrate that there are many existing systems to support people in the social domain. However, applications that can support learning or changes in interpersonal social interactions through *retrospective self-reflection* have yet to be systematically explored. This lack of systematic exploration is reflected in several aspects.

First, it is still unclear what kind of retrospective self-reflection existing systems intend to support (see Background for related concepts). Existing frameworks for designing for reflection have been developed to help us understand how TSR works and they are useful for analyzing how TSR can support social interactions. For example, what level of reflection [18] do these systems target?

Second, how different technological components (e.g., data collection, information integration, and presentation) of existing systems are involved in support reflection and reflective learning [29] in social interactions. This includes but is not limited to 1) whether they provide guidance or explanation of data and behaviors, 2) whether they support a structured process for self-reflection, and 3) whether the information presented by the system is attached with a valence (positive, neutral, or negative).

Third, what common design challenges or limitations do these systems face. This can be addressed through 1) analyzing existing systems in frameworks for designing for reflection (e.g., which phases of reflection are these systems able to address), and 2) commonalities and differences in what technological components these systems implement.

To acquire a good understanding of the current landscape of technology that supports reflection on social interactions, we conduct a systematic literature review to provide a structured foundation for future research that targets the three issues listed above.

2 Background

2.1 Defining retrospective reflection

Although reflection is commonly regarded to have several benefits such as offering self-insights, motivating behavior change, and supporting life changes [7, 9], there is no technical consensus on how reflection should be defined to provide support via TSR.

In the majority of literature on human-computer interaction, reflection has been identified as "an individual activity and cognitive process", which includes re-visiting and re-thinking past activities, ideas, and feelings, providing insights, new perspectives, and changes for future behaviors [43].

Bentvelzen et al. [9] also suggest that while a sizable amount of work uses working definitions for reflection or defines reflection by proxy, *learning, awareness, and engagement* remain highly frequent constructs associated with reflection.

2.1.1 Retrospective: Reflection in and on action. A prevalent framing of reflection distinguishes reflection-in-action and reflection-on-action [53]. The former can happen immediately following an action during an ongoing activity. The latter is considered to focus on it in retrospect, i.e., after the activity's conclusion.

2.1.2 Growth-directed: Reflection vs. recollection. Reflection, as an activity and process, focuses on outcomes (i.e., learning and change) and is growth-directed in our sense. This emphasis differentiates reflection from rumination, venting, or sense-making [43]. Similarly, while some authors conflate reflection with reminiscence due to the commonality of recalling past events [7], the two are separate processes. Notably, reflection goes beyond merely recalling the past and requires synthesizing remembered events to arrive at some greater understanding [7].

2.1.3 Growth-directed: Reflective learning. In addition, as reflection processes often emphasize the transformative outcome, i.e., perspective and/or behavior change. As suggested by the frequent constructs associated with reflection [9], reflection is closely intertwined with learning [10]. This makes the support for learning and transformation a major goal and challenge in designing systems for reflection. Krogstie et al. [29] have defined *reflective learning* as a "conscious re-evaluation of experience to guide future behavior" ([29], pp. 152). To achieve such a goal, Slovac et al. [54] emphasize the need for having a structured or guided learning process through reflection, as well as enabling users to construct knowledge by themselves in a realistic and safe setting that provides them with learning experiences.

In summary, reflection is a complex process as it is often ill-defined and can take different forms. For this work, we emphasize several aspects of *self-reflection* concerning the properties listed above: 1) *retrospective*: reflection is an activity happening in retrospection on past events; 2) *growth-directed*: reflection aims to bring about a greater understanding based on revisiting or rethinking the past, in a way that mere recollection or rumination does not seem to fully achieve;

2.2 Existing frameworks for designing for reflection

Frameworks have been constructed to conceptualize the activity and process of reflection from different perspectives by representing reflection as two parts: what is being reflected on and what is changed [43].

For example, Fleck and Fitzpatrick [18] conceptualize reflection as five *levels of reflection*, where the next level builds upon the previous level: revisiting, reflective description, dialogic reflection, transformative reflection, critical reflection. Revisiting can be considered the same as reminiscing, as only recollection of the past is involved. While reflective description and dialogic reflection involve the explanation of past events (the former) and gaining new perspectives through exploring the relationship among past events (the latter), these two levels do not necessarily include a learning or transformative experience. Transformative and critical reflection involves the intention of reorganization (of knowledge and perspectives) and behavioral change, with the latter considering a wider context [18].

Another framework outlines *phases of reflection* from a designer's perspective [6, 43], where designers first aim to identify and break down moments for reflections driven by elements of surprise, puzzlement, conflicts, etc. Given the reflection moments, inquiries and investigations are made (by the individual during the reflections), and a transformation of perspectives and/or behavior is achieved [6].

In addition, *phases of reflection* is closely connected to reflection support systems based on personal informatics[31, 32]. Specifically, once a task or task goal (of reflection) has been determined (i.e., a preparation for reflection has been made), the support system will collect and integrate data for facilitating reflection. This allows users to reflect upon given information, and consider the transformation of their perspectives and/or behaviors for the future. However, such personal informatics systems often face additional design challenges, including how to trigger reflection, and how to adapt to the users' rhythm and need for reflection with flexibility [8].

3 Methods

We report the details of our search strategy for literature identification, exclusion criteria, and the screening process in the sections below based on the PRISMA scheme [55] (Figure 1).

3.1 Literature identification

To scope our literature survey, we focus on a framework containing three parts: retrospective self-reflection, support systems, and the domain of social interactions.

3.1.1 *Search strategy.*

To identify a corpus or relevant literature, we queried the *Scopus*, *PubMed*, and *ACM Digital Library* databases (until August 23, 2024). We chose the former two because of its broad coverage of scientific literature, while the latter focuses more specifically on the development of technological systems, including for intelligent support.

Following Bentvelzen et al. [9] and Baumer et al. [7], who reviewed definitions, themes, design resources and patterns, and evaluations of reflection systems within human-computer interaction, we used a keyword-based search to help us survey the current state of the field.

We used three sets of key concepts to scope our survey. First, we selected *reflect*, *reflection*, or *reflecting* as keywords to specifically focus on systems designed for promoting reflection. Second, we specified that *social*, *social interaction*, or *social decision* should appear in the title, abstract, or keywords to focus our search in the social domain. In addition, to further narrow down the results to technology or systems, we specified that the title, abstract, or keywords of the resulting articles should include *system* or *technology*.

Besides searching in the above-mentioned databases, we also included an additional 13 articles which were identified through other sources. The specific queries and number of articles generated through each search can be found in Table 3, Appendix A.

3.1.2 *Inclusion criteria and filtering.*

We defined the criteria below for screening:

i. Targets Retrospective self-reflection:
  (1) The paper must focus on reflection in the meaning of a thought process.
  (2) The paper must focus on retrospective self-reflection. In other words, we exclude papers where systems facilitate reflection-in-action or collective reflection.

ii. Describes Support system: The paper should describe either
  (1) "an artefact-system, prototype or tool that was designed with a declared intention to enhance or provoke reflection among users" ([9], pp. 2:6), or
  (2) a conceptual design of a system with a declared intention to enhance or provoke reflection among users.

iii. Focus on Social Interaction:
  (1) The paper should focus on reflection on interpersonal interaction with individuals or groups.

The initial comprehensive search from three databases generated 1394 results. We then added addition 13 papers that we found through other sources. All papers were imported to and processed in EndNote 20 software. After the automatic removal of duplicates, 1346 records were left for screening with the specified exclusion criteria based on paper titles and abstracts. The first author screened all records at both title-abstract and full-text stages. This procedure is reported following the PRISMA [55] reporting scheme (Figure 1). Given that titles and abstracts included limited information, the first author was lenient during the initial screening.

To ensure the validity of screening, a second coder with a background in social psychology and computer science coded a random selection of a third of the records at each stage (439 records during the first stage and 39 records during the second stage). Inter-coder agreement at the first stage was 0.91, with fair inter-coder reliability (Cohen kappa: 0.34; [4, 30]). Inter-coder agreement at the second stage was 0.72, with fair inter-coder reliability (Cohen kappa: 0.33; [4, 30]).

3.2 Information extraction

To provide an overview of current technology that facilitates retrospective self-reflection for social interactions, we constructed

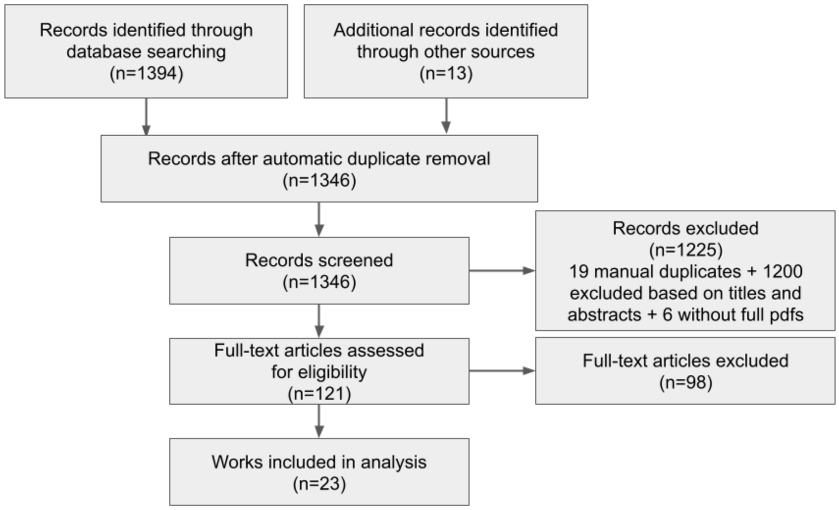

Figure 1: PRISMA[55] diagram of the screening process, as completed by the first author.

Feature dimension	Description
Levels of reflection	The level of reflection [18] the system directly supports.
Phases of reflection	The phases of reflection [43] that have been addressed by the design of the system.
Goal	The specific goal for perspective and/or behavior change the system provides support for.
Data	How the system engages with data—including the type of data the system uses, and how the system collects data.
Ubiquity	Whether the system is ubiquitous based on the definition in [19] (see Table 4 for the full definition).
Disruption	Whether the system prompts or notifies user and whether reflection session always happens after a round of activity.
Support duration	The duration of support the system provides (e.g., event-based support v.s. supporting for an extended period of time
Input modalities	What modalities does the system support for information input from users.
Output modalities	What modalities does the system support for information output to users.
Explanation	Whether the system provides explanations for why it suggests something to the user.
Structure	Whether the self-reflection facilitated by the system is a structured process.
Valence	The valence (i.e., positive, neutral, or negative emotional tone) of the information the system presents or triggers reflection with (see Table 4 for the full definition).
Application domain	The task domain the system supports for.
Adaptivity	If and in what ways the system adapts to the user.
Evaluation	If and in what ways is the system evaluated.

Table 1: Overview of feature dimensions in the framework for describing reflection systems.

a framework with a set of features spanning several dimensions to comprehensively describe systems that support self-reflection. We provide an overview of the dimensions in Table 1. Full details of the categories within each dimension can be found in Table 4, Appendix A.

Specifically, to address *what kind of retrospective self-reflection do existing systems intend to support*, we integrate existing design frameworks and analyze the *Level of reflection* [18] the system supports by its application domain. We also discuss the *Phases of reflection* [6, 43] these systems address. In terms of *technological components* the system implements to facilitate reflection and reflective learning, we look at feature dimensions including *Data, Ubiquity, Disruption, Support duration, Input Modalities, Output Modalities, Explanation, Structure, and Valance.* Finally, we discuss *limitations and design challenges* these systems face by analyzing our survey results.

For each article, given each category in each dimension, we followed the coding scheme of "yes (1)", "no (0)", or "under specified". In addition, we extracted 5 pieces of information descriptively from the original articles: 1) if the system supports self-reflection for a predefined behavioral or perspective-changing goal, what is the goal? 2) If the system supports the user for an extended period of time, what is the length of a typical activity-reflection cycle? 3) What is the task domain the system provides support for? 4) If there is an objective evaluation of the system based on user performance of the task that the system is intended for, what kind of performance measure is used? 5) If there is a subjective evaluation of the system, what kind of evaluation method is used?

Two coders completed the information extraction process on all 23 articles separately using spreadsheets. After completing the coding for analysis separately, the first author put the coding results for each paper side-by-side in a table, and then the two coders resolved the differences for ambiguous cases by each going through the papers with different coding results again, providing evidence and concrete reasons for why they gave the specific code, and making notes of excerpts from original text. If one could extract original text to back up the coding decision, and the other could not, then the final decision followed the one with concrete evidence. If neither coders could find concrete evidence, then the coding was "under specified". The two coders took turns until agreements were reached.

4 Results

In this section, we report the results based on the analysis of 23 systems/designs, following our research questions.

In our current analysis of systems based on the categories in our framework, we only differentiated coded values between "yes (1)" (i.e., the system has the corresponding feature) and "not yes". We did not differentiate between "no (0)" (i.e., the system does not have the corresponding feature) and "under specified" (i.e., whether the system has the corresponding feature or not is unclear) values.

4.1 What kind of self-reflection do systems intend to support?

To address the kind of self-reflection the systems support and the systems' technological components, we first identify the application domains of the surveyed systems. In total, based on the extracted text of each system's goal and application domain, we identified 6 domains containing 13 types of tasks (Table 2). The application domains with most to least number of systems are: *communication* (6), *social emotional learning* (6), *well-being* (5), *public speaking* (4), *community engagement* (1), and *personal insight* (1).

All systems except one have specific task goals they help users to achieve. The system without specific, well-defined task goals [17] focuses on helping users to 1) self-reflect based on visualization of their personal socializing data (collected through mobile-based sensing), and 2) set relevant goals based on their insight.

We then identified the *level of reflection* that systems in each application domain can support (Figure 2A). Most systems target at *transformative reflection*, with at least one system in each application domain supporting it.

Systems that support reflection for *social emotional learning* have the largest variety in terms of the *level of reflection* they target. This includes one system designed for *critical reflection*, which addresses various socioeconomic issues for self-reflection, such as diversity and equity in education [1].

Some systems target lower levels of reflection (*reflective description*, *dialogic reflection*) or even only directly support users on the *description* level. While systems that support users on the *description* level do not actively afford more actions beyond letting users revisit or rethink the past in terms of their functionality, they are still designed to *trigger and promote* self-reflection based on descriptions of the past.

In addition, we analyzed the phases of reflection these systems engage with (Figure 2B) and found that systems across all application domains except *Creativity and Community Engagement* address all design phases (i.e., preparation, data collection, integration, reflection, and action) to some extent. However, regardless of their application domain, most systems do not necessarily address the *action* phase, where the user considers the transformation of perspectives or behaviors for the future. This could be due to that evaluations of the system are limited during the initial system design process.

4.2 How do the systems provide support with different technological features?

Below we show the results of different technological features implemented by systems in each application domain (Figure 3). We group our results into six subsections to address 1) how the systems interact with data, 2) how the systems are present in users' daily lives, 3) what the systems' interaction modalities are, 4) how the systems support learning, 5) how do systems adapt to the user, and 6) how are the systems evaluated.

4.2.1 Data usage and data collection. Data collection is one of the crucial phases in the design framework for technology that supports reflection (e.g., phases of reflection [43]). Based on our survey, we can observe that systems designed for reflection in all application domains engage with data in some way. Specifically, systems in all domains collect data for the tasks they intend to support. For example, a system that supports online meetings will collect data on virtual meeting behaviors [48]. Systems in most domains also collect data for the intended reflection technology. For example, the system that intends to help children reflect on their engagement in creative online communities will record their posts in the online community [13]

However, systems in most domains do not collect data on system usage, i.e., data that describe users' habits and preferences for interacting with the systems, for the system to dynamically adapt to those habits and preferences. In terms of methods for data collection, both implicit data collection (i.e., "passive" data collection of users' behaviors while the system is at work; e.g., [48, 50]) and user input data (i.e., requiring users to "actively" input data such as engaging in text exchanges with a conversational agent; e.g., [40]) are widely used.

4.2.2 Ubiquity, disruption, and support duration. To understand how systems support reflection for social interactions, we also look at how the systems are present in users' daily lives. Therefore, we analyze whether systems are *ubiquitous* [19] or *disruptive*, and how systems with these qualities aim to support users.

While there exist systems in all application domains that are ubiquitous [19], most systems are not [1, 2, 28, 33, 39, 45, 47, 48, 59–61].

Similarly, most systems do not prompt or notify the user for self-reflection [1, 2, 13, 14, 21, 22, 25, 28, 35, 38, 39, 47, 48, 60, 61]. Rather, systems often support self-reflection at a set stage, with a lot of them providing event-based support (e.g., the system supports for a reflection session after one occurrence of the event) [1, 2, 22, 26, 28, 34, 36, 45, 47, 48, 59–61].

Application domain	Task
Community engagement	Creativity and community engagement for kids [13]
Communication	Medical student-patient interaction [14], communication in work scenarios [28], parent-child interaction [38], intercultural communication [45], online meeting [48], VR collaboration [59]
Social emotional learning	Perspective changing and perspective taking [1, 2, 33, 34, 36, 60]
Well-being	Social connection [21, 40], sense-making of emotions related to meaningful relationships [35], daily interactions [26, 47]
Public speaking	Presentations [22, 39, 61] and speeches [25]
Personal insight	Goal setting [17]

Table 2: Application domains and tasks based on the extracted text of each system's goal and application domain from the final set of articles (N=23).

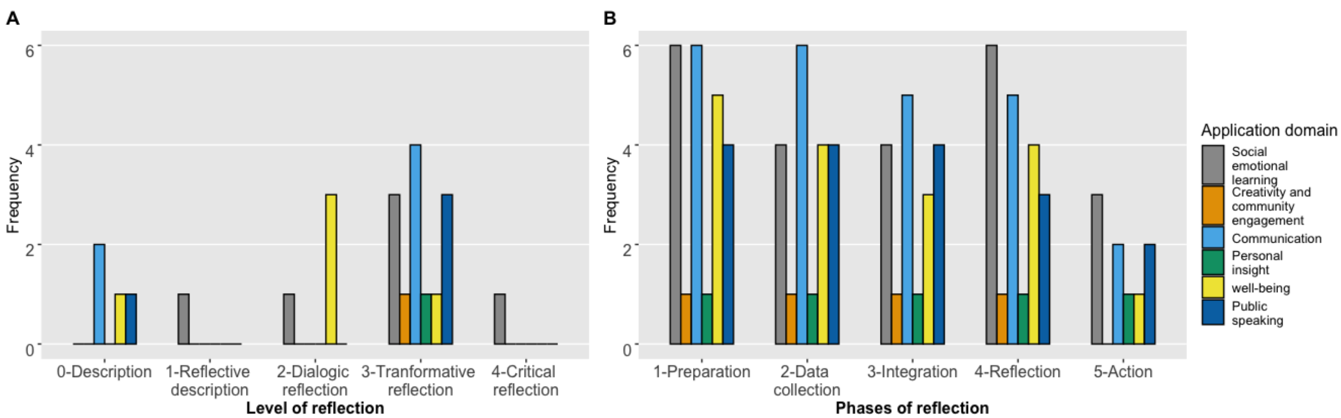

Figure 2: Number of systems in each application domain that A: support each level of reflection, and A: engage with each phase reflection (N=23).

Systems supporting most domains either do not provide or do not yet provide support for self-reflection for an extended period. For those that do, the duration of a typical cycle of activity and post-activity reflection is often unclear.

4.2.3 Input and output modalities. To have an overview of what kind of interactions or interfacing is supported from the technological point of view, we also analyzed the *input modalities* (i.e., user-to-system) and *output modalities* (i.e., system-to-user) each system affords. The most common input and output modalities are verbal, visual, and auditory. Haptic input and feedback are less common in all domains and are used mostly in virtual reality systems.

4.2.4 Explanation, structure, and valence. As reflection processes are closely intertwined with learning [10, 54], we review how existing systems can support learning in different domains. Particularly, we are interested in whether systems provide explanations to users, whether they support a structured reflection process, and whether their interactions with users (e.g., the information they present to users) have valence.

We found that across the six domains, while most systems implement a structured process for self-reflection, few systems provide explanations for how they support self-reflection [1, 48], or present information relevant to self-reflection with positive [1, 13, 40] or negative valence [1].

4.2.5 Adaptation. We also analyze whether the systems can adapt to the users. There are three types of adaptation that we focus on. The first one is that systems can dynamically adapt to users based on users' habits and preferences—this kind of support requires systems to collect user data related to their habits and preferences and is related to systems' ability to provide support for an extended period of time. The second one is that systems can adapt to users in a goal-driven manner, where each individual user's personal task-relevant data are used. The third one is that systems can prompt or guide users given users' personal lifestyles and learning patterns as reflected by the task-relevant data.

We found that although systems across domains do not collect data related to user habits for the systems to update their knowledge about the user dynamically, most systems *do* adapt to users through goal-driven adaptation by applying each user's task-relevant data for supporting self-reflection [13, 17, 22, 25, 26, 28, 33–36, 38–40, 47, 48, 59–61]. For example, in Feustel et al. [17], the system helps each user reflect on their personal goals based on visualized data of each user's own mood, social and physical activity and their cohorts' data. Systems in most domains also take into consideration each user's individual lifestyle and learning pattern [13, 34–36, 48, 61].

4.2.6 System evaluation. Most systems included in our survey across domains have been evaluated with user studies. However, the majority of systems were only evaluated based on their users'

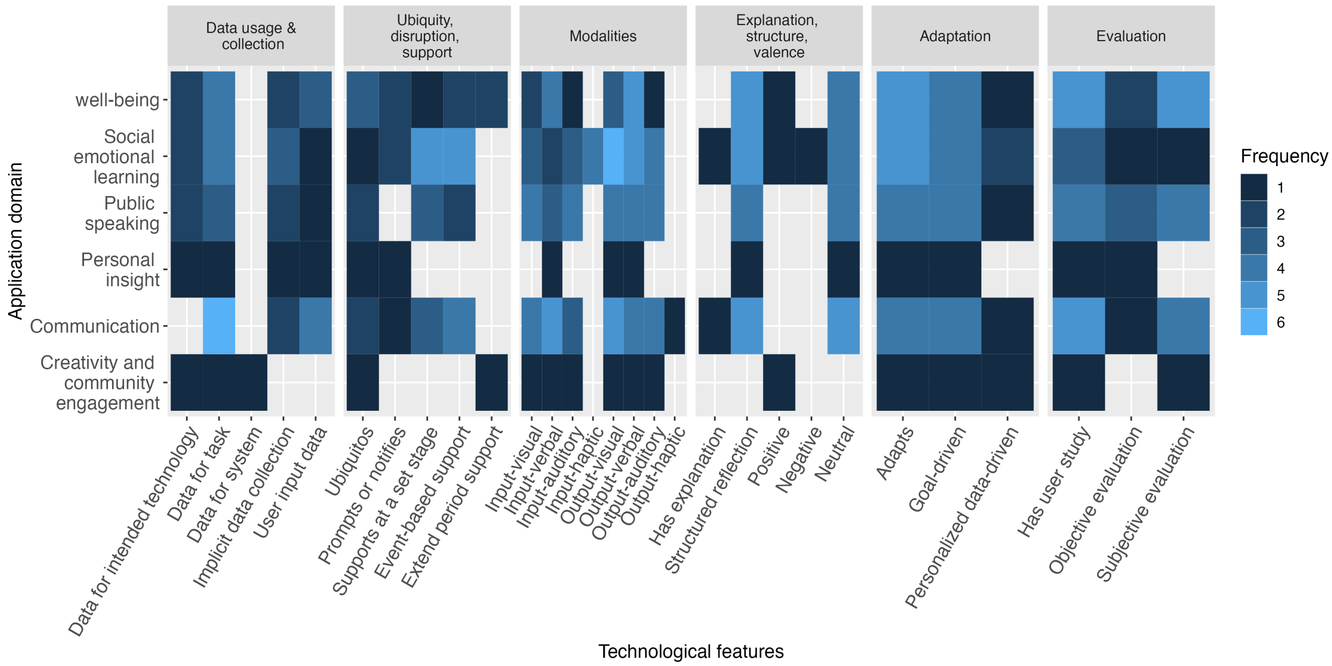

Figure 3: Heatmap of technological features realized by systems designed for each domain (N=23). Lighter color indicates *higher* frequency.

opinions, i.e., through subjective questionnaires (e.g., system usability questionnaire [22]) or interviews about their experiences. Studies did not or only rarely attempt to measure the effects of systems on users' behaviors (e.g., [22, 34, 61]).

5 Discussion

5.1 Principle findings

From our results, we identify and discuss the *limitations and design challenges in current systems* that provide *Technology-Supported Reflection (TSR)* for social interactions in several main aspects.

5.1.1 Existing TSR systems for social interactions are mostly directed by specific tasks and task goals. Similar to systems that provide *Ad Hoc Interventions (ADI)* to social interactions, systems that provide TSR in the social domain tend to have specific goals of perspective or behavior change in well-defined tasks (e.g., presentation skills). This includes systems that provide support for social-emotional learning (e.g., taking the perspectives of patients with psychosis [2]) and well-being (e.g., improving social connections through meditation [21]). Few systems provide people with insights for goal setting (e.g., [17]).

While these tasks are prominent examples of the type of social interactions people encounter in daily life, we still see a lack of technology that promotes reflection for social interactions across different social contexts. This can be partly because a well-defined task affords relatively clearer constraints for system design and evaluation.

However, the space of social interactions in everyday life is more complex than these existing application domains. With the increasing amount of intelligent technology incorporated into our daily lives, do we need to find a particular system oriented for every specific training that we need? Or can we find a more holistic solution that provides us with better insights into our social behaviors and decisions, teaches us to explore our goals and intentions in a creative manner through self-reflection, and helps us transfer that skill of exploration into different social contexts?

In contrast with existing systems, this highlights a trade-off between a *direct* change of behavior (or perspective) through learning in a specific social context and a potential *change of perspective* on a meta-level that could lead to further unknown behavior change over time.

5.1.2 Existing TSR systems for social interactions facilitate learning mainly through neutral and structured reflection processes, with little explanation for the users. Presenting data in a neutral way can be helpful for learning through reflection as the presentation of information, especially ambiguous information, can induce sensemaking and thus promote reflection, e.g., [11, 37]. In addition, the widely-observed design of structured or guided processes for learning through reflection is also in line with Slovac et al. [54]'s emphasis on the importance of structure and guidance in reflective learning.

However, besides providing support for self-reflection in a neutral manner, we believe that TSR systems also need to take a step towards a position that balances understanding and explaining social behaviors and decisions with regard to the task or context. This way, such systems can help users understand how different aspects of behaviors affect interactions dynamically given a context and thus reflect upon not only their behaviors in a task but also their behaviors about their own goals and different social contexts.

5.1.3 Existing TSR systems for social interactions can adapt to users to some extent, but not dynamically. While existing systems are adaptive, they cannot adapt to users' habits and lifestyles dynamically—this is in line with observations based on our finding, where most systems do not collect data on users' habits or provide users with continuous, extended support. However, it is also worth noting that the extent to which a system adapts to users could be affected by the level of reflection [18] this system aims to support, as well as the phases of reflections [6, 43] this system intends to engage with by design.

To support individual's reflections on social interactions concerning their own goals and different contexts, TSR systems need to trigger reflections while taking individual differences in reflection rhythm and learning into account [8]. For systems that intend to provide event-based support, this could also mean to maintain and update a "memory" of the user (see, e.g., Dudzik et al. for a relevant discussion [16])

One approach for TSR systems to achieve this requirement could be allowing users to not only interact but also communicate with the system itself for better personalization, e.g., via implementing conversational agents, [46, 51].

5.1.4 Existing TSR systems for social interactions are mainly evaluated with user studies based on subjective measures. Based on our survey, most user studies on TSR systems are focused on subjective user experience (evaluated with questionnaires and interviews), rather than objective improvements with regard to specific task goals. This could be due to some of the following reasons: 1) practically, user studies may span a long period of time or several sessions depending on the task or domain in which TSR systems provide support, making it challenging to implement task performance-based objective evaluations and collect related data continuously for such evaluations, and 2) the nature of self-reflection for social interactions is *multi-faceted* and complex—it is not purely about improving objective performances of well-defined tasks, but also about gaining personal insights or greater understanding about the past, oneself, and the social context. This also leads to challenges in defining appropriate and comprehensive evaluation metrics.

5.1.5 Practical implications. These limitations and design challenges in existing TSR systems provide practical implications and opportunities for future TSR system development. Researchers can use our comprehensive framework of system features, in combination with existing frameworks of system design, to consider what type of TSR system they would like to develop. Particularly, corresponding to our highlighted challenges in designing for social interactions, researchers can consider to: 1) design systems that help users to reflect on a meta-level and set individual goals, 2) design systems that not only provide users with a structured reflection process for learning, but also facilitate users to understand the reflection process and their goals and behaviors, 3) design systems that adapt to individuals, and 4) apply more comprehensive evaluation methods (e.g., by considering different phases of reflection the system interacts with).

5.2 Ethical challenges

Many aspects of TSR systems can raise ethical concerns due to how they potentially influence behaviors and how they collect, process, and analyze personal data.

Here, we want to highlight three main ethical challenges in developing TSR systems for social interactions:

1) Mitigating unwanted side effects from ruminating: TSR systems involve revisiting the past, requiring systems to mitigate unwanted side effects while prompting memory (e.g., rumination on past events can have a negative impact on well-being [24]). In particular, intelligent mitigation strategies for broadly addressing this challenge likely require careful adaptation for how interactions dynamically shape reflective experience [16] (e.g., through multimodal user-modeling [15]);

2) Mitigating potentially negative effects on user agency: TSR systems, especially ones that promote self-reflection for reaching specific behavioral goals in specific tasks, may influence behaviors via nudging, or unintentionally influence social behaviors, requiring researchers and designers to consider how to maintain users' sense of agency in social context [52];

3) Personal data usage and privacy concerns: TSR systems often (sometimes continuously) collect, process, and analyze personal data, requiring researchers and designers to address personal data usage and privacy concerns, e.g., through implementing features that allow users to negotiate and communicate with the system.

5.3 Study limitations

Finally, we also acknowledge several limitations in our literature survey. First, we limited our investigations to research papers and there could be existing applications that people use in their daily lives to support social interactions. Second, our search strategy, including database choices and keyword selections, could potentially limit our scope of search. Given the lack of consistent terminology and definitions for TSR systems as mentioned in [9] and [7], it is likely that there exist systems that aim to facilitate retrospective self-reflection under different terminologies. Third, while analyzing articles based on the categories in our framework, we did not distinguish between "no (0)" (i.e., the system does not have the corresponding feature) and "under specified" (i.e., whether the system has the corresponding feature or not is unclear). The features that are often "under specified" could potentially provide us with insights into how system features are usually reported, offering support for related research in the future.

6 Conclusion

In this paper, we systematically surveyed systems that provide *technology-supported retrospective self-reflection* for social interactions. We found that existing technologies tend to improve interaction behaviors towards specific task goals, with limited application domains, limited ability to provide explanations, and limited ability to adapt to individual differences in terms of reflection or life habits and support duration. To propose a way moving forward, we envision a support system that balances the understanding and explanation of social interactions in different social contexts for self-reflection and support self-reflection in a continuous, adaptive manner. We hope our survey can provide new insights into technologies helping people navigate the complex social domain through self-reflection.

7 Author contribution

We follow the CRediT (Contributor Roles Taxonomy) [3] to recognize individual author contributions below. **Chenxu Hao**: conceptualization, methodology, formal analysis, investigation, data curation, writing - original draft, writing - review & editing, visualization, project administration. **Tiffany Matej Hrkalovic**: formal analysis, validation, writing - review & editing. **Daniel Balliet**: conceptualization, funding acquisition. **Hayley Hung**: conceptualization, writing - review & editing, funding acquisition, supervision, project administration. **Bernd Dudzik**: conceptualization, methodology, writing - original draft, writing - review & editing, project administration, supervision.

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A Supplemental Materials

Table 3 provides the exact search queries used for literature identification and number of articles found with each source.

Table 4 provides our full framework for describing reflection systems, including the feature dimensions, categories within each feature dimension, and definition or examples for the categories.

Database	Query	Results
Reference set	NA	13
Scopus (08-23)	TITLE-ABS-KEY (techn* OR system) AND TITLE-ABS-KEY ("social interaction" OR "social decision" OR social) AND KEY ("reflection" OR "reflect" OR "reflecting")	1262
PubMed (08-23)	("social"[Title/Abstract] OR "social interaction"[Title/Abstract] OR "social decision"[Title/Abstract]) AND ("techn*"[Title/Abstract] OR "system"[Title/Abstract]) AND ("reflect"[Other Term] OR "reflection"[Other Term] OR "reflecting"[Other Term])	30
ACM DL (08-23)	"query": Keyword:(reflection OR reflect OR reflecting) AND (Abstract:(social OR 'social decision' OR 'social interaction') OR Title:(social OR 'social decision' OR 'social interaction') OR Keyword:(social OR 'social decision' OR 'social interaction')) AND (Title:(system OR techn*) OR Abstract:(system OR techn*) OR Keyword:(system OR techn*)) "filter": ACM Content: DL	102

Table 3: Overview of query and number of articles found.

Feature dimension	Feature category	Definition or necessary example
Levels of reflection	Description	"Description or statement about events without further elaboration or explanation. Not reflective."
	Reflective description	"Description including justification or reasons for action or interpretation, but in a reportive or descriptive way. No alternate explanations explore, limited analysis and no change of perspective."
	Dialogic reflection	"A different level of thinking about. Looking for relationships between pieces of experience or knowledge, evidence of cycles of interpreting and questioning, consideration of different explanations, hypothesis and other points of view. "
	Transformative reflection	"Revisiting an event or knowledge with intent to re-organise and or do something differently. Asking of fundamental questions and challenging personal assumptions leading to a change in practice or understanding."
	Critical reflection	"Where social and ethical issues are taken into consideration. Generally considering the (much wider) picture."
Phases of reflection	Preparation	A task or task goal of reflection has been determined.
	Data collection	The support system collects relevant data for reflection.
	Integration	Collected data is prepared and integrated for reflection.
	Reflection	The user will reflect upon given information.
	Action	The user will consider transformation of their perspectives and or behaviors for the future.
Goal	What is the goal the system facilitate for?	A specific goal for perspective and behavior change.
Data	Does the system use data for the intended technology?	Data related to a specific task that the system is designed for, rather than data related to the user's habit for interaction (e.g., monitoring when the user interacts with the system)
	Does the system use data for the intended task?	This includes user data that is related to the specific task or goal the system supports through reflection (e.g., video recording of social interaction behaviors).
	Does the system collect user data for the systems itself?	This includes user data that describe user's habits and preferences for interacting with the system (e.g., when does the user like to reflect?)
	Does the system collect user data implicitly?	Implicit data collection: system collects data in parallel to user activities (e.g., video and audio recordings in the background).
	Does the system require users to input data?	User input data: system collects data by prompting user (e.g., diary entry, dialogues and conversations).
Ubiquity	Is the system ubiquitous?	"The word ubiquitous means omnipresent, universal, global, or ever-present. Ubiquitous computing means a computing environment that appears to be present everywhere, anywhere, and anytime. Unlike a traditional unconnected desktop computer, which is stationary and can only be accessed while sitting in front of it, the concept of ubiquitous computing points to availability of a computing power through use of any device or infrastructure, in any location, in any format, and at any given time." ([19], pp. 19)
Disruption	The system prompt or notify user (e.g., for reflection).	
	The system only supports reflection at a set stage	e.g., reflection session always happens after a round of activity
Support duration	The system provides event-based support	e.g., reflection session after one event
	The system supports for an extended period of time	e.g., a smart watch with visualized feedback at the end of the day
	What is the length of an activity-reflection cycle?	
Input modalities (user to system)	Visual	e.g., video or image data from the user
	Verbal	e.g., text entry
	Auditory	e.g., audio information can be given from the user
	Haptic	e.g., VR systems that allow physical interactions
Output modalities (system to user)	Visual	e.g., visualization of user data to display
	Verbal	e.g., dialogue system, text prompts
	Auditory	e.g., sound for prompting
	Haptic	e.g., haptic feedback from the system
Explanation	System provides explanations for its guidance	System provides explanations for why it suggests something to the user
Structure	The self-reflection facilitated by the system is a structured process.	The reflection follows a series of steps (e.g., looking at data and then reflect, or reflect and then look at data).
Valence	Positive	The system presents information positively or triggers reflection in a positive framing.
	Negative	The system presents information negatively or triggers reflection in a negative framing.
	Neutral	The system presents information or triggers reflection neutrally.
Application domain	What is the task domain the system supports for?	
Adaptivity	The system is somewhat adaptive to the user.	
	Explicit externally determined goal driven adaptation	The system uses and analyzes individual data and providing guidance based on individual data (of task performance).
	Personalised data-driven adaptation	Adapts to user habits by providing prompts and guidance according to individual's lifestyle and learning pattern.
Evaluation	Has user study?	The system is evaluated through a user study.
	User study sample size	
	Objective evaluation based on user's task performance	
	Subjective evaluation by users through questionnaires	

Table 4: A framework for describing reflection systems.