Design for Long-term Memory Augmentation in Personal Knowledge Management Applications

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ABSTRACT

In our digitized world, we increasingly rely on technology for remembering. Personal Knowledge Management Applications (PKMAs) help us save and organize relevant and worth-remembering digital information. Thus, PKMAs serve as an external memory prosthesis but with the innate risk of substituting our organic memory. Our results from an online survey ($N = 58$) on user motivation for PKMAs show that users rarely revisit their digitally saved content. As a result, any memory about previously obtained knowledge naturally attenuates over time. However, being able to recall from one's organic memory is pivotal for creative processes such as brainstorming and the successful integration of new information. We propose endowing PKMAs with a memory-augmentation feature that periodically reminds one (e.g., on one's mobile device) to revisit stored content for counteracting long-term forgetting. Periodic revisiting may consolidate the memory recall of the stored information, and thus the memory about saved information becomes gradually augmented. To address the specific requirements of reminders in PKMS, we conducted a follow-up focus group ($N = 7$) to discuss potential design features, in particular in regards to timing and presentation format. Ultimately, we elicit a set of design principles for future PKMAs that support memory augmentation.

CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous and mobile computing systems and tools*; *User centered design.*

KEYWORDS

Personal knowledge management applications, memory augmentation, notification, reminder

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1 INTRODUCTION

Having continuous access to the internet from our personal devices enables us to consume a sheer amount of information on a daily basis. As a result of this development, our memory is evolving so that we rather remember how to locate information (i.e., what we have to type into a search engine to find it) instead of remembering the actual content [21]. Technology can support our memory in many ways, for example, through browser bookmarks, making it easier to revisit complex URLs, or digital sticky notes enable us to access our memos on-the-go. Exceeding the complexity of sticky notes, Personal Knowledge Management Applications (PKMAs) support users in saving information in a more organized manner. As they enable users to easily find and revisit all information they consider worth remembering, PKMAs act as users' memory prosthesis. Applications such as Evernote[1] or Notion[2] provide a great set of interwoven functions to manage personal knowledge: bookmarking, annotation, goal road maps, and others.

To better understand how such applications are used, we conducted an online survey ($N = 58$) on PKMAs, exploring participants' motivation for using them, the content they save, as well as their usage behavior. The results show that although participants invest time and effort to save information with PKMAs, they are not satisfied with their technique for revisiting prior content. As a result, any knowledge acquired through such content falls victim to forgetting if not rehearsed periodically [19]. According to Ebbinghaus' forgetting curve, the amount of information one can recall decreases rapidly after acquisition. However, the more frequently this information is recalled afterward, the more one remembers [15, 19]. Moreover, how we retrieve memories—e.g., if the retrieval is meaningful or not—influences later memory strength [10].

Since being able to recall from one's organic memory is pivotal for creative processes such as brainstorming and the successful integration of new information, we propose extending PKMAs with a memory-augmentation feature. We aim to support the engagement with formerly saved content; thus, counteracting long-term forgetting. Saved information can be rehearsed by inviting the users to revisit it (e.g., on a mobile device) or posing questions about it in the form of reminders. To actively engage the users to their saved knowledge, the reminders have to be designed carefully. To find out how, we conducted a follow-up focus group ($N = 7$) to discuss the specific design requirements for memory-augmenting PKMAs. Based on the analysis of related work from the areas of notification and interruption management, and findings from our two studies, we elicit and discuss a set of design implications for future PKMAs.

[1]Evernote: https://evernote.com/, last accessed November 10th, 2020
[2]Notion: https://www.notion.so/, last accessed November 10th, 2020

2 BACKGROUND

An important consideration for the design of reminders is the timing of their presentation to the user. Prior work on memory transience suggests that it is necessary to consolidate knowledge within a week after acquiring or the last revision [15, 19]. However, PKMAs would benefit from detecting opportune moments for reminding users of saved content to maximize the chances for active engagement; thus, fostering elaborate rehearsal over simple maintenance rehearsal [12]. The most common form of reminder on mobile devices are notifications. Prior work has explored how to detect opportune moments for users to engage with notifications (cf. [7, 16–18]), e.g., by analyzing users' current activities and detecting breakpoints (e.g., in between tasks) [8, 9], or by detecting boredom through mobile phone usage behavior [3]. Those detection mechanisms determine when users are reachable rather than receptive to engage in elaborate rehaersal [23]. However, the specific requirements of PKMAs as tools for memory-augmentation go beyond mere notification interaction; they require the design and evaluation of strategies for long-term periodic elaborate rehearsal mechanisms.

In addition to the timing, the design of reminders is crucial to trigger the process of remembering priorly saved knowledge. In pedagogical research, the terms *open* and *specific* memory re-activation are often used to describe the process of recalling information. Open re-activation refers to activating a broad topic, e.g., through brainstorming [22]. Specific knowledge re-activation targets unique information chunks, e.g., by asking a question [13]. Further, techniques such as "cued recall"—the practice of augmenting one's memory with memory cues [1], can be used to trigger a memory. Such cues can often be semantic. Cued recall differs from free recall in that a cue (e.g., word) is presented, related to the memory one is attempting to recall, for enhancing one's ability to recall that memory. Typical cued recall tasks in psychology include the provision of category names, in which words are originally grouped, and the presentation of related words for recalling a series of spoken words. For example, for remembering the word "branch," the word "tree" could be used as a memory cue in a cued recall task. **In this work, we theorize that a reminder may at times serve as a memory cue but primarily as an invitation to revisit saved information**.

3 ONLINE QUESTIONNAIRE

We performed an anonymous online survey with 58 participants to explore the usage of PKMAs and the concept of using notifications to remind users of previously stored information. We recruited our sample through our university's social media channels, mailing lists, and personal contacts. We stated a brief introduction including the purpose of the study and informed the participants about our data processing, their data protection rights, and their right to withdraw from this survey. After consenting, the participants were presented with 23 questions. The questions covered digital media consumption (for educational purposes), participants' habits of saving information, and especially their need for reminders to help them revisit content. To analyze the open-ended question and find recurring patterns in the answers, we applied the contextual inquiry method [6]. We clustered similar statements into categories and report on them as well as state exemplary quotes.

3.1 Results

We asked our participants which media formats they use to learn something new or to gain insights. The majority, 53 out of 58, stated to use online articles. Further, 36 listen to podcasts, 32 to non-fiction books, 15 to newsletters, and 10 people stated other sources, such as videos or scientific articles. When inquiring about the frequency of use, participants answered similarly: consume online articles most frequently (daily), then podcasts (monthly to weekly), and non-fiction books monthly or less.

To collect more specific details on participants' habits of saving information from media content, we asked them to remember exemplary situations in which they did exactly that. In particular, we asked them to give an example of what content they wanted to save and why. The examples aligned with the statements of the aforementioned questions and ranged from online articles (most frequently noted) over podcasts to more specific content. Examples for the very diverse reasons for saving are "to build my overall professional competence," "to improve/develop a skill," because it is "useful for my future career [...]," or just out of "casual interest." Besides specific examples, we asked participants about their most common reason for saving content. The most frequently-stated reason is learning a new skill (13), followed by job-related explanations (7). Following this general inquiry, we asked more detailed questions about participants' habits of saving content. When asked where or how they save information, participants stated using note-taking tools (41), browser bookmarks (31), or analogue methods (i.e., pen-and-paper (25)). Six participants added further ways of saving information, such as in file managers, chat conversations, via screenshots, or just their (organic) memory.

Upon saving information, participants displayed diverse behavior when it comes to their habits of annotating the content. On a scale from 0 ("never") to 6 ("always"), the results show a mean rating of 3.07 ($SD = 1.38$). Following up on this question, we asked every participant who rated a 2 or lower (16) why they did not need to add notes or annotations. The main reasons stated were "*too much effort*" (10), "*no need*" (9), or "*not the right moment*" (1).

For participants who rated the aforementioned questions with a 3 or higher, we inquired into their annotation behavior, in particular, what they usually add and why. They stated to write down quotes, key takeaways, their reasons for saving this information, and thoughts and interpretations. When thinking back about how much information they usually remember from previously saved content, participants state to remember at least parts of it (scale of 1 ("nothing") to 10 ("every detail"), $M = 5.28$, $SD = 1.49$). About three quarters (72 %) state they are not satisfied with the amount of information they retained. So far, 31 participants used tools and techniques to remember information better, ranging from flashcards to drawings to digital tools. The majority, 81 %, declared to have revisited previously saved content before, some randomly (25), some actively (23), or via reminders (15). As the main reason for not revisiting content, participants stated not remembering having saved the information (5). In summary, 70 % of our participants state to be unsatisfied with their technique for revisiting content, outlining that "[...] *it would be nice to see older stuff more often*," *get a "better overview*," "[...] *a plan on what to revisit*," or to receive "*reminders to look at my notes more frequently*."

4 FOCUS GROUP

In our focus group, we assumed an in-depth perspective over people's reasons for saving and revisiting content. Moreover, we wanted to explore specific design features for a PKMA that would help the users achieve their memory goals. After a brief introduction, participants reflected on their own information management behavior. We started by discussing participants' goals for saving content in relation to the topic and the clusters generated. Further, we asked participants about the level of detail and the depth of engagement with content of different goals, and the need for support to revisit saved content. The format of reminder presentation and their timing were then discussed in detail. We conducted the focus group via the video conferencing tool *Zoom*[3] combined with the digital whiteboard tool *Miro*[4]. We exported the Miro board and audio-recorded the discussion for further analysis with participants' consent. For their participation, every focus group participant received a 20 Euro Amazon Voucher.

4.1 Sample

Our focus group consisted of seven participants (7 male), aged 23–26 ($M = 25.33$, $SD = 1.11$). All participants had higher education degrees (bachelor or higher), four were currently enrolled at a university, two were engineers, and one was a manager. Of our seven participants, three stated to have experience with knowledge management approaches and / or were currently using related software or tools. One participant preferred the pen-and-paper method, while two used technology support (1 *Evernote*, 1 *Pocket* and *Notion*).

4.2 Results

4.2.1 Memory Goals. In the focus group, participants stated examples of various goals they pursue when they save digital information. They clustered and labeled them as follows:

- "**Generally good to know**," including tips and tricks articles, recommendations for podcasts or TV series, prices in stores, information about events, menus of restaurants, or articles on challenges of founding a start-up.
- "**Important for a new skill**," such as tutorials on different topics, programming courses, Stack Exchange articles, API documentation, but also non-technical skills such as books on negotiation techniques.
- "**Safety issues**," meaning documentation of important (personal) information. This can include website content with contract information, conference dates, or software documentation, but also bills, documents needed for the tax declaration, emails, or important conversations.
- "**Inspiring**" content includes digital content on self-improvement in terms of relationships, awareness, gratefulness, or leadership competencies, but also information on products.
- "**Important for personal or professional goal**" included articles on master thesis topics or general research field, scientific papers, or a guide on video production techniques.
- "**Other**," which in the case of our participants included examples that could not easily be added to the other categories. For example, one participant stated to have seen a visualization that could come in handy at some point, or keeping a backlog of articles to read which need further prioritization.

Finally, participants noted that it might be difficult to clearly distinguish between a personal goal and learning a new skill, as they can be closely related. We asked them to prioritize the goal clusters regarding their frequency of appearance. Participants stated they most often save content for the clusters "Important for a new skill," "Generally good to know," and "Important for personal or professional goal." In the following, we focus on these clusters.

4.2.2 Save. Considering the different goal clusters, we asked the participants if they would like to save additional information associated with the content. One type of information that was frequently mentioned is an importance rating for the content, especially for learning a new skill or personal / professional goals. For the latter, participants would also like to sort the content into their goal road map or to certain projects, add deadlines, key takeaways, tags, the date, or highlight paragraphs. Further, they stated they would appreciate drawing relationships to other saved content (i.e., creating a knowledge map). When aiming to learn a new skill, participants mentioned that it might help to note down the technology or tool planned to use it for. If information is saved because it is "generally good to know," participants would like to add a topic, the date, tags, relationship to other content, and information on what needs to happen so that the information becomes relevant / important.

4.2.3 Remind - Timing & Frequency. For the design of reminders, we differentiated between the timing / frequency and presentation format. We first asked the focus group participants: **What are aspects that determine the timing of the reminder?** Participants wished for reminders based on their current goal situation, meaning their current priorities and the deadline of the goal (i.e., more reminders closer to a deadline). Further, reminders should fit the momentary situation, thus, be context-aware. Context can be measured as place and time, but also the personal schedule, or when searching for related content. Lastly, participants stated they would want the application to account for the general importance of the content piece, the amount of information that is saved on the topic (they coined it "hotness" of the topic), and the time elapsed since the last reminder.

We further asked participants to state **exemplary situations and their context in which they would be particularly interested in being reminded** of a topic. As already mentioned, participants liked the idea of reminders in situations in which they are currently engaged with similar content. They also highlight the opportunity to exploit short breaks in the daily schedule, such as on commutes, while brushing teeth, right before going to bed, or in waiting situations. When asked if the goal of saving information influences the timing or reminders, participants stated that they see a difference when it comes to personal or job-related goals, especially in terms of timing. Job-related content should only be presented during working hours, while information related to personal goals can also be shown in the morning, evening, and weekends. They also note that the frequency of reminders should be in relation to the assigned topic relevance or urgency.

[3] www.zoom.us, last accessed April 22, 2021
[4] www.miro.com, last accessed April 22, 2021

4.2.4 Remind - Presentation. Participants stressed that the **detail of the reminder could and should vary according to the moment of representation**. They suggest providing shallow reminders (i.e., headlines only) when sending reminders on a commute or in waiting situations, and more detailed reminders close to deadlines, when the topic is mentioned in the personal schedule, or when actively engaged with similar content. As a form of representation, the participants distinguished between two main views: a **constantly available** one (e.g., dashboard, sidebar, etc.), and **excerpts conveyed as messages or notifications**. Constantly available views could be included in the browser or be visualized as a dashboard when opening a PKMA (e.g., grouped by topics or arranged by momentary importance). Furthermore, one participant mentioned the idea of a screensaver, which presents the latest or currently most relevant information a person has saved.

Reminders could be sent in the form of emails (e.g., a "daily digest"), as push notifications according to the importance of a topic, or entered in the calendar. One participant stressed that it is important for him to **actively engage with the content** and not "*just read it*." He proposed to present the content in the form of a small test or question, e.g., as a fill in the blank statement or asking the user to paraphrase the information to encourage deeper processing. The depth of information that should be shown ranges, according to our participants, from a simple word cloud, to title and metadata, up to additional related content.

Moreover, we inquired into **mechanisms for adjustment** of frequency/timing of reminders and their presentation format (manual vs automatically). Some participants preferred automatic determination of timing and frequency, e.g., as integration into a calendar so that it can content can be presented in regard to appointments dealing with similar topics. Other participants pleaded for a manual adjustment according to their preferences. Still, they asked for a default option to be set based on the user's behavior.

5 DESIGN FOR MEMORY AUGMENTATION

In this section, we discuss the results of our two user studies and elicit **design principles** to support researchers and practitioners in designing memory augmentation features for PKMAs. In the online survey we performed, participants confirmed that saving digital content is a prevalent practice. In fact, the large majority of our sample indicated that they frequently save information from various media formats and sources for later use. Although saving content is often personally and intrinsically motivated, participants state to only remember key aspects of the information they saved—in nearly 3/4 of the cases, participants are unsatisfied with how much they remember. Revisiting saved content is also a common action many users have performed; however, around 70 % of our participants are not happy about how they revisit saved content.

Need for reminders to revisit saved content. Many participants expressed their need for more structure in revisiting content, active reminders, or a better connection to information they previously saved or are currently looking at. Interestingly, these requests coincide with those in our focus group. While the reasons for saving content were diverse and dependent on the user goal, our participants confirmed the need for a (smart) tool, which presents reminders to invite users to revisit previously saved information.

Balance between user control and system control. The focus group participants expressed mixed opinions regarding control of reminders, e.g., when adjusting the timing. A combination of a (smart) default mechanism based on user behavior seems appropriate, with the option to customize features such as timing, frequency, or amount of content presented. Further, participants liked the idea of using content or context-aware mechanisms (similar to [3, 11, 14]), or by presenting priorly saved content when currently browsing for information on a similar topic. This goes in line with research conducted in the learning domain, in which the retrieval of memories can help with the integration of new information (cf. [5]). For example, when reading an article on amazon monkey populations, one could be asked to recite key aspects of an article saved on the amazon forest fires. Hereby, users will be able to easier integrate the new information into their existing knowledge. The need for control over smart reminders further depends on the user's goal associated with the stored information.

Provide opportunities for adaptation according to user goals. Adapting timing and presentation of reminders to the memory goal was central to our focus group. For example, when comparing the goals of saving information for documentation purposes vs. saving content for improving a skill, one must keep in mind the difference in terms of momentary relevance and urgency of revisiting this information. PKMAs should provide the opportunity to group the stored information by goal and set priorities or deadlines.

Transition from reminders to memory cues. Memory cues differ from reminders in that they do not require one to revisit saved content to remember. Instead, memory cues are hints for triggering information stored in our organic memory. The wealth of information PKMAs hold is an excellent source of memory cues. Indeed, cues can have various designs (cf. [2, 4, 20]). Participants suggested explicit reminders (e.g., notification with article headline) and subtle memory cues (e.g., picture from article as screensaver). The presentation's ambiance could be adapted according to several factors, e.g., the user's goal or priorities, or the time elapsed since the information was stored or rehearsed. Our participants also stated to annotate their digital content often upon saving. As those annotations contain information central to the individual user, they are valuable for the automatic creation of memory cues.

6 CONCLUSION

In this work, we presented the results of an online questionnaire and a focus group on PKMAs for memory augmentation. We explored people's experiences with PKMAs and we probed the need for counteracting the long-term forgetting of saved information. Both studies showed that participants are not satisfied with their currently available options when it comes to remembering and revisiting their saved content. Our design principles facilitate the implementation of PKMAs with a stronger focus on long-term memory augmentation. We encourage future research to focus on effectively exposing users to content of their current memory goals. The focus should also shift from simply storing huge amounts of digital information to fostering the strong integration of new information with prior knowledge. Ultimately, the timing and content of reminders (and memory cues), along with the presentation style of saved information, provide ample ground for future research.

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