Agenda- and Activity-Based Triggers for Microlearning

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ABSTRACT

The ubiquity of mobile devices has fueled the popularity of microlearning, namely informal self-directed learning during brief personal downtime. However, learner engagement is challenging to maintain, and microlearning habits are hard to establish. Scheduled reminders are ineffective as they do not match the users' variable schedules and their intention or capacity to engage. In this paper, we propose a schedule-based and an activity-based trigger for microlearning. The first trigger is sensitive to the learners' agenda and device status and includes a snooze mechanism. A four-week study (n=10) showed slightly lower response times when compared to triggers scheduled at a fixed time but did not improve learner engagement. The second trigger initiates audio-based microlearning when plugging in headphones. Thus, we minimize the access to personal data and capture a moment where learners engage with their device for a listening activity. In an exploratory user study (n=10), the plugin trigger achieved high compliance rates and was less likely to induce annoyance in users than lock screen notifications. We conclude that intelligent reminders with simple interaction options can contribute to learner engagement.

CCS CONCEPTS

• **Applied computing** → **Interactive learning environments**; • **Computing methodologies** → **Planning and scheduling**; • **Human-centered computing** → Empirical studies in ubiquitous and mobile computing.

KEYWORDS

Microlearning, Microproductivity, Reminders, Language learning, Audio

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1 INTRODUCTION

In principle, mobile computing devices provide greater opportunities than a traditional medium (e.g., flashcards) to learn on the go. For example, we could learn new foreign words whenever short periods of free time occur—for example, whilst waiting for the bus to arrive. This is termed microlearning [14, 15]. Unfortunately, the intention to microlearn is often forgotten when opportune moments do arise. Instead, users are more likely to engage in more habitual activities, such as checking their social media feed. Therefore, well-designed reminders or triggers on our mobile devices are a necessary first step towards developing a microlearning habit in the first place.

Many applications are available purely for the purpose of microlearning on mobile devices, in particular for learning a foreign language (e.g., [3, 6, 11, 14, 20]). Some of these applications recognize the need for reminders, and commercial apps could schedule push notifications either at specific times or based on the user's tracked learning activity (e.g., Duolingo, Babbel, Busuu).

To the best of our knowledge, these reminders rarely take the learner's circumstances and availability for learning into account. Thus, such triggers rarely coincide with moments where learners wish to or are able to start microlearning. Nonetheless, identifying idle moments on mobile devices, which are suitable for microlearning, is a complex problem [34].

On the one hand, a system could rely on contextual information that indicates user availability. For example, microlearning could be triggered when users are *waiting* for an explicit event to occur (e.g., an elevator's arrival [6]). However, this would not indicate user intention to interact with an activity. On the other hand, a system could rely on smartphone interactions and application usage to infer user boredom [11] and trigger microlearning instead. Nonetheless, it is non-trivial to infer user boredom with absolute certainty, and it might be a challenge, in itself, to convince learners

to initiate microlearning when they are already interacting with other smartphone activities.

In this paper, we adopt two intermediate approaches that combine the advantages of both ideas: the *Hybrid Agenda Trigger* and the *Plugin Trigger*. The Hybrid Agenda Trigger utilizes availability information, namely the users' calendar events and device activity such as active calls, to schedule push notifications as reminders when users are not busy. Simple interaction with the triggers allows users to easily delay triggers or completely opt out when they do not have the intention to start a microlearning session at that time or on that day. Thus, minimal interaction compensates for the potentially imprecise inference of user intentions obtained through calendar information and smartphone activities. We integrated this reminder into the Android version of the popular flashcard app Anki[1]. We evaluated the Hybrid Agenda Trigger in an exploratory within-subject study over four weeks (n = 10), where we compared its impact on learning engagement and perceived usefulness to a default version of Anki with fixed daily notification triggers. The Hybrid Agenda Trigger did not lead to more frequent learning. There was an observable trend towards shorter response times in comparison to the reminders at fixed times, but the overall acceptance rate was comparable. Given the modest benefits, it is questionable whether reading the participants' calendar information is necessary and justified. Moreover, availability does not automatically infer the intention to engage. Thus, in our second approach, we utilize user activity patterns observed while learners are already engaged on their mobile device as trigger moments. Specifically, the Plugin Trigger relies on the explicit event of plugging in a headphone to indicate user availability and intention to engage with the smartphone via the auditory modality. It prompts users to initiate audio learning sessions whenever the smartphone detects headphone plugin events. Thus, it is based on an event that explicitly indicates user availability and is also based on the user's smartphone usage itself. It has the advantage of being an unambiguous indicator of the user's availability as well as the intention of interacting with a certain modality of the smartphone. We evaluated the Plugin Trigger in an exploratory between-subject study over two weeks (n=10) in order to assess the suitability of these headphone plugin triggers (PT) for microlearning compared to conventional notification triggers (NT).

The two systems were informed by an online survey (n = 83) of the common user strategies for task reminders on mobile devices. Notably, we found that only a small share of people employed specific cues as reminders for productive activities on mobile devices, despite the effectiveness of context-based reminders identified in prior work (e.g., location-based reminders [39]). This is also the case for microlearning, where learners currently tend to rely on app-scheduled reminders that do not adapt to the learners' context or to their own imperfect scheduling habits. Thus, opportune moments such as commuting times often remain unused. Context-based triggers could sense opportune moments for microlearning. The headphone plugin trigger and dynamic scheduling trigger that we implemented serve as examples of such triggers. In our first user study, the plugin trigger achieved a high acceptance rate—learners started sessions with a probability of 87% when this trigger was presented. The hybrid rescheduling system did not increase acceptance rates, but there was a trend towards shorter response times in comparison to the reminders at fixed times. These examples are not one-size-fits-all solutions, but they show that even without complex personalized activity models, individually suitable moments for microlearning–and potentially also other activities on mobile devices–can be identified.

Overall, our work addresses the following research questions:

- RQ1: What are current and potential context- and activity-based triggers for microlearning?
- RQ2: What are the advantages that such triggers offer, relative to traditional triggers (e.g., scheduled reminders and unlock triggers)?
- RQ3: How should triggers be (re-)designed in the future?

2 BACKGROUND AND RELATED WORK

Microlearning refers to learning in bite-sized chunks [3, 14, 15]. Microlearning applications are often implemented for mobile or ubiquitous use. Thus, microlearning could, in theory, be performed anywhere and at any time. In practice, long-term engagement rates are low. A common reason for learners dropping out of online learning courses is a lack of time (or bad time management) [28, 30]. Learners are also likely to forget to initiate sessions and could benefit from learning triggers [28]. Below, we list and explain different kinds of reminders that people rely on for microlearning. We also include reminders for other activities that could potentially be transferred to microlearning settings. In addition, we analyze what contexts actually serve as a proper moment to learn.

2.1 User-Triggered Reminders

As user-triggered reminders, we consider object cues and text cues such as to-do lists, both digital and on paper. For example, everyday objects such as photographs serve as memory cues [45], and written notes or messages to oneself serve as action reminders [9, 23]. This type of reminder may be simple to implement in everyday life, but it requires users themselves to get active. Consequently, it is another potential source for forgetting, in this case, forgetting to set a reminder.

2.2 Scheduled Reminders

System-triggered reminder notifications (i.e., notification triggers) are often used to decrease attrition. They have been shown to increase the frequency of users engaging in targeted activities, e.g., in self-logging [4, 40] and mobile learning [33]. In fact, reminders and task scheduling are also frequently requested features for intelligent assistants [43].

For explicitly scheduling reminders, users can define recurring or non-recurring times. For example, the mobile learning app Babbel sends reminders at user-defined times on different weekdays. In other cases, systems define a point in time. For instance, an app could trigger a push notification when it has not been opened for two days. Time-based triggers are well-suited for vocabulary learning, where repeated sessions with intermissions can improve recall [11, 19]. However, their format is rigid in the sense that a

[1]https://docs.ankidroid.org/, https://github.com/ankidroid/Anki-Android

Table 1: Examples of reminder strategies applied in commercial and research learning apps

Scheduled Reminders	
Babbel[2]	User-defined notification on selected days at selected time
Busuu[3]	User-defined notification on selected days at selected time
Duolingo[4]	Email status reports and progress-based push notifications (competition in "leagues")
PACARD [32]	Daily push notification
Context-Based Reminders	
Dingler et al. [11]	Push notifications on detection of bored user state
FeedLearn [20]	While browsing social media (learning content is integrated into social media)
Lernschoner [14]	On screensaver deactivation
Vocabulary Wallpaper [8]	Exercises on the smartphone lock screen
WaitSuite [6]	Wait times, e.g., at elevator, while messaging, while connecting to WiFi

learner's current context and availability are not considered. Examples of reminders used in mobile learning apps are shown in Table 1.

2.3 Context-Based Reminders

If notifications are sent too frequently, they can lead to increased annoyance [33, 35]. Therefore, task reminders should ideally only be shown when users are actually available for the task they are meant to trigger. But how can suitable moments be detected?

When a task can be associated with a relevant location, location-based reminders can be triggered when a person arrives there [22, 39, 41]. For example, a reminder for grocery shopping is shown when in close vicinity to a supermarket or for emptying the dishwasher upon arriving at home. However, location-based reminders are less suited for mobile learning sessions with apps that are location-independent. Other reminders utilize information about learner state and context, e.g., boredom phases [11] or waiting moments, such as waiting for the elevator or while a call is connecting [6]. Examples of context-based reminders for mobile learning are shown in Table 1.

For activities other than learning, opportune moments that have been suggested are waiting times at traffic lights [1], phone unlock events [44], social media access, walking with headphones on, and the moment after phone calls (all three suggested in [18]).

2.4 Determining Contexts for Learning

In order to derive potential situations for triggering context-based reminders for microlearning, we need to know what characteristics determine a suitable context for learning and how they can be detected. Not all idle times available throughout the day are equally suitable for learning sessions, or rather, for the same type of learning sessions. This depends on several characteristics of a potential learning situation, such as location characteristics (e.g., the noise level), the learner's available time, their interest and motivation, as well as their emotional and attentional state [38, 48]. In particular, learning seems to be most effective in moments where learners have a high level of attention and are able to focus [36]. Yet, this does not mean that learning in other (non-ideal) contexts is not possible. For example, several studies using microlearning apps have shown positive learning outcomes, even when study sessions were short and learners were not necessarily fully focused [6, 8, 12].

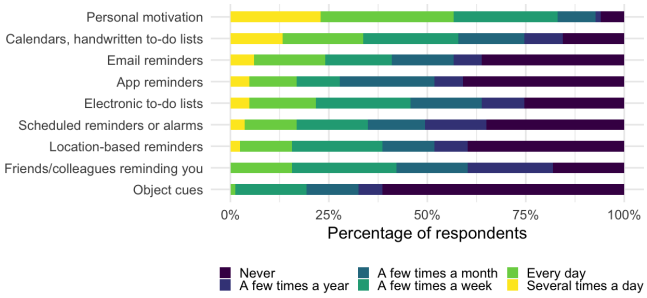


Figure 1: Usage frequencies of different activity reminders

In summary, learning can occur in various situations, but lesson design should be adapted to the requirements of a given situation [38]. Quiet moments at home are probably a good context for presenting new material, whereas short moments on the go can be utilized for revising previously seen material.

In order to adapt learning sessions, information about the current context is necessary. However, implicit on-device activity recognition and sensing of cognitive state are complex [5, 29, 34] and need to be well-adjusted for reliable results. In the examples mentioned above, the context was derived from user activity on smartphones or from instrumented environments. In our work, we aim to detect suitable moments and readiness to engage through context and availability checks as well as explicit user actions. This means that we investigate associations between actions and learner context, such as the headphone plugin event that typically entails a situation where someone is alone and will often start to listen to music or watch a video.

3 SURVEY ON ACTIVITY REMINDERS

We conducted an online survey ($n = 83$) for an overview of common reminder strategies and desired reminders for microactivities on mobile devices. As the aim was to generate a wider set of ideas that could potentially be transferred to microlearning, we included both *productive* activities and *leisure* activities. We recruited participants via social media and a university mailing list (56 female, 26 male, 1 undisclosed). Their ages ranged from 18 to 36 years ($M = 23.7$ years, $SD = 3.7$ years). After completing the survey, participants were invited to participate in a raffle for online shopping vouchers.

The respondents' estimations of how often they used activity reminders are shown in Figure 1. The top items that respondents apply at least once a week are personal motivation (83.1%), i.e., intrinsically motivated impulses, followed by handwritten to-do lists and agendas (57.8%). Digital reminders are less frequent. For example, 34.9% of respondents stated that they schedule task reminders or alarms. Only 19.3% said they regularly work with object triggers. Five respondents listed further reminders like "light signals with hue lights" and seeing other people in the respondent's surroundings working on a task. Specific object cues that were mentioned were stickers, a watering can, cleaning utensils, and other objects directly related to a task, such as clothes or a trash bag "left somewhere in the way".

Overall, physical, location-independent, and time-independent triggers were prevalent. The two top-ranked digital reminders are initiated by apps and agents (email and app reminders) or other people (e.g., emails) and not users themselves. In addition, although object or location cues can be very effective reminders [45], they were not common among our respondents—or at least not consciously applied. This means that there may be unused opportunities for better-matched reminders. In the remainder of this work, we exemplarily investigate a schedule-based and an activity-based trigger for microlearning and evaluate to what extent such triggers can be beneficial for learners.

4 HYBRID AGENDA TRIGGER BASED ON ANKI

As an indicator of learner availability, we first explore a trigger that utilizes break times in learner schedules and device status with simple user interaction, which is only necessary to accept, postpone (snooze), or decline the triggered push notifications. This concept is related to notification management systems such as [27], which aim to minimize distractions caused by ill-timed and superfluous notifications. However, since the application context is known, the trigger system has an advantage over generic systems applied for the entire operating system. Thus, the Hybrid Agenda Trigger can easily adjust to the specific requirements of the use case of microlearning.

The Hybrid Agenda Trigger checks start and end times of all entries in the users' calendars in a daily system routine (see Figure 2). As a potential trigger moment, it selects the first available time slot after a user-defined start time. Once this moment has arrived, the system performs additional availability checks and only triggers the reminder notification if these pass. For example, it verifies if the user added calendar entries in the meantime, or switched on flight mode. Users have several options to interact with the reminder notifications: (1) accepting them starts a new learning session in Anki, (2) postponing them temporarily hides them from the notification drawer, and (3) dismissing them deletes the current and all future triggers for the day. Notifications can be postponed up to three times unless users explicitly restart the count. Thus, the Hybrid Agenda Trigger combines system indicators for availability (e.g., calendar entries, airplane mode) as well as user indicators (accept, snooze, decline).

4.1 Implementation

The Hybrid Agenda Trigger was integrated into the open-source app AnkiDroid, the Android version of the widely used flashcard application Anki[5]. An important component of Anki is the Leitner-based scheduling algorithm for the spaced revision of flashcards, where the performance in previous revision cycles determines when a card is next tested. Users can create decks with their own text or multimedia flashcards, or they can import publicly available card decks.

The unmodified AnkiDroid app provides the option for daily reminder notifications for each deck. These are only triggered when the deck contains cards scheduled for revision on that day.

We added the following features to the AnkiDroid app:

(1) A dialogue presented at the first start of the app where users are asked to provide the earliest and latest time for receiving triggers as well as a default delay for rescheduling triggers.
(2) A daily routine that checks the users' calendar before the earliest possible trigger time and schedules notifications accordingly. Calendar information is retrieved via the Android Calendar Provider[6] once users have granted read permission. Calendar entries are sorted by starting time. The earliest gap of at least 15 minutes between events is determined as the time for a reminder notification and an alarm to trigger the notification is set.
(3) Once the alarm fires, the system checks if an active entry has been added to the calendar, if the device has been switched to airplane or power save mode, if notification filters are active, or if the user is in a phone call. If all checks are negative, the system triggers a reminder notification.
(4) The option to postpone is added as an action item to each notification. The action label includes an estimated time where the notification will be presented again.

4.2 User Study

In a within-subject study, we compared the frequency and timing of learning sessions with our modified version of Anki (*Hybrid Agenda Trigger condition*) to a default version with daily reminders at a fixed time defined by each participant (*Fixed Daily Trigger condition*). Specifically, we measured (1) the response time from trigger to learning session, (2) how often participants accepted, dismissed, or "snoozed" triggers, and (3) what effect this had on the resulting learning sessions. In post-hoc surveys, we additionally asked participants how they liked the different scheduling mechanisms and how an ideal trigger system should be designed.

4.2.1 Procedure. Before starting the study, participants responded to a pre-study questionnaire on demographics, mobile learning habits, and the participants' willingness to share information on calendar entries with a learning app. In the practical part of the study, the participants used either the hybrid rescheduling or the fixed condition in the participants' daily routines for two weeks and then the other app for an additional two weeks. For the Hybrid Agenda Trigger app, the participants were asked to choose the earliest and latest possible time for a trigger and their preferred

[5] https://apps.ankiweb.net
[6] https://developer.android.com/guide/topics/providers/calendar-provider

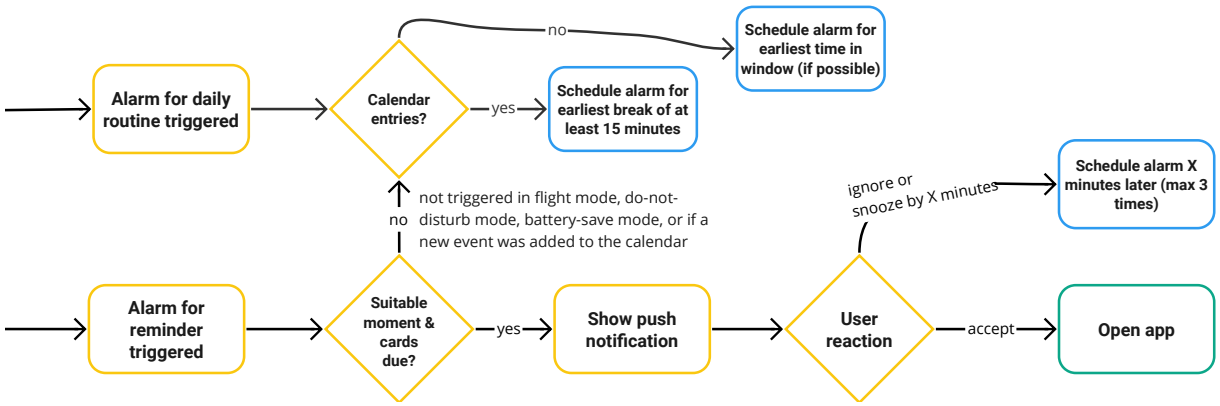


Figure 2: Process of triggering reminders in the extended Anki app.

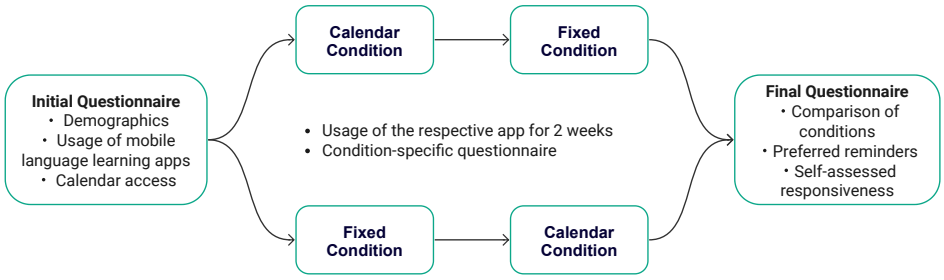


Figure 3: Procedure of the user study comparing our Hybrid Agenda Trigger system to a Fixed Daily Trigger

delay for rescheduling. For the Fixed Daily Trigger app, the participants defined a single point in time for daily triggers. We provided the participants with a flashcard deck on vocabulary for food and drink in French. There were no further instructions regarding the expected frequency or duration of learning sessions, so participants were free to use the apps at their own pace. After each condition, the participants completed a survey on their experience with the triggers in this condition. At the very end, we asked them to compare the conditions and describe an ideal trigger system. The overall procedure is illustrated in Figure 3.

4.2.2 Participants. Ten participants completed all steps of the study procedure (7 female, 3 male). They were between 22 and 47 years old ($M = 29.0$ years, $SD = 8.4$). Of these, seven were currently using mobile learning apps or had used them in the past. Participation was compensated with 15€.

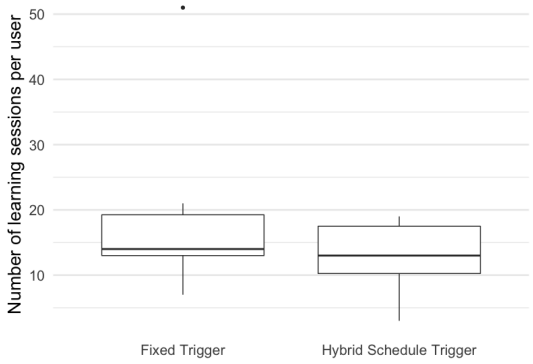
4.3 Results

During the four weeks of the study, we recorded a total of 359 triggers in the Hybrid Agenda Trigger condition (430 unique notifications when excluding reminders) and 360 triggers in the Fixed Daily Trigger condition. We further removed all triggers received within one minute from one another, as these were either intended for multiple flashcard decks or were artifacts of Android notification behavior. This left us with 239 triggers in the Hybrid Agenda Trigger condition (152 without reminders) and 278 in the Fixed Daily Trigger condition. Across both conditions, the ten participants started 307 learning sessions. Below, we report measures on triggers and engagement, details on the rescheduling patterns observed in the Hybrid Agenda Trigger condition, and summarize qualitative statements on the two app versions as well as ideas for ideal learning triggers. We use pairwise Bayesian t-tests to compare results obtained from the Hybrid Agenda Trigger and Fixed Daily Trigger conditions, the alternative hypothesis H_1 being that there is a difference between the conditions. The Bayes factors BF_{10} report the likelihood ratio of the alternative hypothesis H_1 and the null hypothesis H_0 [47]. $BF_{10} > 1$ indicates that H_1 (Hybrid Agenda Trigger ≠ Fixed Daily Trigger) is more likely than the null hypothesis H_0 and vice versa. The likelihood of H_1 increases with larger values of BF_{10}. For illustrative purposes, we additionally performed Welch tests, which revealed no significant differences.

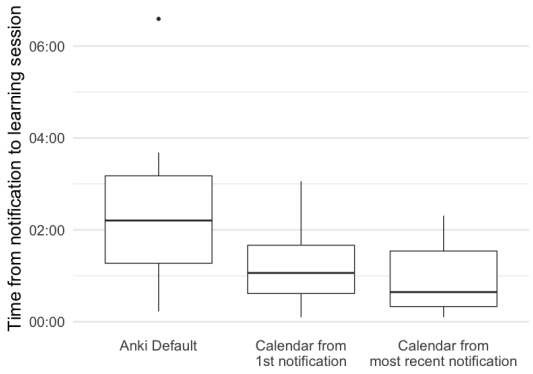
Session Frequency, Session Triggers. As summarized in Table 2, the study participants started 12.9 learning sessions while using the Hybrid Agenda Trigger version and 27.8 learning sessions with the Fixed Daily Trigger version. There was no significant difference between the conditions; Figure 4a shows that the median values are similar, and there was one outlier of 51 learning sessions in the Fixed Daily Trigger condition. Of the started learning sessions, an average of 60.8% per user in the Fixed Daily Trigger condition and 57.5% in the Hybrid Agenda Trigger condition were started from a trigger. The remainder was triggered by learners opening the app directly, without tapping on a notification. In the Fixed

Table 2: Overview of trigger measures and learning sessions (average per user). H_1 is that there is a difference between the conditions.

	Hybrid Agenda Trigger	Fixed Daily Trigger	BF_{10}
Number of triggered notifications	23.9	27.8	0.33
Number of learning sessions	12.9	27.8	0.67
Acceptance rate	25.9%	35.6%	0.64
Acceptance rate incl. reschedules	44.0%	35.6%	0.40
Average delay after trigger (HH:MM:SS)	00:55:24	02:27:37	1.46
Average delay after trigger incl. reschedules	01:19:55	02:27:37	0.65
Sessions started from triggers	57.5%	60.8%	0.32



(a) **Number of learning sessions per user.**



(b) **Time from trigger to learning sessions. The center graph starts counting from the first trigger in a series (i.e., ignoring rescheduled reminders), the right graph counts from the most recently issued trigger.**

Figure 4: Learning activity and responsiveness in the user study on hybrid rescheduling

Daily Trigger condition, participants started a learning session from 28.5% of the triggered notifications, i.e., they were accepted. In the Hybrid Agenda Trigger condition, 21.2% of the total number of triggers were accepted. This also includes triggers that were superseded by later triggers of the same reminder series. Counting only one trigger for each series, the average acceptance rate is 30.5%. Learning sessions were, on average, started approximately 2.5 hours after receiving a notification in the Fixed Daily Trigger condition (cf. Figure 4b). For the Hybrid Agenda Trigger condition, we again distinguish two cases: counting from the initial and the most recent notification in a trigger series. In the first case, the average time from trigger to learning session is approximately 1 hour and 20 minutes. In the latter case, it is 55 minutes. There was no significant difference between the two conditions for either variant.

Rescheduling and Postponing. In the Hybrid Agenda Trigger condition, participants had the possibility to snooze notifications by the time range they had defined when first starting the app. Seven participants had chosen 1 hour, one 2 hours, one 3 hours, and one hat set the snooze time to 10 hours. On average, each participant snoozed 36.9% (SD = 12.7%) of the triggers they received, and the first accepted trigger was the 5.5th (SD = 4.36) notification on that day.

Participant Evaluation of Hybrid Scheduling and Fixed Triggers for Learning. In the post-hoc questionnaires between the two conditions and at the end of the full study period, we asked the participants to comment on the different triggers. Six participants stated that they felt they learned more with the Hybrid Agenda Trigger version, and four with the Fixed Daily Trigger version. For both conditions, eight participants found the trigger notifications helpful and two did not. For example, one participant did not require the triggers as they had established a "routine to learn nearly every day in the evening [...] anyway". On a Likert scale from 1 to 5 (1 = very bad, 5 = very good), the timing was, on average, rated at 3.7 (SD = 0.95) in the Hybrid Agenda Trigger (SD = 1.14) condition and 3.2 in the Fixed Daily Trigger condition. Three participants explicitly mentioned that they appreciated the possibility to snooze triggers (e.g., "I didn't have the time at that moment, I just could 'snooze' them away for an hour - this was perfect!"). However, one participant felt it was tempting to snooze triggers when they could have immediately started a learning session instead.

Scheduling triggers based on calendar events requires access to potentially privacy-sensitive data. We asked the participants if they would be willing to share calendar data with a mobile learning app. Two participants stated that they would share full details of their calendar entries with a mobile learning app, seven would only share the start and end times, and one participant said they would not share any calendar information.

Ideal Learning Triggers. Finally, we asked the study participants what they would expect from ideal study triggers. Several participants asked for additional configuration options, e.g., for excluding work hours, setting different time ranges on the weekends, or skipping weekend triggers altogether. One participant suggested sending triggers "when [they were] finished using [an]other app", where "it seems efficient to just spend another minute on the Anki App". Additional suggestions included dynamically adapting the notification style, e.g., to increase the perceived urgency as the day progresses or to convey information on the learning progress by hinting at incorrectly answered questions or the number of cards due on that day. One participant would have liked the notifications to be more noticeable, e.g., via brighter colors.

4.4 Discussion

Effectiveness of Hybrid Agenda Triggers. The timing of the triggers was considered good in both conditions, meaning that the adaption to participant schedules did not substantially improve the perceived timing, although the response time for the Hybrid Agenda Triggers tended to be shorter. Moreover, the participants often made use of the possibility to snooze triggers. Taken together, this indicates that utilizing schedules and device status alone had little impact on the mobile learning experience. On the other hand, the possibility to interactively and easily adapt suggestions clearly provided a benefit. In the future, user input such as snoozing could, in fact, be used as input for learning user habits and providing an additional channel for optimizing the timing of triggers.

Calendar Access and Privacy. A large majority of the study participants stated that they would share event start and end times with a mobile learning app. This is sufficient for identifying breaks between scheduled events. Nevertheless, the value of calendar access for scheduling triggers substantially depends on how consistent users are in entering events. Another issue is the use of several independent calendars, for example, when work schedules are not synchronized with private mobile devices.

Individual Configurations. The study participants asked for additional configurations options. For example, they said they would like to define individual notification windows for each day of the week or change the snooze time. Individual settings for each day of the week are already a common feature in apps like Babbel and are simple to set up when users have a regular schedule. However, we stress that when adding options, a system should provide sensible defaults, as past work has shown that many users keep default settings in software [2, 24].

Lessons Learned from the Implementation. Scheduled actions can cause substantial battery drain, which is why many device vendors resort to killing apps that run in the background in ways that are not compliant with Android guidelines[7]. This can make scheduling triggers very unreliable. Therefore, we instructed participants not to close the app completely. Nevertheless, we could not trigger the notifications as planned for a third of the participants that had initially signed up and could only use the data of the remaining ten participants. By design, there are also small delays between originally and actually observed notification times, as scheduled alarms are also optimized for battery drain[8]. Such delays are perfectly acceptable for use cases such as ours, where the exact timing is not crucial. As an alternative, developers can, for example, use server-triggered push notifications.

5 THE ASCOLTAMICRO APPLICATION AND PLUGIN TRIGGER

While entries in a user's agenda indicate availability, they do not indicate the intention to engage. Clearly, one method to find out if someone is ready to engage—in our case, with their mobile device—is to see them engage with their device. Thus, for our second trigger, we focus on user activity to infer opportune moments for microlearning. Thus, we additionally eliminate the need for access to personal calendar data.

Specifically, we look at headphone interaction. Many commuters, in particular, young people, use headphones [49]. This provides ample opportunity to listen to audio content in short work or study sessions. Nonetheless, learning activities and podcasts were the least frequent reasons for wearing headphones—nudging people towards productive pastimes might make a difference here. Therefore, we present the Android app AscoltaMicro[9] that combines a headphone trigger with an audio-based mobile learning application. Each time the headphones are plugged in on a mobile device, users receive a notification asking them if they are currently available for receiving audio content. If they confirm, we play audio content for language learning on the headphones. Using audio content instead of flashcards in a comparatively generic app enabled us to match the trigger activity, the learning activity, and the learner environment. For example, headphones are often used on the go, but Anki flashcards require looking at the screen. Specifically, we developed Italian conversation scenarios for German learners that are gradually constructed from vocabulary to the full conversation. For each item, the Italian version is followed by its German translation. For better discriminability, a female speaker spoke the Italian part and a male speaker the German part. Each scenario contains several repetitions of the same item to improve retention (spaced repetition, [19]). The session ends when a user explicitly cancels it or disconnects the headphones. When the next session starts, audio content resumes at the last saved position. The overall duration of the content was set to 2 hours per week, i.e., 4 hours in total for the two weeks we prepared.

The application is built for Android smartphones and works on devices with Android 4.1 or newer, which makes it accessible for a large audience. Besides the notifications, it only provides a static screen showing the progress, reducing the necessary interaction—and, therefore, distraction—to a minimum (see Figure 5).

5.1 User Study

In an exploratory between-subject study, we compared the *plugin trigger (PT)* to a conventional *notification trigger (NT)* that showed in the notification drawer or on the lock screen whenever users unlocked the phone or accessed the lock screen. The aim was to investigate the relationship between the triggers and resulting session

[7] https://dontkillmyapp.com, last accessed 2021-09-29

[8] https://developer.android.com/training/scheduling/alarms, last accessed 2021-09-29

[9] "ascolta" is Italian for "listen"

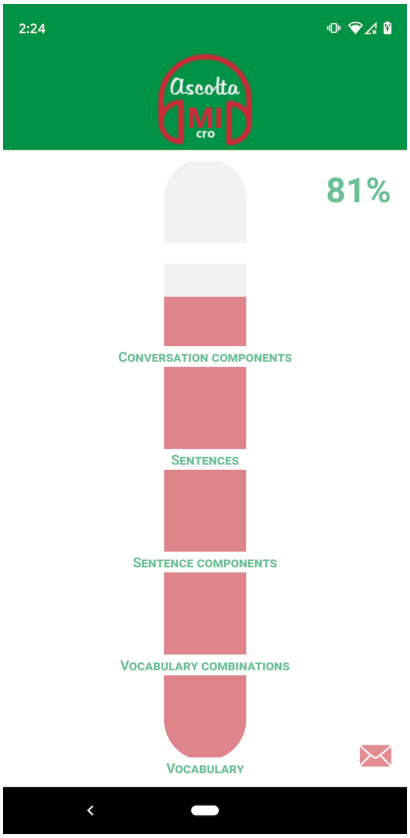
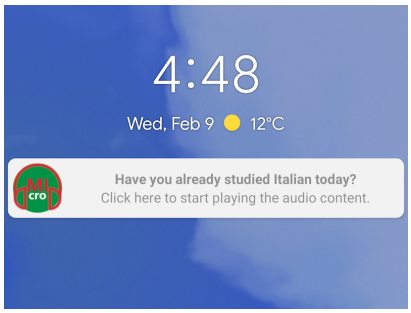
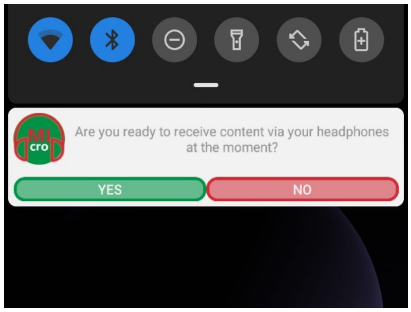


Figure 5: Main screen of the AscoltaMicro app



(a) **Notification Trigger**



(b) **Plugin Trigger**

Figure 6: Notifications displayed for the two different trigger types

characteristics, such as their frequency and duration. Furthermore, we collected the participants' opinions on usability, usefulness, and overall impression, as well as their performance in a conversation test.

We chose notification triggers as the control condition because they have successfully been used as learning triggers in the past [33, 37] and do not require access to personal data. Furthermore, the high frequency of smartphone pickup events [26] made it less likely that we would miss suitable moments. At the same time, we avoided uncertain methods for context inference, such as inferring user boredom (cf., [11]).

5.1.1 Procedure. Before starting the study, participants responded to a pre-study questionnaire on demographics, the participants' commuting behavior, smartphone usage habits, as well as their headphone usage situations and frequency.

The practical part of the study consisted of two one-week phases for using either the PT or the NT app in the participants' daily routines (one week per conversation) and a follow-up conversation test and interview. As for the previous study, there were no further instructions regarding the expected frequency or duration of learning sessions, so participants were free to use the apps and triggers at their own pace. However, in case they usually wore Bluetooth headphones, we asked PT users to switch to headphones with an audio cable instead[10]. During the two weeks of active use, we logged timestamps of all trigger occurrences, the responses to triggers, session duration, and conversation progress.

After the learning phase, the participants met with an experimenter who administered a System Usability Scale (SUS) questionnaire. When participants mentioned issues, we added follow-up questions. In addition, we asked questions that were specific to our project, e.g., in what situations participants confirmed or declined content and how they liked learning with this type of application.

5.1.2 Participants. We recruited ten participants (8 female, 2 male) who had no prior Italian skills and a daily headphone usage and commuting time of at least one hour. They were between 18 and 26 years old ($M = 22.4$ years, $SD = 2.7$ years). They were divided into a PT and an NT group; the groups were balanced based on the commuting behavior, smartphone usage frequency, and daily headphone usage time they had reported in the pre-study questionnaire.

5.2 Results

Below, we report engagement with the AscoltaMicro app, e.g., compliance rate and progress, and summarize qualitative feedback on the usability Again, we use Bayesian t-tests to compare results obtained from the PT and NT conditions, the alternative hypothesis H_1 being that there is a difference between the conditions. We additionally report Welch tests.

[10]We did not implement support for Bluetooth headphones in the current system because of challenges caused by Android versions and drivers on different devices.

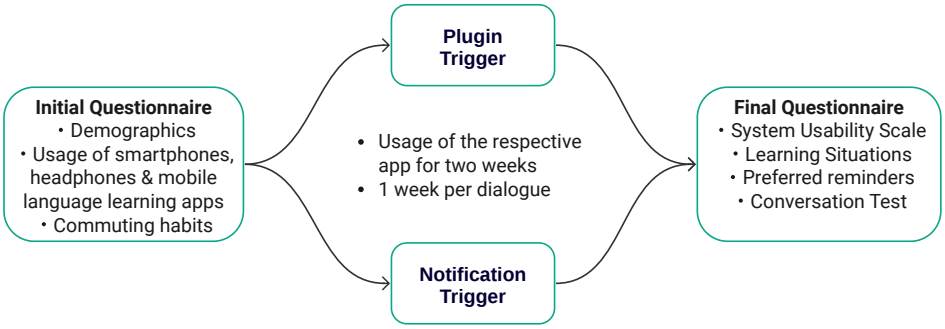
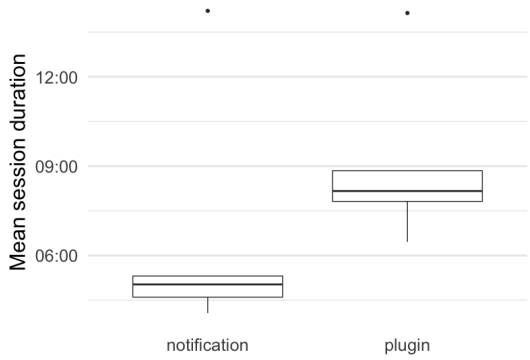
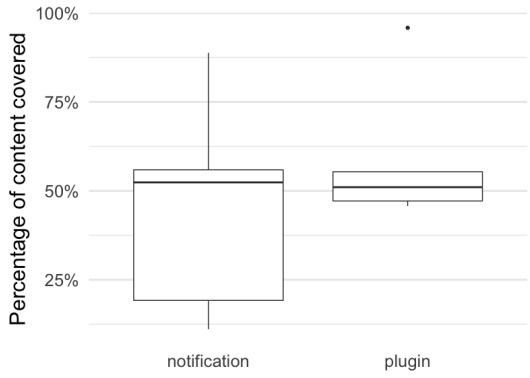


Figure 7: Procedure of the user study comparing triggers based on headphone plugin events to push notifications.



(a) **Mean session duration (mm:ss). The sessions started with plugin triggers tended to be longer.**



(b) **Progress (percentage of content covered). The notification trigger condition resulted in higher variability.**

Figure 8: Learning activity in our user study

Session Frequency, Duration, and Progress. Quantitative logging results are summarized in Table 3. The Bayes factor of 3.74 indicates that the number of triggers differed between conditions; namely, it was higher in the NT condition than in the PT condition, as lock screen events are more frequent than headphone plugin events. The acceptance rate in PT was at 87.0% compared to 8.5% in NT; this data provides strong evidence in favor of H_1. In both cases, effect sizes are large (i.e., Cohen's $d > 0.8$) and, hence, the effect is likely to replicate even with larger sample sizes. On average, participants in the NT condition started more sessions than in the PT condition. Per day, PT users received approximately 2 triggers and started 1.7 sessions, whereas NT users received 35 triggers and started 2.2 sessions. NT sessions were slightly shorter, and in total, the overall progress (i.e., content listened to) was lower than in PT. An average NT user listened to 1:49 hours of content and an average PT user to 2:22 hours of content.

Qualitative Evaluation of App Usage Situations. The concluding interviews gave insights on the perception of triggers, the desired frequency and modality, and preferred usage situations. Below, we use parentheses to indicate how many participants from the two conditions mentioned a given aspect or agreed to a statement. For example, "(4 PT, 1NT)" stands for "four participants from the plugin trigger group and one participant from the notification trigger group". In addition, when we quote participant statements, we use the codes P1 to P5 for the participants in the plugin condition and N1 to N5 for the trigger condition, respectively.

As in the online survey described earlier, participants mostly decided to start learning sessions when they were on public transport or in transit in general (4 PT, 5 NT). Some also used the app in the evening or before going to sleep (2 PT, 2 NT) or as a secondary activity while shopping (1 PT), getting ready to go out (2 NT), or cleaning (2 NT). N4 additionally started learning sessions to avoid other tasks she was not in the mood for. On the other hand, participants did not start sessions when they wanted to study (2 PT, 2 NT), when they explicitly wanted to listen to music (2 PT), when they were doing something else on their phones (1PT, 2 NT), and when they were at work (1 NT), at university (1 NT), or with friends (2 NT).

Qualitative Evaluation of Triggers. For half the participants, there were moments when they found the triggers annoying (2 PT, 3 NT) or even a bit pressurizing (N4). For example, P4 did not like that when she just wanted to listen to music, she was always asked if she wanted to study. The other half did not find the triggers annoying (3 PT, 2 NT). N5 specifically mentioned that she just did not notice them anymore at some point. Overall, the triggers were motivating for the majority of participants (3PT, 4NT). P5 said she

Table 3: Overview of triggers and learning sessions (average per user). H_1 is that there is a difference between the conditions. Comparisons where a Welch test was significant ($p < 0.05$) are marked with an asterisk.

	NT	PT	BF_{10}	Welch test
Number of triggers	489.0*	28.4*	3.74	$t'(4.02) = 3.02,\ p < 0.05,\ d = 1.91$
Number of learning sessions	30.2	23.8	0.50	$t'(7.55) = 0.63,\ p = 0.55$
Acceptance rate	8.5%*	87.0%*	6513.9	$t'(5.49) = 12.88,\ p < 0.001,\ d = 8.15$
Average session duration (m:ss)	6:38	9:05	0.69	$t'(7.13) = 1.01,\ p = 0.32$
Overall time spent listening (h:mm)	1:49	2:22	0.60	$t'(6.99) = 0.81,\ p = 0.44$
Content covered (progress)	45.5%	59.0%	0.60	same as overall time

was motivated by the progress bar shown in the app rather than the triggers. N5 suggested that showing images representing goals, e.g., pictures of a holiday destination, would increase her motivation much more than text notifications.

We also asked the participants how many triggers per day they would consider suitable: 3 PT and 2 NT users opted for 1 to 2 per day, 1 PT and 1 NT user for 3 to 4/5, and 2 NT users for 4 or more. N2 even suggested as much as one notification per hour. To further adjust the triggers, participants suggested setting fixed times of the day (3 NT), defining notification windows (N3), or suspending triggers when the learner has already fulfilled a daily study quota (P3).

Overall Usability. The notification trigger app obtained an average SUS score of 88.0 ($SD = 7.4$) compared to 90.5 ($SD = 5.7$) for the plugin trigger. Overall, the apps were considered very easy to use (4 PT, 3 NT). Three participants particularly mentioned that they liked the idea of learning while doing something else (1PT, 2NT). N5 appreciated the pleasant voice and adequate speed.

The participants also gave some suggestions for improving the overall app design. For instance, four participants would have preferred either only German-Italian item pairs or a mix of both (instead of Italian-German). Hearing the native language before the foreign language part would give them a bit of time to think about the correct foreign-language solution. Some felt that seeing the words or phrases as a text would have helped them to also learn the spelling (1P, 2N). Five participants requested a pause button or the possibility to replay content.

5.3 Discussion and Limitations

Participants in the PT condition accepted around 7 out of 8 session triggers. This suggests that in a majority of cases, headphone usage times coincided with moments considered suitable for audio-based learning. Hence, audio material is a promising match for a headphone event. There were some situations where the audio content would have interfered with the intended usage of the headphones (e.g., listening to music) but overall, our design motivation to match the modality of material and triggers seems to be valid. Nonetheless, further research across different materials and triggers will be necessary to validate this as a design principle. Participants in the NT condition had more learning sessions in total, probably also because they received more triggers than in PT. The fact that the sessions were slightly shorter and that the users reported a larger number of different situations where they did not start a session reflects the variety of contexts where triggers appeared.

In follow-up work, we also plan to evaluate the difference between notification triggers and plugin triggers to no triggers at all. We will add experience sampling questions to assess learner decisions and get more insights into when a trigger was accepted or declined. Thus, we aim to get a better impression of learners' app usage contexts, as well as learners' intrinsic motivation and persistence, especially in the long term.

In both conditions, the triggers contributed to the learners' motivation. At around one hour per week, the average content covered in both conditions was considerable. The overall time was higher than the approximately 0.6 hours reported in a 2013 study on mobile language learning [7] and comparable to the numbers of a more recent self-report study [21]. Even when assuming that motivation decreases over time, this time can be considered a valid addition to language classes or as a standalone solution for learning a limited amount of new material. On the other hand, some participants also mentioned that the triggers were annoying or pressurizing at times. In NT, a major factor was certainly the number of triggers we sent. In the future, it would, therefore, be interesting to evaluate if annoyance decreases when the number of triggers is decreased or limited to specific times and situations.

An important extension of the PT is the support of Bluetooth headphones. As a first step, plugin events would then be replaced by connection events. However, it is important to analyze differences in usage in more detail. For example, if users are wearing their headphones continuously, alternative events such as *play* and *pause* might be more suitable. Moreover, the PT and the Hybrid Agenda Trigger could be combined by checking a user's agenda when they connect headphones. For example, this could avoid triggering learning sessions during online meetings.

Taken together, the results indicate that our current implementation of PT is accepted well, even though it needs modifications before it will result in changes in learning behavior.

6 GENERAL DISCUSSION

Detection of Opportune Moments. Our motivation was to reduce the complexity of modeling a learner's state [11] by including humans in the decision loop, who inherently understand their own situation [10]. In our specific use case, we do so by combining the detection of learner availability and intention to engage with simple user interactions to confirm or decline triggers. Overall, we found that users were less compliant with Fixed Daily Triggers and Hybrid Agenda Triggers than with Plugin Triggers. On the other hand, the average number of training sessions per day was lowest for the Hybrid Agenda Trigger, followed by the Plugin Trigger. Thus, the

Plugin Trigger minimized the overall number of notifications, but further actions are needed to simultaneously increase the overall number of learning sessions, i.e., to identify additional moments.

In addition, we expect that the time spent on activities and the achieved performance could be further increased through triggers that are specifically matched with different content modalities. In our case, PT was utilized for audio content only, but learning is more effective when it addresses several processing channels [25], and several participants mentioned that they would have liked to have additional visual content. A trigger for text- or image-based content would then occur at moments when the visual channel is likely to be available.

In sum, the Plugin Trigger and the Hybrid Agenda Trigger are examples of how comparatively simple inferences with human feedback can be used to build an intelligent system for achieving a specific goal [46]. Namely, our approaches enable adaptation and personalization and, by reducing the number of push notifications, lower the information load on users [16].

Future Developments. The two triggers presented in this work are certainly not the only possible approaches. Besides the trigger strategies presented in Section 2.3, additional approaches that could be used as triggers are changes in the device status, e.g., turning off the do-not-disturb mode or initiating microlearning sessions to redirect user attention from "time-wasting" activities [17]. Beacons that are placed around the house and trigger upon interaction with objects could be used as an extension of Beaudin et al.'s cues representing specific vocabulary items to more generic learning material [3].

Dealing with Notification Overload. Users of mobile devices are constantly confronted with notifications issued by the apps installed on their devices [31, 34]. This leads to constant disruptions and often causes stress and annoyance. Especially for messenger apps, people feel the need to respond quickly, regardless of where they are and what they are currently doing. Therefore, current research explores approaches to notification management [13, 31]. Such systems typically operate on a system level and present notification bundles at activity breakpoints. The triggers for microlearning that we investigated in this work also aim to detect activity breakpoints. However, being rooted in the app itself, they "know" about the actual task they are intended to trigger. By improving the match of situations and triggers, we aim to reduce the overall number of triggers, thus making triggers more effective.

Habit Breaking and Habit Formation. Work in the domain of self-logging has shown that a cue like finishing lunch can contribute to building a habit of reporting food intake and increase self-initiative rates [40]. Traditional push notifications, on the other hand, were less effective at establishing habits, as there was no need for users to remember actions on their own accord. Furthermore, habit building through reminder notifications for activities such as microlearning is challenging because of the pervasiveness of other notifications calling for user attention. Amid the disruptions and stress caused by numerous calls to answer emails, start one's daily exercise routine, read news, check social media, and others, the association of trigger moments to specific activities may prove essential to break "bad" habits and to work on tasks when they best match the circumstances.

7 CONCLUSION AND OUTLOOK

In this work, we summarized prior work on task triggers, and in particular, microlearning triggers. We extended our insights with a survey on microproductivity reminders in everyday life. We found that respondents often started tasks on intrinsic impulses or because they used physical triggers like handwritten to-do lists; fewer respondents relied on digital task triggers. We then implemented two trigger strategies for language learning sessions: a hybrid agenda-based system utilizing calendar entries, device status, and snooze times, and a headphone plugin trigger for audio-based microlearning. The Hybrid Agenda Trigger system did not manifest a higher compliance rate or more learning sessions than daily notifications at a fixed time while requiring access to personal data. This motivated the design of a less privacy-invasive method that would, besides availability, additionally capture the intention to engage with the device. We evaluated the plugin trigger in comparison to a notification trigger that appeared on phone-unlock events and found that the situations where the headphone trigger appeared seemed to have frequently coincided with moments suitable for audio learning.

For future designs, we envision a combination of user-defined and context-based triggers for microlearning. For example, our plugin trigger could be extended with a trigger for textual exercises when opening a game app and a notification trigger that only shows when a user has not studied for a while; the visual design could provide a glimpse at where a user left off. Users could then personalize the set of triggers based on their individual preferences and current availability in different contexts and for different contents. On the other hand, systems could learn from observed acceptance and snoozing patterns. Similar triggers could also be useful in microproductivity contexts as described in [42].

Finally, it remains to note that finding the right balance between productive use of time and time to relax is important. Triggers for microactivities should not make people feel more stressed than they already are. Instead, the idea is that anything that can be managed as a microactivity is taken care of in idle moments. This can leave us with longer streaks of time to deal with the tasks that require continued focus. Thus, well-timed microlearning (or microproductivity) sessions contribute to successful time management instead of increasing the overall perceived workload.

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