Exploration of a Multi-Device Smart Calendar Platform for Smart Homes

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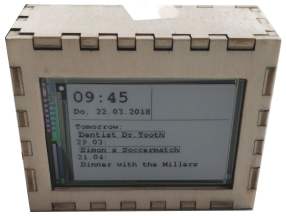
Abstract
Calendars are an essential tool for users to manage their daily schedules. With the expanding availability of Internet of Things (IoT) devices and smart home appliances, more and more connected devices appear in the homes of users. Some of these devices have the potential to complement, extend or even replace existing physical and digital calendars. However, little is known about how these devices should display calendar information without overwhelming users and negatively influencing their digital well-being. In this paper, we report the results of a lab study with 18 participants in which we compared calendars on seven different types of devices in the smart home context, from existing smartphone apps to novel e-paper displays and smart mirrors. We developed a smart calendar platform as a research probe and provide first insights into how different devices should convey information in future smart homes.

Author Keywords
Smart calendar; multi-device; internet of things; smart home; ambient information system.

CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI);** *Empirical studies in ubiquitous and mobile computing;*

(a) Smart Mirror



(b) E-Paper Display

(c) Smart Light

Figure 1: Novel smart home devices presenting calendar information.

Introduction and Background

Nowadays, traditional home appliances and artifacts of domestic environments are being replaced with their "smart" counterparts. For example, regular toothbrushes are replaced with electronic toothbrushes that notify the users using ambient light when they apply to much pressure. At the same time, novel home appliances such as smart speakers are becoming commercially available, and they have the opportunity to support users in their daily lives.

People from all age groups tend to forget upcoming appointments and tasks [5]. Former research has shown that younger people forget more diverse things, while older people forget tasks and appointments more frequently [5]. Therefore, there is a need for smart home reminder systems supporting people from all age groups. Today, people use various strategies including paper-based reminders and technological reminder systems to avoid forgetting upcoming tasks and appointments such as calendars [5].

Related work on calendar usage in domestic environments found that physical wall calendars are the most used calendar type in domestic environments [1]. Furthermore, families use calendars to organize their daily lives and to gain an awareness of the daily schedules of family members [1, 4, 6]. A body of previous work investigated how digital calendar data can be integrated into domestic environments [2, 4, 7, 8, 10, 12]. Calendar information should be displayed in frequently visited places in a home environment [2]. Matviienko et al. investigated using a physical cube to display additional information from another person such as calendar data [4]. Plaisant et al. developed a shared wall calendar using digital paper for multigenerational families [8]. Neustaedter et al. investigated an e-paper calendar and observed that their prototype enabled participants to gain an awareness of activities which influences in return the organization and coordination of their daily lives [7]. Voit et al. investigated the concept of a digital wall calendar that informs users automatically about upcoming events according to their interests [10, 11, 12].

In the era of the Internet of Things (IoT) and the smart home, other internet-connected devices such as smart speakers or smart mirrors enter in the users' homes and can be used to inform users about calendar information. Previous work explored how smart home notifications could be displayed in the future [9, 14]. However, it remains unclear how users experience smart devices displaying calendar data, and which kinds of devices are suitable to present calendar data while respecting the users' attention and digital well-being. In this paper, we explore how different smart devices in a smart home environment can be used to support users in their daily lives. For this purpose, we built a smart calendar platform as a research probe that informs users about upcoming appointments on multiple devices. We conducted a lab study with 18 participants, in which we compared calendars on multiple types of devices, from existing smartphone apps to currently available commercial products such as smart speakers and novel e-paper displays and smart mirrors. Further, we provide first insights into how different devices should be used to convey information in future smart homes.

Study

In a lab study, we explored the suitability of seven smart home appliances for conveying calendar information to users. In detail, we investigated three novel smart home devices (i,e., smart mirror, e-paper display, and smart light) as well as four common commercially available smart devices (i,e., smartphone, smartwatch, smart speaker, and website) for presenting calendar information.

(a) Smartphone

(b) Smartwatch

Figure 2: Part I: Common commercially available devices presenting calendar information.

Design

For the conducted lab study, we used a within-subject design with the device as the independent variable. Thus, all supported devices were presented to each participant. The order of the presented devices was randomized among all participants.

Apparatus

We developed a Smart Calendar Platform (SCP) that can be used to control a wide range of smart devices. The SCP consists of a central database that controls user accounts and appointments. Smart devices connect to the SCP using WiFi and WebSockets. The SCP also supports user detection using Bluetooth Low Energy beacons with a room level precision. This can be used to only display appointments if the user is nearby. We integrated seven smart devices with the platform, including commercially available and novel device types (see Figures 1, 2 and 4).

Smart Mirror We created a smart mirror using a 27" monitor in portrait orientation with a custom wooden frame and a two-way glass mirror (see Figure 6). The device is connected to a Raspberry Pi 3 hidden in the wooden frame running the Android Things operating system and a full-screen Android app for listing the appointments. Important appointments can be highlighted using colors.

E-Paper Display The e-paper display consists of a 2.7" black and white e-paper display from Pervasive Displays connected to a Raspberry Pi Zero W inside a wooden box. Since there is no color, important events are underlined.

Smart Light We combined a LIFX Color 1000 light bulb with an IKEA FADO table lamp and connected it to a Raspberry Pi 3 via WiFi. The smart light fades from white to green to indicate an upcoming event. Important appointments fade to red instead.

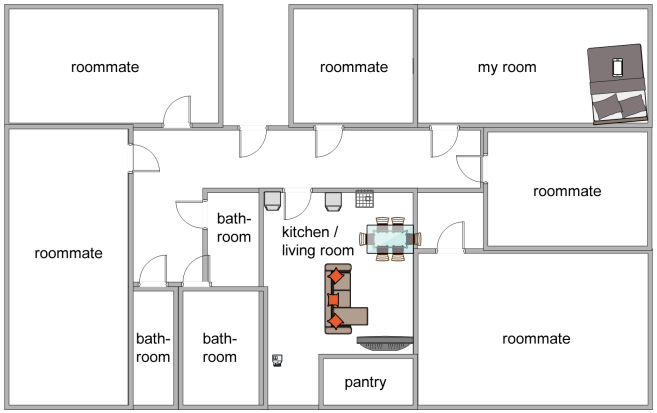


Figure 3: The sketch created by P1.

Smartphone & Smartwatch We created a custom app for Android-based phones and watches that connect to the SCP and displays a list of appointments. Similar to the previous artifacts, the apps can highlight important appointments using color-codes.

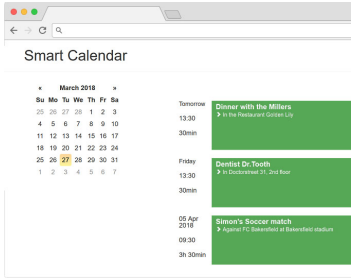
Smart Speaker We developed a custom skill for the Amazon Echo Dot smart speaker. The skill uses a wake word and text-to-speech to announce upcoming appointments aloud.

Website We created a website intended to be used on laptops and PCs that lists upcoming appointments.

Procedure

We individually invited the participants to our lab and asked them to sign a consent form and to fill in a demographic

(a) Smart Speaker



(b) Website

Figure 4: Part II: Common commercially available devices presenting calendar information.

survey form. The participants then sketched their living environment on a desktop computer using the Microsoft Visio diagramming software (see Figure 3). This was done to enable the participants to reflect on their own homes during the study. While the participants were creating the sketches, we asked them about their daily routines. We then presented the seven artifacts (see Figure 6), with three exemplary appointments each. Afterward, we asked the participants to add the artifacts that they could see themselves using to the sketches of their living environments. We asked the participants to speak aloud their reasoning where and why they placed the artifacts. We then conducted semi-structured interviews in which we asked about suggestions and concerns. Finally, we thanked the participants for their participation and rewarded them with sweets. Each session took approximately 45 minutes.

Participants

We recruited participants using university mailing lists, social media (university groups), and flyers on the campus. Eighteen participants participated in the study (4 female, 14 male). They were 20-26 years old ($M = 22.56$, $SD = 1.77$). All participants were students. Six participants lived in shared apartments, four alone, three with their partners, and five together with their families.

Results

Devices

All participants owned a smartphone. Additionally, ten participants owned a tablet, six a smart TV, three a smartwatch, one a smart speaker and one a smart light.

Calendar Usage

All participants except one used digital calendars to organize their appointments. Three participants shared their digital calendars with other people. Thirteen participants

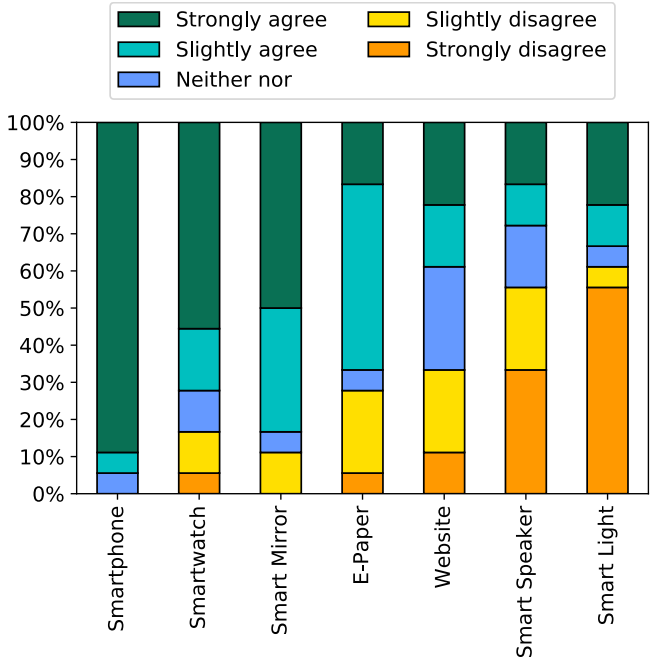


Figure 5: Agreements to the statement *"I would use the device to display my personal appointments."* on a 5-point Likert scale.

stated to use wall calendars. Seven of those share them with other people. Further, three participants use table calendars and two pocket calendars. Apart from these traditional types of calendars, participants also stated to use to-do lists, sheets of paper, alarm clocks, timetables, and reminder functions of devices to manage their appointments.

Types of Appointments

We asked the participants for which types of appointments they use their calendars. Most participants (13) used them to manage their university courses and exams. Other types

of appointments were doctoral appointments (5), birthdays (4), work-related appointments (3), sports (2), vacations (2), meetings with friends (2), and music practice (1).

Artifacts
Figure 5 shows the agreement ratings to the statement that participants would use a specific device to manage their personal appointments.

Figure 6: Placement of the smart mirror in the lab study.

The *smartphone* received high agreement ratings, as participants already use the device and want to continue to use it. Participants liked that they can manage their appointments on-the-go, as the smartphone is always with them. Further, participants liked the fact that they receive notifications about upcoming appointments.

Participants stated that in some cases the *smartwatch* could be more convenient than the smartphone. The smartwatch allows checking appointments at a glance without having to take out the smartphone. Participants stated that they frequently check the time anyway. Further, the like the idea of being notified unobtrusively through vibrotactile notifications. However, some participants disliked wearing a watch.

The *smart mirror* was overall well received for all kinds of appointments. Participants suggested replacing existing mirrors, e.g., in the bathroom and entrance corridor. This way, participants could get an overview of their appointments when they already use the mirror. Participants liked the idea of using the smart mirror in the morning or evening. They suggested that the additional screen real estate could be used to provide additional information, e.g., displaying maps and estimated travel times.

Participants suggested to place the *e-paper display* on their nightstand or desk. They liked the idea of the e-paper display being a flexible device that could be placed almost anywhere. Further suggestions include walls and doors, where it could replace traditional wall calendars.

The participants found the traditional *website* limiting. They disliked the idea of having to boot their PC or laptop to be able to check their appointments. However, they found it a viable alternative if, for instance, their smartphone battery was empty. Similar to the smart mirror, participants suggested making better use of the additional screen space.

The *smart speaker* received low ratings. Most participants disliked the idea of the smart speaker listing their appointments using text-to-speech. Participants stated that the speaker reported the appointments in a monotone fashion, which requires a high cognitive effort to keep up. As multiple appointments could easily overwhelm the participants, the smart speaker should only be limited to important appointments to keep the list short. However, participants stated that the smart speaker could be used while cooking for a hands-free interaction or if the smartphone is not in reach. We used an Amazon Echo Dot in the study that many participants were already familiar with. Some participants raised security and privacy concerns regarding using an always-listening smart speaker that processes voice commands and appointments using cloud services.

Participants found that the *smart light* does not convey enough information. They stated that the smart light could be used as a second channel for notifications, e.g., telling the user when to leave for an appointment in a subtle and unobtrusive manner. However, this should be limited to special appointments to not overwhelm the users. Participants suggested that the smart light could be used in every room by replacing existing light bulbs as the user sees fit. Further, they suggested that the colors and patterns used should be customizable.

Additional Devices
We asked participants about suggestions for additional devices. Participants would like to see an integration of the smart calendar platform in the entertainment system for their cars, in wall clocks, and smart TVs [13]. Further suggestions included using projection to display the calendar on the ceilings or shower curtains [3]. One participant suggested integrating e-paper displays in couch pillows. Another participant suggested blinds that automatically open depending on appointments.

Concerns
Participants raised privacy concerns about calendar appointments being visible in the smart home environment. They stated that the artifacts should only display appointments when the user is nearby. In some cases, sharing appointments with multiple users might be useful. However, this depends on the user's relationship to the other party.

Additional Comments
Participants suggested conveying additional information apart from calendar appointments. Participants mentioned weather updates, news, to-do lists, traffic information, emails, shopping lists, and alarms.

Discussion and Conclusion

In this paper, we investigated the suitability of three novel and four commercially available smart devices for displaying calendar information to users. We developed a smart calendar platform as a research probe and conducted a lab study with 18 participants in which we compared multiple types of devices, from smartphone apps, smart speakers to novel e-paper displays and smart mirrors.

We observed that participants wanted to continue using smart devices that they already use, for instance, the smartphone that is almost always with them. However, participants could also imagine using novel smart home appliances such as smart mirrors or portable e-paper displays that present their daily schedules. Especially for smart home appliances that are integrated with the users' homes, the glanceability of the displayed information is an important factor for the acceptance of those appliances. Another important factor is that smart devices should convey sufficient information to users. While smart lights might be suitable to convey additional information in the background as an ambient notification without interrupting the users (e.g., when it is time to leave home to be on time for an appointment); they are inappropriate for displaying other relevant parts of information (e.g., which appointment type it is or where the appointment is taking place).

The results of our study revealed that participants, in general, preferred visual output for presenting calendar information. Auditory output, as current smart speakers nowadays provide, was experienced as too monotone and associated with high a cognitive effort. However, using smart speakers can be a useful addition in specific situations, e.g., for hands-free interactions during cooking.

One limitation of our study is that we explored the suitability for displaying additional information on seven smart devices in a lab study. However, the presentation of the artifacts enabled the participants to imagine how the artifacts would behave in their daily lives. In the future, we plan to connect our smart calendar platform to existing digital calendar applications (e.g., Google Calendar) and to study the different smart devices in a long-term study in participants' homes.

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