Investigating Users' Perceptions of Light Behaviors in Smart-Speakers

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ABSTRACT

Light expressions can communicate and convey information in an unobtrusive manner. Smart-speakers employ light behaviors to indicate a wide range of device states as well as notifying users. However, no prior work has looked into the efficacy of these light behaviors in smart-speakers. That is, can users distinguish and understand information states associated with different light behaviors in smart-speakers? In this work, we aim to address this gap by investigating whether users can accurately identify light behaviors in Amazon Echo and Google Home devices. For this, we conducted an MTurk survey with 243 smart-speaker owners. Our findings reveal that only 34% of the light behaviors are

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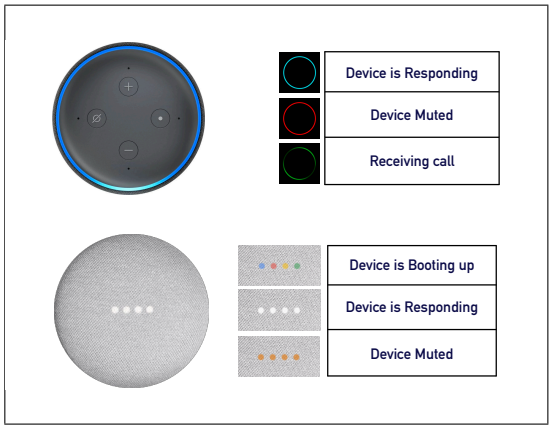
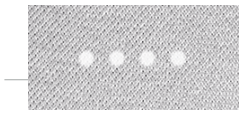


Figure 1: Amazon Echo Dot with the light ring and Google Home Mini with the LED lights along with a sample of their light behaviors. Total no. of light behaviors in Echo Devices: 12; Total no. of light behaviors in Google Home Devices: 17

Scenario: *You initiate a new interaction with your google home device using the "Hey, Google" or "Ok Google" and the following light pattern appears.*



What information do you think the device is trying to convey?

Figure 2: Sample Survey Question

correctly recognized by users on average. Moreover, we found that users find it easier to recognize light behaviors in Amazon Echo than in Google Home devices. These findings show a clear need for rethinking the design of light behaviors in smart-speakers. We also explored novel light behaviors that users might find useful but are not supported by current devices including expressing sentiment and privacy notifications.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in interaction design**; *Empirical studies in HCI*.

KEYWORDS

Smart-speakers, Light behavior, Expressive Light, Notifications

INTRODUCTION

Light as a medium of communication has gained significant popularity in the recent past. Several studies have analyze how expressive lights can be useful in conveying informational states. Harrison et al. [3] discussed the use of point lights in ubiquitous devices and designed a light vocabulary to convey informational states of a smartphone. Similarly, papers focusing on human-robot interaction have also leveraged light to communication states and intentions [1, 2, 5, 7, 8]. Using light as a medium of information delivery can ensure minimal interference with other modalities, while allowing individuals to focus on their primary work without being distracted [4, 6]. In recent years, smart-speakers have also leveraged light patterns to communicate information states in an unobtrusive manner. Although previous work lends considerable merit to using light as a modality of communication, researchers have only focused on utilizing this design space within smartphones and Human-Robot Interaction applications. There is a conspicuous lack of research that applies the efficacy of visual communication within the context of conversational agents and smart-speakers.

The most widely used smart-speakers, Amazon Echo and Google Home devices, have dedicated light apparatuses (the light ring in Echo devices and the LEDs in Google Home devices). These are used to provide crucial information without interrupting the natural flow of voice interactions. Figure 1 shows a sample of the light behaviors for Amazon Echo and Google Home devices. Most smart-speakers do not have screens and hence rely only voice interface and light apparatuses to interact with users. Information conveyed through these light behaviors tend to be time-sensitive and complement voice interactions (such as error in Wi-Fi connectivity, notifications for receiving calls/messages). It is thus important to ensure that users correctly interpret these light behaviors. However, there has been no prior research that has looked into whether and how the users interpret these light behaviors. This project aims to bridge this gap in smart-speaker interaction. For this, we investigated how accurately

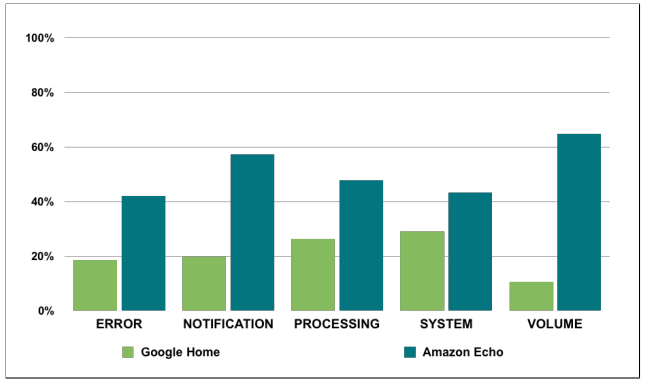


Figure 3: Comparison of average percentage of accurate response to light behaviors among Google Home and Amazon Alexa.

Light Behaviors	Category	Accuracy (%)
AE Message/Notification	Notification	60.2
AE Receiving Call	Notification	54.1
GH is thinking	Processing	53.5
AE processing request	Processing	53.4
GH waiting for response	Processing	50
AE unable to respond	Processing	46.6
GH resetting to factory settings	System	**82.7**
AE Starting	System	46.6
GH ready to set-up	System	46.3
Echo adjusting volume	Volume	64.7

Table 1: Ten Most Identifiable Light Behaviors in Amazon Echo (AE) and Google Home (GH) devices

users can interpret different light behaviors in Amazon Alexa and Google Home devices. We also explored how light in smart-speakers can further augment communication and support novel use cases in the context of smart-speaker interaction.

The primary research contributions of this work are:

- Understanding how users interact with light behaviors to augment voice interactions in smart-speakers (e.g., how frequently do they look at light apparatuses while interacting with these devices; which light behaviors they find most useful)
- Determining the efficacy of these light behaviors in conveying intended information (i.e., how accurately users can identify and interpret these light behaviors?)
- Exploring design opportunities for expressive light in smart-speakers by identifying novel information needs and use cases (e.g., expressing sentiment using light)

STUDY AND PRELIMINARY FINDINGS

Survey

To answer these questions, we deployed an online survey over 243 participants. The survey asked the participants about their smart-speaker use and interactions with light apparatus including whether they pay attention to it, how they orient themselves with respect to the smart-speaker (i.e., if they face smart-speakers while interacting with it), whether they rely on the light apparatus for information, and light behaviors that they find most useful. Participants were also presented with GIFs of light behaviors and were asked to identify the information that these behaviors conveyed (Figure 2). The survey also explored how expressive light can further augment the interaction model of smart-speakers. For this, we presented different novel scenarios to participants (e.g., using light patterns to notify about privacy risks). Participants then rated the perceived usefulness of leveraging light patterns in these scenarios.

Results & Preliminary Findings

Among the 243 participants, most users have had these devices for a year on average. About half the participants owned one smart-speaker device, 30% owned two, and 20% owned three or more devices.

In terms of interactions with the light apparatus, only 25% of the participants said that they 'Always' or 'Almost Always' pay attention to the light when it is trying to notify them. About 20% of the population 'Always' or 'Almost Always' rely on the light to obtain information, and this percentage of individuals does not vary significantly among users of different smart-speakers.

We also analyzed the average accuracy of participants in correctly identifying light behaviors in smart-speakers. Participants were directed to questions related only to the devices they owned (i.e., Echo owners only answering light behaviors in Echo). On average, participants correctly identified

Privacy Scenarios
1. Smart-speaker presenting different light patterns when unusual network activity is detected (such as transmission of personal data in clear text)
2. Smart-speaker presenting different light patterns based on the sensitivity of the information being shared in the interactions with the speaker and what it hears in the background
3. Smart-speaker presenting different light patterns when new devices/smart-devices connect to the smart-speaker at unusual times

Table 2: Participants were asked to rate the usefulness of using light patterns in a number of novel scenarios. For example, this survey question explored using light patterns to indicate privacy risks to smart-speaker users.

Parameter	p-value
Country	1.17e-05
Household Composition	0.0325
Age	0.00107
Possession Duration	0.0158

Table 3: Parameters with significant association with percentage of accurately identified light behaviors

only 34% of the presented light behaviors. Additionally, participants were better at identifying Amazon Echo's light behaviors when compared to Google Mini, Max or Home devices. The ten least identifiable light behaviors (with $\leq$ 15% of participants identifying them accurately) were all those used in Google Devices.

While analyzing the relationships between various parameters, we found that paying attention to smart speaker's light apparatus and frequency of smart-speaker usage have no significant impact on an individual's ability to accurately identify light behaviors. Furthermore, we found that age and duration of possession are statistically significant predictors of an individual's accuracy in identifying light behaviors (Table 3).

Finally, the survey also explored how current light behaviors can be expanded to support other informational states. We specifically focused on three use cases: sentiment, privacy, and discoverability of other smart-devices. Our data shows that 55% of participants indicated that they will find it very useful if emotions were conveyed through light during smart-speaker interaction. Furthermore, conveying emotions of higher valence (happiness, calm, surprise) were perceived more useful than those with lower valence (fear, anger, disgust). At least half of the participants agreed that presenting different light behaviors based on various privacy concerns would be useful (Table 2). Similarly, at least half of the participants agreed that using different light patterns to represent the capabilities of various smart-devices would be useful.

DISCUSSION AND FUTURE WORK

The findings show that a significant number of users are not able to accurately interpret the current light behaviors used in smart-speakers. In particular, participants had difficulty in interpreting a number of light patterns from Google Home devices. This raises the question about the usability and efficacy of current light patterns used in smart-speakers. Our data also points out the wide-ranging design opportunities to further augment smart-speaker interactions using expressive light. For example, participants highly rated the perceived usefulness of employing light patterns to convey sentiment and privacy risks. This will require designing tailored light behaviors while avoiding ambiguity and user confusion. Future work should focus on establishing a "light vocabulary" for smart-speaker interactions. Such a vocabulary will help to identify context-specific good light behaviors with strong and dominant ("iconic" [3]) interpretations.

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