# Investigating Everyday Information Behavior of Using Ambient Displays: A Case of Indoor Air Quality Monitors

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## ABSTRACT

With the advent of the Internet of Things (IoT), people are increasingly gathering and using information through ambient displays every day. While this everyday information behavior has become a common mode of human information behavior, little is known about the factors that constitute such practices to inform the design of information dashboards. Drawing from 729 user reviews of indoor air quality monitoring stations posted to Amazon.com as a case, this study investigates the process through which people gather and use information from an ambient display as everyday information behavior. By using sense-making theory as an analytical framework, we illustrate key themes that constitute ways in which people make sense of information through everyday information behaviors of ambient display use.

**ACM Reference format:**
Sunyoung Kim. 2018. Investigating Everyday Information Behavior of Using Ambient Displays: A Case of Indoor Air Quality Monitors. In *CHIIR '18: Conference on Human Information Interaction and Retrieval, March 11-15, 2018, New Brunswick, NJ, USA.* ACM, NY, NY, USA, 4 pages. DOI: https://doi.org/10.1145/3176349.3176880

## 1 INTRODUCTION

Information behavior is a term used to describe ways in which human beings interact with information "in relation to sources and channels of information, including both active and passive information seeking, and information use" [18]. "Active" and "passive" refer, respectively, to whether the individual does anything actively to acquire information, or is passively available to absorb information but does not seek it out [1]. Everyday information gathering is as important as active information seeking because people absorb much information naturally every day without expending energy to acquire it.

With the advent of new technologies, smart devices, and the Internet of Things, our living environments are increasingly becoming saturated with different types of digital devices and ambient displays. Consequently, the ways people seek information are changing. Moreover, smart environments make available a stream of real-time contextual information about the quality of our daily life and surroundings. Smart environments allow people to passively absorb information as part of daily routines without much effort or intention. Such information behavior is part of traditional everyday life information seeking as it focuses on the legitimate nature of information seeking in "the non-work context", such as health or hobbies, within everyday contexts "without explicit effort for acquisition" [14]. While everyday information behavior of using an ambient display is becoming a popular mode of information behavior, there has been little research to understand the factors that constitute such behavior. To that end, this study, through an analytical lens of sense-making theory, aims to elicit the factors that constitute everyday information behavior, using a device to monitor indoor air quality as an exemplary ambient display.

Indoor air quality (IAQ), as defined by the US Environmental Protection Agency, refers to "the air quality within and around buildings and structures, especially as it relates to the health and comfort of the building occupants" [6]. IAQ is an important determinant of health, as people in modern societies spend the majority of their time indoors, over 65% being in their residence [6]. An increasing body of evidence about a strong correlation between IAQ and health risks [16] has fueled the growing availability of IAQ monitoring stations (i.e., Awair[1], Foobot[2], Netatmo[3], See Figure 1) that make available the information about the current IAQ status to the residents. Consequently, researchers have started examining various aspects relating to the use of the instruments, such as measurement accuracy, behavioral effects, and influences on IAQ [10,17]. Yet another crucial research question requiring more attention is the conceptualization of everyday information gathering behaviors through the use of ambient displays.

Using 729 user reviews of three indoor air quality monitoring stations posted to Amazon.com, we conducted content analysis through the theoretical lens of sense-making theory to investigate how everyday information gathering is constructed, performed, and used. We found that increased health concerns relating to respiratory diseases or allergies are a vital trigger to IAQ information needs. Then, the reliability and interpretability of IAQ information posed gaps in making sense of the information, which can be overcome by observation of information over time and checking data accuracy with other compatible devices. Finally, the process of gap-bridging results in various outcomes of information seeking and use, including emotional anxiety relief and behavioral changes to remove indoor air pollutants. This work is a preliminary study of understanding everyday information behavior of using an IAQ monitoring device, and so we plan to investigate other ambient displays to contribute to our understanding of everyday information behavior.


*CHIIR'18, March 11-15, 2018, New Brunswick, NJ, USA.*

ACM ISBN 978-1-4503-4925-3/18/03...$15.00.
DOI: http://dx.doi.org/ 10.1145/3176349.3176880

[1] Awaire, https://getawair.com/
[2] Foobot, https://foobot.io/
[3] Netatmo, https://www.netatmo.com/en-US/site/


**Figure 1: IAQ monitoring stations: Awair, foobot, and netatmo (from left to right)**

## 2 LITERATURE REVIEW

### 2.1 Approaches to Information Behavior

Historically, the study of information behavior has been dominant in library and information science research. Major approaches to information behavior include information seeking and problem solving to study purposive behavior within a problem-solving framework to models of general problem solving (e.g., [3]); everyday life information seeking to refer to non-work or citizens' information needs and seeking [14]; and information foraging to understand how users search for information [13].

However, none of these approaches alone can completely explain human behavior in relation to everyday information behaviors of using an ambient display. The advent of pervasive and smart technologies has stimulated reconsideration of information behavior, broadening the approach from generic human-information behaviors to paying special attention to the communication patterns within people's particular situation or world to contribute to our understanding of information behavior.

### 2.2 Ambient Display: IAQ Monitor

Air pollution is recognized as one of the leading causes of death worldwide [4]. A growing body of scientific evidence indicates that indoor air pollution within homes and other buildings can be worse than outdoor air pollution even in the largest and most industrialized cities. Traditionally, IAQ measurements have been carried out using sophisticated and expensive equipment. In the past few years, however, there has been an explosion of low-cost IAQ sensors entering the market. Technologies are being developed not only to measure IAQ [18] but also to raise awareness of indoor air pollution and foster healthier everyday life; such developments are coming from industry and academia [7,8]. As interactive computing systems have been increasingly designed to allow people easy access to knowledge relating to health concerns associated with IAQ and to improve IAQ, it is critical to understand information behavior.

### 2.3 Sense-Making Theory and Gap-Building

The sense-making theory is a communications model that has been applied to information seeking and use studies [5]. It is established as a theoretical framework to understand everyday life information seeking, including both purposive (goal-oriented) and non-purposive information behaviors. This theory considers information seeking as a dynamic process situated in a specific space and time within a sociocultural context with four metaphors, including situation, gap, bridge, and outcomes [14]. In the sense making approach, the person is facing a "gap" (i.e., a sense-making need) that arises out of a context-laden "situation." Through the process of "gap-bridging," people seek information that leads to "outcomes" [11]. This theoretical framework is pertinent to understanding the dynamics of everyday information behavior in that it provides guidance to posit contextual questions as to how people interpret information to make sense of it. Therefore, this study examines the factors that constitute everyday information behavior of interacting with ambient displays using these metaphors as a theoretical lens.

## 3 METHODS

### 3.1 Data Collection

A total of 1028 Amazon.com reviews of three indoor air quality monitoring stations that had more than 100 reviews were scraped in July 2017. We chose to use Amazon.com's review corpus for this study because these reviews provide an unsolicited evaluation of the instruments and are a potentially rich source of descriptions of general uses of the instruments. Content analysis of web reviews has been used to understand reviewer opinions. No identifying information about reviewers was collected.

### 3.2 Content Analysis

First, the reviews were checked to ensure that they were related to the actual experience of using the instruments. Thus, reviews that were short or un-descriptive (e.g., "good product" or "Don't buy it") were excluded from further coding. The remaining reviews (N= 729, 71%) were used for analysis.

We analyzed the reviews using a thematic analysis to reveal patterns across data sets that are important to the description of a phenomenon and are associated with our research question. In particular, we applied both inductive and deductive approaches informed by grounded theory and other theory-driven qualitative analysis methods, such as thematic analysis [11,15]. That is, we inductively analyzed the data to allow for the themes to emerge, while we deductively reflected the emerged themes on the four constructs of the sense-making theory, including situation, gap, bridge, and outcomes. We examined if the emerged themes are compatible with the constructs; the emerged theme was categorized as the construct if the emerged theme fell under a subset of any of the constructs, and was introduced as a new theme if not. The final set of the themes has become the analytical framework through which we can understand the relationships among different themes and codes. We integrated all concepts through building relationships across the themes.

## 4 FINDINGS

Most emerged themes are associated with the key constructs of a sense making theory to elaborate on the process through which people gather and use IAQ information. In what follows, we describe the process of IAQ information gathering and use.

### 4.1 Situations to Trigger Information Needs

A "situation" is constructed by a set of contextual circumstances that provoke needs for information. Questions that elicit data on a person's experiencing of a situation include: "what issue were you dealing with?", "what led you to confront this issue?" and "what did you hope to achieve?" [7]. In the context of monitoring IAQ, the situation is made up of various needs to know about IAQ.

Concerns about IAQ are on the rise, triggering information needs about IAQ. The findings demonstrate that health- and space-related issues are the key factors that contribute to seeking IAQ information. The most common contextual cue is the increased health concerns relating to respiratory diseases or allergies. People who suffer from respiratory issues or allergies seek to learn the potential sources of the problem, and polluted indoor air has been known to have serious health effects on the respiratory system. Because many air pollutants are invisible and impossible to detect with human senses, it is very difficult with human perception to detect the changes in air quality. Therefore, people in search of IAQ information may end up purchasing IAQ monitors as a technical intervention.

*"As one of the people who suffered from all sorts of nasal-related illnesses, I was one of the first ones to buy this device."*

*"I'm hoping maintaining healthy air quality will help with the wide range of allergies and health issues between my fiancé, myself and the 2 cats and 2 dogs."*

Having a newborn or a young child with respiratory concerns (e.g., asthma) in the house is a critical trigger to the increased attention to IAQ. Since young children are particularly vulnerable to poor air quality, parents make an effort to ensure the quality of the indoor environment. With the current advancement of technology, an IAQ monitoring station is a plausible solution to cope with the problem, triggering the purchase of IAQ monitors.

*"I bought it a week before my new baby girl arrived."*

*"As a mom of a 2 years old having health troubles since birth I was looking for a device that could help me understand what is surrounding our environment."*

In addition, the change of a physical space has been identified as a spatial trigger. When people move to a new region where outdoor air quality is known to be poor or when people move in to a new house with new furniture, painting, and household materials, information needs for IAQ surge. Uncertainty about the quality of the dwelling environment triggers information needs about IAQ.

*"As an active woman, concerned by the threat of downtown NY pollution, I was looking for an easy way of keeping an eye on my indoor environment."*

*"I moved into a newly renovated home and suddenly had an allergic reaction. It subsided and returned. I was hoping this device would help me identify the VOC levels in the home."*

## 4.2 Gaps in Sense-Making

Ambient displays are designed to support serendipitous information gathering. With having an IAQ monitor installed in a residential space, people have easy and causal access to IAQ information as part of their daily practices. For example, they can glance at the display unintentionally whenever they pass by it as if checking the time on a clock or looking at a mirror with no purpose. However, we found that having easy access to IAQ information does not guarantee that people make sense of the IAQ condition. We identified two significant gaps that prevent people from making sense of IAQ information, namely *interpretability* and *reliability*.

The first is *interpretability* of the presented information. Most IAQ monitors represent the current state of IAQ using a colored graph (e.g., green meaning healthy and red meaning unhealthy) with numeric measures (i.e., the number of particles in the air). Many people reported that it is difficult, if not impossible, to interpret the information as meaningful knowledge. Because health concerns are a key trigger of IAQ information needs, people have sought to interpret the information associated with health concerns. However, the current ways of presenting IAQ information do not support these needs, as it lacks information relating to a healthcare context.

*"I think the information is not of a value. What does it mean? How does it impact health or so is not clear."*

*"Interpretation is a bit confusing. I'm not an air-expert so numeric display of $CO_2$ or VOC can't be easily understood… I wish is if the device told me what the VOCs means… It's really unclear how to interpret the value of the VOC measure e.g. 300 ppb vs. 600 ppb vs. 1200 ppb. I would love to see the meaning behind it."*

An equally critical issue is *reliability* of the available information. Due to the fact that there is no means to measure the accuracy of IAQ information presented on the instrument, people easily doubt its reliability once they experience a negative event with the use of the instrument. Example events include a drastic change of IAQ when nothing has happened or the presented IAQ information is not compatible with other resources.

*"I started to suspect that it the measurements were not accurate when I started to see significant swings in the readings, especially for $CO_2$ and VOC, with no significant changes in my home environment."*

*"My smoke alarm at home was going gang busters and it didn't detect anything. So I'm not entirely convinced of its accuracy anymore"*

As such, making the information just easy to access via an ambient display does not satisfy information needs nor guarantee valuable information. In what follows, the strategies to overcome, or "bridge", these two gaps are reported.

## 4.3 Bridging the Gap

"Bridging" is the process used to move across the gap when making sense of a situation. For example, bridging might involve actions that can influence cognitive or affective shifts, or influence values and stories or narratives. A question to elicit bridges is "what answers helped you better understand the issue?" [7].

A strategy to cope with the issue of *interpretability* is to observe the trend of IAQ information over time. It enables people to identify the repetitive IAQ patterns relating to the potential sources or solutions of indoor air pollution, as well as establishing empirical knowledge of what different IAQ conditions mean and their relationship with indoor activities. This experience is then used to interpret what the IAQ information means in relation to health concerns. Furthermore, building knowledge of the relationship between the IAQ status and its meaning helps improve its reliability, too. *"Since I started using the device, it's given me practical and reliable data about my home's air quality in real-time, as well as sets of graphs and trends that show air quality history."*

*"I find it very sensitive. Turn on the overhead fan, and the dust monitor will kick up. Open the window and $CO_2$ will go down."*

A strategy to overcome the issue of *reliability* other than building knowledge is to compare the IAQ information with other devices. While this is a costly option, those who are serious about IAQ willingly invested to ensure the reliability of IAQ data.

*"I wanted to make sure that I could trust this because my 4-year-old suffers from asthma. This device seems grossly inaccurate. I've now checked it against other devices, and all of the air quality measures seem off ($CO_2$, VOC and particulate)."*

*"The data from this device is crap. VOC is a min of 125 and the other data is way off compared to professionally tested levels in my home."*

### 4.4 Outcome

"Outcome" describes the ways in which people put information into use. The process of gap-bridging results in various outcomes of information seeking and use. In sense making, the outcomes of information use are referred to as helps or hurts. Empirical examples of "outcomes" include "got ideas, understandings", "got pleasure and confirmation" and "got connected to others" [7].

We identified *emotional* and *behavioral* outcomes from information behaviors of IAQ. First, emotional outcome refers to one's reassurance and relief from emotional anxiety or concerns about poor IAQ and its negative influence on health. This outcome was the most prevalent type and many people reported relief from emotional distress as long as they retain confidence in the reliability of the information.

*"I placed the unit nearby my newborn's bed for monitoring environment, and overall I feel much more secured about the air conditions."*

*"Before, all I could do at best is a 'sniff test'. Since I have placed it in our apartment, it has helped us gain immense insight as to how our behavior affects our air quality and vice versa.*

Once establishing empirical knowledge of what different IAQ conditions mean and their relationship with indoor activities, people start to change their behaviors, some of which have become daily habits, which we call behavioral outcomes. Increased awareness and knowledge about IAQ was a substantial factor in motivating people to alter their behavior to improve air quality.

*"I found that some rooms were getting to potentially unhealthy $CO_2$ levels, and that my office had too high of a dust level. This encouraged me to include a higher amount of ventilation throughout the house"*

*"It cultivated some good habits such as reinforcing us to open our windows after each meals we've cooked, or when to mopping and vacuuming the floor."*

## 5 DISCUSSION AND CONCLUSION

This case study reports the preliminary findings of the process through which people gather and use information from an ambient display as everyday information behavior, using IAQ monitoring instruments as a case. By using sense-making theory as an analytical lens, we identified key themes that constitute ways in which people make sense of information through everyday information behaviors of ambient display use. The findings demonstrate that merely making information available does not guarantee that people make sense of information. Thus, several strategies were employed for bridging gaps. However, further study is required as only one type of ambient display was studied.

As a next step, we plan to further investigate everyday information behaviors of ambient display usage to understand how people interact with such instruments in daily practice. We are hopeful that this study provides a step toward understanding the factors that constitute human information behaviors and informs the design of novel information dashboards.

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