Design Guidelines for Contextual Awareness and Management of Hygiene in Daily Life with Infectious Viruses

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Abstract

Background Hygiene management is important in reducing the danger of viral infection. Although various methods for hygiene management need to be considered depending on the context such as space, people, and activity, previous attempts do not consider these contexts. This implies the need for considering more contextual situations on hygiene management systems. Hence, we explored what hygiene-related data need to be received to prevent infectious diseases and how the data can be delivered to users based on different contexts.

Methods To address the above issues, we analyzed previous hygiene management systems to determine which types of devices exist and their features and we conducted a design workshop to determine potential product design based on the space the workshop participants visit and the objects interact by creating virtual personas.

Results We derived design guidelines for future hygiene management devices based on different contexts. First, the device should induce users to notice the hygiene conditions of their private space without being overwhelmed by relief. Second, the system should help users to feel relief in a public space by providing a concrete status. Third, typical misunderstandings about hygiene could be used for assisting users to intuitively obtain information about hygiene.

Conclusions As a result, we could derive new design guidelines for hygiene management systems from the perspectives of users' attention and relief to hygiene status, along with misunderstandings of typical cleanness, which implied design guidelines of future hygiene management devices. Specifically, the personal/public items, smart products and home electronics can be designed by considering users' routines and perceptions about hygiene in private to public spaces.

Keywords Design for a Pandemic, Air-care Systems, Hygiene Management

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1. Introduction

A rapidly spreading airborne virus can cause sudden changes in people's daily lives. Due to the spreading nature of the virus, the risk of droplet infection in viruses capable of airborne infections needs to be considered (Kohanski et al., 2020); thus, the prevention of viruses in the air has become essential in everyday life. In this situation, people are taking various actions (e.g., hand sanitizer, anti-virus film on buttons, wearing of masks) for hygiene management and physical distancing in our daily life to prevent infection by viruses. Recently, a method for detecting airborne viruses using a unique paper sensor has been studied (Bhardwaj et al., 2020); and discussed a convenient way to detect viruses using a menu in a restaurant or wallpaper in a home environment.

However, most studies have focused on providing hygiene solutions for its general use and the suggested design that does not carefully consider individual's everyday life situations. Specifically, previous studies focused on virtual meetings for online conferences (Wiberg, 2020), online classes using non-contact methods (Drohan et al., 2020) or mobile-based location tracking technologies to detect people in possible future pandemic situations (Gupta et al., 2020). These cases still left design opportunities considering the installed place features requiring different methods for precautions in hygiene management. In addition, we found a lack of studies focused on what actions users should take to prevent airborne virus infection in certain places and situations, such as at home, on the go, or in public. Specifically, researchers have rarely studied the misunderstandings of hygiene that can occur in those environments and what information regarding the safety of space (including people and objects in that space) users need to acquire. It suggests the need for further research on contextual systems that prevent misconceptions about user hygiene and help users to maintain continuous reminders, correct hygiene management, and self-prevention of infectious diseases.

Moreover, when providing the right information to the user, the object showing the data, the context (i.e. activity, people, and the surrounding environment) of the place, and the place in which the object is installed can affect the process of interpreting information from the user (Ghajargar et al., 2019). This implies the importance of analyzing the context of everyday life and finding opportunities to minimize the risk of infection in the place. In this respect, we explored what information—hygiene-related data—users needed to receive to prevent infectious disease and how those data could be delivered to users according to context. For this, we have created the classification of existing hygiene management systems by reviewing literature in human-computer interaction and on commercial products. In addition, we conducted a design workshop to find out what makes people anxious about a hygienic place they visit and the objects they touch by creating virtual personas. Furthermore, we investigated what design concepts can be derived to solve those anxiety factors.

Based on the hygiene management classification results and the design workshop, we propose design guidelines for relieving anxiety-related hygiene according to various daily situations and environments.

Table 1 Summary of hygiene management systems

	Deployment place	Hygiene related data measured by product	Feedback and action
Aaron (Ecovac., 2020)	Fixed place, indoor	Measure the dust concentration in each room	Movement of the connected robot (moves to a room with high pollution)
Alert (Naran Inc., 2019)	Attachment to objects (both portable and fixed)	Measure the air quality (e.g., carbon dioxide concentration) in a fixed place or measure the air quality of users' route	Mobile push alert
Safe workplace (Accenture, 2020)	Users' neck (necklace-type)	Measurement of the spacing between employees	Vibration of a necklace.
Philips Sonicare Diamond Clean Smart (PHILIPS, 2017)	Place where teeth are brushed	Brushed teeth and brushing habits	Expresses 3D map of teeth through a smartphone
watchOS7 Hand Washing (Apple, 2020)	Wearable application	Elapsed time of hand washing	Automatically triggers a 20-second timer when handwashing is detected
AETHER (Snow et al., 2019)	Wall	Indoor air quality	Ambient lighting is illuminated on the wall based on indoor air quality
Hilo & Hilo-wear (Zhong et al., 2020)	Hilo: indoor environmental sensing device Hilo-wear: wearable application	User's physiological information according to indoor air quality (e.g., blood pressure)	Hilo measures temperature, humidity, air pressure, CO2, airflow, and ambient noise level Hilo-wear receives sensor data from Hilo. It visualizes the data and provides alerts to users based on the sensor level (e.g., High CO2 level)
Aire (Torres & Campbell, 2019)	Mobile Application	Fine dust concentration	Visualizes particles in the world through augmented reality

2. Literature and Case Review

2. 1. Design for hygiene management

Research on interactive devices for hygiene management is steadily increasing, and Table 1 provides various approaches for making users aware and preventing infection or inhalation of harmful air. Recently, smart devices that combine sanitary functions (e.g., air cleaner) were introduced and actively studied. Also, a study has been conducted on combining devices with autonomous robot technology to solve the imbalance of indoor hygienic status. It was also launched as a commercialized robot air purifying product called Ava & Andy—an autonomous air purifier used in home environments. Aaron is placed in each room to analyze pollutants, and Ava & Andy moves to the space to clean up when an imbalance is detected in indoor air quality (IAQ). Another product, Alert, measures not only harmful chemicals but also temperature, humidity, and CO2 level. It can also detect the exact source of pollution even in the same indoor space.

Additionally, the concept of untact design has emerged due to the possibility of airborne infection during human-to-human contact. A report on the COVID-19 era from Accenture suggested several untact design concepts. For example, 'Safe workplace (Accenture, 2020)' is a concept for keeping a physical distance that provides warning feedback when an employee

is within six feet away. 'Hospital at Home' is another concept to help a doctor reduce unnecessary hospital visits and help the patient observe remotely.

2. 2. Designs for assisting the perception of hygiene information

In designing smart design concepts for hygiene management, Kim & Li (2020) highlighted that it is essential to recognize information and communicate it properly to users. They proposed a conceptual framework for a device that would visualize existing IAQ (Indoor Air Quality) and analyzed 1447 reviews of seven different IAQ visualization products sold by Amazon. To define the awareness that leads people to engage with the products, the researchers considered the information provided by the products and the action of the products according to IAQ. They also mentioned that the devices should make the user aware of hygiene (air quality) and help them efficiently understand the information.

To develop awareness and understanding of contextual hygiene information, a current study has attempted to provide information on air quality and users' physiology information to recognize it as their information (Zhong et al., 2020). In terms of monitoring the user's behavior, for example, some dental products are designed to help guide user's correct brushing of teeth action in real-time by modelling the user's teeth in 3D, and that automatically induced a 20-second timer to wash hands by recognizing the motion and sound of washing hands.

However, some products convey information vaguely (Ishi et al., 1998) for ambient delivery of users' data. Snow et al. (2019) reported that the face-to-face ratio of information was increased through monitoring devices that provide information abstractly using the light of the back of the device. At the same time, the peripheral ways of delivering information using ambient light expressions and natural sound feedback may also cause misinterpretation of that information; thus, it is necessary to have some specificity during the feedback (Kim, 2018). In addition, if the smart device fails to provide the user with trusted information, it can lead to minimum use (Cho et al., 2019), leading to the use of only minimal functions of the interface regardless of the usefulness of the smart function. Therefore, the system should make users understand and reflect on information appropriately.

Even though some prior studies proposed various approaches to delivering hygiene-related information to users, only a few considered the location where the information was transmitted. Particularly, a study providing different contextual information is relatively rare. In this regard, a deeper understanding of the difference between the hygiene data and the method of delivery in public and personal space would be crucial.

2. 3. Understanding and reflecting on hygiene data

To understand how users perceive the information provided by devices and how they reflect them in their daily lives, we investigated how to interact with data through smart devices in the fields of design and HCI (Human-Computer Interaction). In a previous study, Ghajargar et al. (2019) stated that the information provided by smart objects needs to be understood from the activities and objects that exist in a space. They suggested the importance of contextual understanding of a space where devices are installed and where users' interactions

occur. Recently, technologies have been developed to address these issues. For example, Urbanbase is an API that analyzes the image of space using machine learning,and that provides information about activities and objects that can happen in the space. A study was also conducted to analyze the user's activity in a space by automatically generating the profile and predicting the user's role (Bolat et al., 2018).

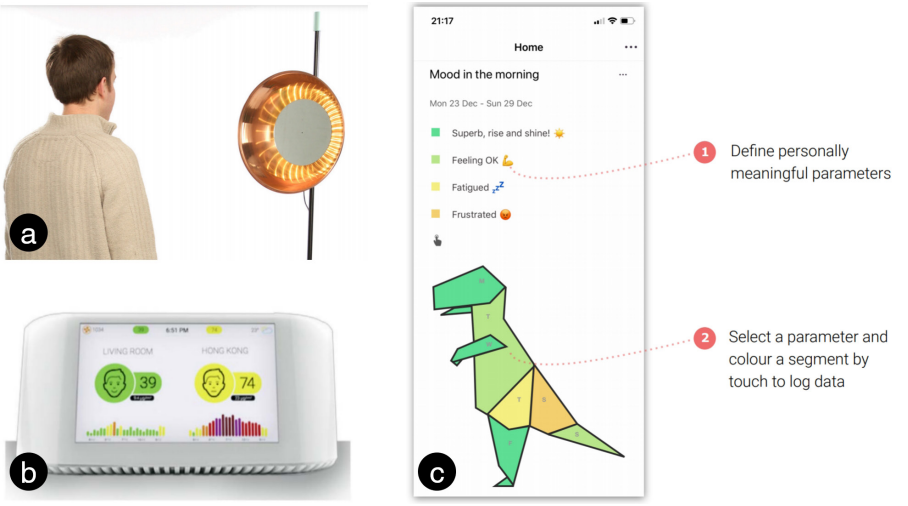

Figure 1 (a) Smart mirror (SelfReflector) (Wallace et al., 2018), (b) Air-quality monitoring sytem (Kim et al., 2020), and (c) Trackly (Ayobi et al., 2020)

For users to better reflect on their data, there were studies considering not only the context but also the form of the object that delivers the information. For example, Wallace et al. (2018) proposed a smart mirror that gives hints to show users' information by illumination (Figure 1a). In another example, a design for an air-quality monitoring system (Figure 1b) for children was introduced (Kim et al., 2020) to provide a better understanding of the indoor air quality status. In Trackly (Figure 1c) – a prototype app that supports people to define and color pictorial trackers (Ayobi et al., 2020) – users may have ownership, identity self-awareness, and a new mindset of data by customizing the visualization method.

Previous studies highlight that various factors, including context, should be considered when delivering information to users. As the interest in hygiene is increasing nowadays, it is expected that users will be able to grasp data more effectively if the context is considered when information is transmitted from devices related to hygiene. Based on the literature review, we have found a design space for a smart device that raises awareness of hygiene for the prevention of airborne infectious diseases and the way to convey hygiene properly considering the context (e.g., objects, people, places) where the device is installed.

3. Method

This study used two research methods to explore what contextual data users should perceive to prevent infectious diseases and how those data can be delivered. First, we created 1) a classification of hygiene systems by systematically reviewing and analyzing the existing cases from both academic and practical fields. Through this, we wanted to understand what types of hygiene-related data were previously delivered, how those data are delivered to users and the purpose of the data delivery. Second, we conducted 2) a design workshop that includes an in-depth discussion session among the participants to identify potential users' contextual needs related to hygiene and a brainstorming session to derive the design concepts from complementing those requirements. More specifically, in the workshop, we let participating designers generate ideas that fit a persona in a specific situation and observed what misunderstandings might occur during their behaviors in the space, and how contextual information (i.e., place, person, things) might be reflected in the concept drawing for hygiene.

3. 1. Classification of hygiene management systems

We classified the existing hygiene management systems by selecting 21 representative cases from academic research publications in HCI(Human-Computer Interaction) conference proceedings and journals (e.g., CHI, SIGGRAPH, DIS, Ubicomp) and commercial products (e.g., Apple, LG, Philips and Kickstarter). The methodology used for our classification process was based on Pousman and Stasko's (2006) approach. This method utilizes four design dimensions for ambient systems to analyze and propose design patterns to improve understanding of existing ambient information systems by reviewing 19 ubiquitous computing research systems. We used this approach because the delivery of hygiene-related information to users is closely related to ambient information systems. In addition, we wanted to discover the current status of hygiene management systems by understanding how information is transmitted and how users are encouraged to participate in hygiene caring activities. During the classification process of the cases, the following four criteria (Table 2) were used. These were adapted from and modified based on Pousman and Stasko's study. As hygiene management systems are developed for individual and public uses, we removed the "aesthetic emphasis" criterion in Pousman and Stasko's research and added an "openness to individuals" criterion. We also modified the terms of the other three criteria to classify the existing systems in perspectives of user interaction with the system.

Table 2 Criteria for classifying cases of hygiene management systems

Classification criteria	Deployment place
Behavior inducing	A measure of how well the user perceives the current hygiene state provided by the device and then continues with the correct behavior for hygiene management
Information accessibility	A measure of how much effort is needed to access the sanitary information measured by the device
User engagement	Level of user interaction with products for hygiene data collection and sterilization
Openness to individuals	The openness of sanitary management devices to specific individuals or general users

Figure 2 shows four classification criteria on each horizontal axis and divides the high-low into five stages (high, somewhat high, normal, somewhat low, low) on the vertical axis. After that, the existing 21 hygiene management systems were placed in four different categories, and colored lines were followed by the system. The change in the system's ranking according to each stage was confirmed by our research team's (1 Ph.D., three Master students and one faculty member; all majoring in Industrial Design and HCI) careful in-depth review of the system. During the process, all researchers discussed and reached an agreement on the rankings by discussing the reasons for the system placed in the rankings considering the system's characteristics corresponding to the criteria.

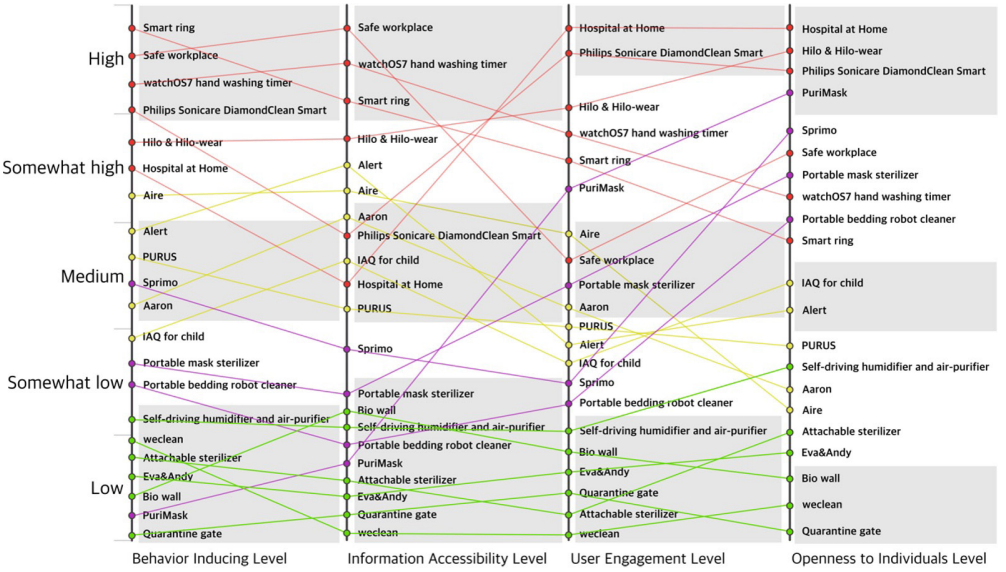

Figure 2 Parallel Coordinate plot of 21 existing hygiene systems across four design dimensions. Colored lines trace each system's ranking along the design dimensions. Different colors are used to denote groups of systems which are similar as explained more fully in Section 3.1.1

3. 1. 1. Four design patterns

By analyzing the classification result and the change of rankings by each system's level, we could derive four different design clusters according to similar colored lines. Figure 3 shows the four design patterns, and the detailed description of each pattern is as follows.

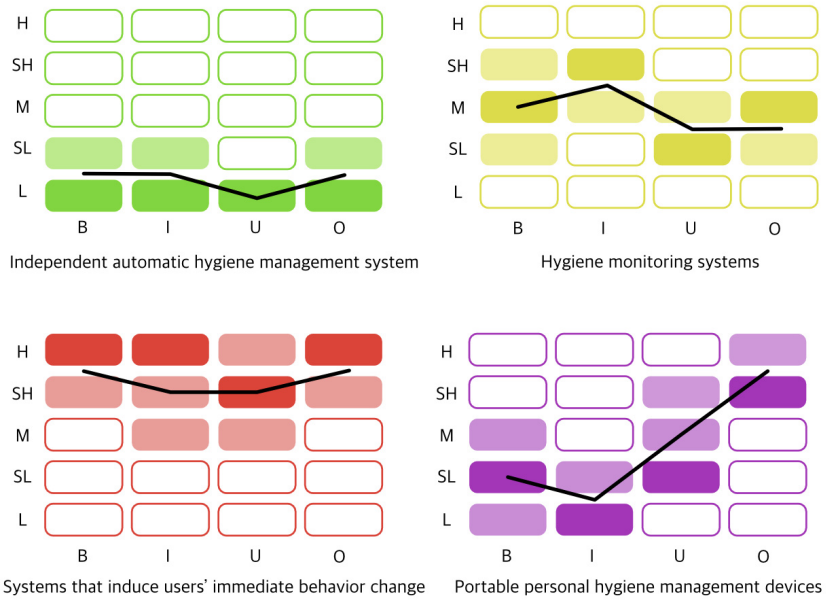

Figure 3 Four design patterns of existing hygiene management systems. Each system design archetype is shown in the context of the design space. Darker toned boxes indicate core design decisions, while light boxes show alternate choices; all are measured weights from the parallel coordinate plot of 21 existing hygiene systems. B.I.U.O, the standard of the x-coordinate, refers to the initials of the four classification criteria mentioned in Table 2.

1. Independent automatic hygiene management systems are devices that automatically sterilize a space or a specific location when they are initially installed. Thus, they do not require users' continuous intervention. These are mainly placed in public spaces used by many people, and they simply focus on making space hygienically safer rather than inducing people's behavior changes to control hygiene management thoroughly. Systems in this category include a self-driving humidifier and air-purifier for managing the air condition, such as the autonomous air purifier Eva & Andy, we clean, which disinfects escalator handrails. They also include an object-attached sterilizer, a bio-wall that purifies the internal air using plants, and a gate that automatically sterilizes people when entering the space.

2. Hygiene monitoring systems collect and deliver hygiene data to users. For example, Aire helps users to understand space by adding air quality data using augmented reality technology. IAQ-for-children, Alert, Purus, Aaron, all of which monitor the state of hygiene through apps, are included in this category. Users of these systems can easily access data through a smartphone or tablet, and the system reminds them if the hygiene condition is bad.

3. Systems that induce users' immediate behavior change help users to perform the correct hygiene managing behavior by recognizing the specific state through their peripheral device (e.g., smartphone, smartwatch, smart ring) and then suggest specific actions. This category includes a hand washing timer, the smart ring, the Safe Workplace, Philips smart toothbrush, and Hilo & Hilo wear. These examples are mainly used as personal hygiene management systems, and users can be easily reminded and motivated to use them.

4. Portable personal hygiene management devices include systems that allow users to care for their objects or themselves in the space through a portal device when a situation may cause contamination hygienically. This category includes a portable mask sterilizer, a bedding robot cleaner, and Sprimo, which can check the space's pollution level. These devices allow users to use personal items more hygienically by sterilizing them directly or examining the pollution level.

Through the analysis of the cases, we could classify the current sanitary management system design based on the types of characteristics we found. Once the classification of the existing designs is done, we conducted a design workshop to determine the current system's deficiencies and devise product/system concepts to improve those issues.

3. 2. Design workshop

We conducted a series of design workshops to derive the significant points to be considered and contextual direction when designing hygiene management systems. We recruited 12 participants (P1~P12, Aged 21~27, 7 Male, 5 Female) with more than three years of experience conducting interdisciplinary projects for the design-engineering industry with companies and government research projects in their design labs affiliated with a Science and Technology University. Furthermore, as the hygiene management systems cover diverse fields within design and engineering, we recruited participants who earned a double-major B.S. in Industrial Design with Human Factors, Computer Science, or Mechanical Engineering. The workshop was conducted three times with four participants in three randomly formed groups to avoid biased information from one group and to hear various opinions from the discussion. The members within group 1 did not know each other, while in the other two groups, some of them knew each other. Thus, compared to group 1, the conversation among members of groups 2 and 3 was slightly more active during the first phase of the workshop, which included making contextual cards.

Within a workshop, there were three phases: 1) exploration of potential design spaces; 2) brainstorming potential product concepts; 3) discussion of the derived concepts. During the process, we also explored what prejudices or misunderstandings could be included in the design concepts. The following is a detailed description of each phase.

3. 2. 1. Three phases of the workshop

Before proceeding in our workshop, we went through a pilot test to set the appropriate time for each step. We also included a formal explanation of the process, method, and purpose of the workshop and ways to use the context card kit (Figure 4).

Phase #1: Exploring potential design space

The first phase of the workshop was conducted for about 40 minutes. The goal was to define the potential problem related to infectious diseases that may happen in the user's context and the situation (e.g. place, object, person). In this phase, we asked each participant to set up a persona and to explore the possible places, users, or objects that the persona would interact with or touch to use. For this, we used a card-kit for context exploration (Figure 3). Four participants in a group discussed issues by placing people, objects in the environment,

and the risk of potential infections on the context card (Lidwell et al., 2010). As participants directly wrote types of objects, people, places and potential infections on the context card, they could repeatedly recall their virtual persona scenario during the discussion. Furthermore, this process helped them to derive a potential design space considering the contextual information. Through this process, we wanted to understand the potential human-object interactions within the environments and encourage the participants to imagine those situations.

Phase #2: Concept exploration

In the second phase (30 ~ 40 mins), participants were asked to brainstorm and draw design concepts based on the insights obtained from the previous phase. We provided A3 size paper, colored pencil, and black liner to each participant. In this step, we aimed to derive design concepts that can prevent virus infection, and to identify how contextual situations derived by users in the previous phase have influenced the participant's concept.

Phase #3: Concept discussion

In the workshop's final phase, participants discussed the concept derived from the second phase. Participants in each group verbally (with the idea sketches & context card) explained the concepts they had derived, including the description of the function, interaction, and context used in connection with a specific pandemic situation. The purpose of the discussion was to discover unexpected issues, to hear perspectives from other participants, and to draw out the design's intention and purpose.

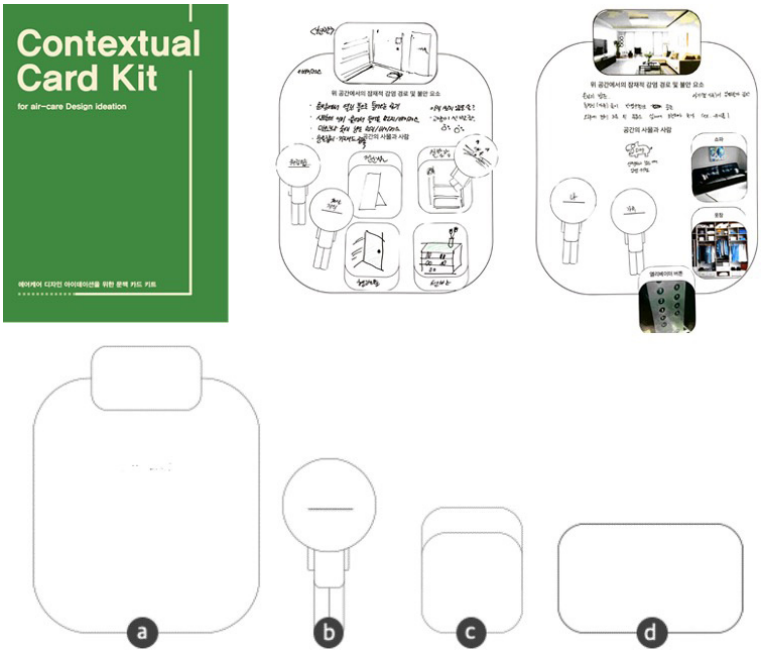

Figure 4 Card-kit for context exploration; Examples (top) and details (bottom) a) context card: the completed place, object, and person card can be attached to grasp the situation and find the design space, b) person card: people who can be contacted in a specific space, c) object card: objects that persona can contact in a specific space, d) place card: represents a place where a particular person can go

3. 3. 2. Data collection and analysis

The three workshop sessions were video recorded, and verbal discussions were transcribed. Also, all context cards (n = 14) and design concept sketches generated by participants were digitally scanned. The data analysis was conducted as follows: four researchers (one Ph.D. student and three Master students, all majoring in Industrial Design and HCI) generated open codes based on the contents from participants' discussions and created context cards. By using those codes, we went through an affinity diagramming process, and created a thematic connection of the open codes. Our research team also investigated interesting or meaningful patterns that we discovered through iterative analysis of the relationship between the contents of the discussion and the codes. During the analysis, we also grouped open codes with contrasted meanings (e.g., specific information delivery and ambiguous information delivery) and can be linked by a similar functional aspect. This process helped us understand the values behind each concept and to identify elements that repeatedly appeared in the contextual scenarios. Finally, we reviewed all the data and found common points between the results from the workshop and design patterns from the classification of hygiene management cases.

4. Design Guidelines for Hygiene Management Systems

By finding the semantic connection between classification results and the workshop's outcomes, we could derive the design guidelines for the contextual awareness and management of hygiene in daily life.

In addition, we conducted interviews with four practitioners with 2 to 5 years of experience working at LG Electronics to explore the initial verification and use of the guidelines. Table 3 shows the information on the four practitioners. In the interview, we asked what strengths the derived guidelines have in practice and how they can be explicitly used at each stage of their design process. The interview took about 1 hour for each participant and was conducted online. A total of 4 hours of interview data were transcribed and used to synthesize opinions on utilization methods for each guideline and to analyze practical usage plans for hygiene management product design guidelines.

Table 3 Details of Four Design Practitioners (S1 to S4, all working in LG)

	Gender	Years of experience	Division	Major work
S1	Female	2 years	Advance Product Planning Office	Trend research, market research and planning for future products in 3–4 years
S2	Female	3 years	Product Technology Strategy Team	Discovering new business concepts in the near future and evaluating them
S3	Female	5 years	Disruptive Product Innovation Research Center	Product planning, user research, 3D design, advanced service design
S4	Female	4 years	Complex Industry Planning Team	Product research and customer research

4. 1. Providing attention for private space and relief for public space

First, we found that the purpose of displaying information about pollutants can be different depending on the context of the place in which the device for preventing infection is installed. Specifically, 1) in a private space, the system should help users be aware of managing their hygiene without being overwhelmed by the psychological relief from the private space. 2) in a public space, the system should provide users with information about the safe hygiene status of the space to make users feel relieved in the place.

4. 1. 1. Bringing users' attention to possible infection in private space

One of the design ideas derived through workshops to prevent infection in personal spaces was to consider when users are in a moment of inattention to hygiene management. In all workshop sessions, participants mentioned that they feel less anxious about infection when they return home as they become relatively relaxed. P4 mentioned, *"When entering a personal space, the awareness of the severity of hygiene seems to decrease rapidly."* P8 stated, *"I won't be wearing a mask in my room even if others visit there since my room is a private space." Also, P12 noted, "I think the awareness of hygiene is decreased because people think they can control pollutants in their own space."*

This potential issue of hygiene in private spaces was used as one of the key problems when deriving participants' design concepts. P4 and P7 proposed the concept of spraying disinfectant liquid at the entrance when returning home (Figure 5). At the same time, this concept can give the user low awareness of hygiene in his or her home by making him or her think it is safe because it has been sterilized.

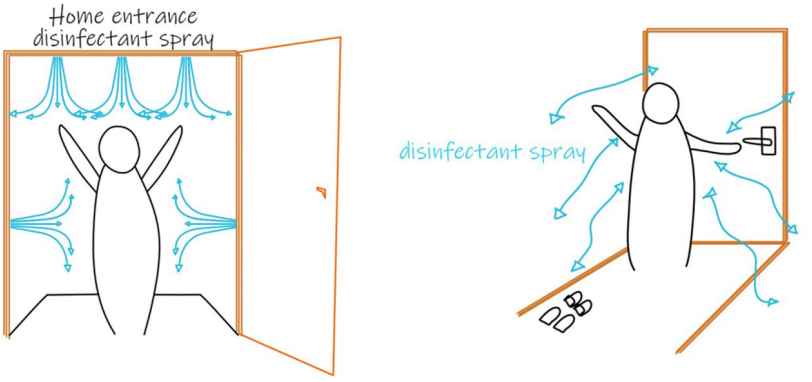

Figure 5 The design concept of spraying disinfectant at the entrance when returning home, proposed by P4 and P7

This issue is related to one of the classification patterns, 'the system that induces the user's immediate behavior change' (Figure 3) and could provide users immediate awareness of space's hygiene status. Specifically, a device can recognize the current context and remind the users in a highly motivating way to take appropriate actions; we emphasize that this system uses personal data specialized to the user. This characteristic is related to the design concept found in the workshop that a system should help the users not to lower their safety boundaries, thus prevent infectious diseases. Considering the above issues, we could derive the following design guidelines.

First, to reduce the user's insensitivity to safety, the condition of a private space must be monitored in real-time, and the information should be delivered in a way that is difficult for the user to ignore easily. To this end, the system should actively provide information by nudging users to remind them even when users are not conscious of current conditions. Alternatively, it is also possible to display consistent information about the user's current behavior. For example, in the case of watchOS7's handwashing timer, when the user starts washing hands, it starts a 20-second timer and naturally induces them to wash their hands for 20 seconds.

Second, it is necessary to consider the notification method to attract the user's attention and empathize with the feedback. For instance, Hilo and Hilo-wear (Zhong et al.,2020) help users quickly know their condition and spatial hygiene conditions effectively considering an individual's physiological information. The design reflecting these points can help users effectively recognize hygiene conditions and lead to behavior changes to prevent unconscious infection.

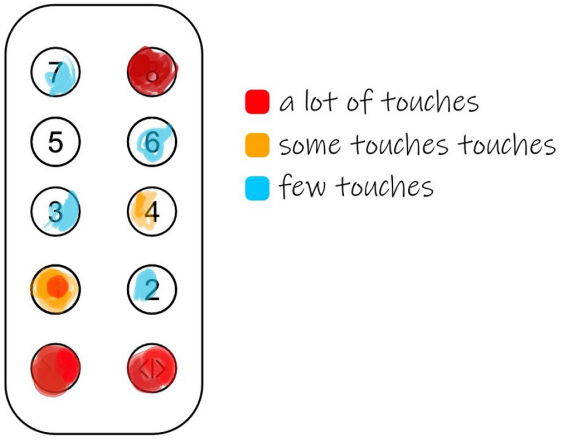

Figure 6 The concept of elevator buttons that change color according to the number of presses proposed by P8.

4. 1. 2. Providing relief on hygiene safety in public spaces

During the discussion of public spaces at the workshop, most participants remarked that it is appropriate to provide abstract information that can be perceived at once rather than specific information that cannot be recognized immediately. In addition, they wanted confirmation that the place they were in is hygienically safe from infectious viruses to stay in the place with confidence. Regarding this, P2 mentioned, *"Because we are already acting carefully, it seems that we need less trust in the data in public places."* P3 also noted, *"In public spaces, I am already being cautious to some extent, so the information does not need to be specific."* These responses from the participants can also be explained by the nudge according to the social context proposed by Caraban et al. (2019). For example, inducing the act of wearing a mask in a public place can be stimulated from the gaze of others to a person who does not wear a mask, acting as a social signifier (Norman., 2008).

More specifically, we identified that it is essential to make users feel relief about hygienic safety in public places. People tend to be careful and pay attention to their public spaces'

hygiene status regarding infectious viruses. In these situations, providing too much information may confuse the interpretation of the information and prevent an accurate understanding of its meaning. Thus, a design that can be easily and quickly recognized should be proposed for the user to feel relief about hygienic safety. At the same time, one study (Kim, 2018) highlighted that excessive ambiguity when providing information could cause problems with the reliability of the information. In this respect, when generating concepts, participants in the workshop used various approaches to balance the level of expressiveness in ambiguity that can intuitively convey information and provide the concreteness of information for reliability. Representatively, participants drew concepts that 1) abstractly displayed potentially dangerous information, and 2) included strategies for the public to participate in the disinfection process.

P8 proposed an abstract data visualization system (Figure 6) that displays the frequency of contact on parts where the public directly touches through color-coding, such as elevator buttons and bus handles. This mainly uses a method in which the color gradually changes depending on the number of presses. The expression of abstract information used here (e.g., the more pressed, the more the red gradually changes) makes it easier for the user to recognize information about the number of presses relatively faster than the expression of specific information (e.g., just numerically displaying the frequency of presses).

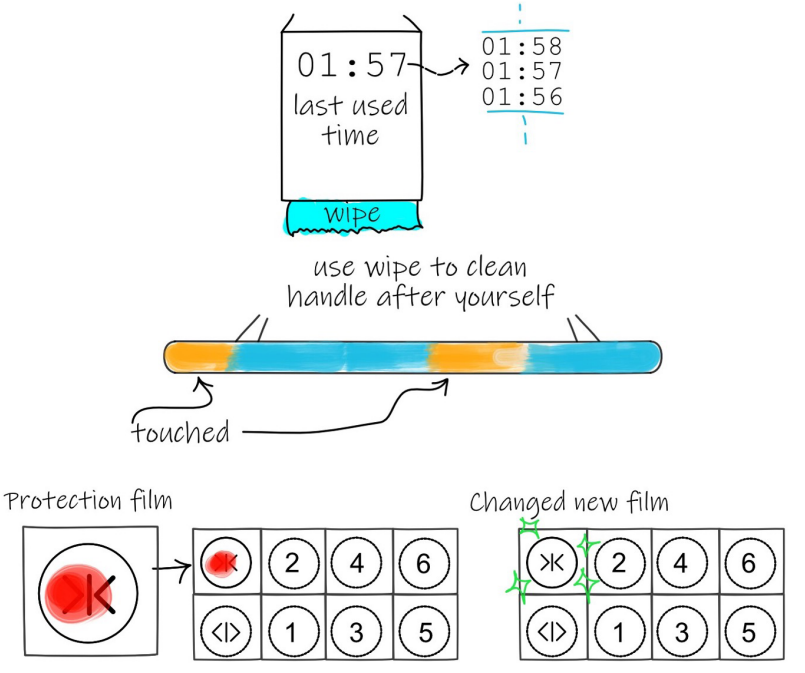

Figure 7 (Top) a concept that users can replace old copper protection film themselves – proposed by P11; (bottom) the concept that the color of the elevator handle changes depending on the number of touches on it and the users can clean it themselves – proposed by P9

In addition, in other workshop sessions, participants discussed that a disinfectant tissue around a color-coded object (Figure 7, bottom) could be a design that allows the public

to participate in the disinfection process directly. In other words, displaying information through color-coding can convey the frequency of the use of buttons intuitively, and the disinfection process through which the user directly intervenes can provide safety about the hygiene of the space.

Simultaneously, these concepts that require users' participation can be affected by the amount of time a user stays in the space. In this respect, when designing objects for infectious viruses in public spaces, it is essential to consider how users can receive the feeling of psychological safety through hygiene information.

These findings from the design workshop may relate to the "Independent automatic hygiene management systems" (Figure 3) among the classification patterns. This type of device is mainly placed in public places where many people gather or focus on making objects safe that were contacted by several people. It also uses automated systems to keep public places safe. However, these devices provide only the function of automated sterilization and lack features that encourage people to stay in a space with relief. Considering these classification and workshop results, the following guidelines can be suggested:

- It should be considered that users are likely to feel anxious, and it may be difficult for them to recognize whether a space is hygienic. Data should be easily recognized by using graphic images (e.g., color coding based on data, ambient light containing information of data) rather than showing specific numbers to help users quickly recognize that a space is hygienic. Providing users with a room to *Do it yourself* on hygiene management (e.g., Place disinfectant, cleaning tissue, self-changeable prevention film) could give them a sense of trust and make them use the space with confidence in its hygiene.

4. 1. 3. Potential use of the guidelines in practice

Through interviews with design practitioners, we confirmed from all participants that using this design guideline can help inspire employees to discover which areas to focus on when designing a product—for example, identifying functional requirements and what research into trends or the market to conduct. Specifically, two practitioners mentioned that they would derive keywords for market research using this guideline. S3 noted, *"If there is a statement that information on hygiene should be delivered in public places, I think we [her design team] will be able to select a need that fits and design products and services that match it."* Similarly, S1 mentioned, *"I think we will be able to perform market research on the target product after deriving various solutions on what monitoring is exactly and what is difficult to ignore."*

We also found that this guideline can help in selecting specific parts for designing interactions with the product. S3 remarked, *"I think [this guideline] can help solve potential problems by considering the guidelines for selecting the parts for the notification function and thinking about the method of interaction."*

4. 2. Considering misunderstanding about typical cleanliness

To design objects to prevent infectious diseases, the following design guidelines are needed to make users intuitively and efficiently obtain information about the right hygienic status using their misunderstandings of hygiene. First, we need to identify the gap between necessary hygiene information and the information users accept with their senses. Second, the target user group's stereotype should be considered appropriately when designing a hygiene management product for them.

The difference between the public's misunderstanding of hygiene and the factual status of hygiene needs to be considered in a design for infection prevention. In line with this, participants suggested that it is important to understand what stereotypes people have about hygiene. We found that participants in the workshop tended to believe information that they accepted and interpreted using their own senses regarding the level of pollution in space. For example, P3 and P6 mentioned that the object or space should be disinfected well and have a good scent to make the user feel clean. Indeed, pleasing scent and hygiene are not always directly related; however, such stereotypes affect users' acceptance of information and understanding of the environment (Hamilton, 1979). In other words, when cleaning pollutants, it is important to represent the perception of cleanliness to the user and intuitively deliver the status of cleaning. Regarding this, P6 suggested in the workshop a sterilizer concept (Figure 8, left) that shows the disinfection time of things inside the cabinet through colors, since users want to select a cup, which was disinfected for a long enough time.

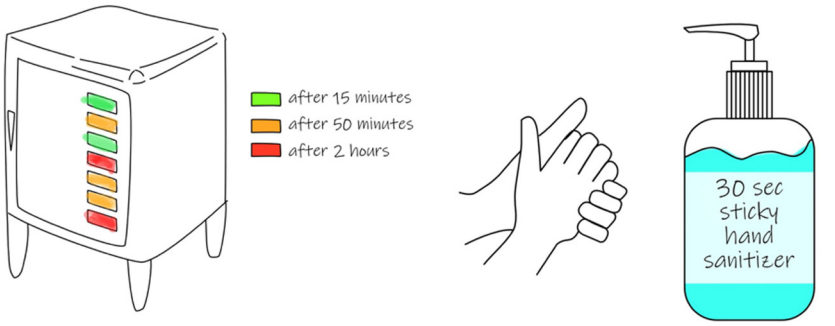

Figure 8 (left) UV cup sterilizer concept that shows the disinfection time of the cups through color, proposed by P6; (right) A hand sanitizer concept that eliminates stickiness by rubbing hands for at least 30 seconds, proposed by P7

In addition, it is important to consider what people think is hygienic (even if it is not). In previous studies, it was mentioned that a child's understanding of the world might not be as accurate a point to consider when designing a device that displays air quality data for children (e.g., hot air is bad air) (Kim et al., 2020). Moreover, we confirmed that not only children but also adults tend to misunderstand through their senses when understanding hygienic status (e.g., it is hygienic if it smells good). Furthermore, Rich (1979) remarked that typical stereotypes about hygiene could also be added to enhance users' sense of relief on hygiene. More specifically, this misunderstanding can be used to give users a feeling of relief. For example, during the discussion in the workshop, participants proposed using white foam, which can be considered as a clean attribute, as disinfecting feedback instead of sticky

solution as in P11's concept (Figure 8, right). Doing so may induce hand disinfection for a certain period using hand sanitizer containing sticky additives removed after rubbing for a certain period; however, the sticky texture could also lead to less use due to its fundamentally negative tactile perception. The same strategy could be applied to P6's concept (Figure 8, left). Thus, if a fragrant scent is added when UV is sterilizing cups, the user can recognize it as hygienic and use it more comfortably.

In sum, the following points of misunderstanding should be considered:
1) Positive misunderstanding about hygiene (e.g., white bubbles and fragrant scents will be clean) can be used additionally to provide reliability and user confidence in existing hygiene management products.
2) Considering whether the product does not provide users with negative hygiene misconceptions (e.g., the sticky texture will not be clean; if it smells bad, it will not be clean).

4. 2. 1. Potential use of the guidelines in practice

All design practitioners mentioned that this design guideline could serve as a basis or criterion for determining a new design direction that would improve an existing product in the early stages of product planning. In addition, we confirmed that it could be used to inspect prototypes just before product launch. Specifically, two design practitioners mentioned that this guideline could help decide whether to maintain the factors that cause positive misunderstandings or eliminate the factors that cause negative misunderstandings. Regarding this, S2 mentioned, *"I think we [her design team] can think about how to solve 'the damp smell of steam' as a positive misunderstanding."* In order to solve this problem, S1 mentioned that it is likely to be reflected by investigating which scents feel cleaner through an initial user survey. In addition, they added that it could be used to make a checklist for a final inspection to check whether there are factors that stimulate negative stereotypes in the prototype immediately before product release.

Based on the practitioners' interviews, we summarized how our proposed design guidelines for hygiene management could be used in the design process.

1. Determination of the context for proper use and purpose: First, the guideline can be utilized to determine where the hygiene management product needs to be deployed and what information should be shown. Specifically, S4 emphasized the guideline can be used in this phase. In this stage, researchers decide whether the product is fixed and used in personal space (e.g., air purifier) or shared space. In addition, when improving the previous product, the guideline can be used to investigate whether there were factors that cause negative or positive misunderstandings from the users.

2. Expanding thoughts during the market and trend research: All design practitioners (S1 to S4) remarked that, once the product usage context and purpose are determined, the design guideline can be used to provide inspiration for keywords to conduct market/trend research. For example, designers could conduct research by exploring the following questions: "How do users receive notifications in personal space?" "What notification method is suitable for personal space?", and "What method should be used to deliver information at a glance

in public space?" Additionally, designers can find answers to questions such as "What stereotypes can be caused by the current hygiene products on the market?" and "What scents do users feel are cleaner?" Furthermore, the answers gained from the above process can help derive the requirements for future design concepts for hygiene management.

6. Conclusion

In this study, we proposed design guidelines for hygiene management systems considering different types of contexts. Through the classification process of the previous hygiene control systems, we could discover four different design patterns for hygiene management devices and those provided insights into what characteristics existing cases of sanitary management system design have and how they can be categorized. In addition, we conducted a design workshop to investigate better hygiene management methods regarding specific contexts in our everyday lives. Through the classification of existing cases and design workshop results, we could derive new design guidelines for hygiene management systems from the perspectives of users' attention and relief to hygiene status, along with awareness of typical cleanness. From those guidelines, we suggested that hygiene devices should be designed differently according to the user in personal or public spaces. Also, we confirmed that using misunderstandings about public hygiene properly is essential. Based on the results, our study implies the design of future hygiene management devices, specifically how the personal/public items, smart products and home electronics can be designed by considering users' routines and perceptions about hygiene in private to public spaces.

At the same time, there are two limitations to this study that can be addressed through future work. First, the number of cases used in the classification of hygiene management systems included 21 examples. Although we referred to a previous approach from Pousman and Stasko's taxonomy method, adding recently developed devices for the COVID-19 situation may also provide new insights during the classification process. Second, to confirm the in-situ value of our design guideline, going through a design development and field trial of a hygiene management system using the design guidelines would be possible for the guideline's validation. In our future work, we are considering devising and implementing an interactive system for hygiene management. This process would be an opportunity to apply our design guidelines during the concept design phase and observe the experience of the system for potential users.

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