Designs for Sensing Radiation: Deployment of a Tangible Interface and a Visual Projection Interface for User Interaction

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Abstract

Background This study pursues two objectives. First, we propose prototypes with intuitive interface designs for sensing radiation through a tangible form of a physical sensor and a projection-type physical interface design that can share information. Second, we Identify design attributes and effects of direct visuals and color codes influencing the process whereby users realize electromagnetic field (EMF) radiation exposure risk from the perspective of human computer–interaction.

Methods This paper proposes to design an EMF radiation ball and an EMF radiation visual projection using color codes to help users to perceive EMF radiation exposure. In a field trial, user experiences were recorded through in-situ observations, video recordings, and surveys.

Results The experience of using the proposed prototypes indicates that instantaneous visualization through color codes depending on EMF radiation exposure level influences the perception of the users concerning EMF radiation exposure.

Conclusions This study concludes the impacts on the awareness of EMF radiation from the user perspective with respect to the developed prototypes, which use color-coded lights to visualize the sensor outputs and new types of interfaces. This paper explores the effect of different shapes of design interfaces and visual color code lights to sense radiation concerning user interaction with the environment.

Keywords Design, Sensor Devices, Sensor Interface, Social Design, User Research

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Citation: Won, H. (2020). Designs for Sensing Radiation: Deployment of a Tangible Interface and a Visual Projection Interface for User Interaction. *Archives of Design Research, 33*(2), 57-71.

http://dx.doi.org/10.15187/adr.2020.05.33.2.57

Received : Oct. 15. 2019 ; **Reviewed :** Nov. 19. 2019 ; **Accepted :** Mar. 26. 2020
pISSN 1226-8046 **eISSN** 2288-2987

1. Introduction

Social design is involved, directly and indirectly, in social problems related to design processes considering social innovation issues (Whiteley, 1993). In this regard, social design has brought designers into contact with social processes (Koskinen & Hush, 2016; Papanek, 1984), interaction designs (Dourish, 2004), social innovation (Mulgan, Tucker, Ali, & Sanders, 2007; Manzini, 2015), and the public sector (Dorst, 2015). Margolin (2015) showed how utopian design intervenes in social issues. Moreover, he also showed his vision of design as an agent for helping lay the groundwork for a radical rethinking of how human beings can change to ensure well-being. When designers create social designs, they sometimes focus on improving situations they face without paying attention to larger structures that create those situations (Koskinen & Hush, 2016). Nevertheless, social design, such as critical design, presents alternatives in the pursuit of social transformation (Gamman & Thorpe, 2006) and the reality by creating a design-driven utopian discourse. According to Antonelli (2011), the term, "critical design" was developed by Anthony Dunne in his articles, "Hertzian Tales: Electronic Products, Aesthetic Experience, and Critical Design" (1999) was developed by Anthony Dunne and later in "Design Noir: The Secret Life of Electronic Objects" (2001), written with Fiona Raby. Dunne and Raby developed a new field of practice following the footsteps of critical design from the late 1960s and 1970s. Critical design focuses on studying the consequences of new technologies and worldwide social and environmental trends and outlining new goals and areas of interest for designers.

The art of design considers social problems, such as electromagnetic field (EMF) radiation exposure, environmental pollution, social innovation, and sustainability. The field has subsequently evolved under the name of social design (Cipolla & Bartholo, 2014) that, in turn, has evolved into the socially responsible design (SRD), raising social problems as design themes, and addressing them from the educational perspective. Thus, SRD imposes social, moral, and ecological responsibilities on design (Papanek, 1985) and embodies the definition of design as a carrier of social responsibility by responding to the needs of people (Margolin & Margolin, 2002; Papanek, 1985). Moreover, SRD has evolved into a design applied to both crime prevention and design process, which contributes to solving social problems. According to the design against crime (DAC; Davey, Wootton, Cooper, & Press, 2005), transformation design involves putting design ideas into action for social change through crime prevention (Burns, Cottam, Vanstone, & Winhall, 2006).

Manzini (2002, 2007, 2008) notes that social design is a process of social problem solving or self-organizing toward new possibilities, as well as learning about social and environmental sustainability (Manzini, 2007). Social design is also defined as social innovation. That is, "new ideas that work to meet pressing unmet needs and improve people's lives" (Mulgan et al., 2007, p.7). According to the definition by Burns et al. (2006), social design fundamentally changes the public (Huang & Deng, 2008) and social services (Sangiorgi, 2011). The latest trends of social design employ design tools to solve various socially diverse and complicated problems. Social design (Secomandi & Snelders, 2011) has gradually evolved into the design of experience and transformation through design action (Pine & Gilmore, 1999; Sangiorgi, 2011). The speculative design presents alternatives to pursuing social transformation and reality by creating a design-driven utopian discourse (Wodiczko, 1999).

Social design has emerged by increasing the perception of the surrounding information and social interactions (Visser, Vastenburg, & Keyson, 2011). The field complements traditional forms of communication and encompasses technologies and services requiring the attention of the users and their participation. The study relies on the theory of how social design could provide information to the user effectively. The approach for evaluating the device and its effect on design attributes and behavior are discussed in this paper..

From a design perspective, this study shows that we are exposed to electromagnetic waves in real life. Note that this is a potentially unnecessary cause concerning EMF radiation exposure due to human–computer interaction. However, as critical design, this study allows researchers to raise a critical perspective while raising public awareness on the exposure to electromagnetic waves. Therefore, this study provides basic resources concerning a design perspective and the possibilities for users to respond to the design. Moreover, the results from the user's experience research provide insights for future design of sensing devices.

Within the scope of critical design, this paper proposes a design that induces users to become aware of their exposure to EMF radiation in an environment surrounded by EMF radiation that they are uninformed. Although how this affects the human body is not considered, the study focus on how the user can become aware of the effects of electromagnetic waves in everyday life.
Dunne and Raby in “Speculative Everything: Design, Fiction, and Social Dreaming” introduced the topic of EMF radiation into the speculative design. The study established a new direction for meta-creation at the design level as social fiction. They argue that design has the ability to “make things tangible?” Baxter (1997) proposed a design providing visualized data as a tool for educating users to interpret EMF radiation correctly when referring to EMF radiation sensors. Dunne and Raby (2001) conceived the “placebo project”—their flagship work—using an interface controlled by an EMF radiation sensor. This was an interesting project proving the effectiveness of imagined EMF radiation risk on the user, similar to the placebo effect. The project relies on a pilot user review experiment where the user was provided with false information that the reviewed product had a particular function related to EMF radiation. Vaucelle, Ishii, and Paradiso (2008) presented a project with wearable EMF radiation sensors (antennas and bracelets) made of copper fabric that could instantly detect EMF radiation released from objects used frequently.

This paper presents the problems of EMF radiation exposure (Kheifets, Hester, & Banerjee, 2001) and raises the question that forms the basis of the study: which design attributes (e.g., visual and form-related attributes) influence the users’ perception of risk.

Moreover, this study proposes intuitive designs, such as a physical sensor in the form of projection, a form of collectively sharing information with a spatial experience, and in the form of tangible designs that detects radiation. The study focus on whether the intuitive designs are useful for color recognition and as intuitive interface because of user observation, and interaction with safety, regardless of user actions. The study provides insights on radiation sensor design concerning user interface design and user interaction in the environmental and spatial design domains.

2. EMF radiation sensors

Technology can be a crucial design material in design development (Nordby, 2010). A sensor is often defined as a device that receives and responds to a signal or stimulus (Fraden, 2004). We developed a design object with a sensor. Moreover, to provide a detailed explanation on the sensor part, an EMF radiation signal-based sensor (Reitz, Milford, & Christy, 1992) is designed to detect EMF radiation exposure, and the exposure level is measured at the midpoint between the sensor and the target object. The sensor has a detection range of 0 to 20+ milliGauss (mG), a detection frequency of 30 - 20,000 Hz, easy-to-read multi-segment LED display, and an accuracy of 5% at 50-60 Hz.

The sensor output is visualized as five scales of lights (LEDs) interacting with the users (Figure 1). The light spectrum of each channel is controlled by the amount of electromagnetic radiation and the interactions with the users. The sensor used in this study was designed to alert users immediately when encountering EMF radiation. The sensor detects the standard EMF radiation that is always around the user and provides the corresponding light depending on the amount of EMF radiation measured. As shown in Table 1, the 1st light (green) indicates EMF radiation in the range between 0 to 1.5 mG. The 2nd light (green-yellow) indicates a low-level of EMF radiation, ranging between 1.5 and 2.5 mG. The 3rd light (yellow) indicates a mid-level of EMF radiation in the range between 2.5 to 10 mG. The 4th light (orange) indicates high-levels EMF radiation in the range between 10 to 20 mG. Finally, the 5th light (red) indicates an extremely high EMF radiation range of 20+ mG.

Table 1 Intensity-dependent light color codes for the sensor outputs depending on the amount of EMF radiation exposure. (LED = light-emitting diode; RF = radio frequency).

LEDs	Green	Green Yellow	Yellow	Orange	Red
Detection Range (mG)	0-1.5 mG	1.5 to 2.5 mG.	2.5 to 10 mG	10 to 20 mG	20+ mG
Detection Frequency	30 - 20,000 Hz				
Accuracy	Accuracy of 5% at 50-60 Hz.				

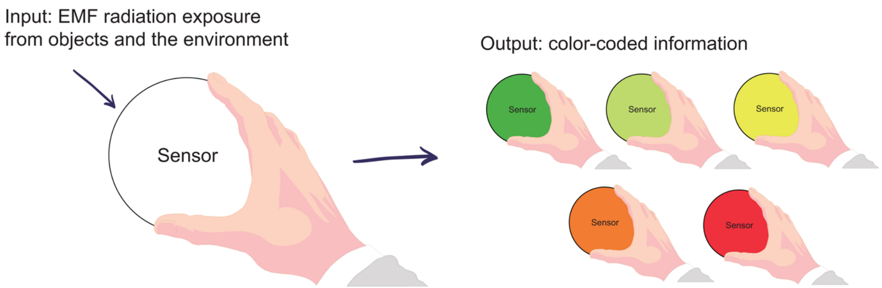

Figure 1 EMF radiation perception and operating mechanism (©Author).

3. Design Prototypes

This paper proposes two types of interface designs: (1) a physical sensor with a tangible design form and (2) a physical sensor with a visual projection form able to share and present the collective information.

Both designs enable users to perceive EMF radiation invisible within an indoor space where the electronic appliances are present. Each design consists of the following parts: 1) A sensor detecting EMF radiation exposure. Both prototypes were structured such that the EMF radiation input and output ports of the sensor light were physically connected to the social interactive design (Schwartzman, 2011).

The sensors in each prototype are the same, with the same standard, precision, accuracy, and response time. 2) A light code allowing users to perceive EMF radiation exposure by visualizing the sensor outputs through five-color light values. 3) A physical interface form. As for the prototype shape, two types were designed: (1) tangible ball prototype: a spherical ball type of variable size (Figure 2); and (2) projection prototype: a visual projection mapping out the visual output codes in the space, installed for easy perception. The result of the EMF radiation measurement is shown as color-coded light; see Section 2. This method is different in comparison to conventional EMF radiation detectors that show the measurement results like a color light coded with a tangible and transparent object, projecting the results to the public interactively.

This study chose two types of intuitive interface forms of user interaction because, first, we observe how the complexity of the user experience of a tangible intuitive interface affects user perception and radiation sensing. Second, we seek insights on how the user experience and intuitive cognition change when personal perception is more shared.

3. 1. Prototype of Tangible Interface: EMF radiation Ball

The Type 1 sensor, the EMF radiation ball, is a tangible, spherical, bouncy object consisting of an EMF radiation sensing port and a five-step color light output port. Its surface material is translucent rubber. The EMF radiation ball diameter is of is 3.25 inches and employs an inbuilt sensor to detect EMF radiation exposure. This enables the user to perceive the presence of EMF radiation easily with a tangible colored light by the user interaction to the surrounding environment by throwing, bouncing, and approaching the ball (Figure 3).

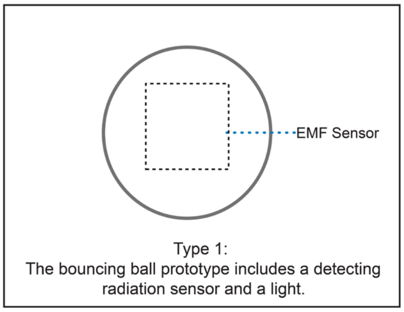

Figure 2 Tangible interface prototype of the physical EMF radiation sensor (□Author)

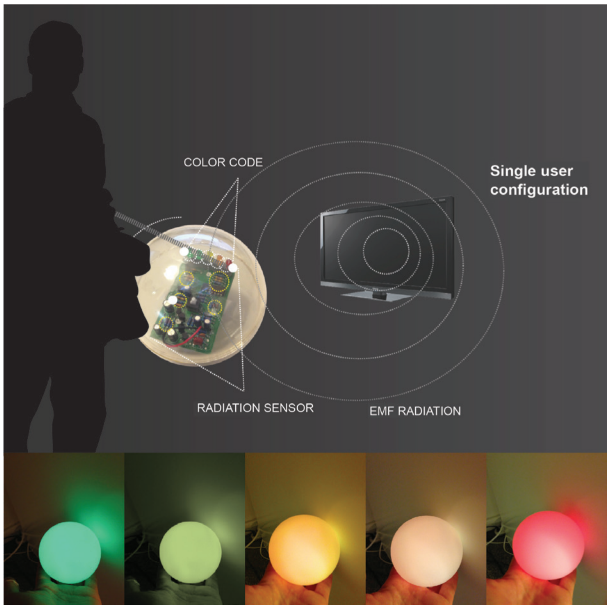

Figure 3 Five colors are emitted in the intuitive tangible interface depending on the sensing radiation (©Author).

3. 2. Prototype of design interface: EMF radiation spatial projection for collectively shared information

As a physical sensor in the form of projection sharing information collectively, the EMF radiation spatial projection is a prototype using a visual projection of an EMF radiation sensor. The electromagnetic wave value measured by the **EMF radiation** sensor is sent to the smartphone as Bluetooth signals, and the result provided by the smartphone maps the color of the corresponding measurement in real-time to space via projection. This prototype consists of an EMF radiation sensing unit and an output projection unit which the user can carry around to detect EMF radiation exposure. The projected exposure intensity is mapped in the space using colored lights (Figure 4). This visual-spatial mapping on the environments of the EMF radiation exposure level makes it possible to perceive the level anywhere, regardless of space or size. As a physical sensor in the form of a projection, which can collectively share information, this sensor can be developed in the form of an interface for transmitting collective information about exposure to electromagnetic waves.

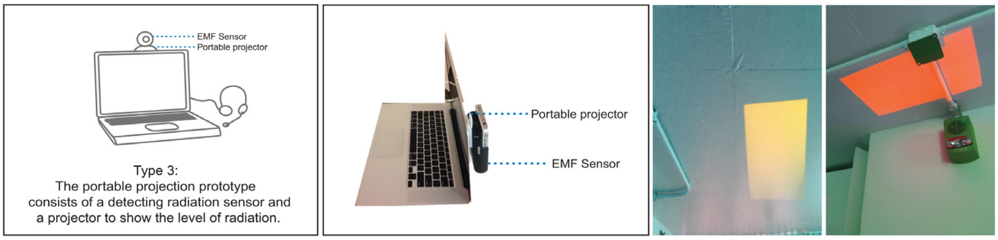

Figure 4 The portable projection prototype consists of a radiation detecting sensor and a projector to show the level of radiation.

4. Field Trials

4. 1. Method

A field trial (Figure 5) was designed to answer the following questions: (1) Can users easily perceive EMF radiation exposure through the proposed objects? (2) Which of the proposed prototypes is best suited for easy perception of EMF radiation exposure? (3) Are the proposed prototypes more effective than existing EMF radiation detectors? (4)

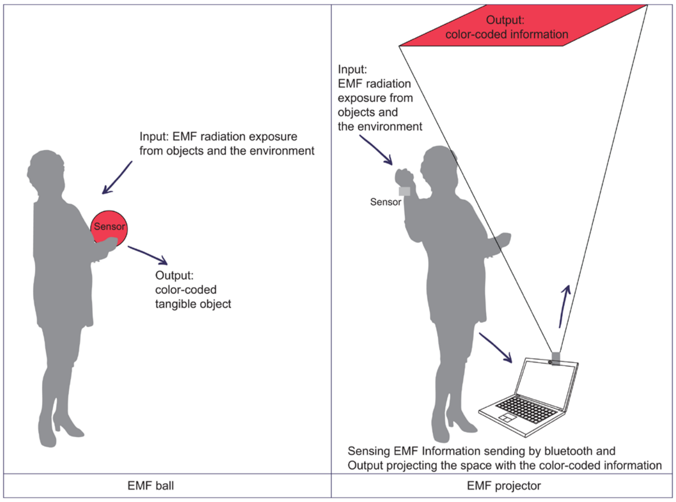

Figure 5 User behavior for each prototype.

Is the user perception to EMF radiation exposure be influenced by the form (two prototypes) and delivery method (personal or open) of the visual color-coded output? To answer these questions, we obtained the results of the field trial using three methods (Figure 6): in situ observations of user behaviors, video recordings, and surveys. The results of the surveys were averaged to analyze the collected data.

Three EMF radiation detectors were prepared: a conventional EMF radiation detector, an EMF radiation ball, and an EMF radiation visual projection. A studio at Peabody Terrace, Harvard University Housing, MA, USA, was chosen as the location for the field trial. The room had a concrete floor, and the walls were painted red and gray. To detect the sensor's output light in the space equipped with objects of daily use better, curtains were installed to obscure natural lighting, and three floor-lamps were installed to create stable lighting conditions.

Figure 6 Examples of user behavior for EMF radiation detection using the prototypes.

4. 2. Participants

The field trial was conducted for four days, with 24 participants from the design field. The gender ratio was 1:1, and the participants were selected randomly to obtain feedback for the interface and user experience. The participants included researchers, instructors, designers, and students of diverse ethnicities: Korean, Chinese, and European. Each day, six participants used three EMF radiation detectors (EMF radiation ball, EMF radiation visual projection, and conventional EMF radiation detector) one-by-one for 20 minutes for each detector. The participants were instructed to freely experience EMF radiation exposure with the EMF radiation detectors in an environment similar to their daily living space. The experiment considered the variance of the block effect because of the color luminosity issue based on the day, hour, and weather during which the experiment was conducted. Nearly the same weather was experienced on all four selected days, and the experiment was conducted simultaneously in the afternoon in an indoor space with windows that were blocked with curtains. All participants took part in the in-situ observation, video recording, and the survey.

4. 3. Measurement

Electronic appliances of everyday use were placed in the trial room to ensure similar EMF radiation exposure experiences and feedback. The following electronic appliances were used for this purpose: wall lamps, a microwave oven, an electric radiator, a laptop, a monitor, a keyboard, a printer, a multi-plug socket, and a refrigerator. The appliances, marked by yellow stickers, were positioned to allow the user to move around freely.

4. 4. Procedure

Twenty-four participants were assigned to four trial sessions over four days (six participants per day). Each participant was instructed first to experience the indoor space where the electronic appliances were placed without an EMF radiation detector. Subsequently, they were asked to use the EMF radiation detectors (both of the proposed prototypes and the conventional EMF radiation detector) by approaching each yellow-marked appliance within 30 cm such that the detectors could sense the EMF radiation and perceive the information. The primary assessment during the trial session took place while each participant perceived the visual data near an electronic appliance by using each detector. The detectors and appliances were presented in a random order (under the given conditions). However, to ensure unbiased measurements, it was prohibited to use the same sensor twice or to perform measurements two or more times. The entire field trial was supervised by the researchers without any breaks between the tests. Each trial session lasted 20 minutes. For user observations and video recordings, a video camera was installed on the wall 30 cm below the ceiling, and each session was recorded.

The instructions for the trial were written beforehand separately on an A4 paper. The main task of the researcher was to have each participant trying the sensors to explore the EMF radiation of the electronic appliances and record his/her behavior in real-time (Figure 7). The participant was then asked to answer the survey items on a scale of 1–100 (0 = not at all, 100 = extremely). Throughout the survey duration, the participant was allowed to continue using the detectors to sense EMF radiation. The basic survey items were formulated based on the model proposed by Russell and Mehrabian (1977) to measure the level of user experience and on the research method proposed by Özcan, Cupchik, and Schifferstein (2017). The survey included five questions in Korean, which have been translated below. Participants answered these questions on a scale of 1–100 (0 = not at all, 100 = extremely).

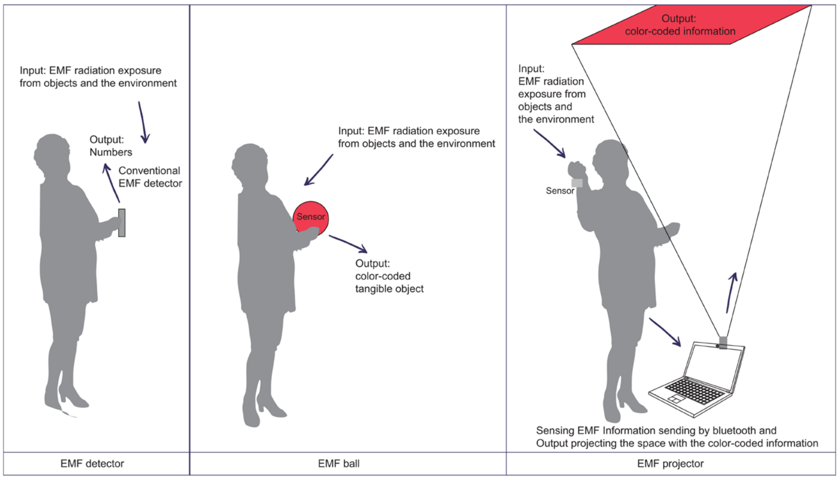

Figure 7 User behavior for each prototype.

•Q1: To what extent did you perceive the level of EMF radiation exposure before the experiment?

•Q2: To what extent can you perceive (see Figure 7) your EMF radiation exposure while you are in the indoor space using the following detector types?
- EMF radiation Detector (0 = not at all, 100 = extremely)
- Tangible EMF radiation Ball (0 = not at all, 100 = extremely)
- EMF radiation Projection for Shared Information (0 = not at all, 100 = extremely)

•Q3: To what extent can you perceive the EMF radiation exposure in this space via the color-coded interface? The color codes represent a process whereby the sensor light output generated by the colored LEDs is expressed by different colors depending on the intensity of the EMF radiation. Thus, it provides qualitative visual feedback on the level of EMF radiation exposure.

•Q4: To what extent can you perceive EMF radiation exposure in this space via the number interface?

•Q5: After the experiment, to what extent do you perceive the level of your exposure to EMF radiation?

5. Results and Experience

5. 1. Result

The questionnaire survey results were analyzed by examining the participants' ratings of the EMF radiation exposure perception through the experience of using the three prototypes of EMF radiation. Figure 8 shows the exposure perception based on repeated measurements.

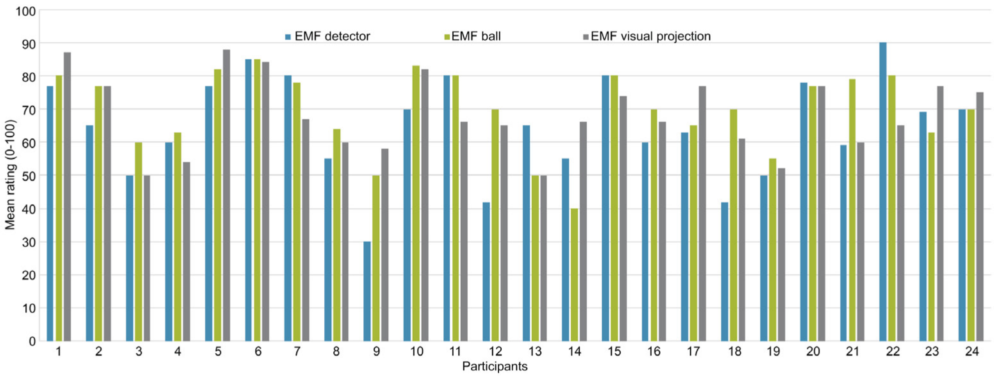

Figure 8 Results after quantifying the individual responses.

Table 2 Survey outcomes

<table>
<tr><th>Object Type</th><th>Mean Score of Individual Exposure Perception</th><th>Mean Score of Object Type and Visual Type Exposure Perception</th><th>Mean Score of Exposure Perception</th></tr>
<tr><td>EMF Detector</td><td>64.66</td><td rowspan="3">66.93</td><td rowspan="3">81.66</td></tr>
<tr><td>EMF Ball</td><td>69.62</td></tr>
<tr><td>EMF Visual Projection</td><td>68.25</td></tr>
</table>

Table 2 shows the results of the survey using the average scores of each evaluation item. The mean score (M) for the exposure perception (Q5) was 81.66, suggesting that the proposed prototypes were efficient in EMF radiation exposure perception. As for the effectiveness of the proposed prototypes versus the conventional EMF radiation detector, the highest score was obtained by the EMF radiation ball (M = 69.62), followed by the visual projection (M = 68.25). Both prototypes outperformed the conventional EMF radiation detector (M = 64.66). That is, the EMF radiation ball and the visual projection obtained almost the same mean scores for exposure perception, as did the EMF radiation detector. This allows to conclude that the proposed EMF radiation models are more efficient than the conventional EMF radiation detector, which displays the sensor output in numbers. To determine whether the two design prototypes and visual light codes of the five-color variations affect users' perception of EMF radiation exposure, we calculated their respective mean perception scores. Therefore, the sensor light was found to have much higher scores than the prototype interface, implying that color codes have a stronger impact on users' exposure perception than the design object types.

Furthermore, an analysis was conducted on the survey results to determine which prototype had the most substantial effect on EMF radiation exposure perception and whether the form of the two object types and color codes of the five-level color-coded lights had different effects on the user perception of EMF radiation exposure. "EMF radiation exposure perception" survey statistics result were set as the dependent variable for the independent variables (designs based on the two object forms of EMF radiation exposure perception, namely, EMF radiation ball, visual projection, and the sensor color code). An analysis was conducted by deriving a regression equation for each item to observe the contribution of each item's attributes toward the users' perception activities in the EMF radiation exposure environment. The regression equation was applied to the results of the field trial, wherein 24 participants experienced EMF radiation exposure with three different types of detectors in an indoor space with electronic appliances and rated their EMF radiation exposure perception. All independent variables (EMF radiation ball, visual projection, and sensor color code) and the dependent variable (EMF radiation exposure perception) were rated on a scale of 0–100. Based on the results of Q3 and Q4 in the survey, 67% of the participants replied that their perception of EMF radiation exposure in this space was better using the color-coded interface than the numbers. According to the results of Q5, 87% of participants stated that their level of awareness about electromagnetic wave exposure increased due to both the color-coded interface and numbers interface.

5. 2. Overall Experience

The observations of the behaviors of the users with the EMF radiation ball can be summarized as follows. The translucent EMF radiation ball displays one of five color codes when detecting EMF radiation in the vicinity of an electronic appliance. When users perceived the visual information of the red light, they became aware that they should maintain a safe distance from the appliance as the color began turning from green to red and moved away accordingly. They relied on visual information rather than bouncing or throwing the ball to perceive exposure. They also showed interest in the ball by repeatedly approaching the ball to the appliances and then moved it away from one side to the other.

The EMF radiation visual projection projects a color in the space and on a surface upon detecting EMF radiation when it is brought within 30 cm of an object. The projected light becomes weaker as it goes farther away from the appliance. Users perceived exposure with the sensor and obtained open information allowing information sharing. Given the attribute of visual projection of displaying the result in the space, users could experience the color instantaneously. They preferred using this method; however, they seemed surprised by the suddenly appearing light projection. They reported that they perceived the level of EMF radiation exposure more intensely through the color codes. When they recognized the exposure to the EMF radiation, they proceeded with one of five steps forward to the object. When the user became aware of the red light, the user understood that they should maintain a safe distance from the object. If the light was not caught within a certain period of time, the distance was adjusted. Twenty percent of the users responded by walking, carrying, or changing positions, or showed that they had observed changes in the color of the light. The user sensed the invisible information of the surrounding electromagnetic wave exposure through the provided design. Moreover, the result was shown as a light on the object; hence, the user immediately experienced the color and was aware of the exposure to the electromagnetic wave in space.

6. Discussion

The field trial verified the significant effects of the EMF radiation sensors designed as objects to perceive EMF radiation exposure in an everyday environment surrounded by electronic products. These sensors can provide qualitative visual feedback on EMF radiation exposure detection while providing cognitive and sensory experiences using color codes generated by LEDs that change colors according to the intensity of EMF radiation.

Users could perceive EMF radiation exposure more efficiently by using the proposed design prototypes of intuitive interface for radiation sensing as tangible forms of a physical sensor and a projection-type physical interface design that can sharing information.

The participants showed interaction with respect to their EMF radiation exposure perception through intuitive visual and tangible interface and visual projection interface. First, they discovered how to detect EMF radiation levels through interfaces. Second, they captured data on EMF radiation exposure through instantaneous color experience with color-coded lights or numbers, and they perceived and responded through personal (EMF radiation detector) or open (EMF radiation ball or visual projection) information. Third, when the perceived red lights by EMF radiation appliances, they tried to maintain their distance from the appliances or moved back from them. Using the proposed designs, they could detect EMF radiation exposure, interact with their surroundings more intensively. This study showed that an intuitive tangible visual interface and intuitive visual projection experience of sensor output through color-coded lights are more effective for EMF radiation perception than is sensor output displayed as numbers.

7. Conclusion and Future Research

7. 1. Conclusion

This study concludes that the users perceive the surroundings more effectively using an EMF radiation sensor through the instantaneous color feedback result when using open information such as an EMF radiation ball or visual projection. Therefore, it can be inferred that users primarily relied on visual feedback on EMF radiation exposure; more precisely, they relied on the experience of perceiving visual codes. This activates memory connections related to safety and perception of the surrounding environment at the cognitive level. These findings lead to the conclusion to recommend the advantage of the experience of intuitive perception and visual colors and lights to effectively design the interface and form of social design objects associated with safety to ensure a practical impact on user behavior. This discussion is also presented in Schifferstein, Otten, Thoolen, and Hekkert (2010); Hallnäs (2011); and Hung and Chen (2012), which can be conceived in the context of interaction design practice on the foundations of ongoing discussions. In the future, such undetectable variations, such as in Eisenberg's "WHAT'S NEXT: Transforming a fluorescent glare into a guiding light" (2001, October 11), can be used to detect optical signals that are transmitted to the processor and software that generate the voice, music, or text messages to create an inexpensive data network. It can be developed into a communication device connecting to a new way of visualizing something invisible.

The study shows that in the future, designers require developing a multi-cognitive design to sense radiation. Moreover, the study shows that the user's interaction behavior connected to an intuitive interface sharing information. Therefore, this study shows a specific spatial context and sharing intuitive information; it also considers to design interface to radiation sensing. Given that information delivery based on both interfaces of instantaneous color experience using visual color codes and open display are efficient for users' perception of social information, this finding has practical significance for designers towards implementing social design. Schifferstein et al. (2010) note that a visual product attribute (e.g., color) influences decision making. The visual attribute of a design is a product attribute that is most widely explored among designers (Blijlevens, Creusen, & Schoormans, 2009; Hekkert, Snelders, & van Wieringen, 2003; Hung & Chen, 2012).

The results revealed that prototypes of open-mode information delivery, such as visual projection or ball sensors extending the sensor output to the spatial experience of color-coded lights, can help users perceive EMF radiation exposure more easily compared with personal-mode information delivery, such as the conventional detector. The conventional sensor was found, although with lower perception capacity, that also had significant effects on the users' EMF radiation exposure perception. Based on these findings, the author proposes that an interface that openly displays the sensor output of social information, such as visual projection or a transparent design object, is a more effective social design for raising awareness about a social issue or the risk of exposure.

7. 2. Research Limitations and Future Research

Because this design project did not involve engineering or technicians, the EMF specific technology, physical sensor systems, and sensors are oversimplified. Instead, this project focuses more on the interface with a sensor, such as the application of the tangible ball interface or visual projection interface. Therefore, this study contributes to the basic resource with a design perspective and possibilities of user's response to the design and the results of the user's experience research to the future sensing design. Moreover, the sensors covered a frequency range of 30 Hz-20 kHz, i.e., the sensor output provides a broadband response. Based on current knowledge, biological effects, such low levels EMF (if there are any), could occur depending on the frequency. Thus, in the future, a more accurate sensor shall be developed to sense radiation levels. Moreover, the study of a small number of representative groups limited the group experiment of this study. Therefore, in the future follow-up research for the public is necessary to overcome the limitations.

Acknowledgement

This paper was conducted and re-quoted based on the Harvard GSD Design Studies Thesis Project: Sensing Radiation: Exploring Social Designs.

First, I appreciate to my thesis advisor Prof. Krzysztof Wodiczko at Harvard GSD, who inspired and instructed me to focus on the social design. I also would like to gratitude to my thesis co-advisor Prof. Federico Casalegno at the MIT Media Lab for comments to design developments.

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