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UNDERSTANDING DYNAMIC DESIGN ELEMENTS FOR INFORMATION REPRESENTATION OF AMBIENT MEDIA

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ABSTRACT:

As newly emerging dynamic elements in the time based design area, such as interaction design, dynamic design elements are evolving under new principles. It is different from the static design elements – color, form or material – of conventional design fields like visual design or product design. Ambient Media (or ambient display, Wisneski et al 1998) represent information through subtle changes of everyday objects and environments. Representing information of ambient media has temporal and dynamic characteristics, utilizing dynamic design elements.

We explored and refined the type of the dynamic design elements, analyzing dynamic qualities of ambient media cases as well as various time based design fields. As a result, 4 dynamic elements – tempo, direction, rhythm and volume – were proposed. Besides, analyzing representation qualities of ambient media, we found diverse representation methods according to the type of information and centralizing types of peripheral information. Understanding the dynamic design elements is expected to help the systematical approach in information representation at users'

peripheral or central attention. We believe this can be helpful in designing various time based design outcomes as well as ambient media.

1. INTRODUCTION

Nowadays, the advanced technology enables products and media to become more interactive and dynamic. It has caused the emergence of new design field, like interaction design, which is dynamic and temporal. Alec Robertson (1994) called this novel area as the fourth-dimensional design, distinguishing it from conventional designs, such as visual design or industrial design. These conventional design fields have been applying form, material, and color as common design elements. On the contrary, the emergent design has used dynamic and temporal design elements, such as tempo, direction, rhythm, and so on. Accordingly, the novel design elements, dynamic design elements, are getting more important in order to understand the emerging 4D design.

Ubiquitous environment that provide information whenever and wherever supports more convenient human life, whereas it can bring about information overload at the same time. As few people control a range of information, a minor error by one can trigger huge problems for the whole. In this sense, M. Weiser (1996) gave weight to the “periphery” of our attention, aware of surrounding without attending to it explicitly. Delivering information at the periphery of a user’s attention enables her/him to be calm and comfortable without being annoying.

Ambient media are inspired from and representative of this agenda. It presents information through subtle changes in our surroundings, which can be processed in the background of awareness (Wisneski et al, 1998). Information becomes ambient when less important, while it attracts the user’s attention as necessary. Ambient media are suitable means to keep users aware of people or general states of large systems without overload (Wisneski et al, 1998). It has become the new subject of design, naturally embodying digital technology into daily products – for instance, ambient umbrella shows the rain forecast by a glowing pulse in its handle[1].

Information of ambient media is represented through our surroundings and objects, especially dynamic changes of light, sound, movement, temperature, or smell. As its temporal and dynamic characteristics in representation, ambient media can be distinguished as one of 4D design with dynamic elements not in the squared screens of the virtual world, but in the tangible objects of the real world. To design ambient media, consequently, it is essential to understand the dynamic design elements, which is discriminated from the static design elements, such as form, color, or

[1] Ambient Device Inc. (2005) http://www.ambientdevices.com/cat/umbrella/ambientumbrella.pdf

layout. The dynamic design elements applying the various changes of our surroundings, however, haven't been focused on much. Since the concept of ambient media was introduced, a growing number of studies have been trying to embody it for the advanced display system of the ubiquitous environment. Most of them, though, have focused on introducing examples controlling specific condition, so there is a limit in taking a general view of the dynamic design elements and its principle to apply.

The goal of this study is to understand and refine the type of the newly emerging dynamic design elements, and to propose how to apply them in order to represent information of ambient media. Specifically, this paper aims to propose the dynamic design elements of ambient media in order to lead a new user-experience by the main feature of ambient media, placing information in the periphery and recentering it as necessary. We first redefined ambient media for our study. Then, dynamic attributes of diverse time-based design fields were looked over to interpret the dynamic elements. Moreover, various cases of ambient media were selected and analyzed in order to understand the dynamic elements of the ambient media and the way to be applied as well. Finally, the representation qualities of ambient media were analyzed to apprehend how to apply the dynamic elements to design ambient media.

2. AMBIENT MEDIA

The lexical meaning of *ambient* is 'surrounding, encircling, encompassing, and environing'. (Oxford English Dictionary) Ambient media is recognized at the periphery of a user's attention, while most of the existing media require users to pay focused attention to conduct a given task. The fundamental characteristic of ambient media, "Peripheral awareness", was influenced by *Calm Technology* of Weiser (1996). In his paper, he described it as what we are attuned to without attending to explicitly. Ordinarily when driving, our attention is centered on the road, the radio, our passenger, but not the noise of the engine. But an unusual noise is noticed, we can swiftly attend to it. He introduced "Dangling String" as an example, a piece of media artwork by artist Natalie Jeremijenko (Fig. 1), which attunes the peripheral awareness. Each passing bit of information is presented visually by a string's movement hanging a small electronic motor mounted in the ceiling and auditorily by the motor sound. This novel media artwork has had huge impact to emerge many new media, not only ambient media but also ubiquitous computing, tangible media, graspable media and so on.

Figure 1: Dangling String

Ullmer & Ishii (2001) explained difference among tangible media, graspable media and ambient media with representation and control. Tangible media can be interpreted as the relationship between representation and control. As the representation expectation is relaxed, graspable media is highlighted. In contrast with graspable media, the spaced of ambient media is highlighted when the control expectation is relaxed.

Recently, ambient media covers a range of media, introduced as ambient display, ambient intelligence, ambient device, etc.

Ambient Display: Ambient displays are defined as media to present information within a space through subtle changes in light, sound, and movement, which can be processed in the background of awareness (Wisneski, 1998). Its original notion was introduced by Ishii & Ullmer, reflecting “Tangible Bit”, which is the vision of MIT Tangible Media Lab. Ambient display media are mainly used to present information at the peripheral attention of general users. As the representative example, “Pinwheels” (A. Dahley, C. Wisneski, H. Ishii, 1998) visualize the flow of digital bit by spinning at different speeds based upon their input information source (Left picture of Fig. 2). Embedded in public space, “Pinwheels” can easily notify people how fast the digital information flows. As another example, “Breakaway” (N. Jafarinaimi, J. Forlizzi, A. Hurst, J. Zimmerman, 2005) presents how long a user has been sitting in front of her/his desk in private space (Right picture of Fig. 2). Its shape and movement changes over time, reflecting a slouching pose. “Breakaway” peripherally encourages the user, whose job requires them to sit for long period of time, to take breaks more frequently.

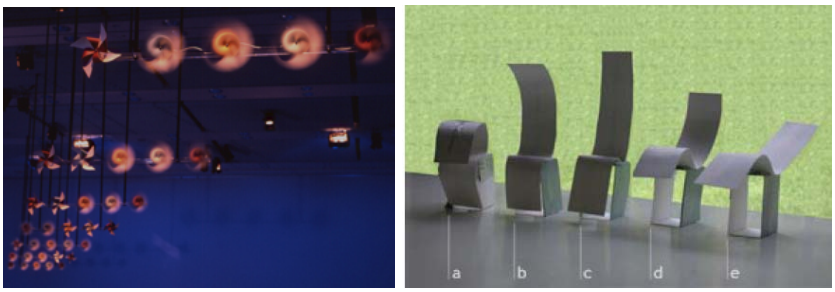


Figure 2: Pinwheels (left) and Breakaway (right)

Ambient Intelligence: The concept of ambient intelligence is a vision where humans are surrounded by computing and networking technology unobtrusively embedded in their surroundings[2]. While ubiquitous computing focuses on network to efficiently find out information embedded into everyday objects and activities, ambient intelligence takes a more human-centered approach aiming to unobtrusively deliver the appropriate information for certain users and contexts (E. Aarts, 2004). Aarts & Marzano (2003) explained the features of Ambient Intelligence as following: Embedded, Context aware, Personalized, Adaptive, and Anticipatory. Its remarkable point of difference from ambient display is to represent personalized information for certain users. For instance, "Gossip Wall" (Streitz, et al. 2003) shows light patterns to present information interesting to the user, passing in front of the installation, by catching the personal information from the user's mobile device (Fig. 3).

Figure 3: Gossip Wall (ambient media installation) and View Port (personal mobile device)

Ambient Device: Although a number of ambient media have been proposed as an installation embedded in space or a fixture, some of them form a product or a device. The products of "Ambient Devices Inc." stand for the sort of ambient device. Among their works, "Ambient Orb" is a glass lamp that uses color to show weather forecasts, trends in the market, or the traffic in your homeward commute (Left picture of Fig. 4). Additionally, they show product type of Ambient Clock Google Gadget, Ambient Clock. It ties into the Google Calendar and displays events coming up as well as how much time it will take to get there (Right picture of Fig. 4).

[2] http://en.wikipedia.org/wiki/Ambient_intelligence

Figure 4: Ambient Orb (left) and Ambient Clock (right)

Ambient Advertisement: Ambient advertisements are effective means of pushing a brand message in front of consumers and can develop even better top of mind recall within target audiences[3]. It can make people accustomed to a brand's image or message, presented on the shopping cart or the backs of car park receipts, on hanging straps in railway carriages and on the handles of supermarket trolleys. At the point of utilizing peripheral awareness, it comprehends the notion of ambient media, but at the point of not applying dynamic elements in surroundings to present information, it is different from "ambient media" studied in this paper.

Embracing ambient display and ambient intelligence, the notion of ambient media in this paper was apprehended; media to represent information at the peripheral attention and attract a user's attention as necessary through dynamic changes of our surroundings.

3. RELATED WORKS

In order to understand dynamic design elements, we explored several studies of dynamic attributes applied to time based design. The time based design, dynamic design, can be divided as dynamic design on screen and dynamic design in the physical environment.

In the dynamic design area on screen, visual dynamic attributes have been formulated. In kinetic typography, Wong (1995) presented frameworks and concrete design solution for temporal typographic design. Especially, he described the characterization of temporal forms by two basic concepts: dimension and manner. Dimension stands for the physical attributes of typographic form, such as color, weight, size, and position. Manner describes 'how' the form changes. It is determined by what direction a dimension changes toward and at what speed. Uekita (1992) classified motion of kinetic typography to connect the relationship between its motion and emotion. In motion graphics, Lee (2004) described the composition of motion graphics as color, form, rhythm, speed, and direction. In screen-based interaction design, Bacigalupi (1998) provided a

[3] http://en.wikipedia.org/wiki/Ambient_media

guide to apply movement in visual art to interaction design. Petersen (2002) redefined the motion language in movies and utilized it in web interface. Even though these studies can help to understand visual dynamic characteristics, it is limited to visual graphics on screen. Moreover, most of studies do not independently focus on the dynamic attributes of each area, but synthetically approach the attributes to understand the general characteristics of each area. In consequence, it is hard to apply their results to ambient media directly.

In the dynamic design area in the physical environment, the dynamic attributes of physical movement have been studied by at large. Vaughan (1997) defined the characteristics of movement as path, area, direction and speed by analyzing movement on the stage of a performance. As to interaction with products, Wensveen (2004) developed the design framework to match action and function, and Dajajadiningrat (2004) examined human's intuitive motor skill. These studies can be useful to understand dynamic characteristics of movement, though it has its limit for other material, such as light, temperature, or sound. Kinetic architecture uses physical movement as design elements of architecture, yet it is used more to develop new cases rather than to organize its dynamic attributes.

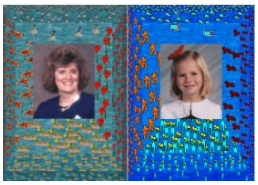
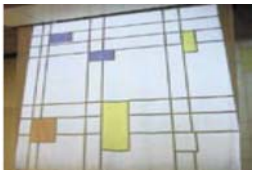
4. ANALYSIS OF AMBIENT MEDIA CASES

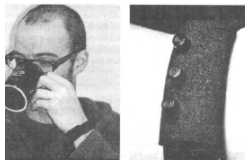
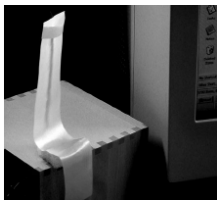
We analyzed existing examples of ambient media to comprehend the characteristics of representation in ambient media and dynamic attributes applied in it. 25 ambient media were searched from papers with key words, such as ambient media, ambient display, ambience, and periphery, and from media mentioned as related works[4] of ambient media. Among them, we selected 13 media, which utilized dynamic and temporal changes as expression and selectively represented information at a user's peripheral attention and central attention as needed. Adding 2 more ambient device media form web search, we finally collected 15 ambient media (Table 1).

Table 1: Ambient media examples

Title	Image	Description
Pinwheels (Dahley et al, 1998)		An ambient fixture which visualizes an artificial airflow and uses it as a medium to visualize a flow of digital information. They spin in a wind of bits that blows form cyberspace.
Stockwatch		A personal and mobile ambient display which uses temperature to convey information about changes in stock rates. The back of a watch becomes a display which changes its temperature depending on

[4] It referred to the works of Hansson et al (2001) and Plaue et al (2001)

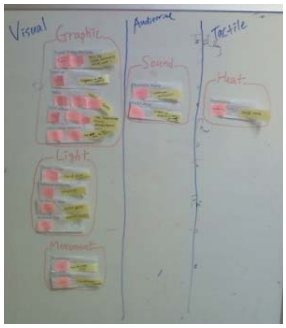
(Wisneski, C., 1999)		fluctuations in the user's stock.
Nomadic Radio (Sawhney et al, 1999)		A wearable notification tool which uses audio messaging to convey scalable and contextual notifications. It conveys notifications differently depending on message priority, usage level, and environmental context.
Water Lamp (Dahley et al, 1998)		An ambient fixture which visualizes the raindrops of "bits" by projecting water drops.
Digital Family Portraits (E. Mynatt, et al. 2001)		A digital frame of a family portrait which provides qualitative visualizations of a family member's daily life related to health, relationships, activity and events with iconic imagery. It represents time by changing background bands and the size of icons.
Informative Artwork (Holmquist et al, 2003)		An ambient display which visualizes bus departure times by graphically moving abstract images. A Mondrian styled colored square on the screen represents one bus and indicates when it leaves by changing size and color.
InfoCanvas (T. Miller and J. Stasko, 2002)		A peripheral display that conveys awareness information graphically as a form of information art. It presents various types of information, such as time of day, a weather forecast, a temperature forecast, traffic condition, and so on, by a variety of objects moving or changing size or color.
Miro (K. Boehner, et al. 2003)		A display system in an office building to provide building occupants with a sense of the overall emotional climate in the office. The emotional data collected through surveys and entry station is aggregated and displayed through the movements and colors of objects in the display.
perCue (C. Obermair, et al. 2006)		An ambient display on public spaces to persuade users to behave in an ecological sustainable way, specifically to increase the awareness for environmental pollution, by demonstrating the effect from whether users take public subway or not.
The Gossip Wall (N. Streitz, et al. 2003)		A compound artifact with sensing technology. It serves the function of "spreading gossip" by providing awareness and notifications to people passing by via light patterns. Different patterns correspond to different types of information. People can access details via portable M-size artefacts as the ViewPort.

Reminder Bracelet (R. Hansson et al, 2000)		A notification tool that is worn on the wrist and connected to a PDA. It notifies its user of scheduled events in a subtle and silent manner using light, color and patterns.
Audio Aura (E. Mynatt, et al. 2001)		A wireless headphone that provides serendipitous information, via background auditory cues, which is tied to people's physical actions in the workplace.
Breakaway (N. Jafarinaimi et al, 2005)		A small sculpture that encourages people, whose job requires them to sit for long periods of time, to take breaks more frequently. Its shape and movement reflect the form of the human body; an upright position reflecting the body's refreshed pose, and a slouching position reflecting the body's pose after sitting for a long time.
Ambient Orb (http://www.ambientdevices.com)		A glass lamp that uses color to show weather forecasts, trends in the market, or the traffic on your homeward commute. The Orb preset to track the Dow Jones Industrial Average, glowing more green or red to indicate market movement up or down, or yellow when the market is calm.
Ambient Umbrella (http://www.ambientdevices.com)		A forecasting umbrella with the glowing handle, which tunes into AccuWeather.com predictions for your specific geographic location. If the chances of rain are 100% the light in the handle will pulse 100 times per minute. If rain is less likely the pulse rate decreases proportionally.

At the point of expression and notification, we conducted card sorting with the selected examples.

4. 1. DYNAMIC EXPRESSION QUALITIES

Before inspecting the characteristics of information representation in ambient media, we sorted various material of dynamic expression in ambient media. As the result, the sorts of dynamic changes of examples were classified into three parts: visual changes of graphic, light, and movement, auditory changes of sound, and tactile changes of temperature (Fig. 5). Specifically, the dynamic qualities applied to each changes were derived: degree, intensity, volume and direction in graphic, tempo, rhythm, degree and volume in light, speed and direction in movement, and finally degree in sound and heat (Right picture of Fig. 5).



Visual Change	Graphic	Miro	Color, Size, Amount	Hue Brightness Size Amount Position	Degree Intensity Volume Volume Direction
		InfoCanvas	Size, Form, Position, Color		
		perCue	Size		
		Digital Family Portraits	Brightness, Size		
		Informative Artwork	Size, Color		
	Light	Water Lamp	Form, Frequency	Frequency Pattern Color Rate Brightness	Tempo Rhythm Degree Tempo Volume
		Gossip Wall	Blink Pattern		
		Reminder Bracelet	Blink Pattern		
		Ambient Orb	Color		
		Ambient Umbrella	Blink Rates		
	Movement	Pinwheels	Speed	Speed Form	Speed Direction
		Breakaway	Form		
Auditory Change	Sound	Audio Aura	Types of sound	Degree	Degree
		Nomadic Radio	Types of sound		
Tactile Change	Heat	Stock Watch	Degree	Degree	Degree

Figure 5: the result of card sorting to understand dynamic expression qualities

To understand the dynamic expression qualities, we reviewed dynamic qualities of visual, auditory, and tactile expression from the related works presented ahead.

1) Visual Dynamic Qualities

Bacigalupi (1998) said polytechnic engineers, Kepes and Moholy-Nagy, analyzed the aesthetics of movement in visual art and resulted formal movement qualities: rhythm, tempo, sequence, and direction. He described each quality as the following: Rhythm occurs as a result of changes in intervals from one active movement to the next. Tempo can be defined as the cadence or pace of a rhythm. Related to both rhythm and tempo, sequence illustrates events occurring over time. As an object exhibits a sequence of events that occur over time and therefore space, it must move within that space, and this gives it direction.

Young et al (2006) further developed the work of 'Understanding Movement'; Vaughan (1997) and derived appropriate variables (grammar) for motion in product notation to be: path, volume, direction, and velocity. Path is the line that an object movement follows. Volume is the use of space by the object including scale change and kinesphere. Direction is the direction in which the object moves; up, down, towards and away. Finally, Velocity is the speed, acceleration and tempo of the object.

Sequence by Kepes and Moholy-Nagy is the affair or event of diverse dynamic qualities over time rather than dynamic quality itself. Path can be understood as the result of the change of direction. Liner path, curve path and rotation are created by liner direction, curve direction and rotating

direction. Consequently, the dynamic qualities from the studies can be adjusted as rhythm, direction, volume, and speed.

2) Auditory Dynamic Qualities

Music is the art of sound composed by the construction of sounds and its combination on time base (Lee, 2003). Comparing with other art areas like paintings or sculpture, which is fundamentally based on space, music is the most representative time based art, expressed with sound within a certain period of time. In the music curriculum of MMCP (Manhattanville Music Curriculum Program) of USA, basic qualities of music consist of pitch, rhythm, intensity, timbre and form (Thomas, 1971). In Seong & Hwang's basic study for the revision of the music curriculum (Seong, 1987), they consist of rhythm, melody, form, intensity and timbre. As the part of the musical structure, they are constructed by adding timbre and form to the three fundamental elements of music: rhythm, melody and harmony (Lee, 2003). Rhythm is the most basic constituent of the formation of music, so there is no music without rhythm[5]. The importance of rhythm in music has been emphasized as shown in the saying "Im Anfang war der Rhythmus"[6]. Rhythm is of mixing 'long or short' notes or intensity over time, and melody is of mixing 'high or low' notes or 'long or short' notes. Harmony is the condition of simultaneously resonant notes, which have different pitch. Aside from them for the musical qualities, there are tempo, meter, accent, nuance, beat, etc. From the above, rhythm, intensity, tempo are selected as the musical qualities related to time.

3) Tactile Dynamic Qualities

Although many novel cases of tactile interface have been suggested, studying tactile dynamic qualities hasn't been done much yet. "Stockwatch", an example of ambient media with tactile feedback, represents information by the variation of high or low temperature. As a strong or weak stimulus, it can be connected with intensity of a stimulus. When we write down something on our hand with a finger, we can feel the direction or speed of the stimulus as well. Using this kind of tactile feedback, "Forehead Retina System" is a novel tactile display for the visually impaired (H. Kajimoto, 2006). A small camera and 512 forehead-mounted electrodes capture the frontal view, extract outlines, and convert the data to tactile electrical stimulation[7]. From the above, intensity, direction and speed of tactile stimuli can be considered as dynamic qualities.

[5] CHoi, H.D., http://www.kguitar.net/
[6] It was said by Hans von Bulow, 1830~1894
[7] http://www.siggraph.org/s2006/main.php?f=conference&p=etech&s=forehead

Centering for the common qualities of all material – visual, auditory and tactile, we resorted the extracted qualities above. Accordingly, we can grasp the dynamic elements, which can be generally applied to the time based quality of ambient media: tempo, direction, rhythm and volume (Fig. 6).

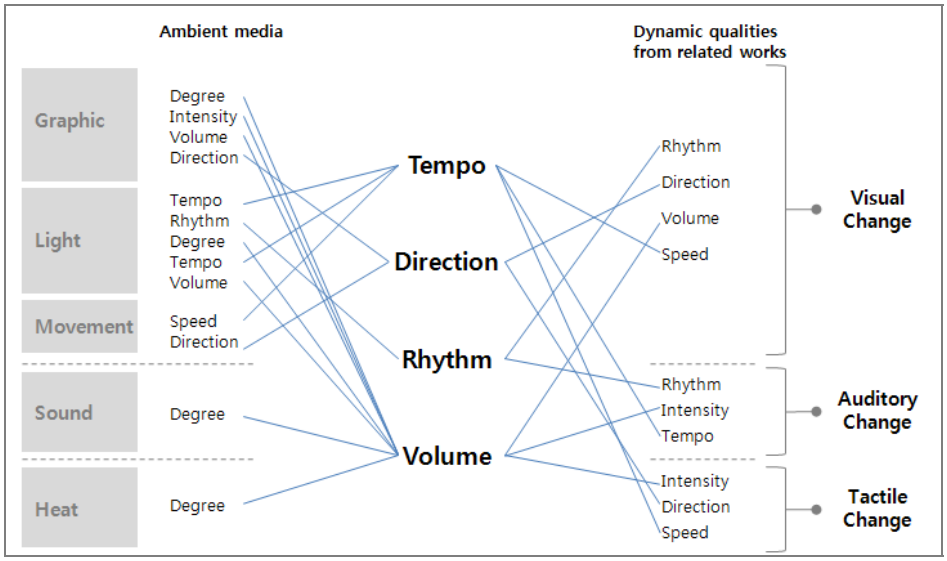


Figure 6: Dynamic design elements extracted from ambient media and related works

- Tempo: Pace or its variation of time flow

  Tempo is the most basic quality of time flow. This is the time length of an interval of the variation of an object on time base (see picture B of Fig. 7). Tempo is fast with a wide interval, and slow with a narrow one. It generally means speed or pace of dynamic changes. The regular variation of tempo – getting longer or shorter of the interval – causes acceleration.

- Direction: The progressive direction of an object or time flow over time

  Direction is the progressive direction of an object by the change in space over time, or the progressive direction of time. The progressive direction of an object is made up of back-forth, left-right and up-down, and classified as linear direction, curve direction and rotating direction by the path of the object's movement. The progressive direction of time consists of the obverse and the reverse of time flow (see picture B of Fig. 7).

- Rhythm: The regularity of time intervals between dynamic changes

  Rhythm is the rhythmical alteration of time intervals between dynamic changes or volume in a time unit. Through rhythm, the alteration on time base has a rhythmical shape, which is composed with a straight line or a curve line (see picture B of Fig. 7).

- Volume: the scale of changes over time or the variation of intensity

  Volume is the scale of the difference from the previous variation to the next variation, increasing or decreasing the property of an object. On the horizontal time axis, volume can be described as the vertical height (see picture B of Fig. 7). Its numerical value can match diverse properties of an object, such as an object's size, the range of movement, brightness of light or color, sound volume and so on. Figure 7 shows the example of changing size of dot. The positive side of volume axis means the increase of the dot's size, and the negative side displays the decrease of it.

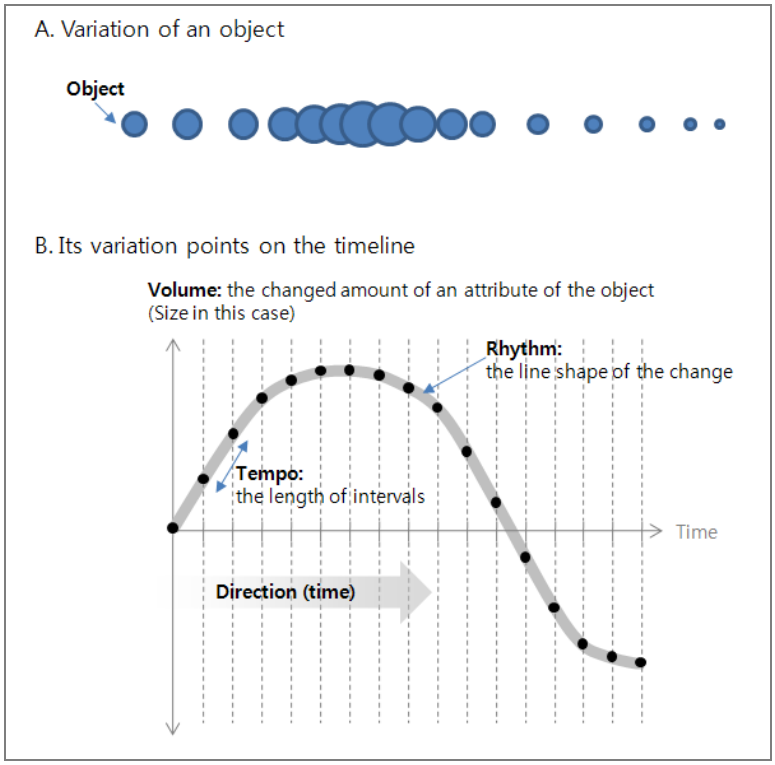


Figure 7: The features and relationship between dynamic design elements on time base (a size variation example)

4. 2. INFORMATION REPRESENTATION QUALITIES

1) Diverse Representation Methods According to the Type of Information

As the result of card sorting, the information of ambient media was found to be differently represented according to its types: simple or complex information (Fig. 8).

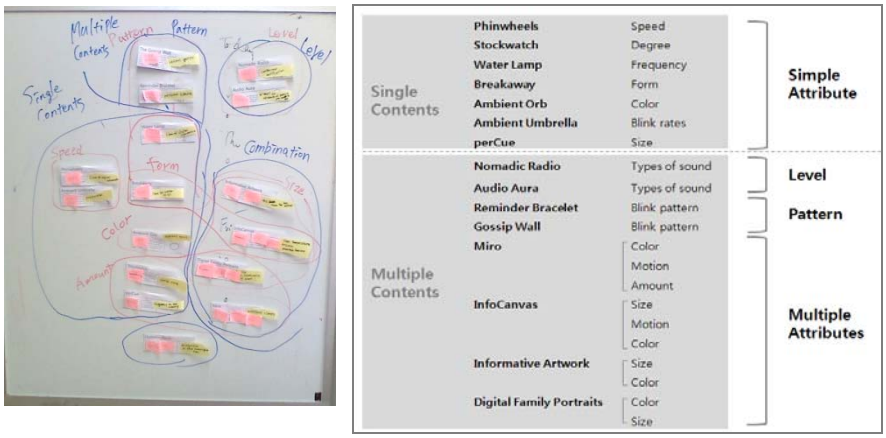


Figure 8: Diverse representation methods according to the type of information extracted from card sorting

In the case of presenting simple information, a simple attribute or quality, such as speed, amount, form or color, is matched to the information. Complex information, on the other hand, tends to apply more manifold expression structures. First of all, multiple attributes are attached to map one by one. Secondly, various patterns of simple or multiple attributes show each. Unlike applying multiple attributes, each attribute doesn't have any meaning, while only each pattern as a set of variation does. Finally, hierarchical level can be provided to present information as the proper mode for the context. The more important information is, the more concrete mode it can be. For example, "Nomadic radio" shifts its display mode from abstract and ambient sound when information is unimportant, to more concrete way, such as voice or dialogue, as necessary.

2) Centralizing Types of Peripheral Information

In order to understand the characteristics of centralizing the peripheral information of ambient media, representation methods to get a user's attention were classified (Fig. 9).

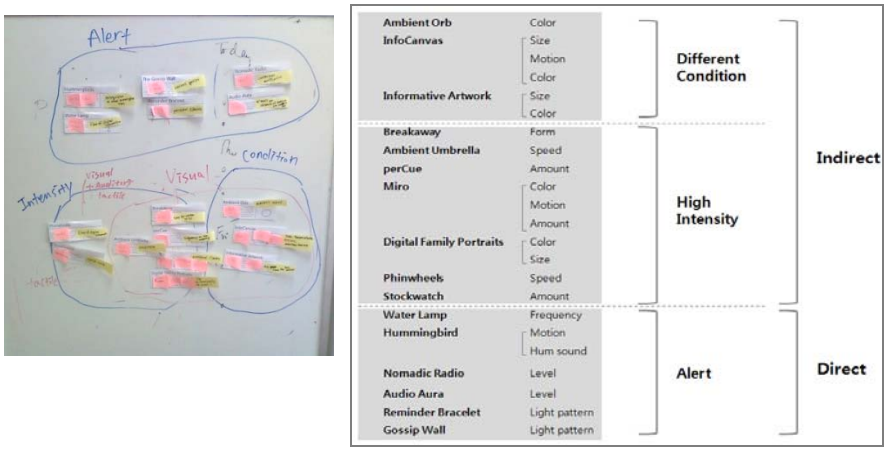


Figure 9: Centralizing types of peripheral information extracted from sorting ambient media cases

First, some ambient media indirectly shift the peripheral information to the center of a user's attention. In this case, a user can decide whether the information presented with ambient media becomes significant or not. Tracking the Dow Jones Industrial Average, "Ambient Orb" glows more green or red to indicate the market movement up or down, or yellow when the market is calm. Its user should additionally learn what each color means. "Pinwheels", which visualizes the flow of digital information by the speed of pinwheels, or "Ambient Umbrella", which shows the chance of rain by the pulse of light on its handle, gets more intensity according to the significance of information. Catching the intensity, their user can intuitively recognize that something is wrong or its significance without the extra learning.

Secondly, other ambient media more directly alert a user, deciding the timing to inform the information by themselves. "Reminder Bracelet" alerts a user his/her schedule by turning on the LEDs on the device. When a user is passing by "Gossip Wall", it shows various light patterns to alert the user her/his interests, catching her/his personal information via the mobile device. The user can download the more specific information with the mobile device. "Nomadic Radio" reports abstract and ambient sound or direct voice message according to degree of information significance. Alerting the information, it simultaneously takes the explicit way to present the information as needed.

5. CONCLUSION

Dynamic design elements that newly emerged in design fields is the key method to represent information in ambient media. It is used for peripherally representing information through various changes in our surroundings. This study explored the dynamic design elements in diverse points of view to efficiently apply them to provide the new user the experience of ambient media. As the result of analyzing dynamic qualities in various areas and ambient media cases, four dynamic elements – tempo, direction, rhythm and volume – could be extracted. We could, moreover, find that they had different types of application and influence as the characteristics of information. When the peripheral information was centralized, each dynamic element could trigger different effects. Understanding the dynamic design elements is anticipated to help the systematical approach in information representation at users' peripheral or central attention. It is expected to utilize them for various time base fields as well as ambient media design.

As future work, we plan to clarify concrete characteristics and practical use methods of the dynamic design elements by designing ambient media case with them. According to diverse representation methods – using simple or multiple attributes, pattern, or level – and centralizing types of peripheral information – indirect and direct – as mentioned above, each dynamic element will be tested within the ambient media case.

6. ACKNOWLEDGEMENT

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