Original Article

Study on understandability and design elements of cardinal directions

Minju Kim (Graduate School of Science and Technology, Kyoto Institute of Technology, minjukim06@gmail.com)
Kazunari Morimoto (Graduate School of Science and Technology, Kyoto Institute of Technology, morix@kit.ac.jp)
Noriaki Kuwahara (Graduate School of Science and Technology, Kyoto Institute of Technology, noriaki.kuwahara@gmail.com)

Abstract

Cardinal directions are presented as visual information for guidance and leading. The purpose of this study is to clarify the elements of design for an intuitive better understanding of cardinal directions. First, current cardinal directions were collected from the literature and field studies, and components of design that should be considered when drawing cardinal directions were extracted. Then, using the four types of cardinal directions based on design components as the stimulus, the perspicuity of each diagram was analyzed through paired comparison method. As a result of the integrated evaluation of four types of cardinal directions, the use of the letter N meaning the north direction in any of the types was proved to lead to better understanding. However, depending on the type of cardinal directions, the appropriate state of design element that could help the audience to understand differed. Specifically, if the pointer only indicated north, it was answered that it would be better to understand to display only the letter N, but if there were four pointers indicating four directions, it would be better to display all the four directions. In other words, it will be optimal if the design elements and displayed characters combine appropriately depending on the respective direction number. In addition, since excessive simplification comes to reduce the perspicuity instead, it is required to denote the necessary character information for orientation.

Key words

cardinal direction, design elements, understandability test, paired comparison method, ranking method

1. Introduction

A lot of information is required to live and move in the city. One useful means for obtaining this information is signs. It is required that signs should be drawn to express clearly the contents needed to be transmitted and be simple and easy to see so that anyone can easily understand.

As one of the signs, cardinal directions can provide directional guidance and necessary information on moving in the streets, on the roads, or in buildings, etc. In particular, since there are many visitors from other cities on mountain trails and in tourist areas, they often rely on guidance maps with cardinal directions drawn. Although the importance of a cardinal direction is especially high in unfamiliar land, it is also important in scenes close to life. Therefore, cardinal directions are used in various forms in guide maps and at public places with an unspecified large number of people such as on the ground of sidewalks directly after walking up from an underground station, on the evacuation route maps of subways, and on the guide maps of buildings, etc.

For the direction policy of pedestrian's guide signs included in the sign system guide maps in the passenger facilities of public transportation agencies, "if the range of the map is wide like a passenger facilities' surrounding guide map, it is better to put north on the top from a geographical perspective" during the use of cardinal directions. It is also said that "current position, orientation, and scale must be clarified in maps" (Foundation for Promoting Personal Mobility and Ecological Transportation, 2002). From the study of signs up to now, it has been pointed out that the visibility and recognition difference due to age is important during the development of pictogram design used in public transportation facilities (Amano, 2010). In addition, it has also been reported that when it is a text sign, the complexity, the number of elements composed with kanji or alphabets, and its visibility during walking can all affect the readable threshold of pedestrians (Furusho et al., 2008). On the other hand, when text is added to pictograms, it has been confirmed that the comprehensibility is highlighted (Hishinuma et al., 2012). In particular, the sign system should be planned so that it can be easily seen and understand by anyone no matter elderly, handicapped, or foreigners (Masaki and Shiizuka, 2008). The standard can only be that the orientation of the actual cardinal directions should match the lines of sight of person standing in front of the sign. On the other hand, there are also many cardinal directions served with artistry as well as other complex cardinal directions with decorations that have nothing to do with orientations. As displayed information quantity varies greatly in those cases, the original function of indicating directions may fail in some cases.

Study of sign systems have been made mostly on the present condition of pictograms or signs. Studies related to sign systems until now are mainly about the spatial condition of pictograms and signs (Saigusa, 2007; Mito et al., 2010; Nishikawa and Yamamoto, 2003). However the study of information contents display for a better perspicuity of cardinal directions is not enough. To clarify the design elements during the

design of intuitively easy-to-understand cardinal directions, this study has carried out subjective evaluation experiments. First, the existing cardinal directions were collected, and the design elements of each cardinal directions were extracted. Then, evaluation experiments were conducted on the understandability of each element.

2. Design elements of cardinal directions

Cardinal directions are derived from the symbols used in a compass invented in China (around B.C. 200), and this compass spread to Europe in about the 12th century and began to be used widely (Imai, 2007). Cardinal directions were mainly labeled with kanji for directions, and each direction used feng shui terms with geographical meanings. This Chinese cardinal direction marked mainly with characters was more symbolized and added with more design after spreading to Europe. For example, the cardinal direction "compass rose" designed by Jorge de Aguiar in 1492 is displayed in Figure 1. It took a rose's shape, and used complex patterns and was polychromed. However later, along with the development of geography and medicine, it was simplified and symbolized (Imai, 2007).

Figure 1: An example of cardinal direction named compass rose

From current cardinal directions, the 3 most commonly used diagrams were extracted and shown in Figure 2. Although they were simplified compared to the compass rose of Jorge de Aguiar, the basic shapes of cardinal direction did not change much. Also, the 8-directions, 4-directions, and 1-direction diagrams all use north as the standard but use various different shapes.

In order to select the cardinal directions used in this study,

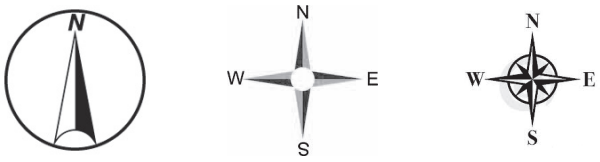

Figure 2: Examples of cardinal directions

design magazines with cardinal directions, maps, guide maps on streets, and sources on the internet were searched. After eliminating similar shapes, the number of collected cardinal directions became 405. As a communication media, a sign must have three attributes: "information contents" as the message, "expression style" as the expression form, and "spacial position". This is a well-known general principle derived from the planning elements of many projects, however this study only talked about two attributes, "expression form" and "information contents" after defining "information contents" as "information element" and "expression form" as "shape element".

In order to extract the design elements to be considered from the cardinal directions, the components of design of the 405 cardinal directions were extracted by analysis through visual observation. As shown in Figure 3, shape element determined the overall shape of the cardinal directions, and it was classified into 11 types as "black and white color, multicolor, surface, straight, curve, diagonal, circle, triangle, rectangle, symmetrical, and asymmetrical". Information elements were marks indicating the orientation, such as characters like east (E), west (W), south (S), north (N), northeast (NE), southeast (SE), southwest (SW), and northwest (NW).

In addition, design based on the shape element of cardinal direction is shown in Figure 4, and it has been classified into

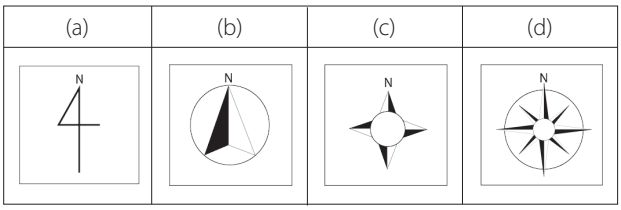

Figure 4: Classification of cardinal directions based on shape element

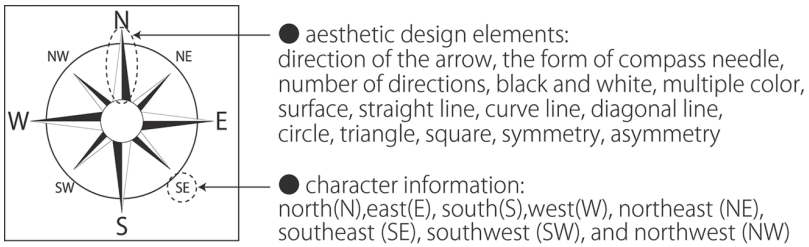

Figure 3: Design elements of cardinal direction

(a), (b), (c), (d) four groups. Considering the form of pointer, number of orientations, and direction of arrows, the shape of cardinal direction was classified into four types including (a) the shape of number 4, (b) arrow shape pointing one direction, (c) arrow shape pointing four directions, and (d) arrow shape pointing eight directions. In the design of each group, they are characterized by symmetry and orientation to indicate the number of differences. The characteristic of design of each group differed according to the number of explicit orientations and symmetry.

3. Experiment I: Understandability of cardinal directions (paired comparison method)

In order to investigate easy-to-understand cardinal directions based on the shapes shown in Figure 4, a paired comparison method was used to evaluate. The sample used for evaluation was drawn based on the design components of Figure 3.

3.1 Experimental method and conditions

(1) Stimulus for experiment

Cardinal directions for evaluation are shown in Figure 5. These cardinal directions were created after adding the basic shapes in Figure 4 and orientation information in Figure 3, and considering symmetry and others.

Group a consists of the basic shape of number 4, with straights and character information indicating four directions. The form is asymmetric both vertically and horizontally. a1, a5, and a6 have different character information added to the shape of number 4, while a2, a3, a4 are different because of adding horizontal lines of a segment. a7 has further added patterns and also displayed character information indicating 4 directions.

Group b took the basic shape of having one pointer indicating north, with a circle and character information (N) indicating direction (North), and it is asymmetric vertically. b1 and b3 deformed the "triangle", while b1 blacked out the left part of the arrow, b3 blacked out the whole. Also, b2 and b5 showed the difference of the orientation of the triangle. b2 had only one direction and blacked out all the others. b5 pointed to two directions and had the upper part triangle blacked. b4 and b6 simply take the shape of arrow but the thickness of lines and shapes of the arrows are different.

Group c takes the basic shape of having four directions including east (E), west (W), south (S), and north (N), and consists of a circle and character information indicating four directions or the mark shown in c5. c1, c3, and c4 have the same character information but different arrow shapes. c2 and c5 are different on whether having charac-

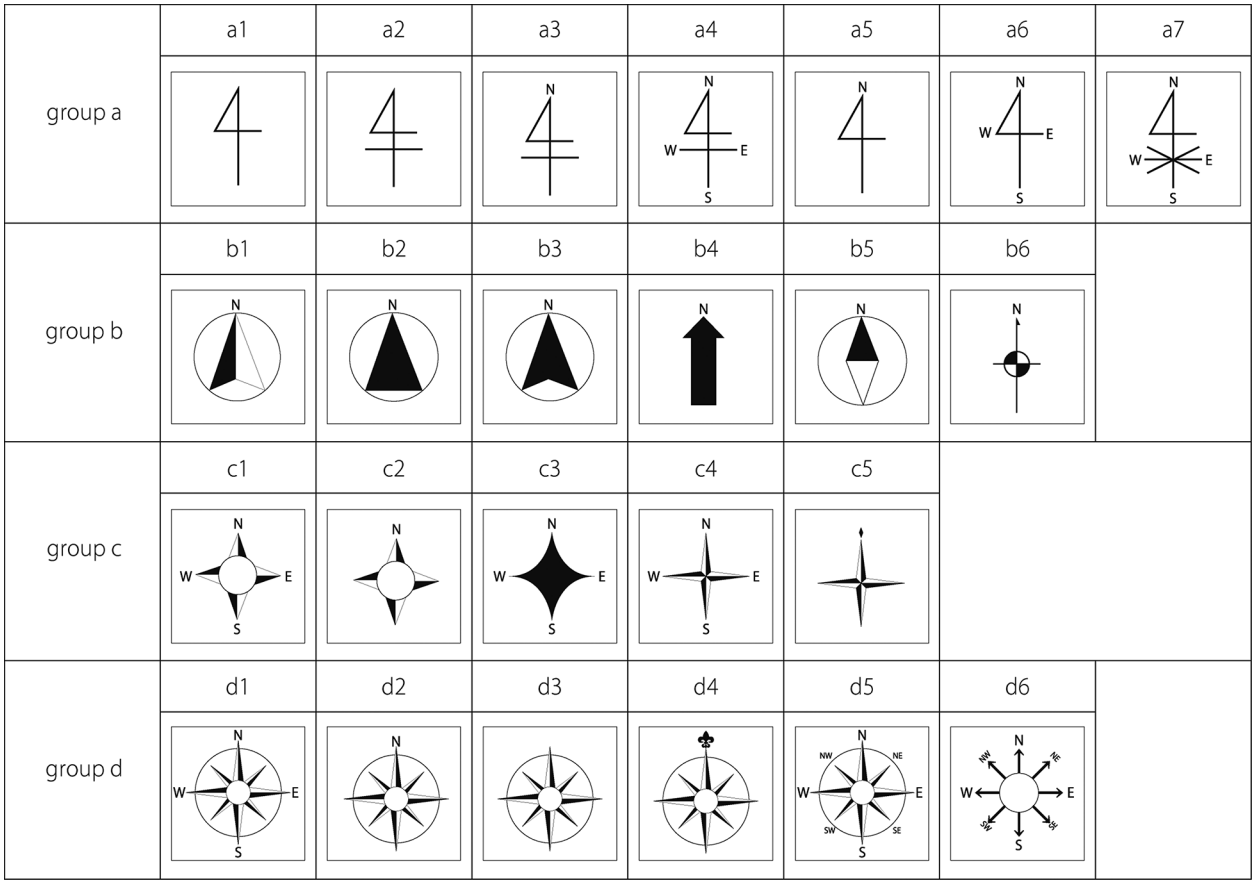

Figure 5: Example of cardinal directions used for subjective evaluation test

ter information.

Group d uses the arrow shape indicating 8 directions as the basic shape, including east (E), west (W), south (S), north (N), northeast (NE), southeast (SE), northwest (NW), and southwest (SW). It is composed of a circle and character information indicating eight directions or a mark. Its shape is symmetric both vertically and bilaterally. d1, d2, d3, d4, and d5 are different on whether having character information. d6 and d8 have different arrow shapes.

(2) Experimental subjects

The subjects were 40 college students in their 20s or 30s (male: 20 people, female: 20 people). The experiment was rated by paired comparison method (Thurstone's Paired Comparison). As the judge of evaluation was easy and the reliability and validity were high, this method was chosen.

(3) Experimental method

Given that the upper part of the monitor shown in Figure 6 was north, the experimental subjects were required to answer which cardinal direction was easier to understand while giving two stimuli on the left and right. Comparison of samples had to be within each group and the display order of the two cardinal directions and their left and right positions were random. For comparison, group a performed 21 times, group b performed 15 times, group c performed 10 times, and group d performed 15 times, and the total number of comparison was 61 times.

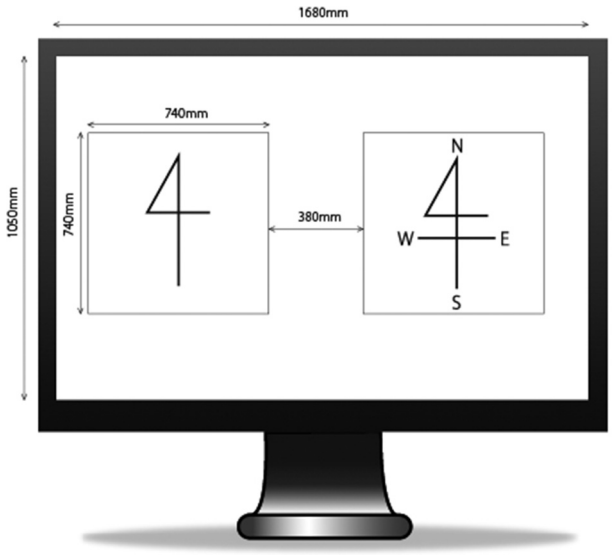

Figure 6: Cadinal dircetions displayed on screen

3.2 Experimental results and discussion

3.2.1 Selectance and rank of evaluation on understandability inside each group

The ranking scale values obtained by comparison of the clarity of the combination of character information elements and shape elements is shown in Figure 7. A higher evaluation scale value indicates better understandability.

While looking into the scale values of the stimulus samples of group a, the understandability grows higher in the order of a6 > a5 > a4 > a3 > a1 > a2 > a7. The relationships of a1 and a5, a2 and a3 show that despite of the same shape elements, a3 and a5 have higher evaluation because of sharing the same character information of north (N). Furthermore, though a1 and a6, a2 and a5 have the same shape elements, a5 and a6, which have the character information of east, west, south, and north, have higher evaluation compared to those without character information. In the comparison of a3 and a4, a5 and a6, the result shows that a4 and a6 without transverse lines have higher evaluation. Although the two samples all have character

information element, the increase of one single line in the shape element has decreased the understandability. Also, the fact that a6 has higher evaluation in the comparison of sample a6 and a7 proves that extra shaded or transverse lines can lead to low understandability.

The scale values of stimulus samples from group b showed that the understandability increases in the order of b5 > b3 > b1 > b2 > b6 > b4. Although b5 and b4 all point to the north direction, cardinal directions similar to a compass rose were rated to be easier to understand than those with only direction arrows. Sample b4 and b6 using arrow shapes are considered hard to be recognized as cardinal directions. Also, in the comparison of b2 and b5, compared to b2 taking a triangle shape and pointing to only one direction, b5 was rated to be easier to understand as it had a symmetric shape and pointed both upward and downward.

The evaluation of understandability grows in the order of c4 > c1 > c2 > c3 > c5 from the scale values of stimulus samples in group c. From the comparison of c5 and c4, the evaluation was higher for cardinal direction with character information of east, west, south, and north. Also, the understandability changed according to the amount of character information in c1 and c2. On the other hand, though c3 and c4 all had character information indicating each direction, the one combined with triangle shape elements like c4 was rated to be easier to understand.

The evaluation of understandability grows in the order of d1 > d2 > d5 > d6 > d4 > d3 from the scale values of stimulus samples in group d. From the evaluation of d1 and d5, it was clear that instead of writing all 8 directions, character information of 4 directions was better even when the shape elements had 8 directions. In addition, from the comparison of d3 and d1, it is known that the existence of character information can affect the evaluation of understandability greatly. On the other hand, though d4 and d5 had the same character information, a compass shape combined with a triangle still had better evaluation compared to simple arrow shapes.

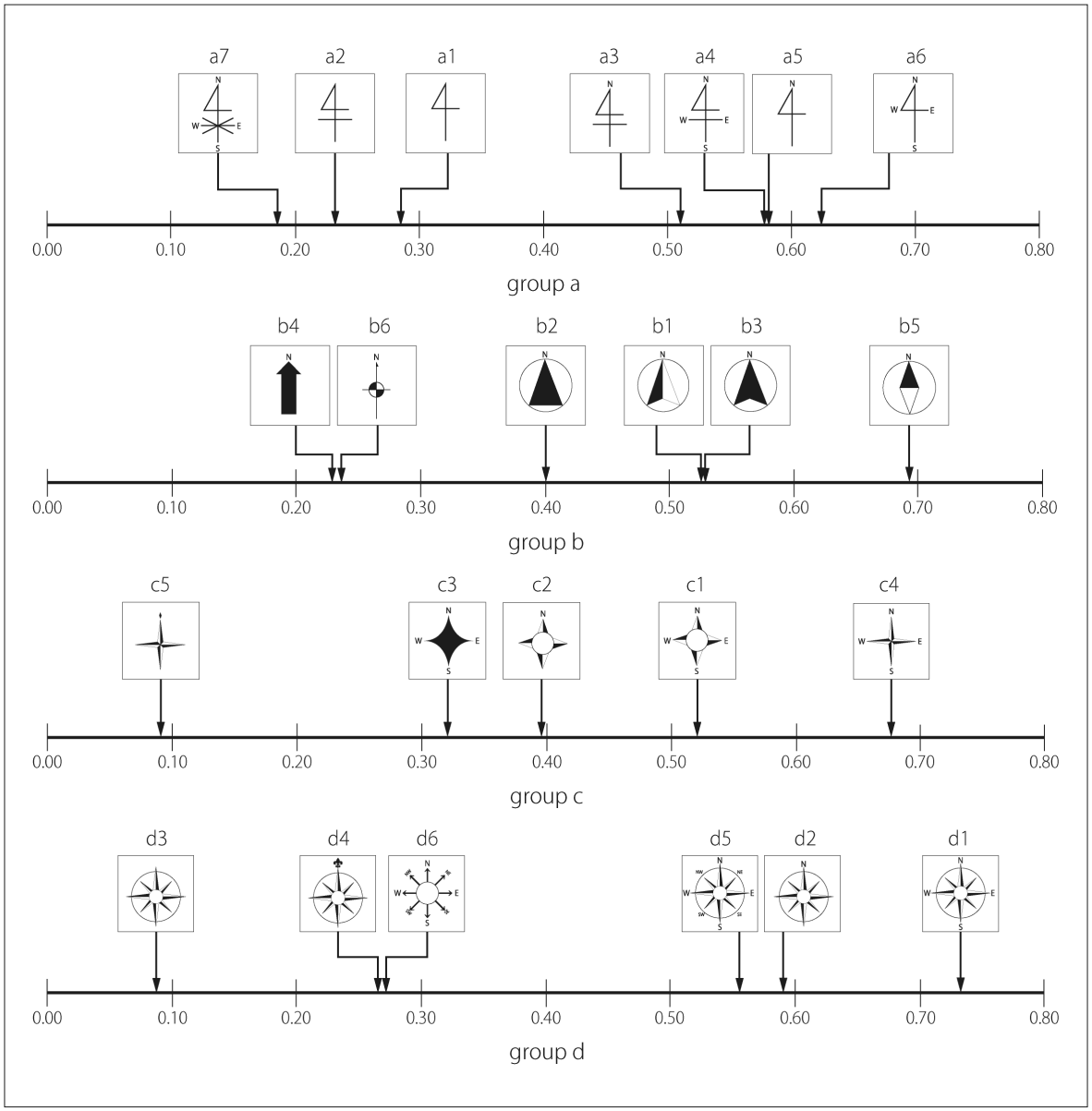

Figure 7: Rating values of easy-to-understand by a paired comparison method

From the results above, it is proved that the existence of character information can affect the understandability greatly. Furthermore, even for samples with the same amount of character information, the difference of shapes can also lead to different understandability.

4. Experiment II: Understandability of cardinal directions (ranking method)

In Experiment I, the influence of the shapes and character information of each cardinal direction on understandability was studied among each group with similar diagrams. As the ranking of understandability in Experiment I was only within each group, the comparison with other groups was not possible. In Experiment II, in order to examine all the understandability of all the evaluation stimuli forms, the understandability of all the samples was compared instead of comparing only inside each group.

4.1 Experimental method and conditions

(1) Stimulus for experiment
The cardinal direction samples used in this experiment were the same 24 diagrams used in the paired comparison method.

(2) Experimental subjects
The subjects were 50 college students in their 20s or 30s (male: 31 people, female: 19 people).

(3) Experimental method
After presenting 24 sample papers with cardinal directions drawn on, the subjects were asked to "rank them to an order of better understandability without having two samples sharing one rank". It is said that the judge of evaluation of ranking method is easier as there are rela-

tively more samples to compare. The obtained evaluation points were "easiest to understand" -- 23 points, and "hardest to understand" -- 1 point.

4.2 Experimental results and discussion

In order to clarify the evaluation factors of being easier to understand for the subjects, a normalized ranking method was used to analyze the ranking score data. As a measure to reveal the consistency of the ranking of more than three experiment samples, the ranking correlation coefficient of Kendall was used. If the consistency coefficient of Kendall was obtained and the consistency of the ranking among the subjects was confirmed, a normalized raking method would be used to obtain the interval scale from ordinal scale. Then Fisher's l.s.d. (Fisher's least significant difference test) was carried out to examine the significant differences between samples. Although the test table of Friedman should be used if the number of samples n is equal or lesser than 4, since the number of samples in this experiment was 24, it was used according to the χ^2 distribution of flexibility k-1 for examination. If the χ^2 value obtained is under 5 % of the significant level, it can be considered that it has consistency with ranking based on answers.

For the independence of the test, the consistency coefficient W of Kendall was 0.363. The χ^2 was 417.45. As the value of χ^2 was larger than that of $\chi^2_{0.05} = 35.2$, the consistency of the ranking list from the answers of 50 people was confirmed. Then, to obtain an interval scale value from the ordinal scale value, the normalization scores of ordinal scale was used to convert to interval scale. The obtained l.s.d. value is shown in Figure 8. Also, as the l.s.d. obtained as 5 % of the significant level was l.s.d. (5 %) = 0.302, it proved that there could be a bigger significant difference between distant samples.

From Figure 8, it can be seen that b5 is the easiest to understand among the 24 cardinal directions. However for those without character information, the evaluation of all was lower than the others. Also, the common feature of the top four samples is the display of character N indicating north. In particular, cardinal directions with character information north (N) or four directions including east (E), west (W), south (S), and north (N) all have higher ranking than those without any character information. However even for samples like d6 with all the character information written on, the use of arrows instead of patterns indicating the directions can still lower the evaluation of understandability.

In addition, according to the shape or number of the pointers of cardinal directions, the understandability also changed. Although c1, c3, and c4 from group c all had character information, the evaluation of them differed because of the shape of the pointers. Even with the same north characters, compared to b5, a3, a5, b1, b2, b3, b4, b6, c2, and d2 had significant differences on understandability due to the difference of shape elements. The arrows of sample b6 and d6 also had lower evaluation because the shapes were straight instead of triangles. As complex direction patterns are more difficult to recognize, the understandability will also decrease.

From the results above, it was proved that cardinal directions where orientation could be easily found based on east, west, south, and north can also receive higher evaluation. Even for the same amount of character information, the number of pointers (number of directions) and the shape of pointers can still affect understandability.

5. Discussions

In this study, a paired comparison method (Experiment I) and a ranking method (Experiment II) were conducted to perform a subjective evaluation on the understandability of cardinal directions, and discussed the design elements affecting the intuitive understandability of cardinal directions based on the experimental results. Although most of the ranking scores in the paired comparison method (Experiment I) and the ranking method (Experiment II) were the same, there were also several replacements on the ranking of samples. In particular, this fact was more often observed among samples with lower evaluation scores.

5.1 Features of character information

The existence of character information in cardinal direc-

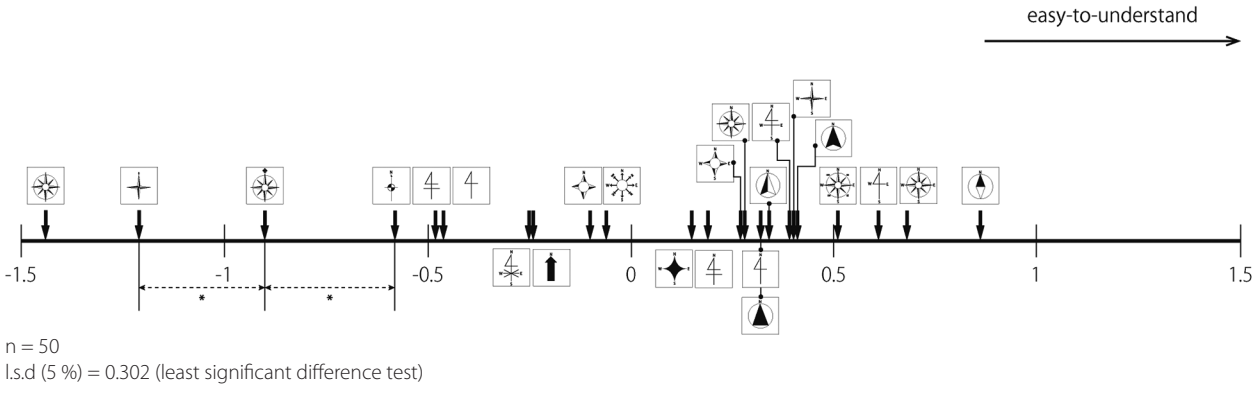

Figure8 : Rating values of easy-to-understand by a ranking method

tions affected the understandability greatly. In Experiment II, b5, which was evaluated as the easiest to understand with one arrow pointing only one direction, and d1, a6, d5, and c4, which were evaluated as easy to understand, had the common feature of using characters to indicate directions. On the other hand, for diagrams without character information like a1, a2, c5, d3, and d4, the evaluation was relatively low.

From this result, it is known that the character N indicating north as the general reference of orientation, or N, E, S, and W indicating all four directions are required in the design of cardinal directions to be intuitively easy-to-understand. In addition, as one important feature of shapes is to visualize the meaning of characters and help to understand, character information and patterns should rely on a significant complementary relationship. Therefore, the way of the combination of characters and patterns and the balance of them can greatly affect the understandability.

5.2 Design components of cardinal directions

The extracted components of cardinal directions were intended to affect understandability. After analyzing all the design components affecting each diagram, the following can be summarized.

In order to improve the visibility actually: (1) undoubted direction information should be provided; (2) elements except those indicating the orientations should be omitted as much as possible; (3) simple arrows that indicate only the directions are insufficient; (4) since patterns have their own meanings, it is recommended to ensure certain isomerization on them. Considering this reason, since cardinal directions should clearly have special meanings on certain directions to the expression targets, there should be certain relevance between the expression elements and functions. That is, patterns similar to the basic shape of a compass rose are considered to be easy to understand even after certain simplification since expression targets have fixed ideas on patterns.

The features of sample b5, which had obtained highest scores in the evaluation, were analyzed. First, there is a white circle; then there are triangles on the top and bottom as a result of contrasting colors; furthermore, there is an alphabet word indicating north on the top. Therefore, without omitting necessary information, this simple pattern could indicate the orientation well. From the above results, by expressing a silhouette similar to the compass rose using an outline expression or arrows (Kanou et al., 2005), it will be easier to understand the directions quickly from the patterns, information for better understandability will also be expressed, and the visual effects will also be promoted. In addition, it is also necessary to utilize all the features of ground (lines) and figure (surface) from shape elements. By drawing the sight using the contrast of ground and figure, and the features expressed with lines drawing to the detailed parts of patterns, the visibility will not decrease even when it is extremely shrunk so that the visibility will be promoted (Kitagami, 2002).

Furthermore, the design concept of cardinal directions can be considered from the following example. It is proposed that the design should not lose specificity, expression elements should be squeezed to the minimum, and the expression should be easy.

In addition, it is necessary to reduce the chance of misunderstanding and be intuitively understandable during the design (Muroi, 2002). Therefore, the relationship of the shape elements and information elements of the cardinal directions should also be considered.

6. Conclusion

The purpose of this study is to clarify the elements of design for an intuitive better understanding of cardinal directions. In order to understand the current state of cardinal directions, cardinal directions with different shapes were collected. There are mainly four types of basic patterns among cardinal directions. Based on these four basic patterns, different designs were obtained by changing the existence of characters indicating directions, and geometric plus and minus. Due to the design elements extracted, understandability difference among all the types can be considered, so comparison on each design element was carried out among each group of all the four types. In order to investigate how the character information and shape elements of each type can affect the understandability of the targets, the paired comparison method of Thurston was used to conduct a subjective survey. From the results, three features of the cardinal directions with higher understandability were concluded.

(1) From the overall results of all the four types, the character N indicating north direction was believed to be able to increase the understandability. It is inferred that maybe the character N is the first information that can be recognized when looking at a cardinal direction.
(2) With the same amount of character information, it was confirmed that a change of patterns could affect the understandability.
(3) In order to promote the understandability, cardinal directions should be similar to type b with one direction and less character information. On the other hand, in the case of having four directions or 8 directions like type c or type d, it was confirmed that the amount of character information had to be larger. Also, in order to promote the understandability or have a better expression, shape elements and character elements should be combined according to the number of directions, to provide enough visual information. That is, simple cardinal directions with the minimum amount of character information will not cause confusion of understanding. Then, similar to the feature

of pictograms, it is best to make the patterns easy to understand, and a simple design means that everything inside it should be recognized at first glance. However, it may be difficult to maintain the necessary information for overly simplified shapes, and the understandability will be reduced on the contrary.

For a better understandability on cardinal directions, it is necessary to continue to increase the number of samples and to perform more detailed investigations in the design field.

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