

# Mapping of Usability Guidelines onto User's Temporal Viewpoint Matrix

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**Abstract.** There are many sets of usability guidelines that could be used to quantitatively evaluate products or systems. There were, however, no quantitative means so far to evaluate a set of usability guidelines by comparing with another set of usability guidelines of an established reputation. In this paper, a new evaluation method of usability guidelines is introduced and verified as an applicable evaluation method to all kinds of usability guidelines. Our method has characteristics of employing two temporal scales, forming a user's temporal viewpoint matrix with a scale of utilization timeline and a scale of applied principles, as the means of improving the comparison accuracy. By comparing the graph patterns for each scale, we can provide a means of qualitative evaluation of the targeted guidelines; by comparing the computed similarity value of user's temporal viewpoint matrix, we can provide a means of quantitative evaluation of the targeted guidelines.

**Keywords:** Usability guidelines, quantitative evaluation, temporal viewpoint, usability principles, utilization pattern.

## 1 Introduction

To what extent usability guidelines as a whole are based on human-centered design is judged qualitatively by the expertise of usability specialists, and there is no research example of a method to do the comparative and quantitative evaluation of a targeted set of usability guidelines and a base set of usability guidelines which have a good reputation. This paper describes a comparative evaluation method for usability guidelines by comparing a targeted set of usability guidelines and a base set of good usability guidelines, based on a methodology that compares both set of guidelines qualitatively by distribution patterns of guideline items and quantitatively by the computation of pattern similarity. This is not to evaluate the value of guideline content, but to find out the undesirable concentrations, distributions, or deficiencies of usability guideline items as human-centered design guidelines.

## 2 A Comparative Evaluation Method of Usability Guidelines

This paper describes the comparative evaluation methodology of usability guidelines by combining the two methods from the recent research results about human-centered design methodologies that cover the time flow from the viewpoint of users: One is the methodology to consider the aspect of time flow in using products or systems; the other is the methodology to consider human factors.

### 2.1 Utilization Time Axis of Products or Systems

Kuramochi [1] analyzed the temporal process of consumer usage of products, and classified the stages between "not using" and "start using" into three stages of 1) "get interested in them," 2) "understand them," and 3) "decide to buy them." Moreover, even if they begin to use products or systems, whether users keep using them or not depends on the user's evaluation of the easy-to-use level. In addition, Ando et al. proposed the idea of a long-term usability [2]. If the temporal stage from "not using" to "start using" and the temporal stage from "start using" to "using for a long time" are organized as the process on a time axis, the distribution pattern of usability guideline items on the time axis is one of the comparison elements. Therefore, a time flow in the use of products or systems is adopted as one of the time axes of the user aspect to compare the usability guidelines in this paper.

### 2.2 Principle Time Axis of Products or Systems

As usability principles are thought to be representing human factors, another time axis should utilize the aspect of human factors. Kobayashi [3] introduced seven natural usability principles focusing on the human factors: "feel matching," "distance matching," "speed matching," "balance matching," "tangibility matching," "spatial matching," and "reflection matching." Natural usability principles are temporal-based ones, and also a subset of ISO 9241-110 [4]. They are not as usable as ISO 9241-110, because only temporal and partial evaluation is possible in comparison with evaluations done with ISO 9241-110. The covering check of ISO 9241-110 by natural usability guidelines makes the lacking concepts apparent. To cover all the guidelines of ISO 9241-110, natural usability principles should be enhanced to include principles of "time matching," "deduction matching," and "flow matching." [5] Now natural usability principles consist of ten principles.

### 2.3 User's Temporal Viewpoint Matrix

This section describes a comparative evaluation method of usability guideline sets by introducing User's Temporal Viewpoint Matrix (UTVM) which combines the two time axes adopted in the previous sections. This method maps usability guidelines on the matrix formed by Utilization Time Axis (UTA) and Principle Time Axis (PTA). UTVM can be used to quantitatively perform comparative evaluations.

UTA categories consists of six categories. Usability principles defined in ISO 9241-110 are for office work, and the consideration of principles during the temporal stage between "not using" and "start using" is not enough. This paper divides the

Utilization Time Axis into the six following stages by organizing utilization stages such as "until start using" or "from start using to keep using for a long time": 1) Usability at the first impression, 2) Usability during the trial use, 3) Usability at the decision to introduce, 4) Usability at the start of use, 5) Usability during the continued use, and 6) Usability during the long-term use.

PTA categories should be ordered in a certain pattern. Ten natural usability principles are mapped onto a time axis. No fixed temporal order is set among those principles. Though many distribution patterns can be made, this paper hypothetically adopts the most natural distribution pattern according to the following thinking, to be validated of its appropriateness by the comparison results:

- Feeling, visibility, and distance are the decisive factors when considering the introduction of products or systems
- Speed, time, and space are the problem finding factors during the use of products or systems
- Deduction and balance are the problem solving factors during the use of products or systems
- Flow and reflection are the factors for everyday operation during the long-term use.

Ten principles are set in this order on the PTA axis, and inspections of the comparative evaluation method of usability guideline sets are done.

As both UTA and PTA are defined by time factors, use them to create a User's Temporal Viewpoint Matrix (UTVM) — UTA as the horizontal axis and PTA as the vertical axis. Targeted usability guidelines are mapped onto this matrix, and are compared and analyzed with the pattern of authoritative typical usability guidelines by their position, distribution, and concentration.

## 2.4 Creating UTVM, PTA, and UTA

When mapping a specific usability guideline onto a UTVM, due to the high abstract nature of ten principles for PTA, the most suitable principle is decided case by case by the person in charge. For example, "Conformity with user expectations," is a very ambiguous and widely usable ISO 9241-110 principle, may be mapped onto any of the ten principles defined for PTA.

More specifically writing, such as "Dialogues should reflect data structures and forms of organization which are perceived by users as being natural," one of guidelines defined for "Conformity with user expectations" principle, is mapped differently onto PTA, depending on the order of mapping check. Therefore, so as not to blur the judgment, keywords that help decide the mapping and the order to consider which principle to apply are provided.

Moreover, as the UTVM is two-dimensional matrix, usability guidelines are easily mapped by classifying them sequentially for each axis; at first temporarily map usability guidelines onto PTA of principle time axis and then classifying them again onto UTA of utilization time axis. Sequential mapping will make it easy to uniquely classify usability guidelines onto UTVM. If the classification is done according to a defined procedure, usability guidelines can be mapped onto UTVM without much effort.

Make a UTVM for ISO 9241-110 as a comparison base with other guideline sets. The results is a large table; each block is filled with many guideline sentences. It is inconvenient, however, to continue the work in the form of characters. From now on, the information in a block, now shown in characters, is replaced by the number of guidelines contained in each block (see the case of ISO 9241-110 shown in the left side of Figure 1 below). Next, another UTVM, each block is filled with numbers, is made for a targeted set of guidelines by following the same procedure with the case of ISO 9241-110. A UTVM has a UTA with six utilization stage items and a PTA with ten principle items. An example of UTVM made for ISO 9241-110 and ISO 9241-10 [6] is shown in Figure 1 below.

		ISO 9241-110								ISO 9241-10								
		Usability before start using			4. Usability after start using	5. Usability during the continued use	6. Usability during the long-term use			Usability before start using			4. Usability after start using	5. Usability during the continued use	6. Usability during the long-term use			
		1. First	2. Trial	3. Decision						1. First	2. Trial	3. Decision						
10 Reflection																		0
9 Flow						1	5	6							2			2
8 Balance						4		4				2						2
7 Deduction						5		5			2	9						11
6 Space					1			1										0
5 Time					1			1			1							1
4 Speed					1			1			1							1
3 Distance		4	3	11	3			21	1	5	4	13	2					25
2 Tangibility		1	1	1				3		1	1							2
1 Feeling		2	7	6				15	1	2	2	1						6
		2	12	10	15	13	5	57	2	8	7	18	13	2				50

Fig. 1. An example of UTVMs

### 2.5 How to Compare Pta and Uta

To compare a set of PTAs, a graph is made for each PTA, and two PTA graphs are compared and their visual patterns are analyzed. For example, to make two PTA graphs from Figure 1, a PTA graph for ISO 9241-110 is made from the column of figures in the rightmost column of ISO 9241-110 table in Figure 1, and another PTA graph for ISO 9241-10 is made from the column of figures in the rightmost column of ISO 9241-10 table in Figure 1; then, the two PTA graphs can be compared.

The UTA comparison is made in the same way as PTA; to compare a set of UTAs, a graph is made for each UTA, and two UTA graphs are compared and visual patterns are analyzed. For example, to make two UTA graphs from Figure 1, a UTA graph for ISO 9241-110 is made from the row of figures in the bottom row of ISO 9241-110 table in Figure 1, and another UTA graph for ISO 9241-10 is made from the row of figures in the bottom row of ISO 9241-10 table in Figure 1; then the two UTA graphs can be compared.

### 2.6 Computation of Similarities between UTVMs, PTAs, and UTAs

Qualitative comparisons can be done by analyzing the distribution patterns of Figure 1 above, by analyzing the difference of two UTA graphs, and by analyzing the difference

of two PTA graphs. This paper adopts another quantitative comparison method by computing the similarities between UTVMs. This quantitative method is also applicable to two UTA graphs and two PTA graphs. Similarities can be computed by the following equation. Let  $M(i,j)$  be the number of guidelines that corresponds to the UVTM element of  $i$ th row and  $j$ th column, i.e.,  $i$ th principle on the PTA axis defined in 2.3 and  $j$ th stage on the UTA axis defined in 2.3 respectively. Here, the scope of  $i$  and  $j$  is:  $i=1,2,\dots,10$ ;  $j=1,2,\dots,6$  respectively. Then, the similarity  $C(M_g, M_h)$  between two guidelines,  $M_g(i,j)$  and  $M_h(i,j)$  is defined as:

$$C(M_g, M_h) = \frac{\sum_i \sum_j (M_g(i,j) - \overline{M_g})(M_h(i,j) - \overline{M_h})}{\sqrt{\sum_i \sum_j (M_g(i,j) - \overline{M_g})^2} \sqrt{\sum_i \sum_j (M_h(i,j) - \overline{M_h})^2}} \quad (1)$$

where  $\overline{M}$  is the mean value of  $M(i,j)$ , i.e.,  $\overline{M} = \sum_i \sum_j M(i,j) / 60$ .

Because of  $M(i,j) \geq 0$ ,  $0 \leq C(M_g, M_h) \leq 1$  is true, and the value of  $C(M_g, M_h)$  gets larger in proportion to the similarity between two sets of guidelines. Here, equation (1) is widely employed as the correlation coefficient that represents the similarity between two patterns as shown in [7]. Then, the similarity between two PTAs that represent two sets of guidelines is defined. PTA's pattern  $P(i)$  is defined as the projected distribution of  $M(i,j)$  distribution onto the vertical axis, and denoted as:

$$P(i) = \sum_j M(i,j) \quad (2)$$

Therefore, the similarity  $C(P_g, P_h)$  between PTAs that corresponds to two sets of guidelines of  $M_g(i,j)$  and  $M_h(i,j)$  is defined as:

$$C(P_g, P_h) = \frac{\sum_i (P_g(i) - \overline{P_g})(P_h(i) - \overline{P_h})}{\sqrt{\sum_i (P_g(i) - \overline{P_g})^2} \sqrt{\sum_i (P_h(i) - \overline{P_h})^2}} \quad (3)$$

where  $\overline{P}$  is the mean value of  $P(i)$ , i.e.,  $\overline{P} = \sum_i P(i) / 10$ .

Similarly, the similarity  $C(U_g, U_h)$  between UTAs that corresponds to two sets of guidelines of  $M_g(i,j)$  and  $M_h(i,j)$  is, using UTA's pattern  $U(j)$  which is denoted as

$$U(j) = \sum_i M(i,j) \quad (4)$$

defined as:

$$C(U_g, U_h) = \frac{\sum_j (U_g(j) - \overline{U_g})(U_h(j) - \overline{U_h})}{\sqrt{\sum_j (U_g(j) - \overline{U_g})^2} \sqrt{\sum_j (U_h(j) - \overline{U_h})^2}} \quad (5)$$

where  $\overline{U}$  is the mean value of  $U(j)$  i.e.,  $\overline{U} = \sum_j U(j) / 6$ .

Similarities of PTA elements, UTA elements, and UTVM tables are computed by applying equations (1), (3), and (5) to two UTVM tables to compare and analyze two sets of guidelines.

### 3 Evaluation of Effectiveness of UTVM

This section actually applies the idea of UTVM to the sets of usability guidelines, and verifies the comparative evaluation method of targeted usability guidelines as usable. A combination of usability guidelines is selected to verify the effectiveness of this proposed method: ISO 9241-151 and Research-based Guidelines. Selected reason is as follows: Research-based Guidelines [8] is widely supported and utilized by usability specialists all over the world. ISO 9241-151 [9] is a set of web usability guidelines that was planned to include all the features of Research-based Guidelines. All the details of both sets of guidelines are known and comparable. Therefore, it is possible to correctly interpret and evaluate the differences of visual UTA pattern, visual PTA pattern, and the meaning of its similarity.

In this evaluation, two sets of usability guidelines are used: ISO 9241-151 and Research-based Guidelines. For this combination, a UTVM table is created, and the UTA pattern and the PTA pattern are visually compared. By computing a similarity for this combination, the degree of similarity can be analyzed, and used to prove the appropriateness of the results. If appropriateness is adequately shown, the proposed comparative evaluation method is also proved.

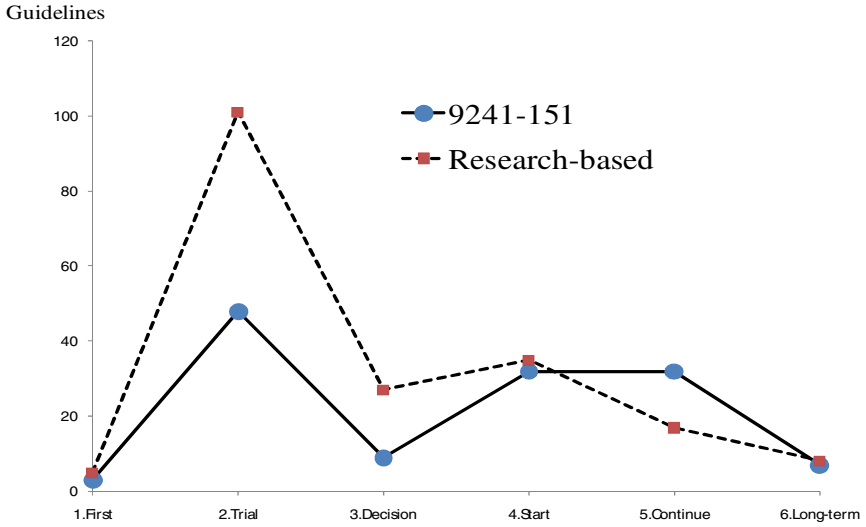
#### 3.1 Visual Pattern Comparison of UTA and PTA

Qualitative comparison of visual pattern for ISO 9241-151 and Research-based Guidelines is made by visually comparing UTA and PTA.

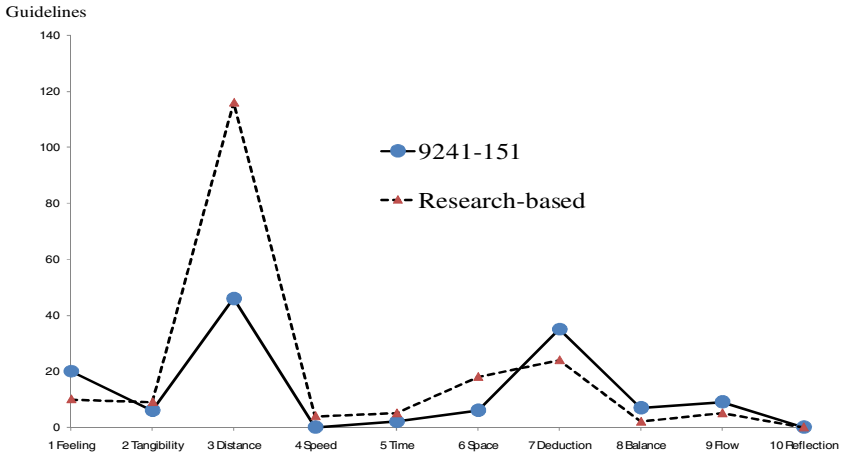
UTA comparison is shown in Figure 2 below. Two things can be pointed out in this graph:

- In Research-based guidelines, the number of guidelines in the "Trial" stage double that of ISO 9241-151.
- In ISO 9241-151, the number of guidelines after the Start stage is relatively large considering the total number of guidelines. No noteworthy differences are found after the Start stage.

These findings match the concept of the Research-based Guidelines that are noted for their familiarity with abundant visuals: Research-based Guidelines provide many high-quality and easily understandable guidelines. On the other hand, ISO 9241-151 does not aim to provide decisive guidelines at the Decision stage; it provides comparatively many guidelines after the Start stage to be usable in practical situations. Therefore, the results show the validity of this comparative evaluation method of two sets of usability guidelines.



**Fig. 2.** UTA comparison between ISO 9241-151 and Research-based Guidelines



**Fig. 3.** PTA comparison between ISO 9241-151 and Research-based Guidelines

PTA comparison is shown in Figure 3 below. This is a comparison based on the repertory of usability principles in temporal order. In this graph, it is apparent that Research-based Guidelines are concentrating their efforts in shortening the distance between users and web systems. The rest of principles show nearly the same distribution pattern. This result matches the creation process of ISO 9241-151. In the creation process of ISO 9241-151, the guideline repertory of ISO 9241-151 was always compared with that of Research-based Guidelines so that ISO 9241-151

covers all main features provided in Research-based Guidelines; this resulted in the nearly same distribution pattern of usability guidelines except the "Distance" stage. Therefore, again, the results show the validity of this comparative evaluation method of two sets of usability guidelines.

### 3.2 Comparison of Similarity

To compare two sets of UTVM tables, UTA elements, and PTA elements, similarities can be computed using the equations described in 2.6. Whether or not the values computed are valid is easily shown by checking the actualities of the relationships of sets of usability guidelines.

**Table 1.** The similarity among UTVMs, UTAs, and PTAs

Similarity	UTVM	UTA	PTA
ISO 9241-151 and Research-based	0.82	0.81	0.83

Table 1 shows the similarities among UTVMs, UTAs, and PTAs. The UTVM similarity between ISO 9241-151 and Research-based Guidelines is 0.82, which is the expected value if the creation process of ISO 9241-151 is considered. The UTA similarity between ISO 9241-151 and Research-based Guidelines is 0.81, which is the expected value. The PTA similarity between ISO 9241-151 and Research-based Guidelines is 0.83, which is the expected value.

## 4 Discussion

The results in comparing graph patterns and similarities showed the validity of the comparative evaluation method using UVTM matrix. This means that the two-dimensional matrix UTVM is effective in comparing any two sets of usability guidelines. In actuality, UTVM is composed of UTA and PTA, and both of them were proved to be valid by inspecting the set of world-famous usability guidelines. The temporal layout of principles on the principle axis is also thought to be valid because the shape of UTA and PTA has similar characteristics of having two humps.

Applying the comparative evaluation method to use UVTM is not limited to ISO standards. It is applicable to any two sets of usability guidelines as a general comparison method. It should be noted, however, the object of this method is the evaluation of the validity of guideline distribution patterns. It is not intended to evaluate the effectiveness, efficiency, or user satisfaction of usability guidelines. The accuracy or correctness of the targeted guidelines is to be certified beforehand by other usability methodologies.

This methodology can be applied to qualitatively and quantitatively diagnose the appropriateness of following usability guidelines for human-centered design:



- Usability guidelines in general.
- Web usability guidelines.
- Accessibility guidelines.

In addition, following diagnosis is also possible by analyzing graph patterns and similarities:

- What are the key points to improve human-centered design?
- What usability guidelines are, considering the characteristics of the business, to be used or based on?
- What type of considerations is missing or what segment of business is too heavily worked on?

## 5 Conclusion

This research finds no inconveniences in the layout pattern of natural usability principles on the time axis. Results from employing different patterns remain as a future issue. From the pattern comparison result of PTA, it was found that there were very few usability guidelines that correspond to the "speed," "time," and "space" principles. Research should be done on whether or not these guidelines are necessary. In this paper, human-centered design was considered from the viewpoint of the distance between the system and the products or systems, however, it should be also considered from the viewpoint of the distance among humans, such as users and designers.

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