ICIC Express Letters
Volume **18**, Number **3**, March **2024**

ICIC International ©2024 ISSN 1881-803X
pp. **303–312**

A COMPARISON OF VISUAL ANALOG SCALE AND LIKERT SCALE BY VISUALIZATION OF THEIR DISTRIBUTIONS

Satoshi Watanabe[1,*], Naofumi Nakaya[2], Kazuhiro Koshi[3]
Keiji Matsumoto[4], Kenji Moriya[5] and Naruki Shirahama[4]

[1]College of Bioresource Sciences
Nihon University
1866, Kameino, Fujisawa-shi, Kanagawa 252-0880, Japan
*Corresponding author: watanabe.satoshi@nihon-u.ac.jp

[2]Faculty of Medical Science
Juntendo University
6-8-1, Hinode, Urayasu-shi, Chiba 279-0013, Japan
n.nakaya.ac@juntendo.ac.jp

[3]Department of Human-Oriented Information Systems Engineering
National Institute of Technology (KOSEN), Kumamoto College
2659-2, Suya, Koshi-shi, Kumamoto 861-1102, Japan
kkoshi@kumamoto-nct.ac.jp

[4]Department of Creative Engineering
National Institute of Technology (KOSEN), Kitakyushu College
5-20-1, Shii, Kokura-minami-ku, Kitakyushu-shi, Fukuoka 802-0985, Japan
{ kmatsu; naruki }@kct.ac.jp

[5]Department of Production Systems Engineering
National Institute of Technology (KOSEN), Hakodate College
14-1, Tokura, Hakodate-shi, Hokkaido 042-8501, Japan
moriya@hakodate-ct.ac.jp

Received June 2023; accepted August 2023

Abstract. *This paper describes a comparison of the distribution of the Visual Analog Scale (VAS) and 5-step Likert Scale (LS) by visualization of their distributions. The data are collected from 344 participants, 172 participants are invited to answer VAS questionnaires, and the other 172 participants are also invited to answer LS questionnaires. To apply the same evaluation criteria, VAS data and LS data are transformed to ratio scale values (i.e., 0.00 to 1.00), and the subjective evaluation distributions based on LS and VAS are calculated and visualized (descriptive statistics values, histograms, boxplots, and plots using a 95% confidence interval). As a result, the authors arrive at two suggestions. 1) It is possible to express detailed results by using VAS rather than LS for questions that ask about intensity. 2) For trend questions, the using of LS or VAS yields similar results (in other words, if the question asks for trends, we can choose either VAS or LS). However, these suggestions are derived from a limited example, and it is necessary to apply this method to various fields (such as education, music listening, and image viewing) to obtain stable conclusions.*

Keywords: Characteristics of the distribution, Self-evaluation, Visual analog scale, Likert scale

1. **Introduction.** The purpose of this paper is to obtain basic data on the bias conditions between Visual Analog Scale (VAS) and Likert Scale of 5 steps (LS) measurements. VAS is a continuous scale that measures the intensity of a variable along a line, while LS is a discrete scale that measures the degree of agreement or disagreement with a statement. Both scales are commonly used in research studies to measure subjective experiences,

DOI: 10.24507/icicel.18.03.303

	Poor	Good
Mobile-Phone		
Personal Computer		

(a) Typical types of VAS questionnaires

	Poor				Good
Mobile-Phone	1	2	3	4	5
Personal Computer	1	2	3	4	5

(b) Typical types of LS questionnaires

Figure 1. Typical types of VAS and LS questionnaires [5]

attitudes, and opinions (see Figure 1). Previous studies have shown that the VAS has superior measurement qualities compared to the LS [1]. VAS is more sensitive, reliable, and valid in measuring subjective experiences, such as pain, anxiety, and mood [2]. On the other hand, LS has been criticized for its limited response options, which may lead to response bias and lack of sensitivity [3]. However, some studies have suggested that the LS may be more appropriate for certain types of questions, such as those related to attitudes and opinions [4].

By the way, the authors have confirmed that there is a difference in the trend between LS and VAS. They conducted a comparative study on VAS and LS's subjective ratings in more than 170 subjects and showed some bias between VAS and LS [5]. However, to obtain reliable conclusions, more investigations are needed such as visualization analysis of VAS and LS data. Therefore, as a first step toward the purpose of this paper, the authors visualize the VAS and LS measurements. For this visualization, the methods developed by the authors [6] (histograms, a combination of bee swarm plots and boxplots, and plots using a 95% confidence interval) are used, and the authors also decide to reuse the data from their previous study [5]. As the next step, the authors discuss the bias between VAS and LS measurements using VAS measurements that are equivalently transformed to LS values [5].

Based on the above discussion, the academic and practical contributions of this paper are as follows. The first is to clarify the characteristics of VAS and LS. Then, it is also about developing a better understanding of the application of each method (e.g., measuring the intensity or selectivity). It is expected that these things will contribute to the more accurate use of VAS and LS.

The remainder of this paper is organized as follows. Section 2 describes the theory of VAS, LS, and its visualization analysis. Materials and methods are shown in Section 3. Results and discussion are given in Section 4. Section 5 shows the conclusions and future works.

2. VAS and LS.

2.1. VAS. In recent years, VAS has been applied to studying subjective evaluations such as education [5,7,8], an impression of music [9,10], and an impression received from the response of a communication robot [6]. This paper first introduces VAS. Figure 1(a) shows the typical types of VAS questionnaires [5]. This is to ask the proficiency in operating information devices. To answer Figure 1(a), the response is marked by drawing a vertical line on the horizontal line.

An example of the response to the VAS questionnaire is shown in Figure 2. And the calculation of VAS data is also shown in Figure 2. VAS's results are determined by the ratio of (a) to (b) (in other words, it is determined by the position of the mark on the line). As mentioned above, a value of subjective evaluation (between 0.00 to 1.00) can be obtained.

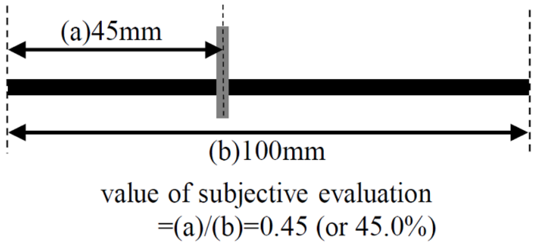

Figure 2. Example of calculation of VAS data

2.2. **LS.** Figure 1(b) shows typical types of LS questionnaires. These are the same as VAS questionnaires. To answer these questionnaires in Figure 1(b), the responses are marked as a discrete value from 1 to 5 on LS (only one place at one questionnaire).

To apply the same evaluation criteria, LS data is transformed to ratio scales value (i.e., 0.00 to 1.00) [11,12]. Figure 3 shows the transformation of LS data. This paper will convert the numbers marked with a circle (only one place in 1-5) to the values as shown in Figure 3.

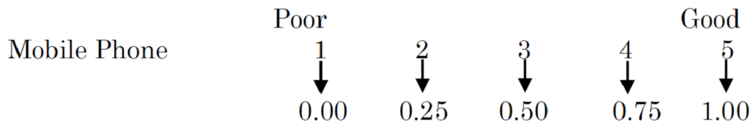

Figure 3. Transformation of LS data: The location with the circle (only one place), converted to the following values (determined to only one value in 0.00∼1.00) [5]

3. Materials and Methods.

3.1. **Participants.** The data are collected from 344 participants. 172 participants were invited to answer VAS questionnaires, and the other 172 participants were invited to answer LS questionnaires.

Ethical considerations are as follows:

The explanation of this study is given orally, and the documents are distributed to the participants. Participation in this study is voluntary. Furthermore, the data has been collected anonymously and has been only used for the presentation of this study.

3.2. **Questionnaires.** It was carried out the following investigation of subjective evaluation based on VAS or LS.

Question 1 (Q1): Are you good at mobile phone operation?

Question 2 (Q2): Are you good at personal computer operation?

Question 3 (Q3): Which one are you good at, mobile phone operation or personal computer operation?

Questionnaires Q1 and Q2 are shown in Figure 1 ((a): VAS, (b): LS), and Figure 4 shows questionnaire Q3.

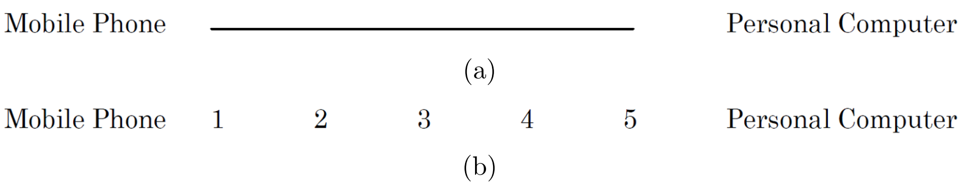

Figure 4. Questionnaire Q3: (a) VAS; (b) LS [5]

3.3. **Visualizations of obtained data.** It is used of the methods developed by the authors [6]. This method has been developed for small sample data analysis based on VAS or LS questionnaires. This method consists of two elements: (a) a Questionnaire on VAS or LS (to ask the subjective evaluation of participants' information skills in this paper), (b) Visualization (histograms, a combination of bee swarm plots and boxplots, and plots of 95% confidence interval).

By the expression of the obtained data in VAS or LS, it is possible to know their characteristics. To clarify their characteristics, the analysis is carried out by R environment. First, the descriptive statistics values and histograms are calculated and obtained, and we can understand the outlines of distribution and relationship values. Next, a combination of bee swarm plots and boxplots and plots of 95% confidence interval is drawn, and this is the authors' unique method [6-10]. Under these procedures, we can show the characteristics of the distribution of VAS or LS. (Note that descriptive statistics value and the result of statistical tests (t-tests) were given by the author's previous study [5].)

3.4. **Conversion of VAS data to LS data.** For the comparison of VAS and LS measurements (to examine bias), the VAS measurements defined by the ranges shown in Table 1 are converted to their corresponding LS values. In addition, the converted VAS measurements (LS value) and the original LS measurements are analyzed and visualized with the method developed by the authors [5], as mentioned above.

Table 1. Conversion table of VAS measurements to LS values

VAS measurements	Converted to LS values
0.000∼0.125	0.00
0.126∼0.375	0.25
0.376∼0.625	0.50
0.626∼0.875	0.75
0.876∼1.000	1.00

4. Results and Discussions.

4.1. **Histogram and descriptive statistics values of VAS and LS measurements.** Figure 5 shows the histogram of measurements obtained data from 3 questions by VAS and LS questionnaires. Although it is self-evident, it can be seen that the VAS measurements are distributed with various values. Such a distribution cannot be obtained with LS measurements.

In addition, according to the authors' previous study [5], there is a significant difference in the Q1 (t-test, t-value $t(344) = -2.41$, $p = 0.016$). However, it is difficult to say that there is a large difference in the descriptive statistics value of the VAS and LS measurements (see Table 2). Therefore, another method is needed to express the characteristics of the distribution of these data. That is, they are visualization of other plots developed by the authors [6].

4.2. **Comparing VAS measurements and LS measurements using boxplots and plots of 95% confidence interval.** A combination of bee swarm plots and boxplots for VAS measurements is shown in Figure 6. From Figures 5 and 6, it is clear that the VAS measurement values which are continuous, show a more detailed distribution than the LS measurement values which are discrete (although it is self-evident, in the 5-step LS adopted in this paper, the distribution of the measured values is concentrated at the 5 points).

In addition, Figure 7 shows the comparing VAS measurements and LS measurements using boxplots. According to Figure 7, the bias between the VAS and LS measurements

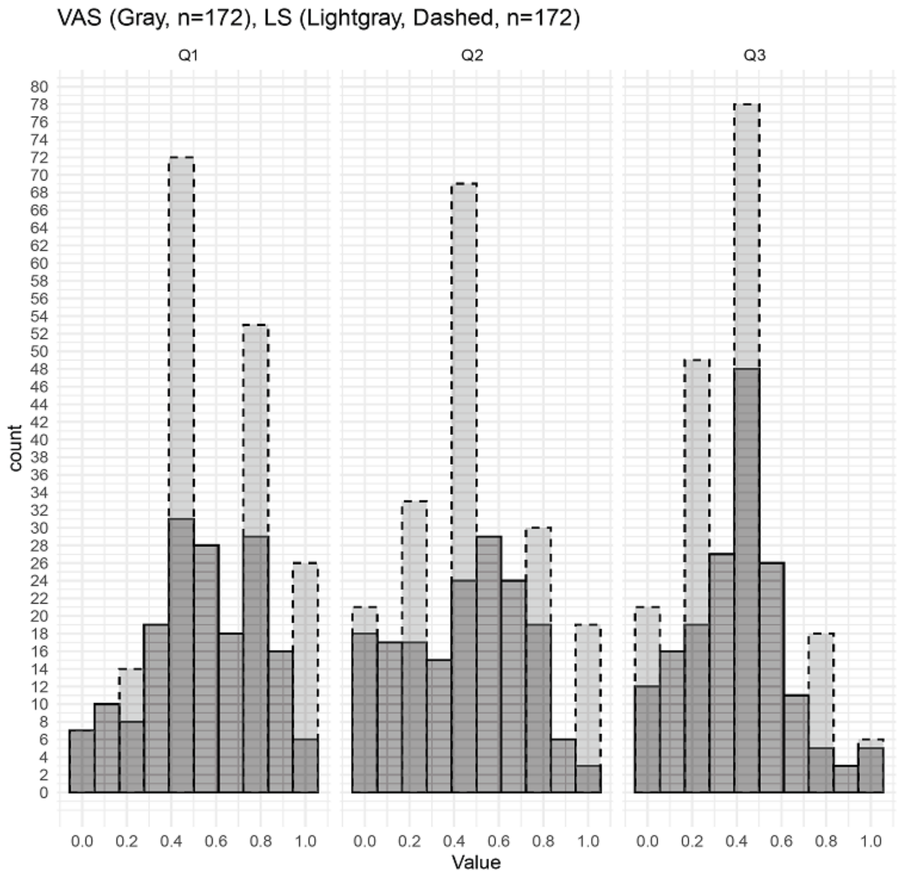

Figure 5. Histogram of measurements obtained from 3 questionnaires

Table 2. Descriptive statistics values of VAS and LS measurements [5]

	Q1		Q2		Q3	
	VAS	LS	VAS	LS	VAS	LS
Maximum	1.00	1.00	1.00	1.00	1.00	1.00
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.55	0.61	0.45	0.49	0.41	0.41
Median	0.52	0.50	0.49	0.50	0.45	0.50
SD*	0.25	0.25	0.26	0.29	0.22	0.24
SE**	0.02	0.02	0.02	0.02	0.02	0.02
95% CI#	0.51∼0.59	0.58∼0.64	0.41∼0.49	0.45∼0.53	0.38∼0.45	0.38∼0.45

*: standard deviation, **: standard error, #: 95% confidence interval

is observed in Q1 and Q2, however, hardly observed in Q3. This fact is consistent with the suggestion of the authors' previous study [5].

By the way, Figure 8 is drawn to compare the 95% confidence interval (95% CI) for VAS and LS measurements. In Figure 8, biases are shown in Q1 and Q2. And it can be said that the 95% confidence intervals of Q3 are equivalent. That is, the same conclusion is also given in Figure 8.

4.3. **Comparing conversions of VAS measurements to LS values and LS measurements.** To further verify this bias, the authors tried to convert the VAS measurements to LS values (CVLS) using Table 1. Figure 9 shows the histogram obtained from CVLS and LS measurements (LS measurements are the same as Figure 5 and Table 2).

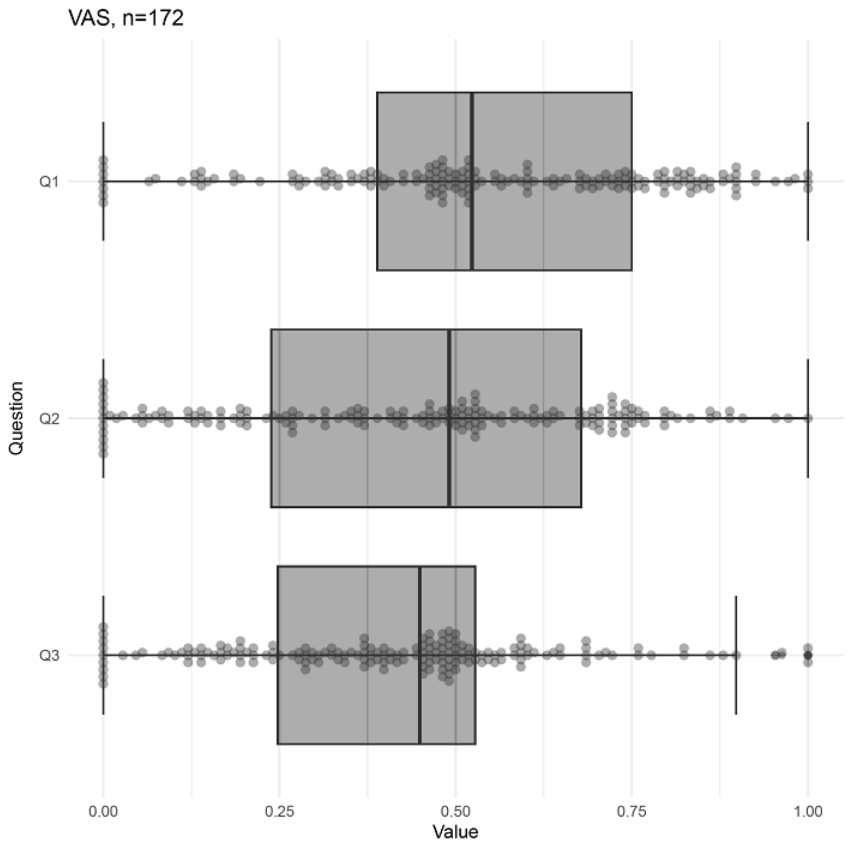

FIGURE 6. A combination of bee swarm plots and boxplots for VAS measurements

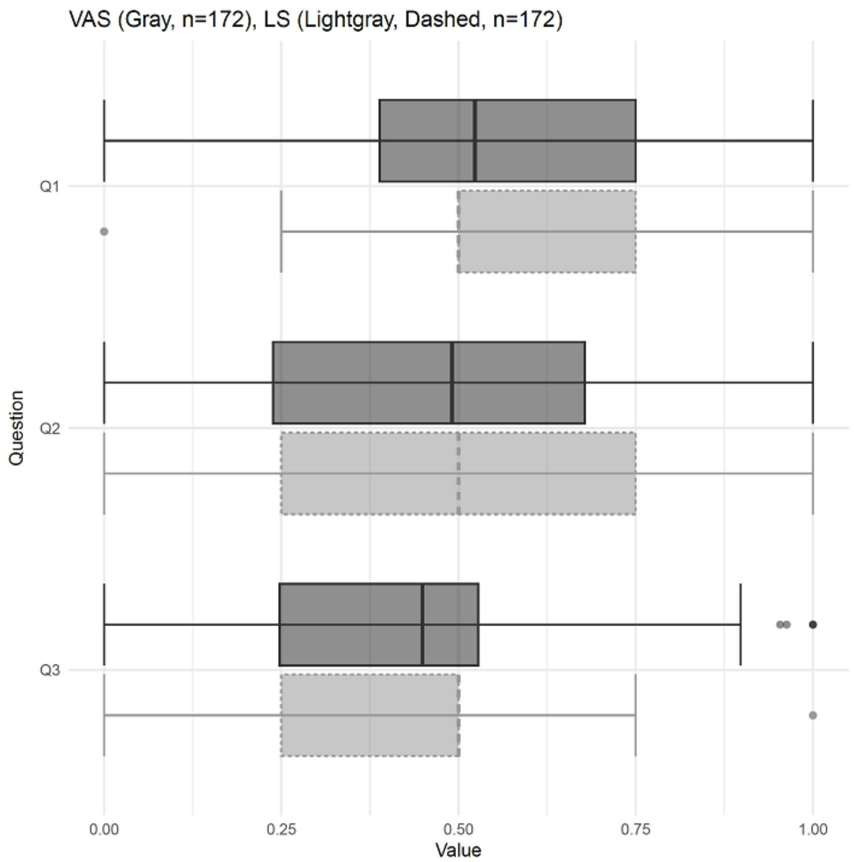

FIGURE 7. Comparing boxplots for VAS and LS measurements

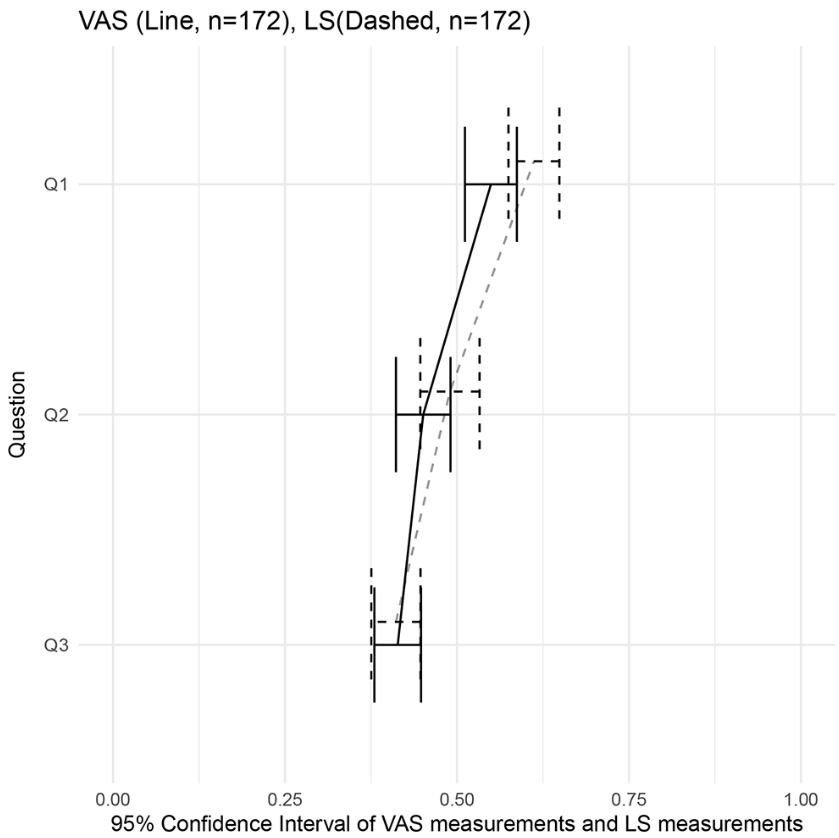

Figure 8. Plots of 95% CI for VAS measurements and LS measurements

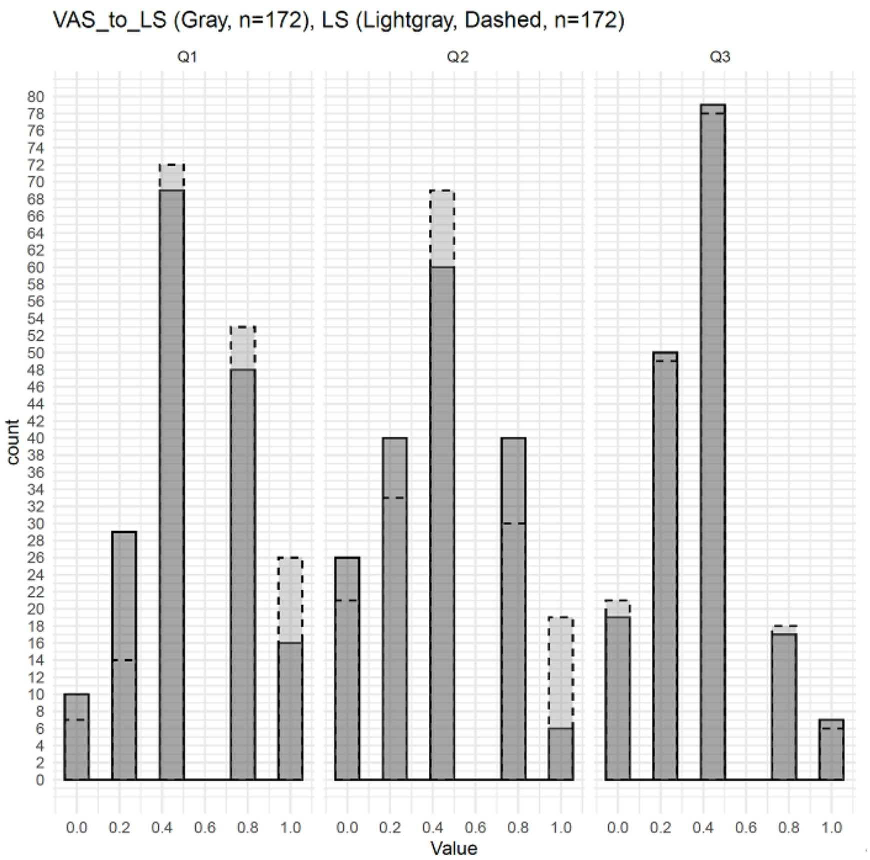

Figure 9. Histogram of obtained from CVLS and LS measurements

TABLE 3. Descriptive statistics values of CVLS and LS measurements

	Q1		Q2		Q3	
	CVLS	LS*	CVLS	LS*	CVLS	LS*
Maximum	1.00	1.00	1.00	1.00	1.00	1.00
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.55	0.61	0.44	0.49	0.42	0.41
Median	0.50	0.50	0.50	0.50	0.50	0.50
SD**	0.25	0.25	0.27	0.29	0.24	0.24
SE***	0.02	0.02	0.02	0.02	0.18	0.02
95% CI#	0.51∼0.58	0.58∼0.64	0.40∼0.48	0.45∼0.53	0.38∼0.45	0.38∼0.45

*: same as Table 2 (original data), **: standard deviation, ***: standard error, #: 95% confidence interval

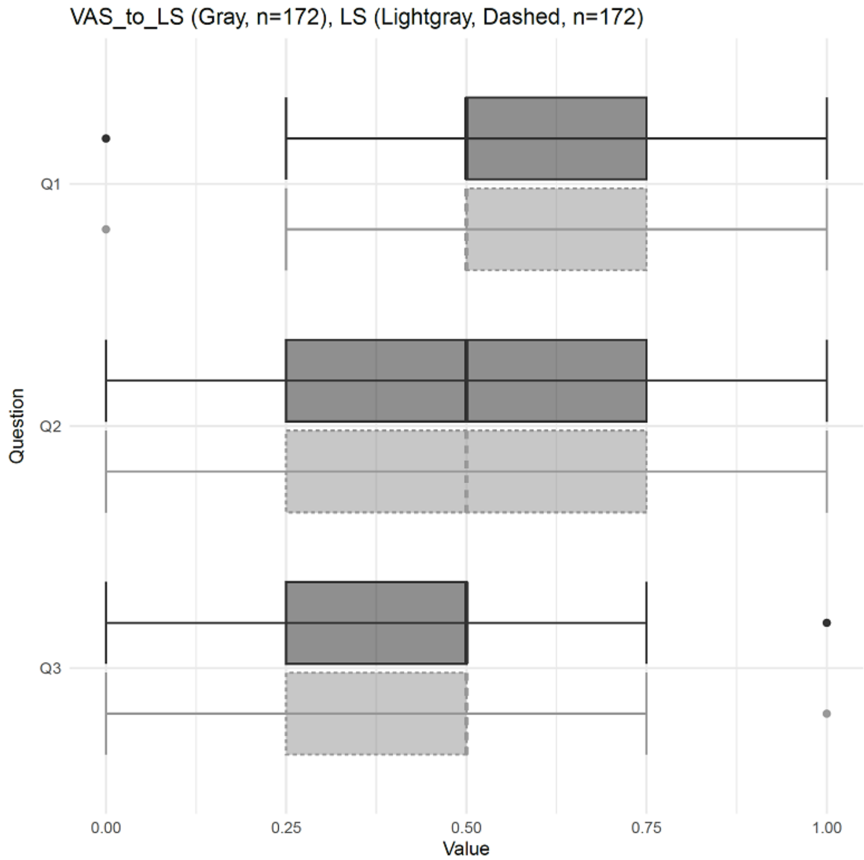

FIGURE 10. Boxplots for CVLS and LS measurements

Biases in Q1 and Q2 are more clearly observed in Figure 9 than in Figures 5 and 7. Moreover, their descriptive statistics values are shown in Table 3. However, the change when compared with Table 2 is not clearly shown in this table. Therefore, Figure 10 is drawn in the same way as Figure 7, and Figure 11 is also drawn in the same way as Figure 8.

In Figure 10, it is shown that there is no difference between CVLS and LS. This fact means that the characteristics of the distribution of CVLS are assumed to be the same as LS by converting VAS measurements to CVLS. Otherwise, in Figure 11, there are biases in Q1 and Q2, and there is no bias in Q3, from this observation, it is thought that the features seemed in Figure 8 are not lost in Figure 11 through the conversion of VAS to CVLS.

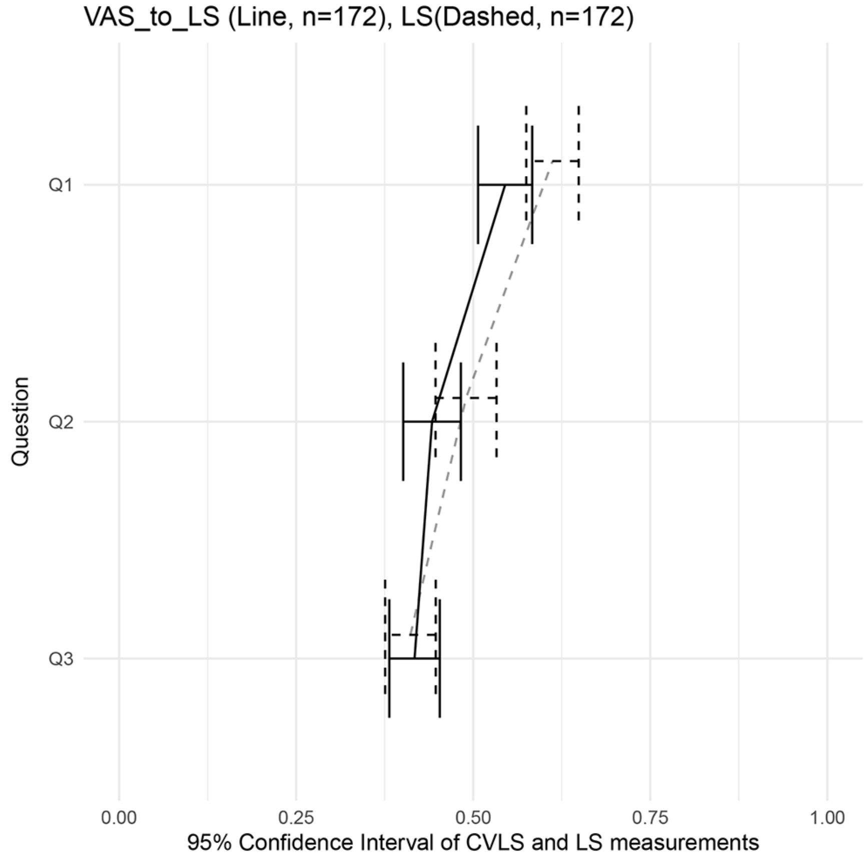

Figure 11. Plots of 95% CI for CVLS and LS measurements

Now, let us remember what these questions are: Q1 (Are you good at mobile phone operation?) and Q2 (Are you good at personal computer operation?) are intensity questions, and Q3 (Which one are you good at, mobile phone operation or personal computer operation?) is a trend question. From these facts and discussions mentioned above, the authors reach two suggestions. 1) It is possible to express detailed results by using VAS rather than LS for questions that ask about intensity (such as Q1 or Q2). 2) For trend questions, the using of LS or VAS measurement yields similar results (in other words, if the question asks for trends, we can choose either VAS or LS (such as Q3)).

LS measurements are easy to obtain, but their distribution has the disadvantage of being less precise than VAS measurements. On the other hand, although the distribution of VAS measurements can be expressed precisely, its measurement is more time-consuming than LS measurement. Thus, these two measurement methods have advantages and disadvantages. Therefore, the authors propose that the VAS measurement method should be adopted when more precise distribution characteristics are desired (results that express precise individual differences such as Q1 and Q2 will be used for future instruction), and the LS measurement method should be adopted otherwise (when it is enough to grasp the general trend).

However, these suggestions are derived from a limited example, and it is necessary to apply this method to various fields (such as education, music listening, and image viewing) to obtain stable conclusions.

5. **Conclusions.** By comparing the distributions and confidence intervals of the VAS and LS measurements ($n = 172$, each participant has been different), the authors reach two suggestions. 1) It is possible to express detailed results by using VAS rather than LS for questions that ask about intensity. 2) For trend questions, the using of LS or VAS yields similar results (in other words, if the question asks for trends, we can choose

either VAS or LS). And the author also proposes that the VAS measurement method should be adopted when more precise distribution characteristics are desired, and the LS measurement method should be adopted otherwise (when it is enough to grasp the general trend). However, these suggestions are derived from a limited example, and it is necessary to apply this method to various fields to obtain stable conclusions.

Future works are as follows: 1) studying the distribution of LS with different steps; 2) applying this method in another questionnaire (e.g., measuring the intensity or selectivity); 3) applying this method in other fields (such as education, music listening, and image viewing); 4) measurement with a larger number of participants.

REFERENCES

[1] T. Kuhlmann, M. Dantlgraber and U. D. Reips, Investigating measurement equivalence of visual analogue scales and Likert-type scales in Internet-based personality questionnaires, *Behavior Research Methods*, vol.49, no.6, pp.2173-2181, DOI: 10.3758/s13428-016-0850-x, 2017.

[2] Y.-T. Sung and J.-S. Wu, The Visual Analogue Scale for Rating, Ranking and Paired-Comparison (VAS-RRP): A new technique for psychological measurement, *Behavior Research Methods*, vol.50, no.4, pp.1694-1715, DOI: 10.3758/s13428-018-1041-8, 2018.

[3] G. B. Dourado, G. H. Volpato, R. R. de Almeida-Pedrin, P. V. P. Oltramari, T. M. F. Fernandes and A. C. de Castro Ferreira Conti, Likert scale vs visual analog scale for assessing facial pleasantness, *American Journal of Orthodontics and Dentofacial Orthopedics*, vol.160, no.6, pp.844-852, DOI: 10.1016/j.ajodo.2020.05.024, 2021.

[4] H. van Laerhoven, H. J. van der Zaag-Loonen and B. H. Derkx, A comparison of Likert scale and visual analogue scales as response options in children's questionnaires, *Acta Paediatr*, vol.93, no.6, pp.830-835, DOI: 10.1080/08035250410026572, 2004.

[5] S. Watanabe, N. Shirahama, H. Tsukamoto, Y. Matsumoto, M. Nakagawa, K. Miyamoto, N. Nakaya, M. Tomita and Y. Mori, Trend of the subjective evaluation based on visual analog scale and Likert scale, *ICIC Express Letters, Part B: Applications*, vol.7, no.1, pp.37-42, DOI: 0.24507/icicelb.07.01.37, 2016.

[6] N. Shirahama, S. Watanabe, K. Moriya, K. Koshi and K. Matsumoto, A new method of subjective evaluation using visual analog scale for small sample data analysis, *Journal of Information Processing*, vol.29, pp.424-433, DOI: 10.2197/ipsjjip.29.1, 2021.

[7] S. Watanabe, N. Shirahama, Y. Matsumoto, H. Tsukamoto, M. Nakagawa, K. Miyamoto, N. Nakaya, M. Tomita and Y. Mori, Distribution trend of the information skills for students based on visual analog scale and Likert scale, *International Journal of Biomedical Soft Computing and Human Sciences*, vol.20, no.2, pp.1-6, DOI: 10.24466/ijbschs.20.2_1, 2016.

[8] S. Watanabe, T. Tsuruta, N. Shirahama, N. Nakaya, Y. Matsumoto, H. Tsukamoto and Y. Mori, Expression of subjective evaluation for the participation attitude to the Internet of male college students based on visual analog scale, *Journal of the Institute of Industrial Applications Engineers*, vol.8, no.1, pp.16-23, DOI: 10.12792/JIIAE.8.16, 2020.

[9] S. Watanabe, N. Shirahama, N. Nakaya, Y. Matsumoto and Y. Mori, An expression of the impression of three pieces of sounds based on visual analog scale analysis, *International Journal of Biomedical Soft Computing and Human Sciences*, vol.24, no.2, pp.75-82, DOI: 10.24466/ijbschs.24.2_75, 2019.

[10] S. Watanabe, N. Shirahama, N. Nakaya and Y. Matsumoto, A study of impressions of one minor music, *Journal of the Institute of Industrial Applications Engineers*, vol.9, no.4, pp.146-151, DOI: 10.12792/JIIAE.9.146, 2021.

[11] R. A. Likert, *Technique for the Measurement of Attitudes*, Archives of Psychology, New York, 1932.

[12] H. Murao, Using Likert-type item data as interval data, *Aomori Public College Journal of Management & Economics*, vol.10, no.2, pp.3-20, 2005 (in Japanese).