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The Effect of the Likert Point Scale and Sample Size on the Efficiency of Parametric and Nonparametric Tests

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Abstract

This research aimed to study the effect of the Likert point scale and sample size on the efficiency of testing statistics of location difference between three populations using both parametric testing (One-way ANOVA: F test) and nonparametric testing (Kruskal-Wallis test: K-W test). The simulation of three distributions consisted of a normal distribution, positive skewness and platykurtic distribution, and a negative skewness and leptokurtic distribution. Specifically, the Likert point scale used included 5 points, 7 points and 10 points and sample sizes consisting of 15, 30, 50 and 100. The simulation study showed that the Likert point scale highly affected controlling the type I error. Specifically, the 7 and 10 points could control the type I error, both the F test and K-W test, for all conditions where populations had a normal and positive skewness and platykurtic distributions. Regarding the population having a negative skewness and leptokurtic distribution, it could control the type I error in cases of 7 and 10 point scales for almost all conditions with the F test. Furthermore, the study showed that the larger sample size, the higher the effect on the power of the test. Therefore, if research aims to compare the location differences of populations, a minimum of 100 samples for each group should be applied. Besides, if respondents have sufficient capability, a questionnaire with 7 or 10 point Likert scales should be employed.

Keywords: Likert point scale, sample size, parametric test, nonparametric test.

1. Introduction

Likert proposed the Likert scale in an article titled “A Technique for the Measurement of Attitudes” in the Journal of Archives of Psychology (Likert 1932). Since then, the Likert scale has been widely utilized in social science research, especially in business, education, tourism, psychology and other disciplines to measure the opinion or attitude of a respondent. A typical scale was designed as “strongly approve”, “approve”, “undecided”, “disapprove” and “strongly disapprove” that can be scored as 5, 4, 3, 2 and 1, respectively. Furthermore, the scale has been developed and implemented in several surveys by researchers nowadays. However, there are other essential factors that must be identified for data analysis presently.

Controversy surrounds how data derived from the Likert scale can and should be analyzed by researchers. The issue frequently mentioned is whether the nature of these data is ordinal or continuous. There is also another question on what extent the parametric data analysis techniques are appropriate or acceptable for the Likert and other rating scales (Harpe 2015). Researchers who disagree with data analysis for the Likert scale by parametric testing. Firstly, they argued that Likert scales are strictly ordinal in nature, thus parametric tests require continuous data (interval or ratio scale) (Kuzon et al. 1996; Pett 1997; Hodge and Gillespie 2003; Jamieson 2004). Cohen et al. (2000) indicated that the range of different levels is not equal in value. Therefore, Likert should be arranged on an ordinal scale. Analysis of data using addition, subtraction, multiplication or division is not appropriate (Vonglao 2017). In addition, it is improper to analyze the data with arithmetic mean or standard deviation (Clegg 1998). Mean and standard deviation reveal vague meanings when they are applied to Likert scale responses (Sullivan and Artino 2013). Secondly, researchers argued that data sets are generated by Likert are often skewed or polarized distribution. Non-normal distribution responses may result in average scores not being useful for measuring data central tendency (Blaikie 2013). Thirdly, the extreme side of the Likert type responses are likely to be less active than the more centralized alternatives, resulting in “anchor effects” (Bishop and Herron 2015).

By contrast, some experts agreed with Likert scale analysis used by parametric statistics for four reasons. Firstly, parametric testing not only can be used with ordinal data but is often more robust than nonparametric testing (Sullivan and Artino 2013; Songthong 2014). Secondly, the research confirms the robustness of the parametric test for the Likert scale when analyzed as a summed composite score scale, not as individual items. However, the scale should be evaluated with the standard psychometric assessment (Carifio and Perla 2008). Thirdly, the data simulation study demonstrates the robustness of Pearson’s correlation for the sample size from 5 to 60 for the normal and uniform distribution of ordinal data (Murray 2013). Fourthly, Monte Carlo studies thoroughly asserted that the F test is greatly robust when analyzing Likert scale data and even analyzing it at the item level (Glass et al. 1972).

From the above, it could be said that experts have been arguing differently about this Likert scale technique. This article, therefore, intends to study the effect of the Likert point scale and sample size on the efficiency of testing statistics of location difference between three populations with both a parametric test (One-way ANOVA: F test) and nonparametric test (Kruskal-Wallis test: K-W test). These statistics tests are well-known and commonly used in research. The efficiency of testing statistics will be considered by the ability to control the type I error and the power of the test.

2. The Testing Statistics

2.1 One-way analysis of variance was developed by Fisher (1925). The technique of one-way ANOVA could be applied to compare the difference of two or more means. The testing statistic computed for an analysis of variance is based on the F distribution. F test is computed (Sheskin 2000) as follows:

$$F = \frac{MS_{BG}}{MS_{WG}}, \tag{1}$$

where F is the testing statistic,

MS_{BG} is the mean square between-groups, $MS_{BG} = \dfrac{\sum_{j=1}^{k}\left[\dfrac{\left(\sum X_j\right)^2}{n_j}\right] - \dfrac{\left(\sum X_T\right)^2}{N}}{k-1}$,

MS_{WG} is the mean square within-group, $MS_{WG} = \dfrac{\sum_{j=1}^{k}\left[\sum X_j^2 - \dfrac{\left(\sum X_j\right)^2}{n_j}\right]}{N-k}$,

$\sum X_j^2$ is the sum of square of observed in subjects of the j^{th} group

$\sum X_j$ is the sum of observed subjects in the j^{th} group

$\sum X_T$ is the total sum of observations of the N subjects

k is the number of groups

n_j is the number of subjects in the j^{th} group

N is the total subjects in all groups.

The criterion in hypothesis testing, if F_{cal} is equal to or greater than $F_{\alpha,k-1,\mathrm{N}-k}$, the null hypothesis will be rejected.

2.2 The Kruskal-Wallis one-way analysis of variance by ranks proposed by Kruskal and Wallis (1952) is used with ordinal data in a test of hypothesis involving a design that has two or more independent samples. The chi-square distribution is employed to approximate the Kruskal-Wallis testing statistics, which is characterized in most sources by notation K-W. K-W is computed (Sheskin 2000) as follows:

$$\text{K-W} = \frac{12}{N(N+1)}\sum_{j=1}^{k}\left[\frac{\left(\sum R_j\right)^2}{n_j} - 3(N+1)\right], \tag{2}$$

where K-W is the Kruskal-Wallis testing statistic

$\sum R_j$ is the sum of the rank of the j^{th} group

k is the number of groups

n_j is the number of subjects of the j^{th} group

N is the total subjects in all groups.

The criterion in hypothesis testing, if K-W is equal to or greater than $\chi^2_{\alpha,k-1}$, the null hypothesis will be rejected.

3. Method

A study of the effect of the Likert point scale and sample size on efficiency of parametric and nonparametric tests is studied through the Monte Carlo simulation by R program version 3.1 (R Core Team 2013). The procedures are as follows:

1. The simulation of three distributions include the normal distribution, positive skewness and platykurtic distribution ($S_k = 0.75, K = 2.8$), and negative skewness and leptokurtic distribution ($S_k = -1, K = 4$) by Ramberg's et al. (1979) formula as

$$R(p) = \lambda_1 + \frac{\left[p^{\lambda_3} - (1-p)^{\lambda_4}\right]}{\lambda_2}, \tag{3}$$

where λ_1 is a location parameter, λ_2 is a scale parameter, λ_3 and λ_4 are shape parameters.

For $\lambda_1, \lambda_2, \lambda_3, \lambda_4$ depend on the level of skewness and kurtosis, which come from Table's Ramberg et al. (1979). Data transforming is the Likert scale used by function Round( ) on R program version 3.1. Conditions of the mean and variance are shown in Table 1.

Table 1 Conditions of simulation including the ratio of means and variances

Scale of point	Means	Variances
5	3.5:3.5:3.5	0.5:0.5:0.5
		0.5:0.75:1
	3.5:3.85:4.2	0.5:0.5:0.5
		0.5:0.75:1
7	4.9:4.9:4.9	0.7:0.7:0.7
		0.7:1.05:1.4
	4.9:5.39:5.88	0.7:0.7:0.7
		0.7:1.05:1.4
10	7.0:7.0:7.0	1.0:1.0:1.0
		1.0:1.5:2.0
	7.0:7.7:8.4	1.0:1.0:1.0
		1.0:1.5:2.0

For the measurement determination of 5, 7, and 10 points scale, it could be said that those 5 and 7 points scales are widely applied as a research tool (Hartley 2013). In addition, the 5, 7, and 10 points scales are relatively convenient to answer the respondent (Preston and Colman 2000).

2. Sample sizes are 15 (small size), 30 and 50 (medium size) and 100 (large size). Three groups have an equal sample size.

3. Testing statistics are parametric tests as one-way analysis of variance (F-test) and nonparametric tests as Kruskal-Wallis one-way analysis of variance (K-W test).

4. Hypotheses are tested with a significant level at 0.05 and 0.01.

5. There are 96 conditions. For each condition, the data set is simulated 10,000 times.

To indicate the effect of the Likert point scale and the sample size on efficiency of testing statistics, the ability of control in type I error and power of the test are used. For the criterion of control of type I error used by Cochran (1954), if significant level is at 0.01 and the probability of type I error is 0.007-0.015 or significant level is at 0.05 and the probability of type I error is 0.04-0.06, the testing statistics could control the type I error.

4. Results

In our simulation for the efficiency of testing statistics considered by ability of control type I error and power of the test, the details are shown as follows:

In Table 2, the population has a normal distribution. The F test and K-W test could control the type I error for the Likert 10 point scale for all situations. For Likert 5 and 7 point scales, the F test could control the probability of type I error for all situations but the K-W test could control for almost all situations. On the Table 3, when we considered the power of the test under testing statistics, it could control the type I error. Overall, the K-W test has the highest power of the test for all used point scales.

In Table 4, populations have a positive skewness and platykurtic distribution. The F test and K-W test could control the type I error for the Likert 5 point scale in some situations. For Likert 7 and 10 point scales, the F-test could control the type I error for all situations while the K-W test could control the type I error for most situations. In Table 5, when we considered the power of the test under testing statistics, it could control the type I error. Overall, the F test has the highest power of the test with 7 and 10 point scales for all situations. For the 5 point scale, the K-W has the highest power of the test with about 50% from all conditions.

In Table 6, the population has negative skewness and leptokurtic distribution. Therefore, the F test and K-W test could not control the type I error for the Likert 5 point scale for 87.5% of all conditions. Nevertheless, it could control the type I error when the sample size was large. In addition, Likert 7 and 10 point scales, the F test could control the type I error for all situations but the K-W test could not control the type I error for some situations. In Table 7, when we considered the power of the test under testing statistics, it could control the type I error. Overall, the F-test had the highest power of the testing in a 7 point scale for 62.5% of all conditions. For 5 and 10 point scales, the K-W test had the highest power of the test with about 12.5% and 75% of all conditions, respectively.

Table 2 The probability of type I error of location difference testing statistics between three populations having normal distribution

n_j	Ratio of variance	Level of significant	5 point		7 point		10 point	
			F	K-W	F	K-W	F	K-W
15	1:1:1	0.05	0.0421*	0.0394	0.0426*	0.0423*	0.0478*	0.0469*
		0.01	0.0066	0.0059	0.0082*	0.0063	0.0105*	0.0081*
	1:1.5:2	0.05	0.0464*	0.0451*	0.0488*	0.0476*	0.0483*	0.0474*
		0.01	0.0097*	0.0078*	0.0093*	0.0076*	0.0106*	0.0081*
30	1:1:1	0.05	0.0484*	0.0465*	0.0463*	0.0468*	0.0477*	0.0480*
		0.01	0.0101*	0.0090*	0.0093*	0.0078*	0.0091*	0.0080*
	1:1.5:2	0.05	0.0535*	0.0513*	0.0480*	0.0463*	0.0541*	0.0516*
		0.01	0.0119*	0.0097*	0.0091*	0.0074*	0.0114*	0.0099*
50	1:1:1	0.05	0.0504*	0.0490*	0.0524*	0.0498*	0.0521*	0.0506*
		0.01	0.0110*	0.0104*	0.0098*	0.0095*	0.0103*	0.0095*
	1:1.5:2	0.05	0.0491*	0.0502*	0.0524*	0.0530*	0.0529*	0.0500*
		0.01	0.0091*	0.0096*	0.0108*	0.0102*	0.0103*	0.0108*
100	1:1:1	0.05	0.0498*	0.0489*	0.0490*	0.0499*	0.0508*	0.0514*
		0.01	0.0095*	0.0097*	0.0107*	0.0106*	0.0101*	0.0097*
	1:1.5:2	0.05	0.0519*	0.0513*	0.0515*	0.0514*	0.0497*	0.0512*
		0.01	0.0099*	0.0106*	0.0094*	0.0105*	0.0097*	0.0092*

Note: * Ability to control the probability of type I error.

Table 3 Power of the test of location difference testing statistics between three populations having a normal distribution once the type I error is controlled

n_j	Ratio of variance	Level of significance	5 point		7 point		10 point	
			F	K-W	F	K-W	F	K-W
15	1:1:1	0.05	0.6528**	0.6530	0.8939	0.9003**	0.9813	0.9817**
		0.01	0.4290	0.4095	0.7577**	0.7585	0.9330**	0.9330**
	1:1.5:2	0.05	0.5706	0.5802**	0.8041	0.8277**	0.9304	0.9443**
		0.01	0.3273**	0.3125	0.5816	0.5967**	0.7990	0.8113**
30	1:1:1	0.05	0.9541	0.9553**	0.9972	0.9974**	0.9999**	0.9999**
		0.01	0.8815**	0.8775	0.9901	0.9926**	0.9993	0.9995**
	1:1.5:2	0.05	0.9120	0.9217**	0.9845	0.9890**	0.9987	0.9993**
		0.01	0.7629	0.7719**	0.9418	0.9558**	0.9937	0.9964**
50	1:1:1	0.05	0.9981	0.9983**	1.0000**	1.0000**	1.0000**	1.0000**
		0.01	0.9919	0.9926**	1.0000**	1.0000**	1.0000**	1.0000**
	1:1.5:2	0.05	0.9920	0.9937**	0.9997	0.9998**	1.0000**	1.0000**
		0.01	0.9620	0.9669**	0.9986	0.9991**	1.0000**	1.0000**
100	1:1:1	0.05	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**
		0.01	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**
	1:1.5:2	0.05	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**
		0.01	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**	1.0000**

Note: ** The highest power of the test.

Table 4 The probability of a type I error of location difference testing statistics between three populations having a positive skewness and platykurtic distribution

n_j	Ratio of variances	Levels of significance	5 point		7 point		10 point	
			F	K-W	F	K-W	F	K-W
15	1:1:1	0.05	0.0475*	0.0444*	0.0497*	0.0506*	0.0494*	0.0473*
		0.01	0.0109*	0.0093*	0.0129*	0.0101*	0.0108*	0.0073*
	1:1.5:2	0.05	0.0592*	0.0598*	0.0551*	0.0553*	0.0542*	0.0554*
		0.01	0.0159	0.0128*	0.0128*	0.0108*	0.0132*	0.0104*
30	1:1:1	0.05	0.0481*	0.0464*	0.0510*	0.0489*	0.0559*	0.0531*
		0.01	0.0084*	0.0079*	0.0099*	0.0083*	0.0112*	0.0103*
	1:1.5:2	0.05	0.0609	0.0719	0.0538*	0.0513*	0.0500*	0.0569*
		0.01	0.0154	0.0150*	0.0115*	0.0094*	0.0125*	0.0133*
50	1:1:1	0.05	0.0502*	0.0491*	0.0486*	0.0474*	0.0458*	0.0469*
		0.01	0.0112*	0.0104*	0.0116*	0.0099*	0.0092*	0.0091*
	1:1.5:2	0.05	0.0597*	0.0777	0.0568*	0.0605	0.0503*	0.0654
		0.01	0.0153	0.0192	0.0144*	0.0140*	0.0114*	0.0160
100	1:1:1	0.05	0.0493*	0.0497*	0.0522*	0.0511*	0.0483*	0.0484*
		0.01	0.0094*	0.0093*	0.0116*	0.0104*	0.0107*	0.0106*
	1:1.5:2	0.05	0.0690	0.1066	0.0568*	0.0652	0.0531*	0.0868
		0.01	0.0188	0.0293	0.0121*	0.0150*	0.0133*	0.0235

Note: * Ability to control the type I error.

Table 5 Power of the test of location difference testing statistics between three populations which have a positive skewness and platykurtic distribution once the type I error is controlled

n_j	Ratio of variance	Level of significance	5 point		7 point		10 point	
			F	K-W	F	K-W	F	K-W
15	1:1:1	0.05	0.5082	0.5161**	0.7395**	0.7324	0.8830**	0.8758
		0.01	0.2665**	0.2544	0.5023**	0.4608	0.6986**	0.6636
	1:1.5:2	0.05	0.3628**	0.3185	0.5817**	0.5455	0.7852**	0.7640
		0.01	0.1512	0.1183**	0.3099**	0.2678	0.5261**	0.4920
30	1:1:1	0.05	0.8473	0.8602**	0.9729**	0.9684	0.9968**	0.9965
		0.01	0.6480	0.6533**	0.9008**	0.8853	0.9809**	0.9772
	1:1.5:2	0.05	0.6884	0.6223	0.8981**	0.8677	0.9893**	0.9848
		0.01	0.4342	0.3650**	0.7256**	0.6748	0.9421**	0.9236
50	1:1:1	0.05	0.9747	0.9773**	0.9994**	0.9990	1.0000**	1.0000**
		0.01	0.9019	0.9109**	0.9946**	0.9933	0.9999**	0.9997
	1:1.5:2	0.05	0.9114**	0.8485	0.9900**	0.9823	0.9997**	0.9996
		0.01	0.7532	0.6628	0.9524**	0.9254	0.9979**	0.9964
100	1:1:1	0.05	0.9998**	0.9998**	1.0000**	1.0000**	1.0000**	1.0000**
		0.01	0.9996**	0.9995	1.0000**	1.0000**	1.0000**	1.0000**
	1:1.5:2	0.05	0.9970	0.9897	0.9999**	0.9999	1.0000**	1.0000
		0.01	0.9829	0.9552	0.9998**	0.9993	1.0000**	1.0000

Note: ** The highest power of the test.

Table 6 The probability of a type I error of location difference testing statistics between three populations which have a negative skewness and leptokurtic distribution

n_j	Ratio of variance	Level of significance	5 point		7 point		10 point	
			F	K-W	F	K-W	F	K-W
15	1:1:1	0.05	0.0026	0.0025	0.0468*	0.0447*	0.0387	0.0352
		0.01	0.0009	0.0008	0.0087*	0.0067	0.0076*	0.0060
	1:1.5:2	0.05	0.0111	0.0114	0.0497*	0.0529*	0.0365	0.0382
		0.01	0.0022	0.0024	0.0104*	0.0097*	0.0079*	0.0078*
30	1:1:1	0.05	0.0021	0.0027	0.0451*	0.0459*	0.0485*	0.0450*
		0.01	0.0007	0.0006	0.0076*	0.0074*	0.0086*	0.0083*
	1:1.5:2	0.05	0.0186	0.0202	0.0522*	0.0639	0.0493*	0.0479*
		0.01	0.0039	0.0046	0.0111*	0.0154	0.0088*	0.0086*
50	1:1:1	0.05	0.0025	0.0024	0.0500*	0.0505*	0.0462*	0.0472*
		0.01	0.0004	0.0005	0.0113*	0.0104*	0.0086*	0.0089*
	1:1.5:2	0.05	0.0271	0.0266	0.0515*	0.0716	0.0529*	0.0567*
		0.01	0.0057	0.0043	0.0117*	0.0170	0.0095*	0.0112*
100	1:1:1	0.05	0.0059	0.0052	0.0523*	0.0517*	0.0537*	0.0541*
		0.01	0.0007	0.0007	0.0100*	0.0095*	0.0100*	0.0098*
	1:1.5:2	0.05	0.0489*	0.0412*	0.0524*	0.1096	0.0507*	0.0654
		0.01	0.0109*	0.0092*	0.0122*	0.0288	0.0117*	0.0141*

Note: * Ability to control the type I error.

Table 7 Power of the test of location difference testing statistics between three populations which have a negative skewness and leptokurtic distribution once the type I error is controlled

n_j	Ratio of variance	Level of significance	5 point		7 point		10 point	
			F	K-W	F	K-W	F	K-W
15	1:1:1	0.05	0.5246	0.5362	0.7572**	0.7766	0.8840	0.9106
		0.01	0.3367	0.3359	0.5650**	0.5757	0.7429**	0.7799
	1:1.5:2	0.05	0.4675	0.5595	0.6306	0.7118**	0.7953	0.8713
		0.01	0.2521	0.3007	0.4180	0.4777**	0.5874	0.6659**
30	1:1:1	0.05	0.8908	0.9023	0.9678	0.9732**	0.9942	0.9954**
		0.01	0.8002	0.8218	0.9254	0.9408**	0.9860	0.9922**
	1:1.5:2	0.05	0.8061	0.9031	0.9186**	0.9645	0.9797	0.9957**
		0.01	0.6068	0.7475	0.8014**	0.8950	0.9259	0.9741**
50	1:1:1	0.05	0.9872	0.9888	0.9956	0.9961**	0.9999**	0.9999**
		0.01	0.9778	0.9807	0.9926	0.9948**	0.9999**	0.9999**
	1:1.5:2	0.05	0.9651	0.9925	0.9925**	0.9981	0.9996	1.0000**
		0.01	0.8871	0.9665	0.9724**	0.9939	0.9973	0.9998**
100	1:1:1	0.05	0.9999	0.9999	0.9998**	0.9998**	1.0000**	1.0000**
		0.01	0.9999	0.9999	0.9998**	0.9998**	1.0000**	1.0000**
	1:1.5:2	0.05	0.9999	1.0000**	1.0000**	1.0000	1.0000**	1.0000
		0.01	0.9982	0.9999**	0.9999**	1.0000	1.0000**	1.0000**

Note: ** The highest power of the test.

5. Discussions

The Likert point scale was used for measuring opinions or attitudes. It was divided into 5 points scored as 5, 4, 3, 2, and 1. This measurement has highly influenced questionnaire development for research. Later on, the modified scale was developed with the aim of having a more precise measurement. According to the brief report of Hartley (2013), the 5 and 7 point scales were extensively applied as a research tool. Furthermore, the 10 point scale was also developed. This is to say that the higher range would increase the precision of measurements and was easy to apply. It is consistent with the study of Preston and Colman (2000) whom stated that the scales were relatively varied on favorite scores. When considering the easiness usability, it was found that 5, 7, and 10 point-scales were the most preferred. Also, if more than 10 point scales were used, the test-retest reliability coefficient was likely to decline. Thus, this study applied all 5, 7, and 10 point scales. The results of this study show that the higher the Likert point scale, the better it could control the type I error and the higher the power of the test on both parametric and nonparametric tests. This could explain that the Likert point scale has a wider interval which affects the variance of variables and has more measurable accuracy. Awang et al. (2016) suggested that 10 points of the Likert scale perform satisfactorily under the parametric based SEM. Both the measurement and structural models can be evaluated with a 10 point Likert scale, which is expected to be more successful in determining construct validity. Furthermore, the items with at least 5 point response patterns may be considered continuous (Harpe 2015). This corresponds to Likert data from the actual survey form that has neither a continuous nor normal distribution, and the number of subgroups is diverse. However, parametric analysis is very robust considering the observation that parametric and nonparametric analysis led to similar conclusions about statistical significance (Mircioiu and Atkinson 2017). When ignoring assumptions on equal variances, it was found that the F-test has higher robustness than the K-W test, especially for the 7 and 10 point scales. They could control error almost all conditions for three distributions. It is similar to Glass et al. (1972) who said that the violation of heterogeneous has a lesser effect on type I errors.

6. Conclusions

The present study is knowledgeable about the Likert point scale influencing the type I error and power of the test. If the Likert point scale is higher, it can control type I error better and it will give a higher power of the test. Therefore, the Likert 7 and 10 point scales are proper for being used as research instruments. Furthermore, the background of respondent and competency of the surveyor should be adequate. Finally, if the Likert scale is used with the objective to compare the differences of population location, a minimum of at least 100 samples is recommended because the power of the test would converge into 1.

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