

Test Of Difference Between Paired Sample By Using Mcnemar Test

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Abstract. Test of difference between paired sample is done to know whether there is a mean difference from two paired samples. If the data of two samples which are analyzed are an interval or ratio and normally distributed then the method of analysis which is correct to be used is paired sample t test but if the data of two samples are not normally distributed then sign test or wilcoxon tes can be used. In addition, if the data of two samples which are analyzed are ordinal then the method of analyses which is correct to be used is sign test or wilcoxon test. While, if the data of two samples are nominal then the test which is correct to be used is Mc Nemar test. The purpose of this article is to describe the ways in using McNemar test and the examples of its aplication in education field.

Key words : *test of difference, two paired sample, McNemar test*

1. Introduction

As Susetyo (2010) said data scales are characteristics on variable which enable to be expressed as a number. There are 4 data scales, those are nominal, ordinal, interval and ratio. Nominal scale is a data scale which has a characteristic just distinguishing, for example gender for man is 1 for man, and 2 for woman. These numbers aim to distinguish not to show the levels. Ordinal scale is a data scale which has characteristics distinguishing and showing the levels, for example parent's education levels of students are Elementary School (1), Junior High Scholl (2), Senior School (3), and Bachelor Degree (4). These numbers aim to distinguish and show the levels. Interval scale is a data scale which has characteristics distinguishing, showing the levels, showing the distancee and not having an absolute 0, for example the temperature in an area are 24°C, 25°C, and 26°C. While ratio scale is a data scale which has characteristics distinguishing, showing the levells, showing the distance, and having an absolute 0, for example the number of people 0 people, 1 people, 2 people and so on.

If the data which is analyzed both nominal or ordinal the the analysis method which is correct is nonparametric statistical method. While if it is both interval or ratio then the data analysis which can be used is parametric statistical method if the asumptions of parametric statistic can be fulfilled (Siegel, 1986).

Parametric Statistics is statistical techniques which based on asumption that distribution of population data is normal. While nonparametric statistics is statistical techniques which is not based on asumption that the distribution of population data must be normal. Nonparametric statistics is also called Statistics which frees of distribution (Dajan, 1986).

The test of paired samples aims to analyze the difference of two paired samples, or the other words to test whether two paired samples are come from the populations which have the same characteristics or not (Suliyanto, 2014). If the data of two paired samples which will be analyzed are interval or ratio and normally distributed the correct analysis is parametric statistics that is paired samples t test, but if the data of those samples are not normally distributed then the alternative method that can be used is

nonparametric statistics that is sign test or Wilcoxon test. Sign test and Wilcoxon test also can be used in an ordinal data. While if the data of two paired samples which will be analyzed are nominal than the correct method of analysis is nonparametric statistics that is McNemar test.

The ways in analyzing the difference of two paired samples by using McNemar test are necessary to be known and so is this example of application. They are important so the researcher is not wrong in doing McNemar test and the people can know the example of application in the daily life as an education field. Therefore, the questions in this article are: 1) How are the ways in using McNemar test, 2) How are the examples of its application in education field.

2. Discussion

Paired samples are same samples but the treatments which are given to them are different (Suliyanto, 2014). The test of difference between paired samples is done to know whether there is a different result of those samples. For example, we will test whether there is a different result between before and after the use of media in learning of mathematics.

If the data of two paired samples which will be analyzed are nominal then the correct method of analysis is nonparametric statistics that is McNemar test. It was introduced by McNemar on 1947 (Daniel, 1989).

The assumptions in McNemar test are:

1. The data is come from N subjects (or items) or paired subjects, depends on whether those subjects also have the function as a control for theirselves or whether the experimental subjects are paired with their control subjects that are equal.
2. The measure scale which is used is nominal scale.
3. If each subjects has a function as a control for theirselves, then those subjects are free each others. (Daniel, 1989)

2.1 The Ways in Using McNemar Test

McNemar test is done by the steps as follows:

- a. Formulating the hypothesis.
 $H_0: Me_1 = Me_2$
 $H_1: Me_1 \neq Me_2$
- b. Determining level of significance (α).
- c. Calculating test statistics

In calculating test statistics on McNemar test, the steps which are done as follows:

- 1) Making frequency table 2×2 to test whether there is a change as an effect of the treatment. That frequency table can be seen in this below.

Table 1. Frequency Table 2×2 for McNemar Test

Before	After	
	-	+
+	A	B
-	C	D

A shows frequency at the prior condition (+) and after treatment becomes (-). B shows frequency at the prior condition (+) and after treatment remains (+). C shows frequency at the prior condition (-) and after treatment remains (-). While D shows frequency at the prior condition (-) and after treatment becomes (+).

- 2) Calculating test statistics

McNemar test follows Chi-Square distribution. The basic equation of Chi-Square is as follows:

$$\chi^2 = \sum_{i=1}^k \frac{(f_o - f_h)^2}{f_h} \dots\dots\dots(1)$$

Note:

f_o = The number of observed frequency in category of i .

f_h = The number of expected frequency in category of i .

In McNemar test, one thing that is necessary to be consider is the changes in the cells, those are cell A which shows frequency changes from (+) to (-), while the expected value for each cells is $(A+D)/2$, so the formula of Chi-Square can be simplified to become

$$\begin{aligned} \chi^2 &= \sum_{i=1}^k \frac{(f_o - f_h)^2}{f_h} \\ &= \frac{\left[A - \frac{A+D}{2}\right]^2}{\frac{A+D}{2}} + \frac{\left[D - \frac{A+D}{2}\right]^2}{\frac{A+D}{2}} \\ &= \frac{(A-D)^2}{A+D} \dots\dots\dots(2) \end{aligned}$$

with the degree of freedom (df) = 1.

Then, that formula is corrected by Yates on 1934 so becomes

$$\chi^2 = \frac{(|A-D|-1)^2}{A+D} \dots\dots\dots(3)$$

with the degree of freedom (df) = 1

(Suliyanto, 2014).

- d. Determining criteria of decision-making.

If $\chi^2_{\text{calculated}} < \chi^2_{\text{table}}$ then H_0 is accepted. Otherwise, if $\chi^2_{\text{calculated}} \geq \chi^2_{\text{table}}$ then H_0 is rejected.

- e. Making decision.

- f. Getting conclusion.

While, the steps in using McNemar test in SPSS are as follows:

- a. Designing variable

In this step, click variable view and define the variable which will be analyzed in name, type, width, decimals, label, values, missing, column, align, measure, and role.

- b. Inputting the data

After designing variable, click data view then inputting the data

- c. Analyzing

The steps in analyzing are:

Click Analyze → click Nonparametric Tests → click Legacy Dialogs → click 2 Related Samples → input variables which will be analyzed in Box of Test Pairs → In Test Type, enable McNemar (disable Wilcoxon) → click OK.

- d. Interpretating the result of analysis.

In this step, interpretate the result of analysis.

2.2 Example of McNemar Application in The Education Field

2.2.1 Example 1

A researcher wanted to know whether there was a difference of students's interest to learn mathematics between before and after the learning which used the media. With 20 students as a random sample, it was gotten the data as follows:

Table 2. The data of students's interest to learn mathematics before and after the learning which used the media.

Attendee's Number	Before	After
1	Dislike	Like
2	Like	Like
3	Dislike	Like
4	Dislike	Dislike
5	Like	Like
6	Like	Like
7	Dislike	Like
8	Dislike	Like
9	Like	Like
10	Like	Like
11	Like	Like
12	Dislike	Like
13	Like	Like
14	Dislike	Dislike
15	Dislike	Like
16	Like	Like
17	Dislike	Like
18	Dislike	Like
19	Like	Like
20	Like	Like

With $\alpha = 0,05$, test whether there was a difference of students's interest to learn mathematics between before and after the learning which used the media!

Answer:

That problem can be solved by using McNemar test because there are two paired samples and the data is nominal. McNemar test is done by using the steps as follows:

- 1) Formulating the hypothesis

$$H_0: Me_1 = Me_2$$

$$H_1: Me_1 \neq Me_2$$

- 2) Determining level of significance (α)

$$\alpha = 0,05$$

- 3) Calculating test statistics

Before calculating test statistics, make table of frequency 2x2 as follows:

Table 3. Table of frequency 2x2 for The Data of Example 1

Before	After	
	Dislike	Like
Like	0	10
Dislike	2	8

$$\chi^2 = \frac{(|A - D| - 1)^2}{A + D}$$

$$\begin{aligned}
 &= \frac{(10-8|-1)^2}{0+8} \\
 &= \frac{49}{8} \\
 &= 6,125
 \end{aligned}$$

4) Determining the Criteria of Decision-Making

If $\chi^2_{\text{calculated}} < \chi^2_{\text{table}}$ then H_0 is accepted. Otherwise, if $\chi^2_{\text{calculated}} \geq \chi^2_{\text{table}}$ then H_0 is rejected.

5) Making Decision.

From the table of Chi-square distribution with degree of freedom (df) = 1 and $1-\alpha = 1-0,05 = 0,95$, it is gotten $\chi^2_{\text{table}} = 3,841$. Because $\chi^2_{\text{calculated}} > \chi^2_{\text{table}}$ that is $6,125 > 3,841$ then H_0 is rejected.

6) Getting Conclusion

The conclusion which is gotten is there was a difference of students's interest to learn mathematics between before and after the learning which used the media.

This result of analysis is same if it is done by using SPSS. Here is the result of McNemar test for the data of example 1 by using SPSS.

Table 4. Result of McNemar Test for The Data of Example 1 by Using SPSS

McNemar Test

Crosstabs

Interest before the learning & Interest after the learning

Interest before the learning	Interest after the learning	
	Dislike	Like
Dislike	2	8
Like	0	10

Test Statistics^b

	Interest before the learning & Interest after the learning
N	20
Exact Sig. (2-tailed)	,008 ^a

a. Binomial distribution used.

b. McNemar Test

Based on Table 4, it is gotten information that Exact Sig. (2-tailed) is lower than 0,05 therefore H_0 is rejected. So the conclusion is there was a difference of students's interest to learn between before and after the learning which used the media.

2.2.2 Example 2

A researcher did a research about students's response toward the learning of mathematics which was done in Junior High School by using the cooperative learning model of TGT on material of flat quadrilateral. Here is the data which was gotten from the questionnaire that was given in the first and second meeting.

Table 5. The Data of Students's Response toward The Learning of Mathematics which was Done in Junior High School by Using The Cooperative Learning Model of TGT on Material of Flat Quadrilateral

Attendee's Number	First Meeting	Second Meeting
1	Interesting	Interesting
2	Interesting	Interesting
3	Interesting	Interesting
4	Interesting	Interesting
5	Not interesting	Interesting
6	Interesting	Interesting
7	Interesting	Not interesting
8	Interesting	Interesting
9	Interesting	Interesting
10	Not interesting	Not interesting
11	Interesting	Interesting
12	Interesting	Interesting
13	Interesting	Interesting
14	Interesting	Interesting
15	Not interesting	Interesting
16	Not interesting	Not interesting
17	Interesting	Interesting
18	Interesting	Interesting
19	Interesting	Interesting
20	Interesting	Interesting
21	Interesting	Interesting
22	Not interesting	Interesting
23	Interesting	Interesting
24	Interesting	Interesting
25	Interesting	Interesting
26	Interesting	Interesting
27	Interesting	Not interesting
28	Not interesting	Interesting
29	Interesting	Interesting
30	Interesting	Interesting

With $\alpha = 0,05$, test whether there was a difference of students's response toward the cooperative learning model of TGT on the material of flat quadrilateral between first meeting and second meeting!

Answer:

That problem can be solved by using McNemar test because there is two paired samples and the data is nominal. That test can be done with the steps as follows:

- 1) Formulating the hypothesis.
 $H_0: Me_1 = Me_2$
 $H_1: Me_1 \neq Me_2$
- 2) Determining level of significance (α).
 $\alpha = 0,05$
- 3) Calculating the test statistics

Before calculating the test statistics, make table of frequency 2×2 as follows:

Table 6. Table of Frequency 2×2 for The Data of Example 2

First Meeting	Second Meeting	
	Not interesting	Interesting
Interesting	2	22
Not interesting	2	4

$$\begin{aligned}\chi^2 &= \frac{(|A - D| - 1)^2}{A + D} \\ &= \frac{(|2-4|-1)^2}{2+4} \\ &= \frac{1}{6} \\ &= 0,167\end{aligned}$$

- 4) Determining the criteria of decision-making.
 If $\chi^2_{\text{calculated}} < \chi^2_{\text{table}}$ then H_0 is accepted. Otherwise, if $\chi^2_{\text{calculated}} \geq \chi^2_{\text{table}}$ then H_0 is rejected.
- 5) Making decision
 From the table of Chi-Square distribution with the degree of freedom (df) = 1 and $1-\alpha = 1-0,05 = 0,95$, it is gotten $\chi^2_{\text{table}} = 3,841$. Because $\chi^2_{\text{calculated}} < \chi^2_{\text{table}}$ that is $0,167 < 3,841$ then H_0 is accepted.
- 6) Getting conclusion
 The conclusion which is gotten is there was not difference of students's response toward the cooperative learning model of TGT on material of flat quadrilateral between first meeting and second meeting.

This result is same if it is done by using SPSS. Here is the result of McNemar test for example 2 by using SPSS.

Table 7.
Result of McNemar Test for The Data of Example 2

McNemar Test

Crosstabs

First Meeting & Second meeting		
First Meeting	Second meeting	
	Not interesting	Interesting
Not interesting	2	4
Interesting	2	22

Test Statistics ^b	
	First Meeting & Second meeting
N	30
Exact Sig. (2-tailed)	,687 ^a

a. Binomial distribution used.

b. McNemar Test

Based on Table 7, it is gotten information that Exact Sig. (2-tailed) value is 0,687 higher than α that is 0,05 then H_0 is accepted. So the conclusion is there was not difference of students's response toward the cooperative learning model of TGT on material of flat quadrilateral between first meeting and second meeting.

3. Conclusion

The conclusion which can be gotten from this article are:

a. McNemar test is a test in nonparametric statistics which is done to compare two paired samples which their data are nominal.

b. The ways ini using McNemar are as follows:

1) Formulating the hypothesis.

$$H_0: Me_1 = Me_2$$

$$H_1: Me_1 \neq Me_2$$

2) Determining level of significance (α).

3) Calculating test statistics.

In calculating test statistics on McNemar test, the steps which are done as follows:

a) Making table of frequency 2×2 to test whether there is a change as an effect of the treatment.

b) Calculating the test statistics

$$\chi^2 = \frac{(|A - D| - 1)^2}{A + D}$$

4) Determining the criteria of decision-making

If $\chi^2_{\text{calculated}} < \chi^2_{\text{table}}$ then H_0 is accepted. Otherwise, if $\chi^2_{\text{calculated}} \geq \chi^2_{\text{table}}$ then H_0 is rejected.

- 5) Making decision
 - 6) Getting conclusion.
- c. The steps in using McNemar test in SPSS are:
- 1) Designing variable
 - 2) Inputting the data
 - 3) Analyzing
The steps in analyzing are:
Click Analyze → click Nonparametric Tests → click Legacy Dialogs → click 2 Related Samples → input variables which will be analyzed in Box of Test Pairs → In Test Type, enable McNemar (disable Wilcoxon) → click OK.
 - 4) Interpretating the result of analysis.

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