

# How to Use a Mann-Whitney U Table to Compare Two Groups

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## The Role of the Mann-Whitney U Test in Data Analysis

The Mann-Whitney U Test (often abbreviated as the Mann-Whitney-Wilcoxon or MWW test) stands as a foundational tool in the field of non-parametric statistics. This specialized test is meticulously designed for comparing two independent groups when the underlying assumptions required for traditional parametric tests, such as the independent samples t-test, cannot be met. Specifically, it is utilized when data distributions are not normally distributed, when sample sizes are small, or when the measurement scale is ordinal rather than interval or ratio. It effectively assesses whether the two populations are stochastically different, meaning it determines if an observation drawn randomly from one population is likely to be larger or smaller than an observation drawn randomly from the other population.

This test focuses on the ranks of the data rather than the raw scores themselves, which grants it robustness against outliers and distributional abnormalities, making it exceptionally valuable in fields such as psychology, ecological studies, and social sciences where data frequently violates the strict requirements of normal distribution. When researchers seek to understand if two different interventions, demographic groups, or experimental conditions yield significantly different outcomes, and their collected data resists normalization, the Mann-Whitney U Test provides a powerful and reliable method for statistical inference. Its reliance on rank sums transforms continuous or ordinal data into a framework suitable for robust comparison without assuming a specific shape for the population distributions.

Crucially, the interpretation of the results from this test hinges upon referencing the appropriate critical values, which are systematically compiled within the Mann-Whitney U Table. This table provides the necessary thresholds that allow the researcher to determine if the calculated test statistic,  $U$ , is sufficiently extreme to warrant the rejection of the null hypothesis. Without these critical values, the calculated  $U$  statistic lacks context, emphasizing the table's pivotal role in the final decision-making phase of the hypothesis testing procedure. The subsequent sections will detail how to calculate the  $U$  statistic and how to effectively navigate and utilize this critical value table.

### When to Utilize Non-Parametric Testing

The decision to employ a non-parametric statistical test like the Mann-Whitney U Test is fundamentally driven by the characteristics of the data collected. Parametric tests, such as the t-test or ANOVA, operate under strict mathematical assumptions--chief among them being that the data are drawn from populations that are normally distributed and exhibit homogeneity of variances. When these assumptions are violated, particularly when analyzing small sample sizes or highly skewed data, the results derived from parametric methods can become unreliable, increasing the risk of Type I or Type II errors.

Non-parametric methods, in contrast, make fewer assumptions about the distribution shape of the population from which the sample is drawn. Instead of requiring interval or ratio data, they often operate effectively on ordinal data, relying on the relative ordering of observations (ranks) rather than the exact numerical difference between them. This approach makes the Mann-Whitney U Test the preferred alternative to the independent samples t-test when data are measured on an ordinal scale (e.g., Likert scales) or when testing reveals significant non-normality that cannot be rectified through transformations.

The core utility of the Mann-Whitney U Test is comparing the medians or the overall distributions of two independent samples. While the t-test directly compares the means, the U test compares the likelihood that a score randomly selected from one population will exceed a score randomly selected from the other. Therefore, understanding the nature and scale of your data is the first and most critical step in choosing the appropriate statistical technique, confirming the necessity of using rank-based methods when parametric assumptions are untenable.

## Understanding the Core Components of the U Table

The structure of the Mann-Whitney U Table is organized to facilitate the rapid determination of the critical threshold required for statistical decision-making. Researchers must carefully identify three primary parameters to locate the relevant critical value: the sample sizes of the two groups, the chosen significance level, and whether the test is one-tailed or two-tailed. Missing or misidentifying any of these components will inevitably lead to an incorrect conclusion regarding the null hypothesis.

The following elements are integral to the proper use of the table:

**Sample Sizes (n1 and n2):** The table is indexed by the number of observations within each of the two independent groups being compared. Since the distribution of the U statistic depends heavily on the size of the groups, locating the intersection of the appropriate row and column corresponding to your precise sample sizes is the initial required step. Most tables are designed symmetrically, meaning the order of n1 and n2 often does not matter, but precision is paramount.

**Significance Level ( $\alpha$ ):** This parameter, denoted as alpha ( $\alpha$ ), represents the maximum acceptable probability of committing a Type I error--the error of incorrectly rejecting the null hypothesis when it is actually true. Researchers most commonly select an alpha level of 0.05 (5%) or 0.01 (1%). The table provides separate sections or columns dedicated to these standard alpha levels, allowing the researcher to match the desired level of statistical rigor to the critical value.

**Critical Values for U:** These are the specific thresholds provided within the body of the table. They represent the boundary value that the calculated Mann-Whitney U statistic must meet or fall below (for a two-tailed test or a specific direction in a one-tailed test) in order to declare the result statistically significant. Separate tables are provided for two-tailed tests (used when comparing

differences in either direction) and one-tailed tests (used when a specific directional hypothesis, such as "Group A is strictly larger than Group B," is being tested).

It is important to note that when sample sizes ( $n_1$  and  $n_2$ ) exceed the limits of the published tables (typically around 20 or 25), the U statistic can be approximated using a Z-score calculation based on the normal distribution. However, for smaller samples, the direct use of the tabulated critical values ensures the highest level of accuracy for decision-making.

## Formulating Hypotheses for the U Test

Before any statistical calculation commences, the researcher must clearly articulate the research question in terms of testable hypotheses. The Mann-Whitney U Test, like all inferential statistical procedures, operates by testing a null hypothesis ( $H_0$ ) against an alternative hypothesis ( $H_1$  or  $H_a$ ). These statements dictate the direction of the expected difference, which in turn determines whether a one-tailed or two-tailed approach is required.

The null hypothesis ( $H_0$ ) for the Mann-Whitney U Test proposes that there is no stochastic difference between the two populations from which the samples were drawn. This is often phrased as: the probability that an observation from Population 1 is greater than an observation from Population 2 is equal to the probability that an observation from Population 2 is greater than an observation from Population 1. In simpler terms,  $H_0$  suggests that the two population distributions are identical, or, if their shapes are similar, that their medians are equal. The goal of the test is to gather sufficient evidence to refute this baseline assumption.

The alternative hypothesis ( $H_1$ ) is the statement the researcher typically seeks to support. For a non-directional (two-tailed) test,  $H_1$  states that the distributions are not identical (i.e., one distribution stochastically dominates the other). For a directional (one-tailed) test,  $H_1$  specifies the direction of the difference, asserting, for example, that the values in Group A are significantly smaller than the values in Group B. Proper hypothesis formulation is essential because it dictates the choice of critical values from the table, particularly concerning the significance level ( $\alpha$ ) across the tails of the distribution.

## The Process of Calculating the Mann-Whitney U Statistic

The calculation of the Mann-Whitney U statistic is a methodical, rank-based procedure designed to quantify the degree of separation between the two groups. This statistic is derived from comparing every observation in Group 1 against every observation in Group 2 and counting the pairs where the Group 1 value exceeds the Group 2 value, and vice versa. However, the standard and more computationally efficient method involves ranking the combined dataset.

**Calculate your Mann-Whitney U statistic:** This initial step requires combining all observations

from both independent groups into a single dataset. Subsequently, the data must be ranked from the smallest value (rank 1) to the largest value. If ties exist (identical scores), they are assigned the average of the ranks they would have occupied. After ranking the entire dataset, the ranks are separated back according to their original group membership ( $n_1$  and  $n_2$ ). The rank sums ( $R_1$  and  $R_2$ ) are then calculated for each group individually.

**Deriving the U Value:** The U statistic is derived from these rank sums using the following formulas for  $U_1$  and  $U_2$ :

$$U_1 = n_1 * n_2 + (n_1 * (n_1 + 1)) / 2 - R_1$$

$$U_2 = n_1 * n_2 + (n_2 * (n_2 + 1)) / 2 - R_2$$

The final calculated U statistic used for comparison against the critical value table is the smaller of  $U_1$  and  $U_2$ . This smaller value is often referred to simply as U, and it is the statistic that quantifies the difference in the distribution of ranks between the two samples.

**Identify the appropriate section:** The directionality of your hypothesis determines whether you consult a two-tailed or one-tailed version of the table. A two-tailed table is used for comparing differences in any direction, suitable for  $H_1$ : distributions are not equal. A one-tailed table is chosen if you hypothesized a specific direction in advance (e.g., that Group A scores will be exclusively larger than Group B scores). This choice is critical as it affects the critical boundary.

The resulting calculated U statistic represents how 'mixed' the ranks of the two groups are. A U value close to the maximum possible value ( $n_1 * n_2$ ) indicates that the groups are highly separated (i.e., most of the ranks from one group are higher than those from the other). Conversely, a U value close to zero indicates that the ranks are highly segregated. It is the proximity of the calculated U to zero that typically leads to the rejection of the null hypothesis when using the smaller U value for comparison against the critical table.

## A Step-by-Step Guide to Using the Critical Value Table

Once the calculated U statistic has been determined, the final stage involves consulting the critical value table to establish statistical significance. The process is systematic and demands careful attention to the parameters derived from the study design. This consultation provides the necessary benchmark against which the observed data difference is judged.

**Locate the row with your sample sizes ( $n_1$  and  $n_2$ ):** Navigate the table structure to find the row or section corresponding to the specific combination of your group sizes,  $n_1$  and  $n_2$ . Since the Mann-Whitney U Test is symmetric, the order in which you enter  $n_1$  and  $n_2$  generally does not affect the resulting critical value, provided both are correctly identified.

**Find the column with your chosen significance level ( $\alpha$ ):** Identify the column that aligns with your predetermined significance level (e.g.,  $\alpha = 0.05$  or  $\alpha = 0.01$ ). If using a one-tailed test, ensure you are either using a dedicated one-tailed table or appropriately adjusting the alpha level on a two-tailed table (e.g., using the  $\alpha = 0.10$  column for a one-tailed test at  $\alpha = 0.05$ ). The intersection of the correct row ( $n_1, n_2$ ) and column ( $\alpha$ ) yields the precise critical value.

**Compare your calculated U statistic to the critical value:** This is the decision point. The critical value serves as the cutoff point for the test statistic. For most standard applications of the Mann-Whitney U Table, the smaller calculated U statistic must be less than or equal to the tabulated critical value to achieve statistical significance. If the calculated U is larger than the critical value, the observed difference is deemed to be within the range expected under the null hypothesis.

**Two-tailed test:** If your calculated U is **less than or equal to** the critical value found in the table for your chosen  $\alpha$  (e.g., 0.05), you must reject the null hypothesis ( $H_0$ ). Rejecting  $H_0$  leads to the conclusion that there is a statistically significant difference in the distributions between the two groups.

**One-tailed test:** When conducting a directional test, special care is required. If your hypothesis is supported (i.e., the ranks fall in the hypothesized direction) and the calculated U is **less than or equal to** the appropriate critical value (often found by using half the alpha level, e.g., using the  $\alpha = 0.05$  column for a one-tailed test at  $\alpha = 0.025$ ), you reject  $H_0$ . If the ranks fall in the unhypothesized direction,  $H_0$  cannot be rejected, regardless of the magnitude of U.

The following tables illustrate the critical values for common two-tailed significance levels.

## Critical Values for Two-Tailed Tests

These tables provide the maximum U value that can be observed while still allowing the researcher to reject the null hypothesis at the specified significance level ( $\alpha$ ). Note that these values assume a two-tailed test, comparing for differences in either direction.

### Alpha = .01 (two-tailed)

n1 \ n2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2																			
3								0	0	0	1	1	1	2	2	2	2	3	3
4					0	0	1	1	2	2	3	3	4	5	5	6	6	7	8
5				0	1	1	2	3	4	5	6	7	7	8	9	10	11	12	13
6			0	1	2	3	4	5	6	7	9	10	11	12	13	15	16	17	18
7			0	1	3	4	6	7	9	10	12	13	15	16	18	19	21	22	24
8			1	2	4	6	7	9	11	13	15	17	18	20	22	24	26	28	30
9		0	1	3	5	7	9	11	13	16	18	20	22	24	27	29	31	33	36
10		0	2	4	6	9	11	13	16	18	21	24	26	29	31	34	37	39	42
11		0	2	5	7	10	13	16	18	21	24	27	30	33	36	39	42	45	46
12		1	3	6	9	12	15	18	21	24	27	31	34	37	41	44	47	51	54
13		1	3	7	10	13	17	20	24	27	31	34	38	42	45	49	53	56	60
14		1	4	7	11	15	18	22	26	30	34	38	42	46	50	54	58	63	67
15		2	5	8	12	16	20	24	29	33	37	42	46	51	55	60	64	69	73
16		2	5	9	13	18	22	27	31	36	41	45	50	55	60	65	70	74	79
17		2	6	10	15	19	24	29	34	39	44	49	54	60	65	70	75	81	86
18		2	6	11	16	21	26	31	37	42	47	53	58	64	70	75	81	87	92
19	0	3	7	12	17	22	28	33	39	45	51	56	63	69	74	81	87	93	99
20	0	3	8	13	18	24	30	36	42	46	54	60	67	73	79	86	92	99	105

Alpha = .05 (two-tailed)

n1 \ n2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2							0	0	0	0	1	1	1	1	1	2	2	2	2
3				0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4			0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14
5		0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6		1	2	3	5	6	7	10	11	13	14	16	17	19	21	22	24	25	27
7		1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8	0	2	4	6	7	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9	0	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
10	0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11	0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12	1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13	1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14	1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	67	74	78	83
15	1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16	1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17	2	6	11	17	22	28	34	39	45	51	57	63	67	75	81	87	93	99	105
18	2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19	2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20	2	8	13	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

Alpha = .10 (two-tailed)

n1 \ n2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2				0	0	0	1	1	1	1	2	2	3	3	3	3	4	4	4
3		0	0	1	2	2	3	4	4	5	5	6	7	7	8	9	9	10	11
4		0	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
5	0	1	2	4	5	6	8	9	11	12	13	15	16	18	19	20	22	23	25
6	0	2	3	5	7	8	10	12	14	16	17	19	21	23	25	26	28	30	32
7	0	2	4	6	8	11	13	15	17	19	21	24	26	28	30	33	35	37	39
8	1	3	5	8	10	13	15	18	20	23	26	28	31	33	36	39	41	44	47
9	1	4	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
10	1	4	7	11	14	17	20	24	27	31	34	37	41	44	48	51	55	58	62
11	1	5	8	12	16	19	23	27	31	34	38	42	46	50	54	57	61	65	69
12	2	5	9	13	17	21	26	30	34	38	42	47	51	55	60	64	68	72	77
13	2	6	10	15	19	24	28	33	37	42	47	51	56	61	65	70	75	80	84
14	3	7	11	16	21	26	31	36	41	46	51	56	61	66	71	77	82	87	92
15	3	7	12	18	23	28	33	39	44	50	55	61	66	72	77	83	88	94	100
16	3	8	14	19	25	30	36	42	48	54	60	65	71	77	83	89	95	101	107
17	3	9	15	20	26	33	39	45	51	57	64	70	77	83	89	96	102	109	115
18	4	9	16	22	28	35	41	48	55	61	68	75	82	88	95	102	109	116	123
19	4	10	17	23	30	37	44	51	58	65	72	80	87	94	101	109	116	123	130
20	4	11	18	25	32	39	47	54	62	69	77	84	92	100	107	115	123	130	138

## Interpreting Results and Making Statistical Decisions

The final step in utilizing the Mann-Whitney U Test involves synthesizing the calculated U statistic with the critical value obtained from the relevant table. The fundamental principle governing the decision is straightforward: if the calculated U statistic falls into the rejection region (defined by the critical value), the results are statistically significant. Conversely, if U falls outside this region, the researcher must fail to reject the null hypothesis.

When the calculated U is less than or equal to the critical value, it signifies that the ranks of the two groups are sufficiently distinct that such a separation is unlikely to have occurred merely due to random sampling variability. The researcher therefore rejects the null hypothesis ( $H_0$ ) and accepts the alternative hypothesis ( $H_1$ ), concluding with a confidence level defined by  $(1 - \alpha)$  that there is a significant difference between the populations. This difference is interpreted in terms of one group tending to have higher or lower scores (ranks) than the other.

If the calculated U value is greater than the critical value, the result falls outside the critical region. This outcome indicates that the observed difference between the two groups' rank distributions is not substantial enough to be considered statistically significant at the chosen significance level. In this scenario, the researcher fails to reject  $H_0$ , meaning there is insufficient statistical evidence to conclude that the two population distributions differ. It is important to remember that failing to reject

H0 is not equivalent to accepting H0; it merely means the data do not support the conclusion of a significant difference. Furthermore, reporting the magnitude of the effect size alongside the U statistic enhances the practical interpretation of the findings beyond a simple binary decision of significance.

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