Article

A desktop calculator for effect sizes: Towards the new statistics

WenJun Zhang
School of Life Sciences, Sun Yat-sen University, Guangzhou 510275, China
E-mail: zhwj@mail.sysu.edu.cn, wjzhang@iaees.org

Received 5 July 2023; *Accepted 11 July 2023*; *Published online 22 July 2023*; *Published 1 December 2023*

Abstract
Effect size is a statistical concept which measures the strength of the relationship between two variables. Effect size has basic properties such as measurement unit independence, sample size independence, and monotonicity. In particular, unlike statistical significance test, effect size is not influenced by sample size. Effect size avoids various problems in statistical significance tests. It is one of the important contents in constructing new statistics. In present study, various effect sizes were mathematically described and a free desktop calculator for effect sizes was presented.

Keywords effect sizes; calculation; offline; software; new statistics.

Computational Ecology and Software
ISSN 2220-721X
URL: http://www.iaees.org/publications/journals/ces/online-version.asp
RSS: http://www.iaees.org/publications/journals/ces/rss.xml
E-mail: ces@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Statistical significance tests (including student's t-test, F-test, χ^2-test, etc.) are one of the most important statistical inference methods in statistics (Fisher, 1935; Yates, 1951; Amrhein et al., 2019; Sellke et al., 2001; Xie, 2022). Researchers around the world widely use statistical significance as a certificate of scientific discovery. Whether a research result is statistically significant is mainly judged by the p-value obtained from hypothesis testing (Bergstrom and West, 2021). The p-value is at the heart of the statistical significance tests. Over the past few decades, statistical significance tests have been used in most statistics-related research papers, monographs, textbooks, and all statistical software worldwide, and numerous scientists in various disciplines have touted the p-value as the gold standard for statistical significance (Sun, 2016; Zhang, 2022c). However in recent years, statistical significance tests have been questioned unprecedentedly, mainly because the paradigm of significance tests is wrong, p-value is too sensitive, p-value is a dichotomous subjective index, and statistical significance is related to sample size, etc (Trafimow and Marks, 2015; Baker, 2016; Wasserstein and Lazar, 2016; McShane and David, 2017; Tong, 2019; Wasserstein et al., 2019; Zhang, 2022a-c). Statistical significance tests have been one of the sources of false conclusions and research reproducibility crisis (Ioannidis, 2005; Open Science Collaboration, 2015; Errington et al., 2021; Huang, 2021a-b; Kafdar, 2021; Nature Editorial, 2021; Vrieze, 2021; Zhang, 2022c). Actually, statistical significance mainly depends on the sample size, the quality of the data and the power of the statistical procedures (Lenhard and Lenhard, 2016;

Zhang, 2022c). Not every significant result refers to an effect with a high impact. If large datasets are used, very small effects may lead to statistical significance (Lenhard and Lenhard, 2016). In the last year, Zhang (2022c) has detailed *p*-value based statistical significance tests, including concepts, misuses, critiques, and solutions, etc. In recent years the search for better statistics to replace *p*-value based statistical significance tests is becoming a hot topic in statistics (Huang, 2018a-b, 2021a-b). Many statisticians invoke to abandon *p*-value based statistical significance tests and replace them with effect size, Bayesian methods, meta-analysis, etc., and scientific inference that combines statistical testing and multiple types of evidence is the basis for producing reliable conclusions (Huang, 2018a-b; Pandey et al., 2022; Zhang, 2022a-c). Reliable scientific inference requires appropriate experimental design, sampling design, and sample size; it also requires full control of the research process (Zhang, 2022a-c).

In order to solve the problem that the *p*-value is too sensitive and the dichotomy is used to determine the statistical significance, as one of the main contents in new statistics (Cumming, 2013), the effect size paradigm can be used. Contrary to the significance tests, the effect size paradigm guides researchers to pay attention to scientific significance, and directly conduct scientific research based on effect size inference (Cohen, 1988, 2008; Elis, 2010; Lenhard and Lenhard, 2016; Huang, 2021a-b; Zhang, 2022c).

Effect size is a statistical concept that mathematically measures the strength of the relationship between two variables (Lenhard and Lenhard, 2016). It can quantify the degree of association between variables, compare the changes before and after itself, compare the differences between groups, etc. Effect size is not just a certain measure, different statistics tests, corresponding to different effect sizes. Effect sizes have been used in the field of statistics, mainly including several fields:

(1) Effect sizes used to measure the difference: Cohen's d, Hedges' g, η^2, etc.

(2) Effect sizes used to measure categories: Cohen's w, Odds Ratio (OR), Risk Ratio (RR), etc.

(3) Effect sizes used to measure correlation: Pearson correlation r, coefficient of determination r^2, ω^2, etc.

Differences in means, proportions explained by ANOVA, proportions explained by regression analysis, etc., can be described by effect sizes. Effect sizes are very important for estimating treatment effects. If the effect size is too small, it means that the treatment has no practical value even if it reaches a significant level.

Effect sizes possess unique properties such as measurement unit independence, sample size independence, and monotonicity. In particular, unlike statistical significance test, effect size is not influenced by sample size. Effect size can solve the problem that *p*-value cannot describe the degree of correlation and difference. The use of effect sizes can also avoid the problems of *p*-value hacking.

At present, more than 100 effect sizes have been reported (Hedges and Olkin, 1985; Cohen, 1988, 2008; McGraw and Wong, 1992; Dunlap et al., 1996; Klauer, 2001; Rosenthal, 1994; Rosenthal and DiMatteo, 2001; Morris and DeShon, 2002; Thalheimer and Cook, 2002; Peterson and Brown, 2005; Morris, 2008; Borenstein, 2009; Hattie, 2009; Elis, 2010; Morris and Richler, 2012; Lakens, 2013; Lenhard and Lenhard, 2016; Zhang, 2022c).

In the past decades, various crises arise in statistics, including those from *p*-value based statistical significance tests (Zhang, 2022c). To address these problems in statistics, the construction of a new statistics, including the wide use of effect sizes, is urgent. In addition to writing, publishing and adopting new statistical monographs and textbooks, the most urgent task is to revise and distribute various statistical software based on the new statistics for further use (Zhang, 2022a-c). For effect sizes, Lenhard and Lenhard (2016) have proposed an online calculator. To further promote the use of effect sizes, in present study, I developed an offline standalone executable calculator of effect sizes based on Lenhard and Lenhard (2016) and other research. In addition, various effect sizes were mathematically described for explicit uses by researchers.

2 Effect Sizes

2.1 Measures of effect sizes

2.1.1 Effect sizes for difference comparison of two independent groups

2.1.1.1 Comparison of two independent groups with equal sample size (Cohen's *d* and Glass *Δ*)

The effect size, Cohen's *d*, is calculated by subtracting the means and dividing the result by the pooled standard deviation if the two groups have the same size. Cohen's *d* is used to compare the difference between two groups (Cohen, 1988).

Glass points out that the standard deviation of the control group rather than the pooled standard deviation is used if there are relevant differences in the standard deviations. He argues that the standard deviation of the control group should not be influenced, at least in case of non-treatment control groups. The resultant effect size is Glass' *Δ*.

The Common Language Effect Size (CLES) is a non-parametric effect size, which gives the probability that one case randomly drawn from the one sample has a higher value than a randomly drawn case from the other sample (McGraw and Wong, 1992; Lenhard and Lenhard, 2016).

(1) Cohen's *d*:

$$d = (m_2 - m_1) /((s_1^2 + s_2^2)/2)^{0.5}$$

where m_1 and m_2 are the mean of the two groups, respectively, and s_1 and s_2 are the standard deviation of the two groups.

95% and 90% confidence interval of Cohen's *d* are $d \pm 1.96\ \sigma$ and $d \pm 1.65\ \sigma$, respectively (Hedges and Olkin, 1985), where the standard error of Cohen's *d* is

$$\sigma = (4/n + d^2/(2*n))^{0.5}$$

and n is the total sample size of two groups.

(2) Glass *Δ*:

$$\Delta = (m_2 - m_1) /s_2$$

where s_2 is the standard deviation of control group.

(3) Common Language Effect Size (CLES):

$$\text{CLES} =1 - D*T*(0.3193815 + T*(-0.3565638 + T*(1.781478 + T*(-1.821256 + T*1.330274)))),\ x>0$$

$$\text{CLES} = D*T*(0.3193815 + T*(-0.3565638 + T*(1.781478 + T*(-1.821256 + T*1.330274)))),\ x\leq 0$$

where $D = 0.3989423*e^{-x*x/2}$, $T = 1/(1 + 0.2316419*|x|)$, $x = |m_2 - m_1| /(s_1^2 + s_2^2)^{0.5}$.

2.1.1.2 Comparison of two independent groups with different sample size (Cohen's *d*, Hedges' *g*)

If two groups have different sample size, then the pooled standard deviation should be adjusted with weights for the sample sizes in the calculation of Cohen's *d*.

In the CLES the higher group mean is used as the point of reference (Lenhard and Lenhard, 2016).

(1) Cohen's *d*:

$$d = (m_2 - m_1) /s$$

where m_1 and m_2 are the mean of the two groups respectively, and s is the pooled standard deviation:

$$s = (((n_1 - 1)s_1^2 + (n_2 - 1)s_2^2)/(n_1 + n_2 - 2))^{0.5}$$

where n_1 and n_2 are the sample size of the two groups, and s_1 and s_2 are the standard deviation of the two groups.

95% and 90% confidence interval of Cohen's *d* are $d \pm 1.96\ \sigma$ and $d \pm 1.65\ \sigma$, respectively (Hedges and Olkin, 1985), where the standard error of Cohen's *d* is

$$\sigma = ((n_1 + n_2)/(n_1*n_2) + 0.5*d^2/(n_1 + n_2))^{0.5}$$

(2) Hedges' g:

When the sample size is small, such as when the overall sample is less than 20 or each group of samples is less than 10, Cohen's d will have a large deviation. In view of this, Hedges and Olkin (1985) proposed a method to calculate Cohen's d based on small samples:

Hedges' $g = ((m_2 - m_1)/s)*(1 - 3/(4*(n_1 + n_2 - 2) - 1))$

If the variables do not conform to the normal distribution, the data needs to be transformed to calculate the effect size. The Box-Cox method can be used for data transformation. If the data transformation still cannot meet the requirements, rank transformation can be tried.

(3) Common Language Effect Size (CLES):

CLES =1 - $D*T*(0.3193815 + T*(-0.3565638 + T*(1.781478 + T*(-1.821256 + T*1.330274))))$, $x>0$

CLES = $D*T*(0.3193815 + T*(-0.3565638 + T*(1.781478 + T*(-1.821256 + T*1.330274))))$, $x\leq0$

where $D = 0.3989423*e^{-x*x/2}$, $T = 1/(1 + 0.2316419*|x|)$, $x = |d|/1.4142$.

2.1.2 Effect size for difference between two correlations

Cohen (1988) proposes an effect size measure, here called Cohen's q, for the difference between two correlations.

Cohen's q:

$q =|0.5*\log((1 + r_1)/(1 - r_1)) - 0.5*\log((1 + r_2)/(1 - r_2))|$

where r_1 and r_2 are two correlations.

Cohen proposes the following criteria: $q<0.1$: no effect; 0.1 to 0.3: small effect; 0.3 to 0.5: intermediate effect; $q>0.5$: large effect (Lenhard and Lenhard, 2016).

2.1.3 Effect sizes for mean differences of two groups with unequal sample size within a pre-post-control design

Generally the intervention studies aims to compare the development of two or more groups (e.g., an experimental group and a control group) (Lenhard and Lenhard, 2016). Unfortunately, the pretest means and standard deviations of two groups do not match. To solve this problem, Klauer (2001) proposes to compute effect sizes (g) of both groups for the two groups and then to subtract both, and different sample sizes and pretest values can thus be corrected automatically. Morris (2008) proposes different effect sizes for repeated measures designs. He uses the pooled pretest standard deviation for weighting the differences of the pre-post-means. By doing so, the standard deviation is not influenced by intervention.

2.1.3.1 Klauer's d:

$d = d_{post} - d_{pre}$

in which

$d_{pre} = (m_{1pre} - m_{2pre})/((((n_{1pre} - 1)*s_{1pre}^2) + ((n_{2pre} - 1)*s_{2pre}^2))/(n_{1pre} + n_{2pre} - 2))^{0.5}$

$d_{post} = (m_{1post} - m_{2post})/((((n_{1post} - 1)*s_{1post}^2) + ((n_{2post} - 1)*s_{2post}^2))/(n_{1post} + n_{2post} - 2))^{0.5}$

where m_{1pre} and m_{2pre} are the mean of the two groups for pretest, respectively; m_{1post} and m_{2post} are the mean of the two groups for posttest, respectively; n_{1pre} and n_{2pre} are the sample size of the two groups for pretest, respectively; n_{1post} and n_{2post} are the sample size of the two groups for posttest, respectively; s_{1pre} and s_{2pre} are the standard deviation of the two groups for pretest, respectively; s_{1post} and s_{2post} are the standard deviation of the two groups for posttest, respectively.

2.1.3.2 Morris' d:

$d = c_p*(((m_{1post} - m_{1pre}) - (m_{2post} - m_{2pre}))/s_{pre})$

where

$c_p = 1.0 - (3.0 / (4.0*(n_{1pre} + n_{2pre} - 2.0) - 1.0))$

$s_{pre} = ((((n_{1pre} - 1)*s_{1pre}^2) + ((n_{2pre} - 1)*s_{2pre}^2))/(n_{1pre} + n_{2pre} - 2))^{0.5}$

2.1.4 Effect sizes for repeated measures designs

Morris and DeShon (2002) propose a measure of effect size for single-group pretest-posttest designs by taking the correlation between the pre- and post-test into account (Lakens, 2013; Lenhard and Lenhard, 2016). If the standard deviation of the pretest is used, the resultant effect size is d_{rm}. Otherwise, if the pooled standard deviation for controlling of the intercorrelation of both groups is used, the resultant effect size is $d_{rm\ pooled}$. If the correlation is 0.5, the resultant effect size equals Cohen's d and Glass Δ as listed above (Lenhard and Lenhard, 2016).

$d_{rm\ pooled} = ((m_2 - m_1)/s)/ (2*(1 - r))^{0.5}$

where m_1 and m_2 are the mean of the two groups, respectively, r is the intercorrelation of two groups, and s is the pooled standard deviation:

$s = (s_1^2 + s_2^2 - 2*r*s_1*s_2)^{0.5}$

where and s_1 and s_2 are the respective standard deviations of the two groups.

95% and 90% confidence interval of $d_{rm\ pooled}$ are: $d_{rm\ pooled} \pm 1.96\ \sigma$ and $d_{rm\ pooled} \pm 1.65\ \sigma$, respectively, where the standard error of $d_{rm\ pooled}$ is

$\sigma = (2/n + d_{rm}^2/(4*n))^{0.5}$

where n is the pooled sample size, and

$d_{rm} = ((m_2 - m_1)/s_1)/(2*(1 - r))^{0.5}$

Cumming's effect size does not consider controlling for the intercorrelation, which is often used in meta analyses (Cumming, 2012):

$d_{av} = (m_2 - m_1)/((s_1 + s_2)/2)$

2.1.5 Effect size from the *F*-value of ANOVA with two distinct groups

Using the *F*-value of Analyses of Variance (ANOVA) with two distinct groups, Cohen's d can be calculated (Thalheimer and Cook, 2002).

Cohen's d:

$d = (f*((n_1 + n_2)/(n_1*n_2))*((n_1 + n_2)/(n_1 + n_2 - 2)))^{0.5}$

where f is the f-test value, n_1 and n_2 are the sample size of two distinct groups (e.g., treatment and control groups) respectively.

2.1.6 Effect sizes from ANOVAs with multiple groups

For the cases that the means of all groups are known from ANOVAs with multiple groups, we may compute the effect sizes, d and f (Cohen, 1988; Lenhard and Lenhard, 2016). In such cases we should determine the minimum and maximum mean and calculate pooled standard deviation of all groups. Additionally, we may compute effect sizes for other cases.

2.1.6.1 Cohen's ANOVA d:

$d = (m_{max} - m_{min})/s$

where m_{max} and m_{min} are minimum and maximum mean of multiple groups, s is the pooled standard deviation of all groups (i.e., σ_{pool}).

2.1.6.2 Cohen's ANOVA f:

If there is a minimum and maximum mean group and the other group means are at midpoint, i.e., distribution of means is minimum variability:

$f = d*(1/(2*k))^{0.5}$

If the means of all groups are evenly distributed, i.e., distribution of means is intermediate variability:

$f = 0.5*d*((k + 1)/(3*(k - 1)))^{0.5}$

If the means of all goups are distributed mainly towards the extremes and not in the center of means' range, i.e., distribution of means is maximum variability:

$f = 0.5*d$ $(k \% 2)=0$

$f = d*(k^2 - 1)^{0.5}/(2*k)$ $(k \% 2)\neq 0$

where k is the number of groups.

2.1.6.3 Cohen's ANOVA f:

$f = (F/k)^{0.5}$

where F is the F value in one-way ANOVA. f=0.10 is a small effect, f=0.25 is an intermediate effect, and f=0.40 is a large effect.

2.1.6.4 ANOVA Partial η_p^2:

$\eta_p^2 = SS_A/(SS_A + SS_E)$

In one-way ANOVA, SS_A is the between-group variation and SS_E is the within-group variation.

2.1.7 Effect sizes from the *t*-test statistics of dependent and independent variables

Effect sizes can be obtained by using the Student *t*-tests (Morris and DeShon, 2002; Borenstein, 2009; Lenhard and Lenhard, 2016).

For dependent groups:

$d = t*(2.0*(1.0 - r)/n_1)^{0.5}$

where t is the t-test value, r is the correlation between two groups, n_1 is the sample size.

For independent group:

$d = t*((n_1 + n_2)/(n_1*n_2))^{0.5}$

where t is the t-test value, n_1 and n_2 are the sample size of two groups respectively.

According to Lenhard and Lenhard (2016), using t_c described in Dunlap et al. (1996) will have the least distortion in estimating d.

2.1.8 Effect sizes from χ^2 and z statistics

The Chi-square χ^2 and z test statistics from hypothesis tests can be used to compute d and r (Rosenthal and DiMatteo, 2001; Elis, 2010).

2.1.8.1 Chi-square χ^2 for 2×2 contingency tables:

$d = 2*r/(1 - r^2)^{0.5}$

$\eta^2 = (d/2)^2/(1 + (d/2)^2)$

in which

$r = (\chi^2/n)^{0.5}$

2.1.8.2 Chi-square χ^2 for $R×C$ contingency tables:

$r = (\chi^2/min(C - 1, R - 1))^{0.5}$

2.1.8.3 z:

$d = 2*r/(1 - r^2)^{0.5}$

$\eta^2 = (d/2)^2/(1 + (d/2)^2)$

in which

$r = z/n^{0.5}$

where n is the total sample size.

2.1.9 Effect size from standardized *β* weights in multiple regression analysis

Peterson and Brown (2005) propose an effect size measure, r, converted from standardized β weights in multiple regression analysis when the β weights range between -0.5 and 0.5 (Lenhard and Lenhard, 2016). r can be further converted into d or other effect size measures.

$$r = \beta + 0.05$$

2.1.10 Effect sizes for non-parametric statistical tests: Mann-Whitney *U*, Wilcoxon *W* and Kruskal-Wallis *H*

In the statistical tests of non-parametric test statistcis, for example, Mann-Whitney U, Wilcoxon W, or Kruskal-Wallis H, the distributions of test statistics are approximated by normal distributions and the test statistics can be transformed in effect sizes (Cohen, 2008; Morris and Richler, 2012; Lenhard and Lenhard, 2016).

2.1.10.1 Mann-Whitney U

(1) η^2:

$$\eta^2 = z^2/(n_1 + n_2)$$

$$\eta^2 = -\eta^2 \qquad \eta^2<0$$

where n_1 and n_2 are the sample size of two groups respectively, z is standardized normal value:

$$z = (U - (n_1*n_2/2))/(n_1*n_2*(n_1 + n_2 + 1)/12)^{0.5}$$

$$z = -z \qquad z<0$$

where U is the (approximate normal) test value.

(2) Cohen's d:

$$d = 2*(\eta^2/(1 - \eta^2))^{0.5}$$

2.1.10.2 Wilcoxon W

(1) η^2:

$$\eta^2 = z^2/n$$

$$\eta^2 = -\eta^2 \qquad \eta^2<0$$

where n is the total sample size, z is standardized normal value:

$$z = (W - (n*(n + 1)))/(n*(n + 1)*(2*n + 1)/24)^{0.5}$$

$$z = -z \qquad z<0$$

where W is the (approximate normal) test value.

(2) Cohen's d:

$$d = 2*(\eta^2/(1 - \eta^2))^{0.5}$$

2.1.10.3 Kruskal-Wallis H

(1) η^2:

$$\eta^2 =|((H - k + 1)/(n - k))|$$

where n and k are the total sample size and the number of groups respectively, H is the (approximate normal) test value.

(2) Cohen's d:

$$d = 2*(\eta^2/(1 - \eta^2))^{0.5}$$

2.1.11 Effect sizes: Risk Ratio, Odds Ratio and Risk Difference

Effect sizes as Risk Ratio, Odds Ratio and Risk Difference are used to compare the differences between the groups if specific incidences occur on a binary basis and if two groups differ in respect to these incidences

(Borenstein et al., 2009). The Risk Ratio is the quotient between the risks, resp. probabilities for incidences in two different groups. The Odds Ratio is the quotient between the odds of the two groups. It is a relative risk and is usually used in meta analyses. The Risk Difference is simply the difference between two risks. It is highly influenced by changes in base rates (Lenhard and Lenhard, 2016). $Log_{RiskRatio}$ or $Log_{OddsRatio}$ are suggested being used when doing meta analyses (Lenhard and Lenhard, 2016).

Risk Ratio:

$RR = (a/n_1)/(c/n_2)$

where $n_1 = a + b$, $n_2 = c + d$. a, b, c, and d are treatment incidence, treatment no incidence, control incidence, and control no incidence.

Odds Ratio:

$OR = (a*d)/(b*c)$

Standardized OR (Yule's Q):

$YuleQ = (OR - 1)/(OR + 1)$

Risk Difference:

$RD = a/n_1 - c/n_2$

2.1.12 Effect sizes: correlations

There are many correlation measures, like Pearson correlation (Pearson, 1895, 1904; Zhang, 2015a-b, 2016, 2018, 2021b; Zhang and Li, 2015), point correlation (Zhang, 2015b, 2016, 2017, 2018, 2021a), Spearman rank correlation (Spearman, 1904; Schoenly and Zhang, 1999; Zhang, 2015b, 2016, 2018), etc. Generally the correlation value is between -1.0 and 1.0. The correlation value 0 means no correlation, 1.0 means the perfect positive correlation, and -1.0 means the perfect negative correlation.

2.2 Relationship between different effect sizes

2.2.1 Between *d* and other effect sizes:

$r = (d^2/(d^2 + 4))^{0.5}$

$\eta^2 = (d/2)^2/(1 + (d/2)^2)$

$f = 0.5*d$

$odd = e^{\pi d/1.7321}$

2.2.2 Between *r* and *d*:

$d = 2*r/(1 - r^2)^{0.5}$

2.2.3 Between η^2 and *d*:

$d = 2*(\eta^2/(1 - \eta^2))^{0.5}$

2.2.4 Between *f* and *d*:

$d = 2*f$

2.2.5 Between *odd* and *d*:

$d = 0.5513*\log(odd)$

2.3 Interpretation of the magnitude of effect sizes

A large value in effect size (i.e., large effect) means a significant difference or a significant effect, which corresponds to the significant statistic difference or significant statistic effect in statistical tests. Cohen (1988) and Hattie (2009) present the meanings and interpretation of the magnitude of some effect sizes. Laterly, Lenhard and Lenhard (2016) make slight adjustment on their intervals. The following Table 1 is their adjusted interpretation table of the magnitude of some effect sizes.

Table 1 Meanings and interpretation of the magnitude of effect sizes (after Lenhard and Lenhard, 2016).

d	*r*	η^2	**Interpretation Cohen (1988)**	**Interpretation Hattie (2009)**
< 0	< 0	-	Adverse Effect	
0.0	0.00	0.000	No effect	Developmental effects
0.1	0.05	0.003		
0.2	0.10	0.010		Teacher effects
0.3	0.15	0.022	Small effect	
0.4	0.20	0.039		
0.5	0.24	0.060		
0.6	0.29	0.083	Intermediate effect	
0.7	0.33	0.110		Zone of desired effects
0.8	0.37	0.140		
0.9	0.41	0.168	Large effect	
≥1.0	0.45	0.200		

3 Software and Codes

The standalone executable desktop calculator, effectSizeCal (version 1.0), was developed using Delphi. The following are the full Delphi codes of the software:

```
unit Unit1;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls;

type
  TForm1 = class(TForm)
    Button1: TButton;
    Button2: TButton;
    Button3: TButton;
    Button4: TButton;
    Button5: TButton;
    Button6: TButton;
```

```
    Button7: TButton;
    Button8: TButton;
    Button9: TButton;
    Button10: TButton;
    Button11: TButton;
    Label1: TLabel;
    Label2: TLabel;
    Label3: TLabel;
    Button12: TButton;
    Label4: TLabel;
    procedure Button1Click(Sender: TObject);
    procedure Button2Click(Sender: TObject);
    procedure Button3Click(Sender: TObject);
    procedure Button4Click(Sender: TObject);
    procedure Button5Click(Sender: TObject);
    procedure Button6Click(Sender: TObject);
    procedure Button7Click(Sender: TObject);
    procedure Button8Click(Sender: TObject);
    procedure Button9Click(Sender: TObject);
    procedure Button10Click(Sender: TObject);
    procedure Button11Click(Sender: TObject);
    procedure Button12Click(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form1: TForm1;

implementation

uses Unit2, Unit3, Unit4, Unit5, Unit6, Unit7, Unit8, Unit9, Unit10, Unit11,
  Unit12, Unit13;

{$R *.dfm}

procedure TForm1.Button1Click(Sender: TObject);
begin
Form2.visible:=true;
end;

procedure TForm1.Button2Click(Sender: TObject);
begin
Form3.visible:=true;
end;

procedure TForm1.Button3Click(Sender: TObject);
begin
```

```
Form4.visible:=true;
end;

procedure TForm1.Button4Click(Sender: TObject);
begin
Form5.visible:=true;
end;

procedure TForm1.Button5Click(Sender: TObject);
begin
Form6.visible:=true;
end;

procedure TForm1.Button6Click(Sender: TObject);
begin
Form7.visible:=true;
end;

procedure TForm1.Button7Click(Sender: TObject);
begin
Form8.visible:=true;
end;

procedure TForm1.Button8Click(Sender: TObject);
begin
Form9.visible:=true;
end;

procedure TForm1.Button9Click(Sender: TObject);
begin
Form10.visible:=true;
end;

procedure TForm1.Button10Click(Sender: TObject);
begin
Form11.visible:=true;
end;

procedure TForm1.Button11Click(Sender: TObject);
begin
Form12.visible:=true;
end;

procedure TForm1.Button12Click(Sender: TObject);
begin
Form13.visible:=true;
end;

end.
```

```
unit Unit2;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls, ExtCtrls;

type
  TForm2 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    RadioButton1: TRadioButton;
    RadioButton2: TRadioButton;
    Label2: TLabel;
    Label3: TLabel;
    Edit1: TEdit;
    Edit2: TEdit;
    Edit3: TEdit;
    Edit4: TEdit;
    Label4: TLabel;
    Label5: TLabel;
    Label6: TLabel;
    Edit5: TEdit;
    Label7: TLabel;
    Edit6: TEdit;
    Label8: TLabel;
    Edit7: TEdit;
    Label9: TLabel;
    Edit8: TEdit;
    Label10: TLabel;
    Label11: TLabel;
    Edit9: TEdit;
    Edit10: TEdit;
    Label12: TLabel;
    Label13: TLabel;
    Edit11: TEdit;
    Edit12: TEdit;
    Edit13: TEdit;
    Edit14: TEdit;
    Timer1: TTimer;
    procedure RadioButton1Click(Sender: TObject);
    procedure RadioButton2Click(Sender: TObject);
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;
```

```
var
   Form2: TForm2;

implementation

{$R *.dfm}

procedure TForm2.RadioButton1Click(Sender: TObject);
begin
label10.Enabled:=false;
label11.Enabled:=false;
edit9.Enabled:=false;
edit10.Enabled:=false;
label6.Enabled:=true;
edit5.Enabled:=true;
label8.Caption:='Glass effect size Δ:';
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit9.text:='';
edit10.text:='';
end;

procedure TForm2.RadioButton2Click(Sender: TObject);
begin
label6.Enabled:=false;
edit5.Enabled:=false;
label10.Enabled:=true;
label11.Enabled:=true;
edit9.Enabled:=true;
edit10.Enabled:=true;
label8.Caption:='Hedges'' effect size g:';
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit5.text:='';
end;

procedure TForm2.Timer1Timer(Sender: TObject);
var
     m1, m2, s, s1, s2, x, cohend, gedgeg, glassd, cles, sigma, D, T: single;
     n, n1, n2: integer;
begin
try
m1:=strtofloat(trim(edit1.Text));
m2:=strtofloat(trim(edit3.Text));
s1:=strtofloat(trim(edit2.Text));
s2:=strtofloat(trim(edit4.Text));
```

```
if (radiobutton1.checked=true) then
n:=strtoint(trim(edit5.Text))
else
begin
n1:=strtoint(trim(edit9.Text));
n2:=strtoint(trim(edit10.Text));
end;
except
edit6.Text:='';
edit7.Text:='';
edit8.Text:='';
edit11.Text:='';
edit12.Text:='';
edit13.Text:='';
edit14.Text:='';
exit;
end;
s:=sqrt(((n1-1)*s1*s1+(n2-1)*s2*s2)/(n1+n2-2));
cohend:=(m2-m1)/sqrt((s1*s1+s2*s2)/2);
if (radiobutton1.checked=true) then
begin
glassd:=(m2-m1)/s2;
sigma:=sqrt(4/n+cohend*cohend/(2*n));
x:=abs(m2-m1)/sqrt(s1*s1+s2*s2);
end
else
begin
gedgeg:=((m2-m1)/s)*(1-3/(4*(n1+n2-2)-1));
sigma:=sqrt((n1+n2)/(n1*n2)+0.5*cohend*cohend/(n1+n2));
x:=abs(cohend)/1.4142;
end;
D:=0.3989423*exp(-x*x/2);
T:=1/(1+0.2316419*abs(x));
cles:=D*T*(0.3193815+T*(-0.3565638+T*(1.781478+T*(-1.821256+T*1.330274))));
if (x>0) then
cles:=1-cles;
edit6.text:=floattostr(cohend);
edit11.text:=floattostr(cohend-1.96*sigma);
edit12.text:=floattostr(cohend+1.96*sigma);
edit13.text:=floattostr(cohend-1.65*sigma);
edit14.text:=floattostr(cohend+1.65*sigma);
if (radiobutton1.checked=true) then
edit7.text:=floattostr(glassd)
else
edit7.text:=floattostr(gedgeg);
edit8.text:=floattostr(cles);
end;

end.
```

```
unit Unit3;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, ExtCtrls, StdCtrls;

type
  TForm3 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    Label2: TLabel;
    Label3: TLabel;
    Edit1: TEdit;
    Edit2: TEdit;
    Edit3: TEdit;
    Label4: TLabel;
    Timer1: TTimer;
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form3: TForm3;

implementation

{$R *.dfm}

procedure TForm3.Timer1Timer(Sender: TObject);
var
   r1, r2, q: single;
begin
try
r1:=strtofloat(trim(edit1.Text));
r2:=strtofloat(trim(edit2.Text));
except
edit3.Text:='';
exit;
end;
q:=abs(0.5*ln((1+r1)/(1-r1))-0.5*ln((1+r2)/(1-r2)));
edit3.text:=floattostr(q);
end;

end.
```

```
unit Unit4;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls, ExtCtrls;

type
  TForm4 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    Edit1: TEdit;
    Edit2: TEdit;
    Edit3: TEdit;
    Edit4: TEdit;
    Edit5: TEdit;
    Edit6: TEdit;
    Edit7: TEdit;
    Edit8: TEdit;
    Label2: TLabel;
    Label3: TLabel;
    Label4: TLabel;
    Label5: TLabel;
    Label6: TLabel;
    Label7: TLabel;
    Label8: TLabel;
    Edit9: TEdit;
    Edit10: TEdit;
    Edit11: TEdit;
    Edit12: TEdit;
    Label9: TLabel;
    Label10: TLabel;
    Edit13: TEdit;
    Edit14: TEdit;
    Timer1: TTimer;
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form4: TForm4;

implementation

{$R *.dfm}
```

```
procedure TForm4.Timer1Timer(Sender: TObject);
var
   m1pre, m1post, m2pre, m2post, s1pre, s1post, s2pre, s2post: single;
   n1pre, n1post, n2pre, n2post: integer;
   klauerd, morrisd, dpre, dpost, cp, spre: single;
begin
try
m1pre:=strtofloat(trim(edit1.Text));
m1post:=strtofloat(trim(edit2.Text));
m2pre:=strtofloat(trim(edit3.Text));
m2post:=strtofloat(trim(edit4.Text));
s1pre:=strtofloat(trim(edit5.Text));
s1post:=strtofloat(trim(edit6.Text));
s2pre:=strtofloat(trim(edit7.Text));
s2post:=strtofloat(trim(edit8.Text));
n1pre:=strtoint(trim(edit9.Text));
n1post:=strtoint(trim(edit10.Text));
n2pre:=strtoint(trim(edit11.Text));
n2post:=strtoint(trim(edit12.Text));
except
edit13.Text:='';
edit14.Text:='';
exit;
end;
dpre:=(m1pre-m2pre)/sqrt((((n1pre-1)*s1pre*s1pre)+((n2pre-1)*s2pre*s2pre))/(n1pre+n2pre-2));
dpost:=(m1post-m2post)/sqrt((((n1post-1)*s1post*s1post)+((n2post-1)*s2post*s2post))/(n1post + n2post-2));
klauerd:=dpost-dpre;
cp:=1.0-(3.0/(4.0*(n1pre+n2pre-2.0)-1.0));
spre:=sqrt((((n1pre-1)*s1pre*s1pre)+((n2pre-1)*s2pre*s2pre))/(n1pre+n2pre-2));
morrisd:=cp*(((m1post-m1pre)-(m2post-m2pre))/spre);
edit13.text:=floattostr(klauerd);
edit14.text:=floattostr(morrisd);
end;

end.

unit Unit5;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls, ExtCtrls;

type
  TForm5 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    Label2: TLabel;
    Label3: TLabel;
```

```
    Label4: TLabel;
    Label5: TLabel;
    Edit1: TEdit;
    Edit2: TEdit;
    Edit3: TEdit;
    Edit4: TEdit;
    Label6: TLabel;
    Edit5: TEdit;
    Label7: TLabel;
    Edit6: TEdit;
    Label8: TLabel;
    Edit7: TEdit;
    Label9: TLabel;
    Edit8: TEdit;
    Label10: TLabel;
    Edit9: TEdit;
    Edit10: TEdit;
    Label11: TLabel;
    Edit11: TEdit;
    Edit12: TEdit;
    Edit13: TEdit;
    Label12: TLabel;
    Timer1: TTimer;
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form5: TForm5;

implementation

{$R *.dfm}

procedure TForm5.Timer1Timer(Sender: TObject);
var
   m1, m2, s1, s2, r, s, sigma, drm, drmpooled, dav: single;
   n: integer;
begin
try
m1:=strtofloat(trim(edit1.Text));
m2:=strtofloat(trim(edit2.Text));
s1:=strtofloat(trim(edit3.Text));
s2:=strtofloat(trim(edit4.Text));
r:=strtofloat(trim(edit5.Text));
n:=strtoint(trim(edit6.Text));
except
```

```
edit7.Text:='';
edit8.Text:='';
edit9.Text:='';
edit10.Text:='';
edit11.Text:='';
edit12.Text:='';
edit13.Text:='';
exit;
end;
s:=sqrt(s1*s1+s2*s2-2*r*s1*s2);
drm:=((m2-m1)/s1)/sqrt(2*(1-r));
drmpooled:=((m2-m1)/s)/sqrt(2*(1-r));
sigma:=sqrt(2/n+drm*drm/(4*n));
dav:=(m2-m1)/((s1+s2)/2);
edit7.text:=floattostr(drm);
edit8.text:=floattostr(drmpooled);
edit9.text:=floattostr(drmpooled-1.96*sigma);
edit10.text:=floattostr(drmpooled+1.96*sigma);
edit11.text:=floattostr(drmpooled-1.65*sigma);
edit12.text:=floattostr(drmpooled+1.65*sigma);
edit13.text:=floattostr(dav);
end;

end.

unit Unit6;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, ExtCtrls, StdCtrls;

type
  TForm6 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    Label2: TLabel;
    Label3: TLabel;
    Label4: TLabel;
    Edit1: TEdit;
    Edit4: TEdit;
    Label5: TLabel;
    Timer1: TTimer;
    Edit2: TEdit;
    Edit3: TEdit;
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
```

```
      { Public declarations }
    end;

var
    Form6: TForm6;

implementation

{$R *.dfm}

procedure TForm6.Timer1Timer(Sender: TObject);
var
     f, cohend: single;
     n1, n2: integer;
begin
try
f:=strtofloat(trim(edit1.Text));
n1:=strtoint(trim(edit2.Text));
n2:=strtoint(trim(edit3.Text));
except
edit4.Text:='';
exit;
end;
cohend:=sqrt(f*((n1+n2)/(n1*n2))*((n1+n2)/(n1+n2-2)));
edit4.text:=floattostr(cohend);
end;

end.

unit Unit7;

interface

uses
    Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
    Dialogs, ExtCtrls, StdCtrls;

type
    TForm7 = class(TForm)
      Panel1: TPanel;
      Label1: TLabel;
      RadioButton1: TRadioButton;
      RadioButton2: TRadioButton;
      RadioButton3: TRadioButton;
      Label2: TLabel;
      Label3: TLabel;
      Label4: TLabel;
      Label5: TLabel;
      Label6: TLabel;
      Edit1: TEdit;
```

```
        Edit2: TEdit;
        Edit3: TEdit;
        Edit4: TEdit;
        Label7: TLabel;
        Edit5: TEdit;
        Label8: TLabel;
        Edit6: TEdit;
        Timer1: TTimer;
        procedure Timer1Timer(Sender: TObject);
        procedure RadioButton1Click(Sender: TObject);
        procedure RadioButton2Click(Sender: TObject);
        procedure RadioButton3Click(Sender: TObject);
    private
        { Private declarations }
    public
        { Public declarations }
    end;

var
    Form7: TForm7;

implementation

{$R *.dfm}

procedure TForm7.Timer1Timer(Sender: TObject);
var
      mmax, mmin, s, cohenf, cohend: single;
      k: integer;
begin
try
mmax:=strtofloat(trim(edit1.Text));
mmin:=strtofloat(trim(edit2.Text));
s:=strtofloat(trim(edit3.Text));
k:=strtoint(trim(edit6.Text));
except
edit4.Text:='';
edit5.Text:='';
exit;
end;
cohend:=(mmax-mmin)/s;
if (radiobutton1.checked=true) then
cohenf:=cohend*sqrt(1/(2*k))
else
if (radiobutton2.checked=true) then
cohenf:=0.5*cohend*sqrt((k+1)/(3*(k-1)))
else
begin
if((k mod 2)=0) then
cohenf:=0.5*cohend
```

```
else
cohenf:=cohend*sqrt(k*k-1)/(2*k);
end;
edit4.text:=floattostr(cohenf);
edit5.text:=floattostr(cohend);
end;

procedure TForm7.RadioButton1Click(Sender: TObject);
begin
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit6.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

procedure TForm7.RadioButton2Click(Sender: TObject);
begin
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit6.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

procedure TForm7.RadioButton3Click(Sender: TObject);
begin
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit6.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

end.
unit Unit8;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, ExtCtrls, StdCtrls;

type
  TForm8 = class(TForm)
    Panel1: TPanel;
    RadioButton1: TRadioButton;
```

```
      RadioButton2: TRadioButton;
      Label1: TLabel;
      Edit1: TEdit;
      Label2: TLabel;
      Edit2: TEdit;
      Label3: TLabel;
      Edit3: TEdit;
      Label4: TLabel;
      Edit4: TEdit;
      Label5: TLabel;
      Edit5: TEdit;
      Label6: TLabel;
      Label7: TLabel;
      Timer1: TTimer;
      procedure RadioButton2Click(Sender: TObject);
      procedure RadioButton1Click(Sender: TObject);
      procedure Timer1Timer(Sender: TObject);
   private
      { Private declarations }
   public
      { Public declarations }
   end;

var
   Form8: TForm8;

implementation

{$R *.dfm}

procedure TForm8.RadioButton1Click(Sender: TObject);
begin
label3.Enabled:=false;
edit3.Enabled:=false;
edit4.Enabled:=true;
edit1.text:='';
edit2.text:='';
edit3.text:='';
edit4.text:='';
end;

procedure TForm8.RadioButton2Click(Sender: TObject);
begin
edit4.Enabled:=false;
label3.Enabled:=true;
edit3.Enabled:=true;
edit1.text:='';
edit2.text:='';
edit3.text:='';
edit4.text:='';
```

```
end;

procedure TForm8.Timer1Timer(Sender: TObject);
var
   cohend, t, r: single;
   n1, n2: integer;
begin
try
t:=strtofloat(trim(edit1.Text));
n1:=strtoint(trim(edit2.Text));
if (radiobutton1.checked=true) then
begin
r:=strtofloat(trim(edit4.Text));
cohend:=t*sqrt(2.0*(1.0-r)/n1)
end
else
begin
n2:=strtoint(trim(edit3.Text));
cohend:=t*sqrt((n1+n2)/(n1*n2));
end;
except
edit5.Text:='';
exit;
end;
edit5.text:=floattostr(cohend);
end;

end.

unit Unit9;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls, Math, ExtCtrls;

type
  TForm9 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    RadioButton1: TRadioButton;
    RadioButton2: TRadioButton;
    RadioButton3: TRadioButton;
    Label2: TLabel;
    Edit1: TEdit;
    Label3: TLabel;
    Edit2: TEdit;
    Label4: TLabel;
    Edit3: TEdit;
```

```
      Label5: TLabel;
      Edit4: TEdit;
      Timer1: TTimer;
      Label6: TLabel;
      Edit5: TEdit;
      procedure Timer1Timer(Sender: TObject);
      procedure RadioButton1Click(Sender: TObject);
      procedure RadioButton2Click(Sender: TObject);
      procedure RadioButton3Click(Sender: TObject);
   private
      { Private declarations }
   public
      { Public declarations }
   end;

var
   Form9: TForm9;

implementation

{$R *.dfm}

procedure TForm9.Timer1Timer(Sender: TObject);
var
     d, r, rs, x2, h2, z: single;
     n, RR, CC: integer;
begin
try
if (radiobutton1.checked=true) then
begin
x2:=strtofloat(trim(edit1.Text));
n:=strtoint(trim(edit4.Text));
r:=sqrt(x2/n);
d:=2*r/sqrt(1-r*r);
h2:=(d/2)*(d/2)/(1+(d/2)*(d/2))
end
else
if (radiobutton2.checked=true) then
begin
x2:=strtofloat(trim(edit1.Text));
RR:=strtoint(trim(edit2.Text));
CC:=strtoint(trim(edit4.Text));
rs:=sqrt(x2/min(CC-1,RR-1));
end
else
begin
z:=strtofloat(trim(edit2.Text));
n:=strtoint(trim(edit4.Text));
r:=z/sqrt(n);
d:=2*r/sqrt(1-r*r);
```

```
h2:=(d/2)*(d/2)/(1+(d/2)*(d/2));
end;
except
edit3.Text:='';
edit5.Text:='';
exit;
end;
if (radiobutton2.checked=true) then
edit3.text:=floattostr(rs);
if ((radiobutton1.checked=true) or (radiobutton3.checked=true)) then
begin
edit3.text:=floattostr(d);
edit5.text:=floattostr(h2);
end;
end;

procedure TForm9.RadioButton1Click(Sender: TObject);
begin
label3.Enabled:=false;
edit2.Enabled:=false;
label2.Enabled:=true;
edit1.Enabled:=true;
label6.Enabled:=true;
edit5.Enabled:=true;
label3.Caption:='z-value (z):';
label5.Caption:='Sample size (n):';
label4.Caption:='Effect size d:';
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

procedure TForm9.RadioButton2Click(Sender: TObject);
begin
label5.Enabled:=false;
edit4.Enabled:=false;
label6.Enabled:=false;
edit5.Enabled:=false;
label2.Enabled:=true;
edit1.Enabled:=true;
label3.Enabled:=true;
edit2.Enabled:=true;
label5.Enabled:=true;
edit4.Enabled:=true;
label3.Caption:='No. rows (R):';
label5.Caption:='No. columns (C):';
label4.Caption:='Effect size r:';
edit1.Text:='';
```

```
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

procedure TForm9.RadioButton3Click(Sender: TObject);
begin
label2.Enabled:=false;
edit1.Enabled:=false;
edit4.Enabled:=true;
edit5.Enabled:=true;
label6.Enabled:=true;
label3.Enabled:=true;
edit2.Enabled:=true;
label3.Caption:='z-value (z):';
label5.Caption:='Sample size (n):';
label4.Caption:='Effect size d:';
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

end.

unit Unit10;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls, ExtCtrls;

type
  TForm10 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    Label2: TLabel;
    Edit1: TEdit;
    Label3: TLabel;
    Edit2: TEdit;
    Timer1: TTimer;
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;
```

```
var
  Form10: TForm10;

implementation

{$R *.dfm}

procedure TForm10.Timer1Timer(Sender: TObject);
var
   b, r: single;
begin
try
b:=strtofloat(trim(edit1.Text));
if ((b>=-0.5) and (b<=0.5)) then
if (b>=0) then
r:=b+0.05
else r:=b;
except
edit2.Text:='';
exit;
end;
if ((b>=-0.5) and (b<=0.5)) then
edit2.text:=floattostr(r)
else
edit2.text:='';
end;

end.

unit Unit11;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, ExtCtrls, StdCtrls;

type
  TForm11 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    RadioButton1: TRadioButton;
    RadioButton2: TRadioButton;
    RadioButton3: TRadioButton;
    Label2: TLabel;
    Edit1: TEdit;
    Label3: TLabel;
    Label4: TLabel;
    Edit2: TEdit;
```

```
    Edit3: TEdit;
    Label5: TLabel;
    Edit4: TEdit;
    Label6: TLabel;
    Edit5: TEdit;
    Timer1: TTimer;
    procedure RadioButton1Click(Sender: TObject);
    procedure RadioButton2Click(Sender: TObject);
    procedure RadioButton3Click(Sender: TObject);
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form11: TForm11;

implementation

{$R *.dfm}

procedure TForm11.RadioButton1Click(Sender: TObject);
begin
label2.Caption:='Test statistic U value:';
label4.enabled:=true;
edit3.Enabled:=true;
label3.Caption:='Sample size for group 1 (n1):';
label4.Caption:='Sample size for group 2 (n2):';
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

procedure TForm11.RadioButton2Click(Sender: TObject);
begin
label2.Caption:='Test statistic W value:';
label3.Caption:='Total sample size (n):';
label4.enabled:=false;
edit3.Enabled:=false;
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit5.Text:='';
end;
```

```
procedure TForm11.RadioButton3Click(Sender: TObject);
begin
label2.Caption:='Test statistic H value:';
label4.enabled:=true;
edit3.Enabled:=true;
label3.Caption:='Total sample size (n):';
label4.Caption:='Number of groups (k):';
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit4.Text:='';
edit5.Text:='';
end;

procedure TForm11.Timer1Timer(Sender: TObject);
var
   U, W, H, z, cohend, h2: single;
   n, n1, n2, k: integer;
begin
try
if (radiobutton1.checked=true) then
begin
U:=strtofloat(trim(edit1.Text));
n1:=strtoint(trim(edit2.Text));
n2:=strtoint(trim(edit3.Text));
z:=(U-(n1*n2/2))/sqrt(n1*n2*(n1+n2+1)/12);
if(z<0) then
z:=-z;
h2:=z*z/(n1+n2);
if(h2<0) then
h2:=-h2;
end
else
if (radiobutton2.checked=true) then
begin
W:=strtofloat(trim(edit1.Text));
n:=strtoint(trim(edit2.Text));
z:=(W-(n*(n+1)))/sqrt(n*(n+1)*(2*n+1)/24);
if(z<0) then
z:=-z;
h2:=z*z/n;
if(h2<0) then
h2:=-h2;
end
else
begin
H:=strtofloat(trim(edit1.Text));
n:=strtoint(trim(edit2.Text));
k:=strtoint(trim(edit3.Text));
h2:=abs((H-k+1)/(n-k));
```

```
end;
except
edit4.Text:='';
edit5.Text:='';
exit;
end;
edit4.text:=floattostr(h2);
try
cohend:=2*sqrt(h2/(1-h2));
except
exit;
end;
edit5.text:=floattostr(cohend);
end;

end.

unit Unit12;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls, ExtCtrls;

type
  TForm12 = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    Label2: TLabel;
    Label3: TLabel;
    Label4: TLabel;
    Label5: TLabel;
    Label6: TLabel;
    Label7: TLabel;
    Label8: TLabel;
    Edit1: TEdit;
    Edit4: TEdit;
    Edit5: TEdit;
    Edit6: TEdit;
    Edit7: TEdit;
    Label9: TLabel;
    Edit2: TEdit;
    Edit3: TEdit;
    Edit8: TEdit;
    Timer1: TTimer;
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
```

```
    { Public declarations }
  end;

var
  Form12: TForm12;

implementation

{$R *.dfm}

procedure TForm12.Timer1Timer(Sender: TObject);
var
   a, b, c, d, n1, n2, RR, ORR, RD, YuleQ: single;
begin
try
a:=strtofloat(trim(edit4.Text));
b:=strtofloat(trim(edit5.Text));
c:=strtofloat(trim(edit6.Text));
d:=strtofloat(trim(edit7.Text));
n1:=a+b;
n2:=c+d;
RR:=(a/n1)/(c/n2);
ORR:=(a*d)/(b*c);
YuleQ:=(ORR-1)/(ORR+1);
RD:=a/n1-c/n2;
except
edit1.Text:='';
edit2.Text:='';
edit3.Text:='';
edit8.Text:='';
exit;
end;
edit1.text:=floattostr(RR);
edit2.text:=floattostr(ORR);
edit3.text:=floattostr(YuleQ);
edit8.text:=floattostr(RD);
end;

end.

unit Unit13;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, StdCtrls, ExtCtrls;

type
  TForm13 = class(TForm)
```

```
    Panel1: TPanel;
    Label1: TLabel;
    RadioButton1: TRadioButton;
    RadioButton2: TRadioButton;
    Label2: TLabel;
    Edit1: TEdit;
    Label3: TLabel;
    Edit2: TEdit;
    Label4: TLabel;
    Edit3: TEdit;
    Label5: TLabel;
    Label6: TLabel;
    Edit4: TEdit;
    Edit5: TEdit;
    Label7: TLabel;
    Edit6: TEdit;
    Timer1: TTimer;
    procedure RadioButton1Click(Sender: TObject);
    procedure RadioButton2Click(Sender: TObject);
    procedure Timer1Timer(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form13: TForm13;

implementation

{$R *.dfm}

procedure TForm13.RadioButton1Click(Sender: TObject);
begin
label5.Enabled:=false;
label6.Enabled:=false;
label7.Enabled:=false;
edit4.Enabled:=false;
edit5.Enabled:=false;
edit6.Enabled:=false;
label2.Enabled:=true;
label3.Enabled:=true;
label4.Enabled:=true;
edit1.Enabled:=true;
edit2.Enabled:=true;
edit3.Enabled:=true;
edit4.text:='';
edit5.text:='';
edit6.text:='';
```

```
end;

procedure TForm13.RadioButton2Click(Sender: TObject);
begin
label2.Enabled:=false;
label3.Enabled:=false;
label4.Enabled:=false;
edit1.Enabled:=false;
edit2.Enabled:=false;
edit3.Enabled:=false;
label5.Enabled:=true;
label6.Enabled:=true;
label7.Enabled:=true;
edit4.Enabled:=true;
edit5.Enabled:=true;
edit6.Enabled:=true;
edit1.text:='';
edit2.text:='';
edit3.text:='';
end;

procedure TForm13.Timer1Timer(Sender: TObject);
var
    F, SSA, SSE, cohenf, hp2: single;
    k: integer;
begin
try
if (radiobutton1.checked=true) then
begin
F:=strtofloat(trim(edit1.Text));
k:=strtoint(trim(edit2.Text));
cohenf:=sqrt(F/k);
edit3.text:=floattostr(cohenf)
end
else
begin
SSA:=strtofloat(trim(edit4.Text));
SSE:=strtofloat(trim(edit5.Text));
hp2:=SSA/(SSA+SSE);
edit6.text:=floattostr(hp2);
end;
except
if (radiobutton1.checked=true) then
edit3.Text:=''
else
edit6.Text:='';
exit;
end;
end;
```

end.

Figs. 1-13 show the main window and the windows of calculator for different effect sizes. The calculator and user manual guide can be freely downloaded at:
http://www.iaees.org/publications/journals/ces/articles/2023-13(4)/e-suppl/Zhang-Supplementary-Materials.rar

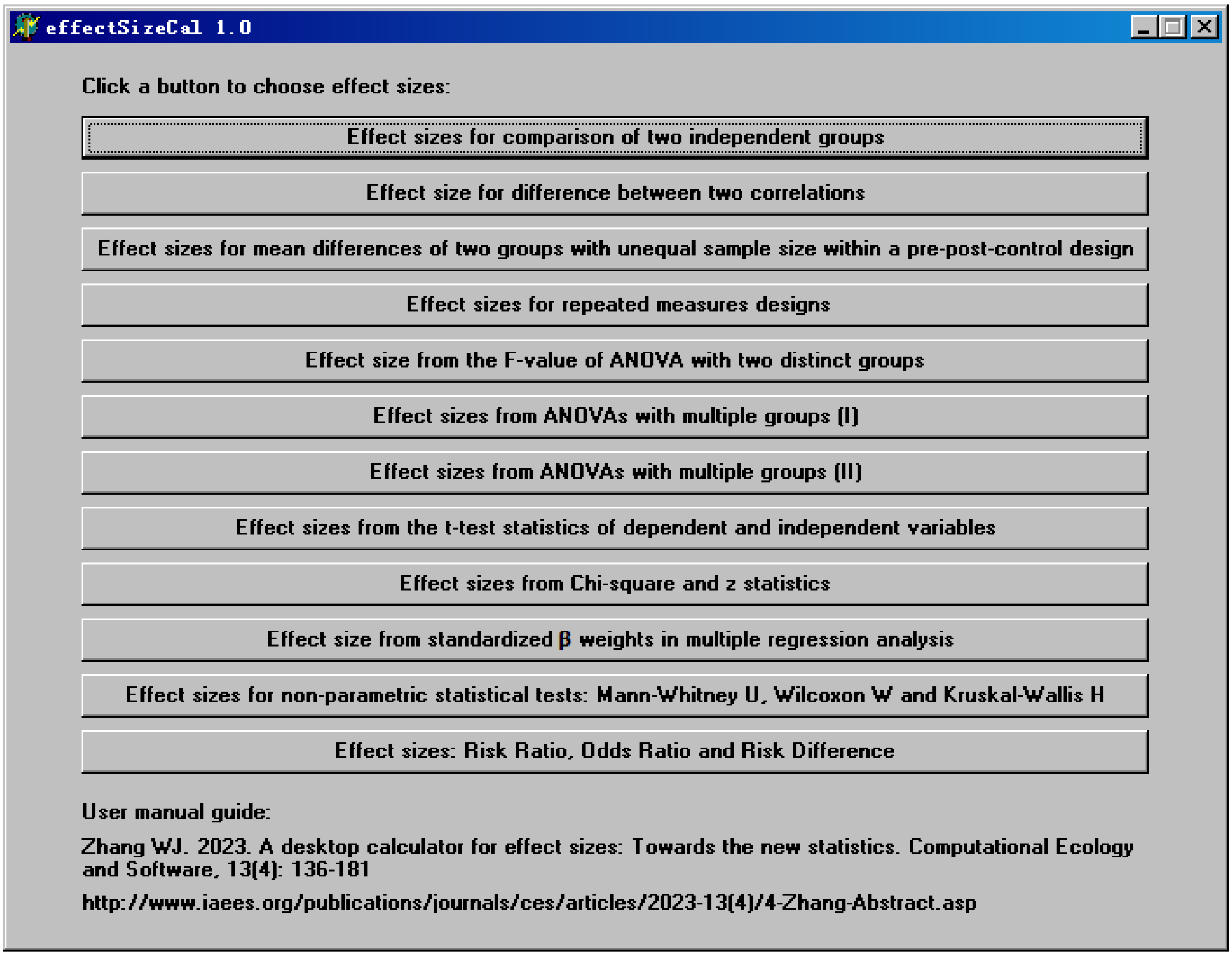

Fig. 1 Main window of the calculator.

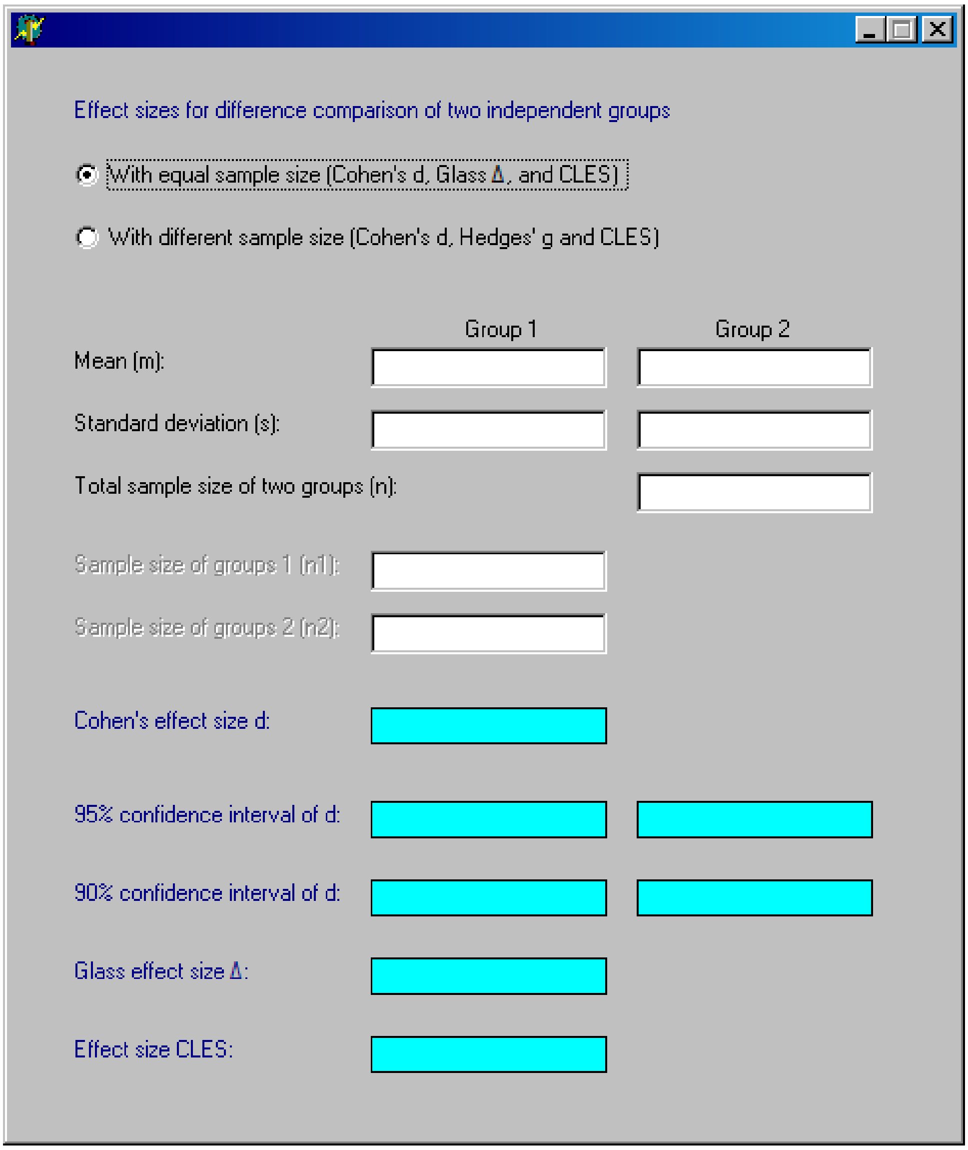

Fig. 2 The window of effect sizes for difference comparison of two independent groups.

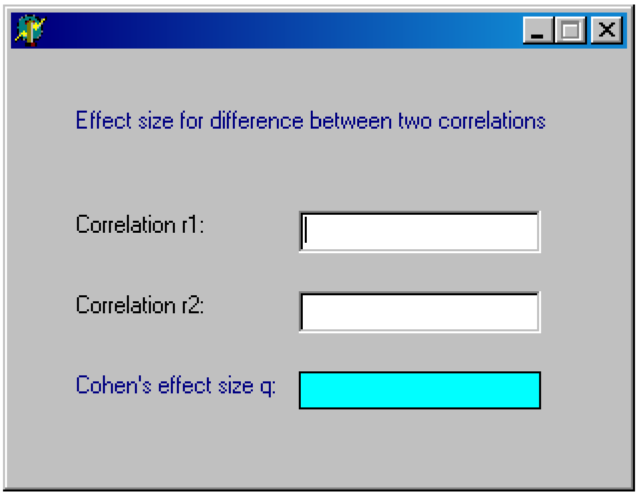

Fig. 3 The window of effect size for difference between two correlations.

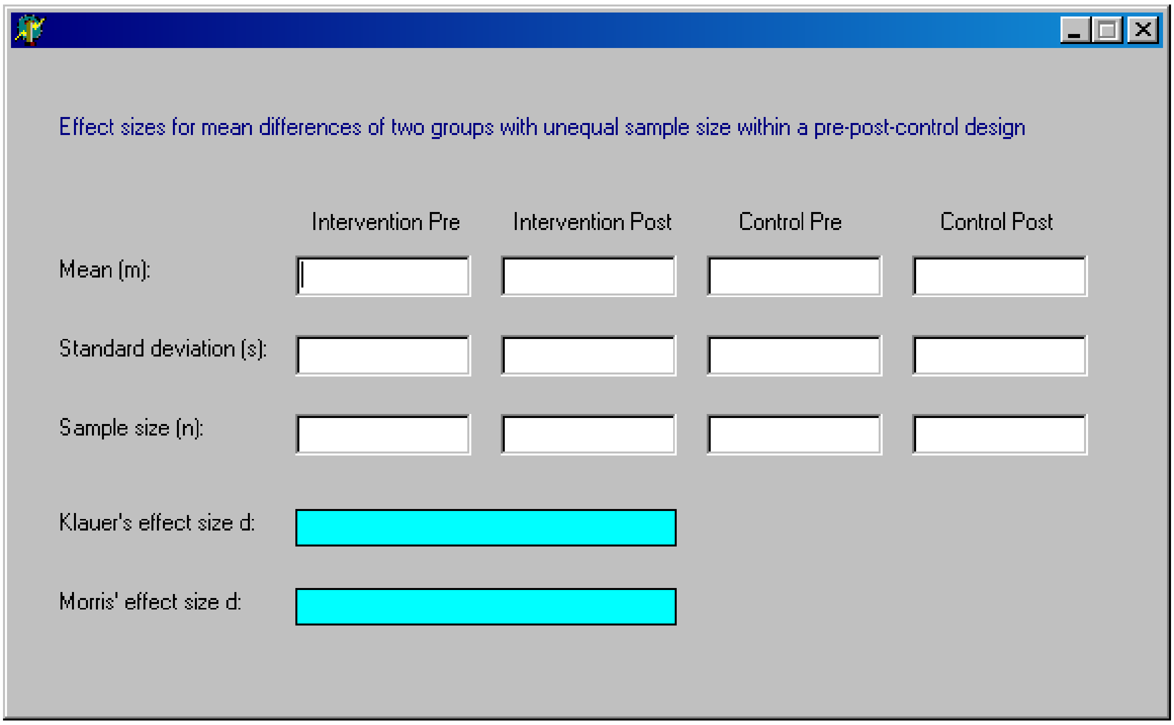

Fig. 4 The window of effect sizes for mean differences of two groups with unequal sample size within a pre-post-control design.

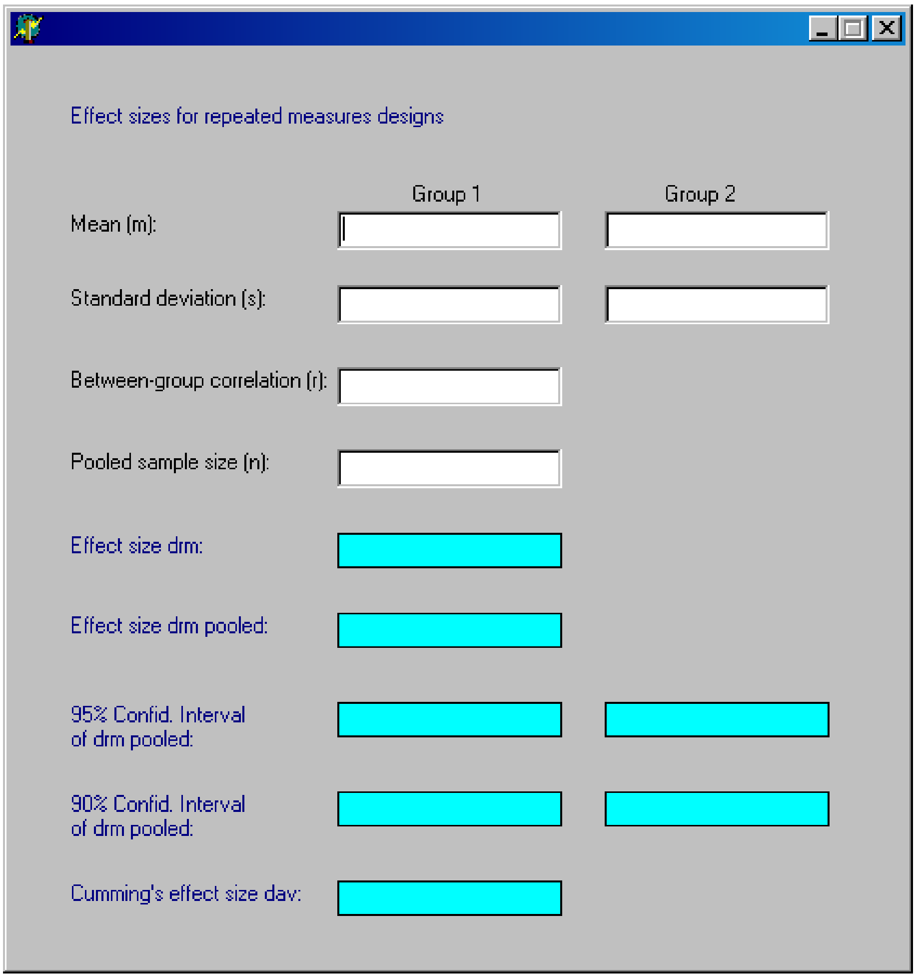

Fig. 5 The window of effect sizes for repeated measures designs.

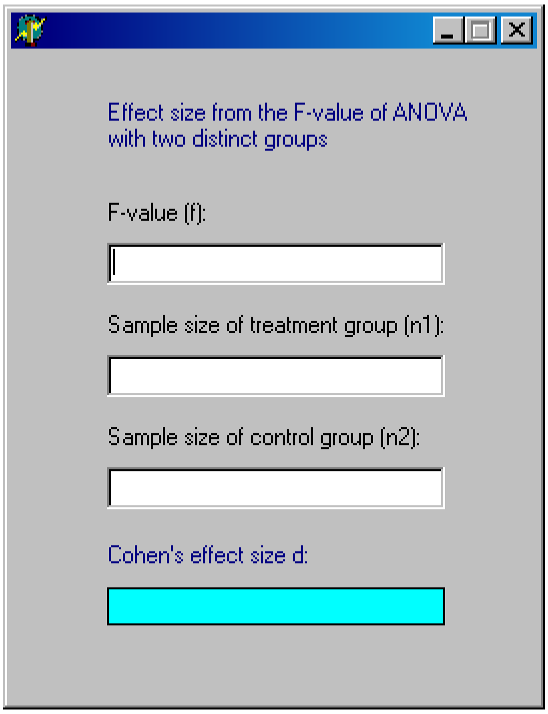

Fig. 6 The window of effect sizes from the *F*-value of ANOVA with two distinct groups.

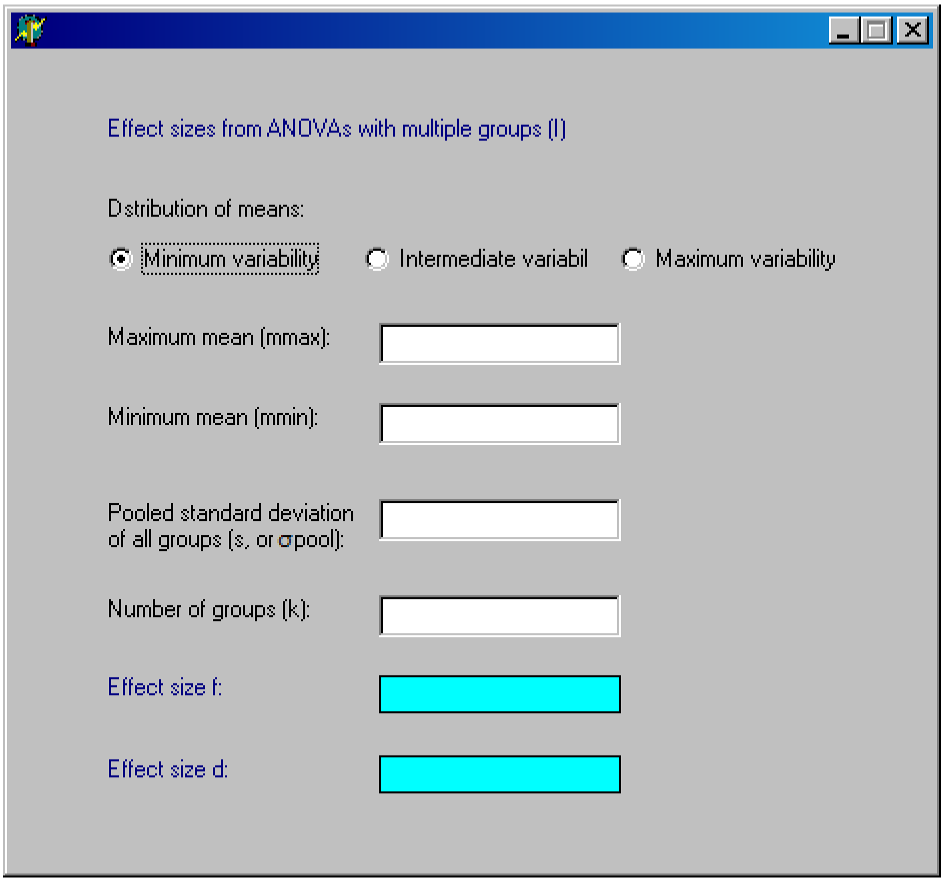

Fig. 7 The window of effect sizes from ANOVAs with multiple groups (I).

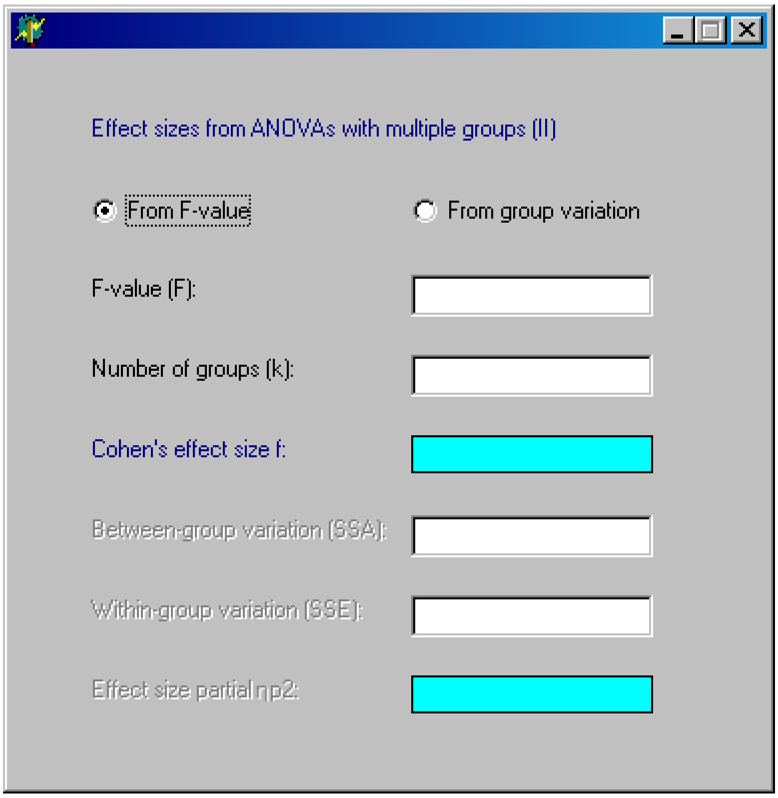

Fig. 8 The window of effect sizes from ANOVAs with multiple groups (II).

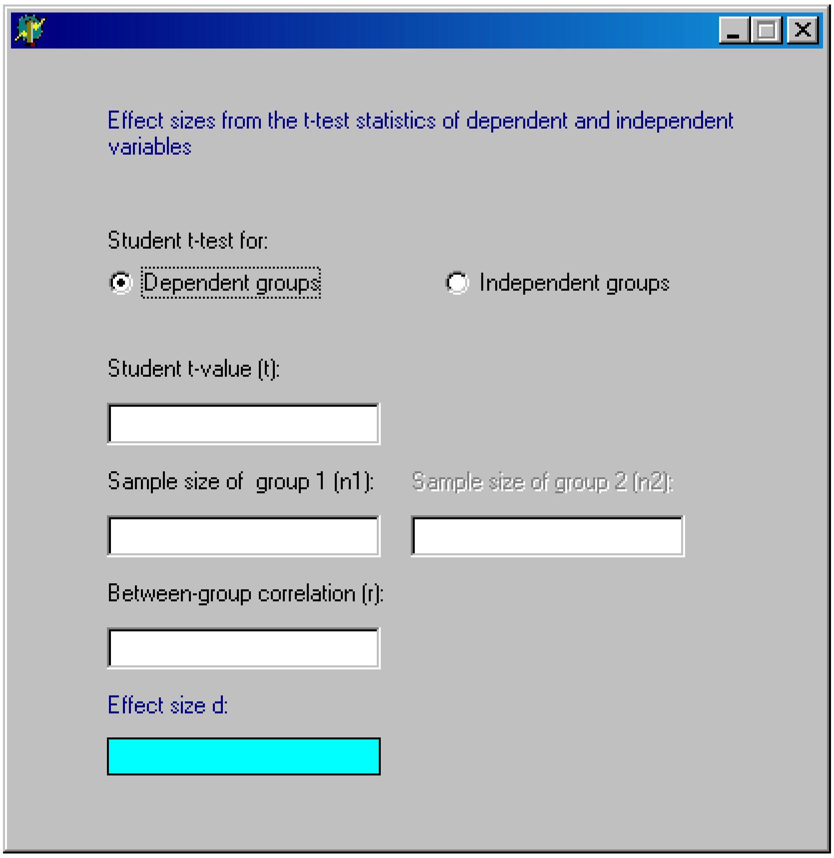

Fig. 9 The window of effect sizes from the *t*-test statistics of dependent and independent variables.

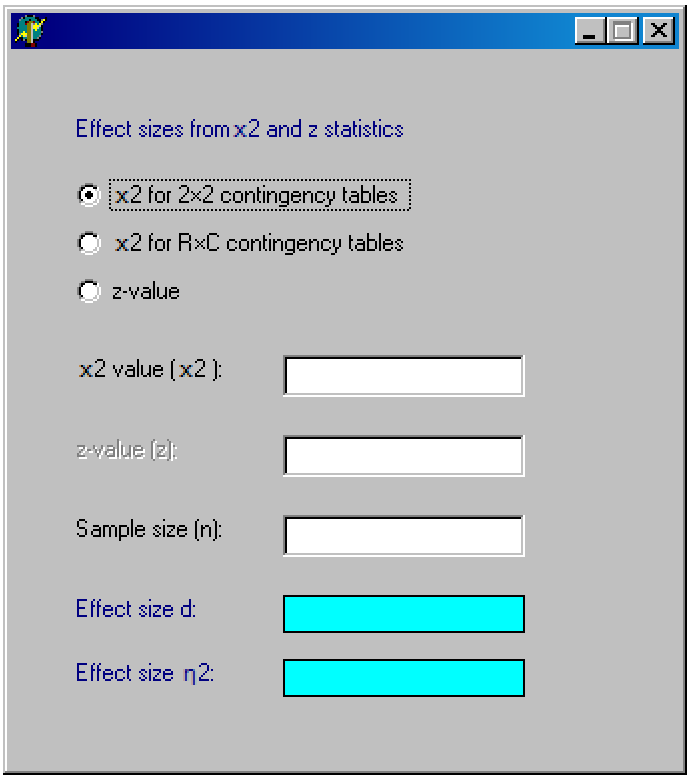

Fig. 10 The window of effect sizes from χ^2 and z statistics.

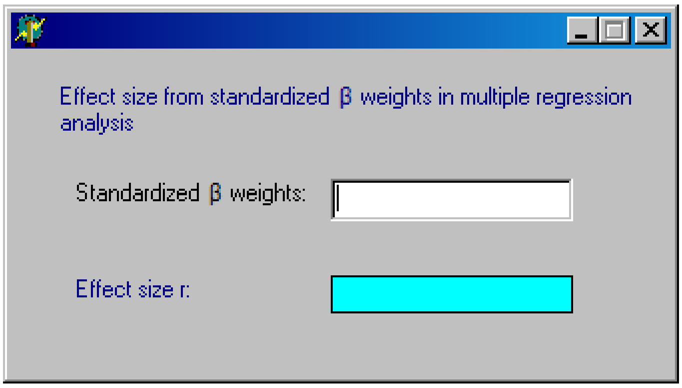

Fig. 11 The window of effect sizes from standardized β weights in multiple regression analysis.

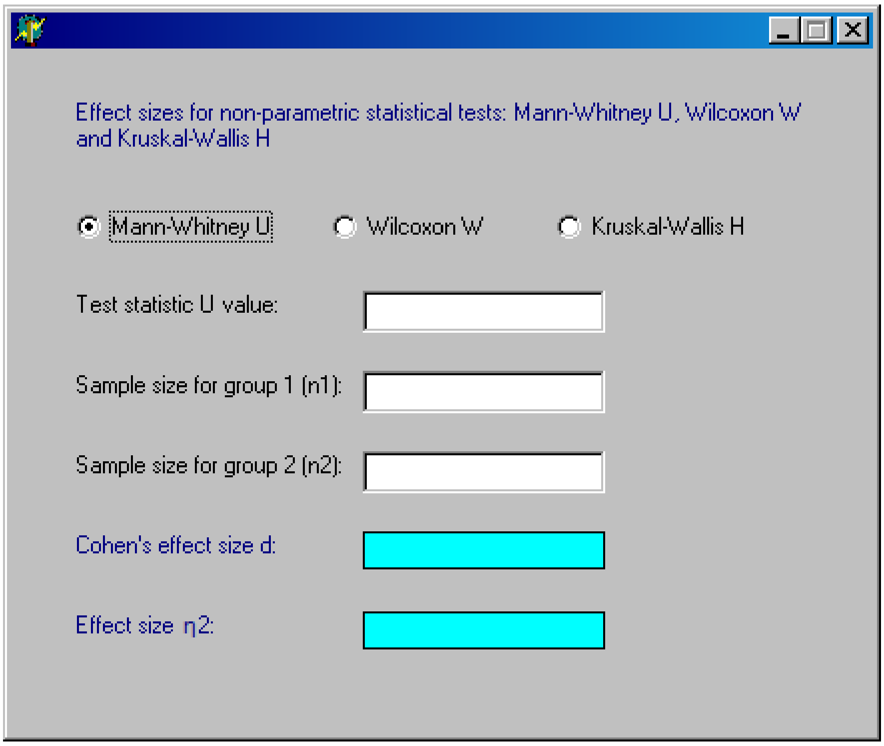

Fig. 12 The window of effect sizes for non-parametric statistical tests: Mann-Whitney *U*, Wilcoxon *W* and Kruskal-Wallis *H*.

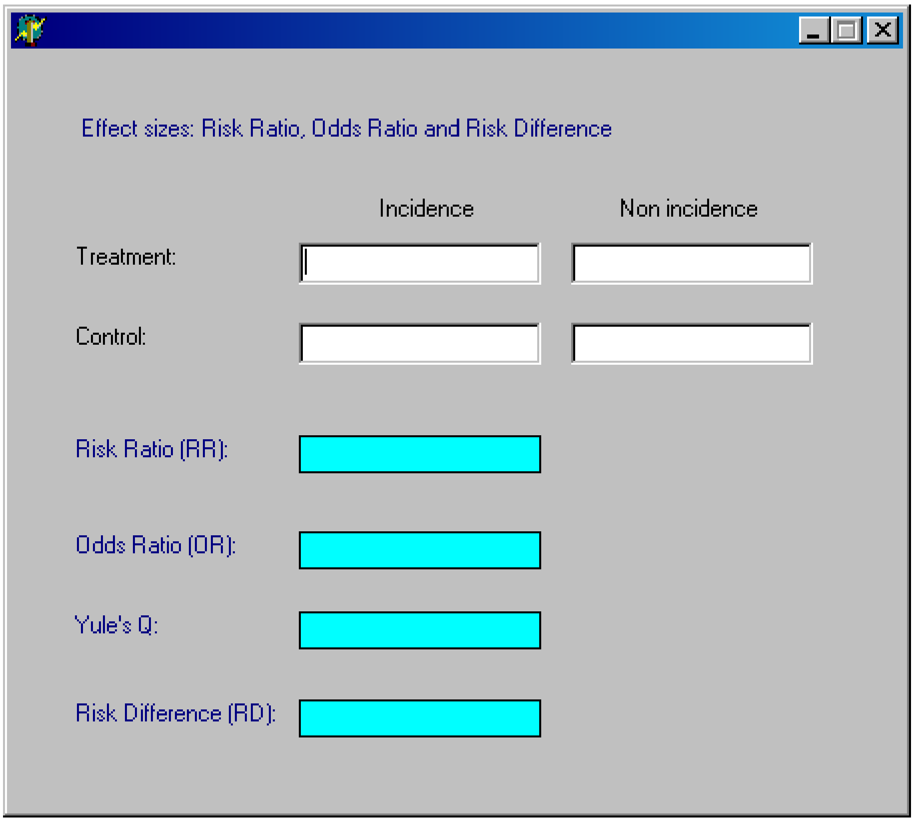

Fig. 13 The window of effect sizes Risk Ratio, Odds Ratio and Risk Difference.

4 Role of Effect Sizes in Complementing Statistical Significance Tests: An Explanatory Example

In the statistical significance tests, the sample size *n*, the mean *m* and the standard deviation *s*, *t*-value or *F*-value, χ^2-value, etc., are usually given. Based on these statistics, the effect sizes *d* and η^2, etc., can be calculated. Reporting both the *p*-value and the effect sizes can complement each other (Li, 2021; Zhang, 2022c).

As indicated above, η^2 is one of the most commonly used effect sizes. A literature example may illustrate the match and difference between *p*-value and effect size (η^2) (Zarkadi and Schnall, 2013; Li, 2021; Zhang, 2022c). In this example, the researchers examine the influence of black and white background or gray background (priming condition) on moral judgment. The experimental material include 6 social issues (pornography, adultery, drug use, littering, smoking, use of profanity), and people are asked to rate their morality on a scale of -5 (very immoral) to +5 (very moral). The researchers predict that priming with black and white visual contrast may lead to more extreme morality than non-priming judgment (Zarkadi and Schnall, 2013).

The researchers propose an index for deviation score, the distance between the results of the subjective judgment and the midpoint of the scale, to evaluate the extreme situation of moral judgment. They find that the mean of deviation score under the black and white condition (m=2.50, s=0.96) is greater than the mean of deviation scores under the grey condition (m=2.05, s=0.91) (F(1,128)=7.35, p=0.008, η^2=0.05). When the researchers analyze the 6 items separately, they demonstrate the same pattern of smoking (F(1,128)=5.69, p=0.02, η^2=0.04), and drug use (F(1,128)=4.31, p=0.04, η^2=0.03), adultery (F(1,128)=8.34, p=0.005, η^2=0.06), and the priming condition effect is significant. Additionally, the difference in mean severity of the two priming conditions (black and white condition: m=-1.79, s=1.57; grey condition: m=-1.05, s=1.32) (F(1,128)=1.05, p=0.31, η^2=0.008) is not significant. Comparing the above *p*-value and the effect size η^2, it can be concluded that *p*-value is much more sensitive than the effect size η^2 (Li, 2021; Zhang, 2022c).

Obviously it can be found that the two indicators of the *p*-value and the effect size η^2 have complementary effects. For example, the contrasting background of black and white will polarize moral judgments and the polarization relates to specific social issues. At the same time, the impact on adultery judgments (p=0.005, η^2=0.06) versus smoking judgment (p=0.02, η^2=0.04) is more obvious. It is particularly remarkable that the effect size of the black and white contrast background on the severity of moral judgments is so small (η^2=0.008), implying that the impact of black and white contrast on moral judgments should not be examined with severity. Even if the sample size is enlarged and the power is improved, it does not produce much more sense. The research shows that the effect of black and white contrast on the polarization of moral judgment does not reach the standard of small effect size. The impact of black and white contrast on moral judgment is quite subtle. Thus if you want to repeat the study, you need to pay attention to improving the power (e.g., increasing the sample size), otherwise you may not get significant results. This example strongly suggests that reporting both the *p*-value and the effect size can complement each other (Li, 2021; Zhang, 2022c).

References

Amrhein V, Greenland S, McShane B. 2019. Scientists rise up against statistical significance. Nature, 567: 305-307. https://doi.org/10.1038/d41586-019-00857-9

Baker M. 2016. Statisticians issue warning over misuse of *P* values. Nature, 531: 151. https://doi.org/10.1038/nature.2016.19503

Bergstrom CT, West JD. 2021. Manipulated P-values: Mathematical nosense in scientific papers.

https://www.laitimes.com/en/article/3km6i_41b77.html. Accessed 2022-4-23

Borenstein M. 2009. Effect sizes for continuous data. In: The Handbook of Research Synthesis and Meta Analysis (Cooper H, Hedges LV, Valentine JC, eds). 221-237, Russell Sage Foundation, New York, USA

Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. 2009. Introduction to Meta-Analysis. John Wiley and Sons, Chichester, West Sussex, UK. https://www.meta-analysis.com/downloads/Meta-analysis%20Choosing%20an%20effect%20size.pdf

Cohen J. 1988. Statistical Power Analysis for the Behavioral Sciences (2nd ed). Erlbaum, Hillsdale, NJ, USA. https://doi.org/10.4324/9780203771587

Cohen BH. 2008. Explaining Psychological Statistics (3rd ed). John Wiley and Sons, New York, USA

Cumming G. 2012. Understanding the new statistics: Effect sizes, confidence intervals, and meta-analysis. Routledge, New York, USA. .https://idostatistics.com/cumming-2012-understanding-new-statistics-effect-sizes-confidence-intervals-meta-analysis/

Cumming G. 2013. The new statistics: Why and how. Psychological Science, 25: 7-29. https://doi.org/10.1177/0956797613504966

Dunlap WP, Cortina JM, Vaslow JB, Burke MJ. 1996. Meta-analysis of experiments with matched groups or repeated measures designs. Psychological Methods, 1: 170-177. https://psycnet.apa.org/record/1996-04469-005

Ellis PD. 2010. The Essential Guide to Effect Sizes: Statistical Power, Meta-Analysis, and the Interpretation of Research Results. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511761676

Errington TM, Mathur M, Soderberg CK, et al. 2021. Investigating the replicability of preclinical cancer biology. eLife, 10: e71601. https://elifesciences.org/articles/71601

Fisher RA. 1935. The Design of Experiments. Oliver and Boyd, Edinburg and London, UK. http://www.medicine.mcgill.ca/epidemiology/hanley/tmp/Mean-Quantile/DesignofExperimentsCh-III.pdf

Hattie J. 2009. Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement. Routledge, London, UK. https://www.routledge.com/Visible-Learning-A-Synthesis-of-Over-800-Meta-Analyses-Relating-to-Achievement/Hattie/p/book/9780415476188

Hedges LV, Olkin I. 1985. Statistical Methods for Meta-Analysis. Academic Press, New York, USA. https://idostatistics.com/hedges-olkin-1985-statistical-methods-for-meta-analysis/

Huang HN. 2018a. A unified theory of measurement errors and uncertainties. Measurement Science and Technology, 29(12). https://iopscience.iop.org/article/10.1088/1361-6501/aae50f/meta

Huang HN. 2018b. Uncertainty estimation with a small number of measurements, part I: new insights on the t-interval method and its limitations. Measurement Science and Technology, 29: 015004. https://doi.org/10.1088/1361-6501/aa96c7

Huang HN. 2021a. Statistics reform: challenges and opportunities. ScienceNet. https://blog.sciencenet.cn/blog-3427112-1318043.html. Accessed 2021-12-26

Huang HN. 2021b. What are the most misunderstood and misleading concepts or theories in statistics textbooks today? ScienceNet. https://blog.sciencenet.cn/blog-3427112-1269013.html. Accessed 2021-1-26

Ioannidis JPA. 2005. Why most published research findings are false. Plos Medicine, https://doi.org/10.1371/journal.pmed.0020124

Kafdar K. 2021. Editorial: Statistical significance, *p*-values, and replicability. The Annals of Applied Statistics. https://doi.org/10.1214/21-AOAS1500

Klauer KJ. 2001. Handbuch kognitives Training. Hogrefe, Göttingen, Germany. https://www.amazon.com/Handbuch-Kognitives-Training-Josef-Klauer/dp/3801713474

Lakens D. 2013. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. Fronters in Psychology, 4. https://doi.org/10.3389/fpsyg.2013.00863

Lenhard W, Lenhard A. 2016. Computation of effect sizes. https://www.psychometrica.de/effect_size.html. Psychometrica. doi: 10.13140/RG.2.2.17823.92329

Li HH. 2021. *p*-values are too sensitive, and the effect size is long and good to save. ScienceNet. http://blog.sciencenet.cn/blog-2619783-1286084.html. Accessed 2021-5-11

McGraw KO, Wong SP. 1992. A common language effect size statistic. Psychological Bulletin, 111(2): 361-365. https://doi.org/10.1037/0033-2909.111.2.361

McShane BB, David Gal D. 2017. Statistical significance and the dichotomization of evidence. Journal of the American Statistical Association, 112(519): 885-895. https://doi.org/10.1080/01621459.2017.1289846

Morris SB. 2008. Estimating effect sizes from Pretest-Posttest-Control Group designs. Organizational Research Methods, 11(2): 364-386. https://doi.org/10.1177/1094428106291059

Morris SB, Deshon RP. 2002. Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. Psychological Methods. 7(1): 105-125. doi: 10.1037/1082-989x.7.1.105

Nature Editorial. 2021. Replicating scientific results is tough — but essential. Nature, 600: 359-360. https://doi.org/10.1038/d41586-021-03736-4

Open Science Collaboration. 2015. Estimating the reproducibility of psychological science. Science, 349(6251). https://doi.org/10.1126/science.aac4716

Pandey S, Johnson AC, Xie G, Gurr GM. 2022. Pesticide regime can negate the positive influence of native vegetation donor habitat on natural enemy abundance in adjacent crop fields. Frontiers in Ecology and Evolution. https://doi.org/10.3389/fevo.2022.815162

Pearson K. 1895. Notes on regression and inheritance in the case of two parents. Proceedings of the Royal Society of London, 58: 240-242. https://doi.org/10.1098/rspl.1895.0041

Pearson K. 1904. On the Theory of Contingency and its Relation to Association and Normal Correlation. Dulau and Co, London, UK. https://www.worldcat.org/title/on-the-theory-of-contingency-and-its-relation-to-association-and-normal-correlation/oclc/63332451

Peterson RA, Brown SP. 2005. On the use of beta coefficients in meta-analysis. Journal of Applied Psychology, 90(1): 175-181. doi: 10.1037/0021-9010.90.1.175

Rosenthal R. 1994. Parametric measures of effect size. In: The Handbook of Research Synthesis (Cooper H, Hedges LV, eds). 231-244, Sage, New York, USA

Rosenthal R, DiMatteo MR. 2001. Meta-Analysis: Recent developments in quantitative methods for literature reviews. Annual Review of Psychology 52(1): 59-82. doi: 10.1146/annurev.psych.52.1.59

Schoenly KG, Zhang WJ. 1999. IRRI Biodiversity Software Series. V. RARE, SPPDISS, and SPPRANK: Programs for Detecting Between-Sample Differences in Community Structure. IRRI Technical Bulletin No.5. International Rice Research Institute, Manila, Philippines. http://books.irri.org/TechnicalBulletin5_content.pdf

Sellke T, Bayarri MJ, Berger JO. 2001. Calibration of p values for testing precise null hypotheses. The American Statistician, 55(1): 62-71. https://doi.org/10.1198/000313001300339950

Spearman C. 1904. The proof and measurement of association between two things. American Journal of Psychology, 15: 72-101. https://doi.org/10.2307/1422689

Sun XJ. 2016. Improper use of *p*-values is a nonsense. ScienceNet.

http://blog.sciencenet.cn/blog-41174-961169.html. Accessed 2016-4-5

Thalheimer W, Cook S. 2002. How to calculate effect sizes from published research: A simplified methodology. https://paulogentil.com/pdf/How%20to%20calculate%20effect%20sizes%20from%20published%20research%20-%20a%20simplified%20methodology.pdf

Tong C. 2019. Statistical Inference Enables Bad Science; Statistical Thinking Enables Good Science. The American Statistician, 73(S1): 246-261. https://doi.org/10.1080/00031305.2018.1518264

Trafimow D, Marks M. 2015. Editorial. Basic and Applied Social Psychology, 37: 1-2. https://doi.org/10.1080/01973533.2015.1012991

Vrieze JD. 2021. Landmark research integrity survey finds questionable practices are surprisingly common. Science. https://doi.org/10.1126/science.abk3508

Wasserstein RL, Lazar NA. 2016. Editorial: The ASA statement on *p*-values: Context, process, and purpose. the American Statistician, 70(2): 129-133. https://doi.org/10.1080/00031305.2016.1154108

Wasserstein RL, Schirm AL, Lazar NA, 2019. Editorial: Moving to a world beyond “p<0.05”. The American Statistician, 79: 1-19. https://doi.org/10.1080/00031305.2019.1583913

Xie G. 2022b. History and recent developments of the statistical significance problem. https://www.researchgate.net/publication/359365092_tongjixianzhexingwentidelishiyoulaijizuixinjinzhan. Accessed 2022-4-15

Yates F. 1951. The influence of statistical methods for research workers on the development of the science of statistics. Journal of the American Statistical Association, 46: 19-34. https://doi.org/10.2307/2280090

Zarkadi T, Schnall S. 2013. “Black and white” thinking: Visual contrast polarizes moral judgment. Journal of Experimental Social Psychology, 49: 355-359. https://doi.org/10.1016/j.jesp.2012.11.012

Zhang WJ. 2015a. A hierarchical method for finding interactions: Jointly using linear correlation and rank correlation analysis. Network Biology, 5(4): 137-145. http://www.iaees.org/publications/journals/nb/articles/2015-5(4)/partial-correlation-analysis-in-finding-interactions.pdf

Zhang WJ. 2015b. Calculation and statistic test of partial correlation of general correlation measures. Selforganizology, 2(4): 65-77. http://www.iaees.org/publications/journals/selforganizology/articles/2015-2(4)/statistic-test-of-partial-correlation-of-general-correlation-measures.pdf

Zhang WJ. 2016. Selforganizology: The Science of Self-Organization. World Scientific, Singapore. https://doi.org/10.1142/9685

Zhang WJ. 2017. Network pharmacology of medicinal attributes and functions of Chinese herbal medicines: (II) Relational networks and pharmacological mechanisms of medicinal attributes and functions of Chinese herbal medicines. Network Pharmacology, 2(2): 38-66. http://www.iaees.org/publications/journals/np/articles/2017-2(2)/networks-and-mechanisms-of-medicinal-attributes-and-functions.pdf

Zhang WJ. 2018. Fundamentals of Network Biology. World Scientific Europe, London, UK. https://doi.org/10.1142/q0149

Zhang WJ. 2021a. A statistical simulation method for causality inference of Boolean variables. Network Biology, 11(4): 263-273. http://www.iaees.org/publications/journals/nb/articles/2021-11(4)/a-method-for-causality-inference-of-Boolean-variables.pdf

Zhang WJ. 2021b. Causality inference of linearly correlated variables: The statistical simulation and regression method. Computational Ecology and Software, 11(4): 154-161. http://www.iaees.org/publications/journals/ces/articles/2021-11(4)/causality-inference-of-linearly-correlated-variables.pdf

Zhang WJ. 2022a. Confidence intervals: Concepts, fallacies, criticisms, solutions and beyond. Network Biology, 12(3): 97-115. http://www.iaees.org/publications/journals/nb/articles/2022-12(3)/confidence-intervals-fallacies-criticisms-solutions.pdf

Zhang WJ. 2022b. Dilemma of t-tests: Retaining or discarding choice and solutions. Computational Ecology and Software, 12(4): 181-194. http://www.iaees.org/publications/journals/ces/articles/2022-12(4)/dilemma-of-t-tests.pdf

Zhang WJ. 2022c. *p*-value based statistical significance tests: Concepts, misuses, critiques, solutions and beyond. Computational Ecology and Software, 12(3): 80-122. http://www.iaees.org/publications/journals/ces/articles/2022-12(3)/p-value-based-statistical-significance-tests.pdf

Zhang WJ. 2024a. molVisual3D: A standalone executable software for 3D visualization of molecules. Network Biology, 14(2): 38-68. http://www.iaees.org/publications/journals/nb/articles/2024-14(2)/1-Zhang-Abstract.asp

Zhang WJ. 2024b. objectVisual3D: A standalone executable software for 3D visualization of objects. Selforganizology, 11(3-4): 28-53. http://www.iaees.org/publications/journals/selforganizology/articles/2024-11(3-4)/1-Zhang-Abstract.asp

Zhang WJ. 2024c. Several digital timers and clocks for desktop computers. Computational Ecology and Software, 14(1): 1-13. http://www.iaees.org/publications/journals/ces/articles/2024-14(1)/1-Zhang-Abstract.asp

Zhang WJ. 2024d. Two image viewers: A projector and a screen saver. Network Pharmacology, 9(3-4): 11-23. http://www.iaees.org/publications/journals/np/articles/2024-9(3-4)/1-Zhang-Abstract.asp

Zhang WJ, Li X. 2015. Linear correlation analysis in finding interactions: Half of predicted interactions are undeterministic and one-third of candidate direct interactions are missed. Selforganizology, 2(3): 39-45. http://www.iaees.org/publications/journals/selforganizology/articles/2015-2(3)/linear-correlation-analysis-in-finding-interactions.pdf