# HIGHLY SIGNIFICANT FINDINGS IN PSYCHOLOGY: A POWER AND EFFECT SIZE SURVEY ***

BY

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DOCTOR OF PHILOSOPHY DISSERTATION

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Abstract

The quality of current psychological research has been questioned because of perceived flaws in the primary methods of inquiry. As early as the late 1930s researchers began criticizing the methods by which psychological research examines hypotheses. The current method of hypothesis testing represents a hybrid of two models of significance testing. The originators of the models never intended for the models to be combined and never suggested the present model. Early psychology textbooks were the first to present the model of hypotheses testing, as we know it today.

The cut and paste manner of the current model of significance testing currently exhibits fatal flaws. Utilizing the Null Hypothesis Significance Testing (NHST) method can result in two errors or a correct decision. The researcher can make the correct decision by either rejecting a false null or failing to reject a true null. The errors occur when a researcher fails to reject a false null or rejects a true null.

Over the last 50 years, researchers have suggested that the American Psychological Association require additional indices to augment findings of statistical significance. Among the indices suggested are statistical power and measures of magnitude of effect size. Statistical power is a consideration that seems to complement NHST perfectly. Statistical power is defined as the probability of discovering a statistically significant result, which should be an automatic concern for researchers utilizing NHST. Measures of effect

size estimate the magnitude of the treatment effect or the differences between groups. They answer the question, "How much of a difference is found?" Similarly, this measure seems to harmonize with the NHST procedure.

While researchers and the APA have suggested utilizing these and other methods to supplement NHST, it seems that researchers are not currently using statistical power and effect size measures to their fullest extent. The current study examined the articles in three psychology journals to assess the current status of statistical power and effect size measures. The results of the current study suggest that about 7% of studies estimate or discuss statistical power, and about 30% calculate effect size measures. These numbers are far below the desired level of mandatory reporting of these measures. Also, when statistical power was calculated for 157 articles (45 in the *Journal of Personality and Social Psychology*, 57 in the *Journal of Consulting and Clinical Psychology*, and 55 in the *Journal of Abnormal Psychology*) for 2,747 statistical tests for a total of 27,705 power calculations (power was calculated for effects beyond the normal small, medium, and large), a slight increase (above the original 1962 study and the replication in 1990) in statistical power was noted. In terms of effect size measures, a medium effect size was discovered as the average effect size across studies, which confirms previous researchers speculations about the average effect size in psychological research.

It would seem that though the average effect size in the current research is of medium size, current research designs do not have sufficient statistical power to detect such an effect size. The current research should also strive to improve current statistical power survey methods to incorporate more advanced statistical methods to gain a more representative evaluation of the average effect size in psychological research.

## Acknowledgements

If I did not believe in God, if I did not pray every day, if I did not place this dissertation in God's hands, it never would have been completed. I found the strength I needed to complete this task through God.

*Philippians 4:13 - I can do all things through Christ which strengtheneth me.*

Without my husband, John, I probably would have given up on finishing this project long before I started. He reminded me daily that I could do it, he made my lunch, he cleaned the house when I was too tired to think, he made sure I took breaks and ate, he held me when I just wanted to quit, he was my cheerleader, and he was my prayer partner. Thanks for believing in me.

I would like to thank my major professor, Dr. Joseph S. Rossi. With his guidance and support, I completed this dissertation project. Next, I would like to thank my committee members, Dr. Joseph Fava, Dr. Colleen Redding, Dr. Bryan Blissmer, Dr. Geoffrey Greene, and Dr. Sara Johnson, for their guidance and suggestions on earlier drafts. I would also like to thank Dr. Jerry Cohen for loaning me his prized Journals of Personality and Social Psychology, and Dr. Mark Wood for loaning me his Journals of Abnormal Psychology.

Finally, I would like to thank my family. They reminded me that learning and joking are a way of life. Thanks for teaching me the importance of an education and making me smile when I was too serious.

## Preface

Every student eventually becomes a teacher. Whether they are a formally employed as a teacher or a professor, or they just become a parent, all students become teachers. This dissertation taught me a lot about many different aspects of psychology, not only the aspects I was looking for, but also many underlying aspects. This dissertation is an effort to replicate earlier power surveys and extend the research on effect size measures, but in the process of being a student of the information, I found myself teaching the material to my students in my introduction to statistics class. This poem and dissertation reflects many of things that I learned from them and they learned from me:

Note to a current student from your professor:

Why do you look at me that way? I stand before you explaining themes and concepts, facts and figures. Carefully repeating items because they'll be on your exam. Trust me, I wrote it last night.

Why do you sit there as I ask a question talking to your friends, commenting about my clothes, hairstyle, mannerisms, or voice? Why can't you just listen to my message and jot down some ideas. Maybe a head nod every so often to let me know that you understand.

Do you understand? I see the doodles on your papers. I see the homework you are working on--that you think that you have hidden beneath your book.

Your book-do you even know what chapter we are on? Have you even bought the book yet? I spend hours creating a lecture to compliment the text. But in order for you to get the gist, you have to read the book.

The tests- I try to be fair. Not too many multiple choice, a couple essays. Trying to target what you need to know from this class. Don't you study or do you think that your past history as a student is going to enhance your grade?

Sometimes I don't understand you. You answer my question with little thought or no desire. Like you had been thinking of dinosaurs before I asked you and were angered by my intrusion.

I came here to teach. It is something I've always wanted to do. I can teach all day, but I need your help. I need someone on the receiving end. I need you to learn.

Note to a professor from a current student:

I know I am here to learn. I know I have responsibilities. Trust me I go home to read more often than you think. I am paying attention in class even when my head is down. Remember that as you have bad days, so do I. There will be days that I am excited to learn, but realize that you can help me with that.

So remember:

Don't read to me. I don't come to class like a kindergartner. I like to read on my own time. TALK to me. I am a person. Lectures are great, but discussions are better. It's ok to tell be the facts, but help me develop my own conclusions. Communication is the key. Use handouts, visuals, e-mail, visuals... Let me say visuals again. Nothing compliments a verbal message better than a visual.

Now the verbal message. Work hard on your verbal message. WE can tell when you decided to use the same lecture for the past 20 years. Voice inflection, hand gestures, and eye contact, basically think of every class as an interview--an interview with your students. It is an interview with us. Maybe it would help you to think of it as a test. We are testing you every class. We want to see how good you are.

Tests- test on what you taught us. Don't test us on what you think we should know. Professor, guider, teacher show me what you want me to learn. Learn, that's why I'm here. That's why you are in front of the class. When you boil down our classes can you answer -what did <u>we</u> learn today?

Yes, I said we. We are learning together.

And that is what <u>we learned</u> today.

Note to a student from your professor:

You want to learn. You want us to learn together. I am open to suggestions. But you never come to see me during my office hours. When you are struggling or uncomfortable with the material, I never know unless you tell me. I have watched you over the semester go through your moods. I have seen you beaming and I have seen the anger weld up beneath your lips.

I am not too old to remember what it was like to be a student. I remember all of the pressure and frustration you feel. But for me to help you better we need to communicate. I need you to be involved. When I try new things, new lectures, new exercises, I need to hear what you think so that I can improve too.

For us to learn together, we both need to have active roles. I need to see your eyes when we are talking.

Note to a professor from your student:

I don't pay attention all of the time. I am sorry. Maybe I should volunteer an answer every so often. Maybe I should show you that I have read the readings. But I need you to be talking to me and not just talking to hear yourself speak.

If I don't' feel your warmth, I am not going to come to your office hours. If I do come, I feel like I am admitting that I am not capable. If I need help, then something must be wrong.

Do you see me trying to improve my grade? Every so often, I take a couple more notes then I used too. If the class is struggling as a whole with the material, do you blame us for not studying or acknowledge that the test may have been unfair?

I read your comments and know that they are valid. I really think that we need to work together to improve them.

A note from a professor to a current student:

When I look out in my classes sometimes, I see children who have been spoon fed their whole lives. Teachers gave you the answers so that you could pass the test. All your life you have thought that you were entitled to the world. Never did you once consider working for it.

You think that my tests are too hard? Or maybe unfair? Or that my lectures are boring? Do you realize that I am trying to challenge you to think?

So I give a lot of readings. So my tests are hard. I am not here to get high student ratings at the end of the semester. I am here to give you knowledge. I am here to help you into your future.

A note from a current student to a professor:

My future does not seem real yet. It is hard for me to think about a future when I don't even know what I am doing tonight.

Don't you think that I can give you knowledge too? Don't you think that you could learn from me too?

A note from a professor to a current student:

Yes, I can learn from you, but you don't seem interested.

A note from a current student to a professor:

I can learn from you too, but you don't seem interested.

This dissertation is an effort to walk in the steps of my predecessors. Recently, my major professor and I tried to trace my psychological lineage. As far as we know it is as follows (from recent to past):

Joseph S. Rossi (University of Rhode Island, Ph.D., 1984)

Charles E. Collyer (Princeton University, Ph.D., 1976)

Ronald A. Kinchla (University of California, Ph.D., 1962)

Richard C. Atkinson (University of California, Ph.D., 1950?)

William K. Estes (University of Minnesota, Ph.D., 1943)

Burrhus Frederic Skinner (Harvard, Ph.D., 1931)

Edwin Garrigues Boring (Harvard, Ph.D, 1908?)

Edward Bradford Titchener (University of Leipzig, Ph.D., 1892)

Wilhelm Max Wundt (University of Heidelberg, M.D., 1856)

It is my hope that one day, I will become a teacher like those who came before me.

April, 2002 *Rose Marie Ward*

## Dedication

I dedicated this to my family.

*My husband, John*

*Raymond and Mary Regan*
*Ray and Sara Regan*
*Dan and Lisa Regan*
*Michael Regan*
*Bernadette Regan*
*John Paul Regan*
*Thomas Regan*
*Robert Regan*
*Elizabeth Regan*

*Willie and Billie Ward*
*Willie and Satomi Ward*
*Caddell and April Bachelor*
*Eve Bachelor*
*Gigi Ward*
*Laura Ward*

Without them, I would have never developed this wacky sense of humor.

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*Delight yourself also in the Lord,*
*And He will give you the desires of your heart.*
*Commit your way to the Lord,*
*Trust also in Him*
*And He shall bring it to pass.*
*Psalms 37:4-5*

## Chapter 1:

## Statistical Power and Effect Size: Why Bother?

For years, the American Psychological Association (APA) has been "encouraging" psychologists to calculate power prior to running their experiments and to calculate effect sizes for their statistics when the studies are complete (most recently APA, 2001). The APA's push for power calculations and effect size indices resulted from numerous researchers publishing the flaws and problems with current statistical methods (e.g. Hunter, 1997; Kirk, 1996; Harlow, Mulaik, & Steiger, 1997; Morrison & Hinkle, 1970; Schmidt, 1996; Thompson, 1996, 1997, 1999). Statistical power estimates and effect size indices have been presented as solutions to the current problems (power: Cohen, 1962; effect size: Thompson, 1999).

### Definition of Statistical Power

In research, there are four possible outcomes to a study. One possible outcome is that in the population the treatment effect does not exist and the researcher rejects the null hypothesis. In this case, the researcher has made a Type I error. Another possible outcome is that the effect is not present and the researcher fails to reject the null hypothesis. This decision is the correct statistical decision. Another possible outcome is that the effect is present and the researcher fails to reject the null hypothesis. This decision is known as a Type II Error. The final possible outcome is when the effect is present and the researcher correctly rejects the null hypothesis. This is known as the power of the statistical test. (See table 1.1 for the table of statistical possibilities.)

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Insert Table 1.1 here

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Cohen (1988) defined power of a statistical test as "the probability that it will yield significant results." It is important to note the power discussed in this study refers to power calculated a priori. Statistical power is reliant on three factors: significance level, sample size, and effect size.

Researchers have often emphasized how statistical power and null hypothesis significance testing should be coupled together (Cohen, 1988; Rossi, 1990). Given that statistical power is the likelihood of obtaining a significant result, one would assume that researchers would seek to examine the statistical power of their study a priori.

Determining Statistical Power

In order to operationalize statistical power, researchers have to make assumptions about the data. Many researchers have utilized the standard definitions set forth by Cohen (1977) and developed statistical programs for calculating power (i.e., PASS: Hintze, 2001). These programs use Cohen's assumptions about effect size to ease the calculation of statistical power. The current study employed Rossi's (1984) BASIC programs and PASS (Hintze, 2001) designed for the same purpose.

Effect Size Measures Used to Calculate Power

Power determinations were made using Cohen's (1962, 1977) definitions of small, medium, and large effect size. Below are the primary effect sizes for which power was calculated which are adapted from Cohen's (1988) power textbook. The definitions for small, medium, and large effect sizes for each statistic are listed in table 1.2 and are based on Cohen's 1962 and 1977 definitions.

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Insert Table 1.2 here

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1. **t-test**: Cohen suggested using a standard metric for the student's t-test. He developed a metric dubbed Cohen's d, which represents the standardized difference between group means (Cohen, 1988):

(1.1) $$d = \frac{(M_1 - M_2)}{s}$$

where $M_1$ is the mean of the first group, $M_2$ is the mean of the second group, and s is pooled standard deviation. Cohen (1988) described the relationship of $d$ to delta, the noncentrality parameter (NCP) for the noncentral t distribution, as follows:

(1.2) $$\delta = d\sqrt{(n/2)}$$

where $n$ is the sample size for each group.

2. **Pearson r:** The effect size measure for Pearson r is the correlation coefficient.

3. **Differences between correlation coefficients:** Cohen (1969) developed an effect size index for the difference between correlations, $q$. This index utilizes a transformation of Fisher's $r$ to $z$ scores:

(1.3) $$q = |z_1 - z_2|$$

To transform $r$ to a $z$ score:

(1.4) $$z = \frac{\ln((1+r)/(1-r))}{2}$$

An equivalent form of the above formula is presented below:

(1.5) $$z = \text{arctanh}\,(r)$$

Rossi (1985) published tables for computing $q$.

5. **Differences between proportions:** Cohen (1988) developed a method for calculating the difference between proportions using $\phi_1$ and $\phi_2$, which are the arcsine transformation for the two proportions.

(1.6) $$h = |\ \phi_1 - \phi_2\ |$$

Eisenhart (1947) suggested using the arcsine transformation to stabilize the variance and normalize the distribution of proportions:

(1.7) $$\phi = 2 \text{ arcsine } \sqrt{p}$$

6. **Chi-square tests:** Cohen also developed a standardized effect size measure for the chi-square test. He called it $w$:

(1.8) $$w = \sqrt{(\Sigma((P_{1i} - P_{0i})^2/P_{0i})}$$

where $P_{0i}$ is the proportion in cell $i$ specified by the null hypothesis, $P_{1i}$ is the proportion specified by the alternative hypothesis, and they are summed from 1 to m (m= the number of cells). He described the relationship between $w$ and $\lambda$ (the NCP of the noncentral chi-square distribution) as:

(1.9) $$\lambda = w^2 * N,$$

where $N$ is the total sample size.

7. **F tests in the analysis of variance**: Cohen defined the effect size measure for the ANOVA as $f$:

(1.10) $$f = \frac{s(m)}{s}$$

where $s$ is the pooled standard deviation of the $k$ groups, and $s(m)$ is the standard deviation of the $k$ groups. For the two-group case, $f$ is related to $d$, the effect size index for the $t$ test, by

(1.11) $$f = \frac{d}{2}$$

The index $f$ is also closely related to $\varphi$, the NCP of the noncentral f distribution introduced by Tang (1938):

(1.12) $$\varphi = f * \sqrt{(n)},$$

$f$ is also related to $\lambda$, the NCP used by Patnaik (1949):

(1.13) $$\lambda = f^2 * n * k.$$

8. **F tests in multiple regression/correlation analysis**: Cohen (1977) suggested $f^2$ as a standardized measure of effect size for multiple regression and correlation analysis:

(1.14) $$f^2 = \frac{R^2}{(1 - R^2)}$$

where $R^2$ represents the squared multiple correlation coefficient. It represents the proportion of variance in the dependent variable accounted for by the set of independent predictor variables. It is related to λ, the NCP for the noncentral *F* distribution, as follows:

(1.15) $$\lambda = f^2 * v,$$

where

(1.16) $$v = N - k - 1.$$

In the above formula, $v$ represents the degrees of freedom for the error term, $N$ is the total sample size, and $k$ is the number of groups.

9. **F test for the one-way multivariate analysis of variance:** Cohen (1988) used $f^2$ as the measure of effect size for MANOVA. F has a slightly different definition when being applied to MANOVA:

(1.17) $$f^2 = L^{-1/S} - 1,$$

where

(1.18) $$L = |E| / |E + H|,$$

Here, $L$ = Wilks' λ, E is an error matrix, and H is an hypothesis matrix and

(1.19) $$S = \frac{\sqrt{(k^2_Y k^2_X - 4)}}{(k^2_Y + k^2_X - 5)}$$

where $k_Y$ and $k_X$ are the numerator and denominator degrees of freedom.

Rossi (1998) developed BASIC software to accomplish this type of analysis. This program was used for computing the power of one-way MANOVA in this study.

10. **Covariance Structure Modeling:** MacCallum, Browne, and Sugawara (1996) developed a framework to assess the power of covariance structure modeling or structure equation modeling (SEM) utilizing the Root Mean Square Error of Approximation (RMSEA). Given the values for alpha, degrees of freedom, sample size, the null hypothesis value of RMSEA, and the alternative hypothesis value of RMSEA, the power for a SEM can be calculated. For a complete discussion of the formulas involved, refer to MacCallum et al. (1996).

11. **Meta-Analysis:** Hedges and Pigott (2001) devised a method for assessing the power of a meta-analytic survey on the basis of whether the survey was a fixed- or random-effects test. They explored the power of meta-analytic surveys assuming that the effect sizes presented were for *k* independent studies and that the conditional variance is not known.

Fixed Effect Surveys: When examining a survey that address mean differences, the following equations are appropriate:

(1.20) $$d_i = (Y_{Ai} - Y_{Bi})/s_i$$

The above formula defines the standardized mean differences (Hedges & Olkin, 1985) where $Y_{Ai}$ and $Y_{Bi}$ are the sample means of the two samples of interest for study $i$ and $s_i$ is the pooled sample standard deviation for each study. To estimate the variance of $d_i$, the following formula is used:

(1.21) $$v_i = \frac{n_{Ai} + n_{Bi}}{n_{Ai}\, n_{Bi}} + \frac{d^2_i}{2(n_{Ai} + n_{Bi})}$$

where $n_{Ai}$ and $n_{Bi}$ are the sample sizes of the two samples of interest in the $i$th study. Then the value of the weighted mean effect size is:

(1.22) $$v. = v/k$$

where $k$ is the number of studies. The next step is to calculate lambda using formula 1.23.

(1.23) $$\lambda = (\theta - \theta_o)/\sqrt{(v)}$$

$\theta$ represents the population effect size which is estimated and lambda is the mean of a normal distribution with a variance of 1. The power of a 1-tailed test is:

(1.24) $$p = 1 - \Phi\,(c_\alpha - \lambda)$$

where $\Phi$ (x) is the standard normal cumulative distribution function. A two-tailed test has the following formula for power:

(1.25) $$p = 1 - \Phi\,(c_{\alpha/2} - \lambda) + \Phi\,(-c_{\alpha/2} - \lambda)$$

For surveys that examine correlation coefficients and tests of heterogeneity of effect size parameters, similar formulas are used (refer to Hedges and Pigott, 2001, for a complete discussion).

Random Effect Surveys: When examining surveys that address mean differences, the following power equations are appropriate. For a one-tailed test:

(1.26) $$p = 1 - \Phi\,(c_{\alpha/2} - \lambda^*)$$

and the following for a two tailed test:

(1.27) $$p = 1 - \Phi\,(c_{\alpha/2} - \lambda^*) + \Phi\,(-c_{\alpha/2} - \lambda^*)$$

where lambda is defined as:

(1.28) $$\lambda^* = (\mu - \mu_0)/\sqrt{(v^*)}$$

Hedges and Pigott (2001) discuss the random effects procedures in complete detail.

Definition of Effect Size

The term "effect size" has come to represent a family of indices that measure the magnitude of an experimental effect or how effective the treatment was. Unlike significance tests and power, the effect size index is not influenced by sample size. Researchers control the size of the sample and the alpha level at which they will test, but they do not control the effect size.

Other researchers have commented on the aspects of research which influence effect size. "The effect size obtained in a research study depends on a variety of factors, including (a) the potency of the treatment, (b) the reliability and validity of the outcome measures in relation to the treatment, and (c) the amount of uncontrolled variation in the research design"

(Kosciulek & Szymanski, 1993, p. 213). While a researcher cannot directly influence effect size, they can make efforts to ensure that their research gives the best estimate of the effect size possible by reducing error and using reliable, valid measures.

<u>What is an Effect Size?</u>

Simply, an effect size is the magnitude of the treatment effect:

(1.29) $$Pr(X_1 > X_2)$$

It is the probability that a random sample for population 1 will be greater than a random sample from population 2. It is measured in two ways. First, it can be estimated as the standardized difference between two means. Secondly, it can be considered the correlation between the independent variable classification and the individual scores on the dependent variable (Rosnow & Rosenthal, 1996).

<u>Two Independent Groups</u>

When examining two independent groups, one can estimate the magnitude of the difference between groups using a variety of effect size measures. The primary measure discussed in this case is Cohen's d. It is a descriptive measure that can be calculated from the following formula:

(1.30) $$d = \frac{M_1 - M_2}{\sigma}$$

Where σ represents pooled standard deviation and can be calculated from the following:

(1.31) $$\sigma = \sqrt{\frac{\Sigma(X - M)^2}{N}}$$

(Note: Formula 1.30 and formula 1.1 are the same.) X, M, and N represent the raw score, mean, and number of cases respectively. Cohen's d can also be computed from the value of student's t:

(1.32) $$d = \frac{2t}{\sqrt{(df)}}$$

Formula 1.32 assumes equal sample sizes. If the groups are unequal, the following formula is appropriate:

(1.33) $$d = \frac{t\,(n_1 + n_2)}{\sqrt{(df)}\sqrt{(n_1 n_2)}}$$

Cohen's d can also be calculated from Pearson's correlation, *r*:

(1.34) $$d = \frac{2r}{\sqrt{(1-r^2)}}$$

If given Hedge's *g*, using the following formula, one can transform Hedge's *g* to Cohen's *d*:

(1.35) $$d = g\sqrt{(N/df)}$$

As mentioned above, Cohen (1988) operationalized the definition of his standardized measure of effect size into small, medium, and large effects. This was an attempt, based on his research experience, to define effect sizes and categorize them into metrics. Table 1.3 presents Cohen's definitions (small, medium, and large), effect sizes, and the percent of nonoverlap between the treatment group and the control group. Cohen defined small as an effect size of 0.2 which means the 14.7% of the two distributions of interest do not overlap whereas a large effect size, 0.8, has 47.7% of the distributions not overlapping.

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Insert Table 1.3 here

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These effect sizes can be thought of as an average percentile standing. When the data are examined, the researcher wants to know how different is the average percentile standing of the average treatment group participant in comparison to the average untreated participant. An effect size of 0.8 (Cohen defines as large), means that the treatment group is at the $79^{th}$ percentile in comparison to the control group. If there is an effect size of zero, the mean of the treatment group is the $50^{th}$ percentile of the control group.

Another effect size measure for two independent groups is Hedge's g. It was named for the pioneer of meta-analysis, Gene V Glass. It is defined as:

(1.36) $$g = \frac{M_1 - M_2}{\sigma}$$

Where σ represents pooled standard deviation and can be calculated from the following:

(1.37) $$\sigma = \sqrt{\frac{\Sigma(X - M)^2}{N - 1}}$$

X, M, and N represent the raw score, mean, and number of cases respectively. Pooled standard deviation can also be calculated from the following formula:

(1.38) $$\sigma = \sqrt{(MS_{within})}$$

Hedge's g can also be computed from the value of student's t:

(1.39) $$g = \frac{t\sqrt{(n_1 + n_2)}}{\sqrt{(n_1 + n_2)}}$$

Formula 1.31 assumes equal sample sizes. If the groups are equal, the following formula is appropriate:

(1.40) $$g = \frac{2t}{\sqrt{(N)}}$$

Similar to Cohen's *d*, Hedge's *g* can also be calculated from Pearson's correlation, *r*:

(1.41) $$g = \frac{\frac{r}{\sqrt{(1 - r^2)}}}{\sqrt{(df(n_1 + n_2))/(n_1 n_2))}}$$

If given Cohen's *d*, using the following formula, one can transform Cohen's *d* to Hedge's *g*.

(1.42) $$g = \frac{d}{\sqrt{(N/df)}}$$

Correlational Measures of Effect Size

The effect size correlation can be defined as the relationship between a dichotomous independent variable and a continuous dependent variable.

(1.43) $$r = r_{dv,iv}$$

It can be computed from the students' *t* value:

(1.44) $$r = \sqrt{(t^2/(t^2 + df))}$$

It can also be computed from a chi-square test result if the chi-square has one degree of freedom.

(1.45) $$r = \Phi = \sqrt{(\chi^2/N)}$$

This value is also known as phi, Φ. If the researcher performs an *F* test with two groups (a single degree of freedom *F* test), the correlation effect size can be computed using the following formula:

(1.46) $$r = \sqrt{(F/(F + df_{error}))}$$

The effect size correlation also has a fairly simple relationship with Cohen's d:

(1.47) $$r = d/\sqrt{(d^2+4)}$$

To compute it from Hedge's *g* is a little more complicated:

(1.48) $$r = \sqrt{\{(g^2 n_1 n_2)/[\,(g^2 n_1 n_2)+(\,g^2 n_1+n_2)df]\}}$$

Cohen also operationalized definitions for small, medium, and large effect sizes for the correlation. He chose 0.1, 0.3, and 0.5 respectively. Table 1.4 compares Cohen's definitions for small, medium, and large for Cohen's *d*, *r*, and percent of variance accounted for ($r^2$). Using the formulas provided above (adapted from Cohen (1988) and Rosnow and Rosenthal (1996)), the values in table 1.4 were calculated. A large effect in correlational research accounts for 13.8% of the variance in the dependent variable from the independent variable. Small and medium effects account for 1.0 and 5.9 percent respectively.

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Insert Table 1.4 here

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Effect Size Measures for the ANOVA

Effect size measures for the analysis of variance (ANOVA) describe the degree of relationship between the effect (main effect, interaction, linear contrast) and the dependent variable. The four most common measures of effect for the ANOVA are (1) $\eta^2$, (2) partial $\eta^2$, (3) $\omega^2$, and (4) $\rho_I$ (eta-squared, partial eta-squared, omega-squared, and intraclass correlation respectively). Eta-squared and partial eta-square primarily pertain to the relationship observed in the sample. Omega-squared and intraclass correlation estimate the degree of relationship in the population. While formulas for each of the aforementioned measures of effect will be given, the effect size measure of primary interest for this study is eta-squared.

Eta-squared describes the proportion of variance that is attributed to the effect. It can be calculated using the following formula:

(1.49) $$\eta^2 = SS_{effect}/SS_{total}$$

An issue with using eta-squared is its value is dependent on the other effects being examined. It is influenced by the other effects' magnitudes. As a solution, partial eta-squared was developed. The formula for partial eta-squared is as follows:

(1.50) $$\text{partial } \eta^2 = SS_{effect} / (SS_{effect} + SS_{error})$$

It is important to remember that though partial eta-squares are calculated for each of the effects, they are not additive by nature. They do not sum together to the amount of variance accounted for in the dependent variable by the independent variable.

Omega-squared is an estimate of the population relationship. Because it is based on the population parameters, it will be smaller then the eta-squared values (which are based on sample statistics). The formula for omega-squared is:

(1.51) $$\omega^2 = (SS_{effect} - (df_{effect})(MS_{error})) / (MS_{error} + SS_{total})$$

The final type of effect size measure used with the ANOVA is the intraclass correlation. It estimates the relationship between the independent and dependent variables in a random effects model. This effect size measure is not common in psychology. The formula for the intraclass correlation is:

(1.52) $$\rho_I = (MS_{effect} - MS_{error}) / (MS_{effect} + (df_{effect})( MS_{error}))$$

<u>Other Measures of Effect Size</u>

Currently, there are 61 different effect size measures available (Elmore, 2001). Among the 61 are measures for log-linear models / logistic regression (the odds ratio), meta-analysis (Glass's delta), nonparametric statistics, structural equation modeling, etc. These effect size measures have not been as researched as the measures mentioned above. Researchers have not formally operationalized definitions for small, medium, and large effects for these indices.

Why Report Statistical Power and Effect Size Measures

The APA has been strongly urging researchers to calculate and report both statistical power and effect size measures for years (Wilkinson, 1999). They have urged most recently to "provide information...replace calculated power in describing results" (p. 596) and to "always provide some effect size estimate when reporting a p value" (p. 599).

Not only does the APA find that these estimates are important, but other researchers have been reporting similar attitudes for years. Glass and Stanley (1970) stated, "in testing any statistical hypothesis is true or that it is false is never made with certainty; he always runs a risk of making an incorrect decision" (p. 275). Glass touches on the importance of knowledge before the research has started how likely it is that significance will be found. Sherron (1988) hypothesizes that "many 'nonsignificant' findings are the result of inadequate research design and data analysis" (p. 170). He emphasizes that calculating power can prevent running studies which have little to no chance in finding significant results.

It is not only important to calculate statistical power a priori and effect size measures upon completion, but it is paramount to psychology improving its research and research techniques. For close to a hundred years, psychologists have relied on Null Hypothesis Significance Testing

(NHST) to support their claims. This process is flawed as noted by Cohen (1969). "This is the usual expectation of the investigator, who has stated the null hypothesis for tactical purposes so that he may reject it and conclude that the phenomenon exists. But, of course, the fact that the phenomenon exists in the population far from guarantees a statistically significant result" (p.3-4). Cohen accentuated the point that just because an effect exists in nature, does not mean that the researcher has enough statistical power to detect that effect with his or her research design.

Later, Cohen (1994) explicated that though NHST is inherently flawed, there is no "magical alternative" to NHST. He concurred with the recent recommendation of the APA that psychology research must understand and improve their data (by calculating power analysis a prior) and report effect sizes (using confidence interval).

In short, there are many reasons for researchers to calculate statistical power and effect size measures. First, it adds to the body of knowledge with sound research designs. Secondly, it allows for future research to get better estimates of costs for research designs. Thirdly, it advances psychology as a science.

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Table 1.1

Possible Statistical Outcomes

| The True Nature of the Null Hypothesis in Reality | | Your Research Decision: Accept the Null Hypothesis | Your Research Decision: Reject the Null Hypothesis |
|---|---|---|---|
| | The Null Hypothesis is true in nature | Correct Decision: You would state that there isn't enough evidence to reject the Null. | Incorrect Decision: You rejected a true Null. This is a Type I error ($\alpha$). |
| | The Null Hypothesis is false in nature | Incorrect Decision: You failed to reject a false Null. This is a Type II error ($\beta$) | Correct Decision: You rejected the Null when it was false. |

Table 1.2

Definitions of Small, Medium, and Large

| | Effect Size Index | Small | Medium | Large |
|---|---|---|---|---|
| Cohen (1962) | | | | |
| *t*-test | *d*= | .25 | .50 | 1.00 |
| Pearson's *r* | *r*= | .20 | .40 | .60 |
| Cohen (1988) | | | | |
| *t*-test | *d*= | .20 | .50 | .80 |
| Pearson's *r* | *r*= | .10 | .30 | .50 |
| Diff. Betw/ Correlation | *q*= | .10 | .30 | .50 |
| Sign test | *g*= | .05 | .15 | .25 |
| Diff. Betw/ Proportions | *h*= | .20 | .50 | .80 |
| Chi-Square | *w*= | .10 | .30 | .50 |
| ANOVA | *f*= | .10 | .25 | .40 |
| ANCOVA | *f*= | .10 | .25 | .40 |
| Multiple Regression | $f^2$= | .02 | .15 | .35 |
| MANOVA | $f^2$= | .02 | .15 | .35 |
| MANCOVA | $f^2$= | .02 | .15 | .35 |

Table 1.3

Interpreting Cohen's d in terms of Percent of Nonoverlap

| Cohen's Standard | Effect Size | Percent of Nonoverlap |
|---|---|---|
| | 0 | 0 |
| | 0.1 | 7.7 |
| Small | 0.2 | 14.7 |
| | 0.3 | 21.3 |
| | 0.4 | 27.4 |
| Medium | 0.5 | 33.0 |
| | 0.6 | 38.2 |
| | 0.7 | 43.0 |
| Large | 0.8 | 47.4 |
| | 0.9 | 51.6 |
| | 1.0 | 55.4 |
| | 1.1 | 58.9 |
| | 1.2 | 62.2 |
| | 1.3 | 65.3 |
| | 1.4 | 68.1 |
| | 1.5 | 70.7 |

Table 1.4

Comparing Cohen's d, correlation, and percent of Variance Accounted for

| Cohen's Standard | Effect Size | *r* | Percent of Variance Accounted for |
|---|---|---|---|
| | 0 | 0 | 0 |
| | 0.1 | .050 | .002 |
| Small | 0.2 | .100 | .010 |
| | 0.3 | .148 | .022 |
| | 0.4 | .196 | .038 |
| Medium | 0.5 | .243 | .059 |
| | 0.6 | .287 | .083 |
| | 0.7 | .330 | .109 |
| Large | 0.8 | .371 | .138 |
| | 0.9 | .410 | .168 |
| | 1.0 | .447 | .200 |
| | 1.1 | .482 | .232 |
| | 1.2 | .514 | .265 |
| | 1.3 | .545 | .297 |
| | 1.4 | .573 | .329 |
| | 1.5 | .600 | .360 |

*All glory comes from daring to begin.*
*Eugene F. Ware*

# Chapter 2:
# A History of Statistical Power in Psychology

In the beginning of the history of statistical power, its predecessor Null Hypothesis Significance Testing (NHST) was being developed. While the idea of systematically examining data is a couple hundred years old, NHST is less than 100 years old. Some of the components of the process are older than that (the .05 level, Cowles & Davis, 1982), but the bulk of the NHST process was published and established in the 1930's.

Fisher and the team of Neyman and Pearson each separately developed a method for examining data. Fisher (1932) published the process of hypothesis testing while Neyman and Pearson (1928a, 1928b, 1933a, 1993b) published the process of significance testing. Fisher posited that a single hypothesis was necessary, while Neyman and Pearson provided for the null hypothesis and the alternative hypothesis. Fisher discussed the p-values while Neyman and Pearson provided critical values. Fisher's theory examined the data given the hypothesis ($p(\text{Data} \mid H_0)$ while Neyman and Pearson discussed fixed value probabilities. Both views are viable. Fisher and Neyman and Pearson openly loathed each other and each other's theory testing process.

Even with the emotions between the two camps, introduction to statistic textbook writers determined that a hybrid of the two methods would be best. The hybrid of the two models mentioned above is what was presented in the textbooks in the 30's and presented in the textbooks currently.

The NHST Debate

The hybrid model has been not accepted without criticism (Berkson, 1938; Hogben, 1957). Some researchers report that NHST has many flaws and others have misused it. Huberty (1993) simply proclaimed that NHST is not at fault. In his opinion, it is the faulty textbooks, the teachers and teaching system, and the editors who are to blame. Chow (1996) found that if one meets all of the assumptions of NHST then there is no problem using it. Knapp's (1998) concern with NHST is that the null hypothesis is uninformative without means and effect sizes. In general, those who support the use of NHST state that the method is not flawed – the researchers who utilize the methods are.

As mentioned above, the NHST dispute is not a new debate. It has been examined from the 30's (Berkson, 1938) to today. Books have been written to examine both sides of the issue (Harlow et al., 1997; Morrison & Henkel, 1970) and articles have been published in a variety of journals. Morrison and Henkel (1970) gathered articles from a variety of researchers (both in psychology and sociology) to present sides of the NHST argument. Researchers like Meehl had articles in that book that condemned the use of NHST (and basically anyone who used the technique). The Harlow et al. (1997) book also provides articles written by a variety of authors (Cohen, Rossi, Meehl, Rosenthal), who support and refute NHST. Some of the critics of NHST have very basic issues. Meehl (1978) essentially states that the Null hypothesis will always be false. He believes that there is no reason to examine it if it is always going to be false. Other critics mention the mass misuse of the method (Cohen, 1994). In Cohen's article "The Earth is round p< .05," he touches on a couple of issues with the misuse of the NHST method. The first issue is with the misinterpretation of the p-level. The second issue is with misinterpretation of the complement of the p-value being the probability of successful replications. Cohen also touches on the misinterpretation of null results indicating affirmation of the null hypothesis. Cohen develops the argument against null hypothesis testing by mentioning that $p(data \mid H_0) \neq p(H_0 \mid data)$. In words, the probability of the data given the null hypothesis does not equal the probability of the null hypothesis given the data.

<u>When Did Statistical Power Analysis Begin?</u>

With their controversial technique of examining data, Neyman and Pearson (1933b) attempted to separate their method out from Fisher's. In their paper presented to the Cambridge Philosophical Society, they spoke of the factor of central importance – the power of the statistical test. It was the first time that the term power was introduced. They defined two types of error in hypothesis testing. The first type of error is the Type I error. It is the error that occurs when the null is rejected (therefore concluding that there is an effect) when the null is true (because there really isn't an effect). The second type of error is the Type II error, which is when the researcher fails to reject the null when it is in fact false (there really is a treatment effect). In this same paper, Neyman and Pearson define power as the probability of rejecting the null hypothesis when it is in fact false.

The Early Research on Power

Five years after Neyman and Pearson established the term power, researchers began publishing articles which conceptualize power in terms of the statistical tests available. Tang (1938) examined the power function for the analysis of variance test. He provided some of the first tables for calculating power. Ferris, Grubbs, & Weaver (1946) also developed the first aspects of power in their article on the operating characteristics for the common statistical tests of significance. In their article, they provide some of the first power curves. Wolfowitz (1949) also provided a general article on power and tests reliant on the normal distribution. Hoeffding (1952) investigated the power of many nonparametric statistics. Stuart (1952) focused in on the power of the two difference sign test and Lehmann (1953) concentrated on the power of rank tests.

Mosteller and Bush (1954) wrote a chapter in the Handbook of Social Psychology entitled "Selected Quantitative Techniques." While the title might suggest a basic statistics overview, the chapter develops the concepts crucial in statistical power. They discuss the power of basic tests such as the

F-test, t-test, and chi-square. A couple years after, Linhart (1957) operationalized the power functions of tests concerning the product moment correlation coefficient.

Introducing Power to Psychology

The researcher who has been reported as being responsible for introducing statistical power to modern psychology is Jacob Cohen. Cohen (1962) conducted the first statistical power survey of psychological research. He examined two popular journals and analyzed the results of the studies to determine post hoc power. From his analysis, Cohen determined that most of the research reported in the journals he examined did not have sufficient power to achieve statistically significant results.

Cohen proceeded to make statistical power accessible to psychologists and researchers alike. In his groundbreaking textbook on the issue (most recent edition 1988), he provided statistical tables for statistics such as the t-test, correlation, differences between correlation coefficients, chi-square, ANOVA, and some multivariate techniques. Not only did Cohen expound on the basics of statistical power, but he also provided tables for sample size calculations so that researchers could develop studies with sufficient power. As if the text was not enough, Cohen continued to write on the subject and provided a statistical "primer" on power in 1992.

Following in Cohen's Footsteps

After Cohen's seminal work, researchers in the 1970's began to analyze other research journals using the power survey method that Cohen pioneered. Ten years after Cohen, Brewer (1972) examined the American Educational Research Journal. The results were similar to Cohen's, in that most articles did not have sufficient power to detect small effects sizes, had about a 50-50 chance of detecting medium effects sizes, and on average sufficient power to identify large effect sizes. Additional power surveys found comparable results. Power surveys were done on Research Quarterly (Jones and Brewer, 1972), the Journal of Research in Science Teaching (Pennick & Brewer, 1972), the Journal of Educational Measurement (Brewer & Owen, 1973), the Journal of Communication (Kattzer and Sodt, 1973), Counselor Education and Supervision (Haase, 1974), American Sociological Review (Spreitzer & Chase, 1974), the American Forensic Association Journal (Chase & Tucker, 1975), the Journal of Communication Disorders (Kroll & Chase, 1975), the Journal of Speech and Hearing Research (Kroll & Chase, 1975), Journalism Quarterly (Chase & Baran, 1976), Journal of Broadcasting (Chase & Baran, 1976), the Journal of Applied Psychology (Chase & Chase, 1976), Research Quarterly (Christensen & Christensen, 1977), and the American Journal of Occupational Therapy (Chase, Chase, & Tucker, 1978). After the power surveys of the '70's, a couple power surveys were conducted in various areas in the '80s and '90s. Though one might assume with the advent of the personal computer and computer programs for conducting power analysis that power surveys might increase in popularity, the appeal of power surveys have seemingly died off. A comprehensive listing of power surveys can be found in table 2.1.

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Insert Table 2.1 here

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To determine if Cohen's work on power analysis had influenced how researchers did their research, Joseph Rossi preformed a follow up power survey on similar journals to Cohen's. Rossi (1990) found that statistical power had not increased since Cohen's original study. It seems that researchers in the eighties still did not calculate a priori the probability of achieving a significant result.

While power surveys are fewer in the literature, they are becoming more specified in nature. A recent power survey (Kazantzis, 2000) examined the statistical power of psychotherapy outcome research. In contrast to the earlier power surveys, Kazantzis did not focus his power survey on one specific or even a couple specified journals. His focus was on the topic area and determining if the research area was built on sound research.

Advancements in Power Analysis

As mentioned earlier, the advent of the personal computer has made statistical power even more accessible. With relative ease, a researcher can determine the correct sample size a priori for a specified alpha level, based on the statistic, and expected effect using programs such as GPOWER (Buchner, Erdfelder, & Faul, 1997), PASS (NCSS, 2001), or Rossi's BASIC programs (1984, 1988).

Researchers have also expounded on Cohen's earlier research by developing statistical techniques for calculating power for a variety of statistical methods. For example, researchers have developed methods for determining the power of structural equation models (MacCallum, Browne, & Sugawara, 1996), the power of randomization tests with multiple baseline designs (Ferron & Sentovich, 2002), repeated measures designs (D'Amico, Neilands, & Zambarano, 2001), meta-analysis (Hedges & Pigott, 2001), Log-Linear Modeling (Schuster & von Eye, 2000), split-plot designs (Bradley & Russell, 1998), dichotomous moderator variables (Aguinis, Pierce, & Stone-Romero, 1994), and configural frequency analysis (Indurkhya & von Eye, 2000).

While research on the concepts of statistical power are continuing, it seems that power surveys and power research are not having an effect on psychological research (Sedlmeier & Gigerenzer, 1989). Even in the most recent power surveys (Kenna & Rossi, 2002), the research articles examined did not have enough power to identify a medium effect size.

## The Future of Statistical Power Analysis

Presently, the APA (2001) strongly encourages a priori statistical power calculations in the most recent version of the publication manual. They also suggest the reporting of power in research articles. Grant applications also require estimates of statistical power. It would seem that with the recommendations and requirements of power calculations that the statistical power in current research would be adequate to detect significant effects. It would also seem that with the push for the calculation of statistical power that students of psychology would be exposed to the concept of power and possibly simple power calculations. Given the recent endorsement of statistical power, one might assume that in the near future that journal might require the reporting of statistical power and that statistical power would be a common topic in statistical textbooks.

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Table 2.1

Statistical Power Research Surveys

| Source | Journals included in the surveys | Years covered | Sample Size | | Statistical Power Estimates | | |
|---|---|---|---|---|---|---|---|
| | | | Articles | Tests | Small Effects | Medium Effects | Large Effects |
| Cohen (1962) | Journal of Abnormal and Social Psychology | 1960 | 70 | 2,088 | .18 | .48 | .83 |
| Brewer (1972) | American Educational Research Journal | 1969-1971 | 47 | 373 | .14 | .58 | .78 |
| Jones & Brewer (1972) | Research Quarterly | 1969-1971 | 106 | 261 | .15 | .54 | .83 |
| Pennick & Brewer (1972) | Journal of Research in Science Teaching | 1969-1970 | 66 | 554 | .22 | .71 | .87 |
| Brewer & Owen (1973) | Journal of Educational Measurement | 1969-1971 | 13 | 267 | .21 | .72 | .96 |
| Katzer & Sodt (1973) | Journal of Communication | 1971-1972 | 31 | 1,671 | .23 | .56 | .79 |
| Haase (1974) | Counselor Education and Supervision | 1968-1971 | 60 | 206 | .19 | .46 | .72 |
| Spreitzer & Chase (1974) | American Sociological Review | 1972-1973 | 34 | 1,049 | .55 | .84 | .94 |
| Chase & Tucker (1975) | American Forensic Association Journal | 1973 | 46 | 1,298 | .18 | .52 | .79 |
| | Central States Speech Journal | 1973 | | | | | |
| | Journal of Communication | 1973 | | | | | |
| | Quarterly Journal of Speech | 1973 | | | | | |
| | Southern Speech Journal | 1973 | | | | | |
| | Speech Monographs | 1973 | | | | | |
| | Speech Teacher | 1973 | | | | | |
| | Today's Speech | 1973 | | | | | |
| | Western Speech | 1973 | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Kroll & Chase (1975) | Journal of Communication Disorders | 1973-1974 | 62 | 1,037 | .16 | .44 | .73 |
| | Journal of Speech and Hearing Research | 1973-1974 | | | | | |
| Chase & Baran (1976) | Journalism Quarterly | 1974 | 48 | 701 | .34 | .76 | .91 |
| | Journal of Broadcasting | 1974 | | | | | |
| Chase & Chase (1976) | Journal of Applied Psychology | 1974 | 121 | 3,373 | .25 | .67 | .86 |
| Christensen & Christensen (1977) | Research Quarterly | 1975 | 43 | NR | .18 | .39 | .62 |
| Chase, Chase, & Tucker (1978) | American Journal of Occupational Therapy | 1980 | 25 | 3,304 | .38 | .62 | .81 |
| Levenson (1980) | Gerontologist | 1961-1977 | 56 | NR | .37 | .88 | .96 |
| | Journal of Gerontology | 1946-1977 | | | | | |
| Reed & Slaichert (1981) | American Journal of Surgery | 1977 | 355 | 2,619 | .138 | .387 | .614 |
| | American Journal of Medicine | 1977 | | | | | |
| | New England Journal of Medicine | 1977 | | | | | |
| | American Journal of Cardiology | 1977 | | | | | |
| | Journal of Pediatrics | 1977 | | | | | |
| | American Review of Respiratory Disease | 1977 | | | | | |
| Sawyer & Ball (1981) | Journal of Marketing Research | 1979 | 23 | 475 | .41 | .89 | .98 |
| Ottenbacher (1982) | American Journal of Occupational Therapy | 1980 | 22 | 205 | .37 | .65 | .93 |
| Daly & Hexamer (1983) | Research in the Teaching of English | 1978-1980 | 57 | 1,233 | .22 | .63 | .86 |
| Woolley & Dawson (1983) | Journal of Research in Science Teaching | 1977-1980 | 192 | 3,556 | .23 | .63 | .85 |
| Woolley (1983) | Journal of Medical Education | 1980-1982 | 100 | 2,220 | .23 | .69 | .90 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Orme & Combs-Orme (1986) | Social Work Research Abstracts | 1977-1984 | 49 | 3,114 | .31 | 76 | .92 |
| Orme & Tolman (1986) | Journal of Social Work Education | 1976-1985 | 64 | 1,998 | .20 | .68 | .88 |
| Mazen, Hemmasi, & Lewis (1987) | Strategic Management Journal | 1982-1984 | 44 | 3,665 | .23 | .59 | .83 |
| | Academy of Management Journal | 1984 | | | | | |
| Mazen, Graf, Kellogg, & Hemmasi (1987) | Academy of Management Journal | 1984 | 84 | 7,215 | .31 | .77 | .91 |
| | Journal of Management | 1984 | | | | | |
| | Proceedings of the Midwest Division of the Academy of Management | 1984 | | | | | |
| Sindelar, Allman, Monda, Vail, Wilson, & Schloss (1988) | Special Education Efficacy Research | NR | 44 | 26 | .12 | .46 | .79 |
| | | | | 27 | .12 | .45 | .76 |
| Kazdin & Bass (1989) | Comparative Psychotherapy Outcome Research | 1984-1986 | 85 | 2,501 | NR | NR | NR |
| Sedlmeier & Gigerenzer (1989) | Journal of Abnormal Psychology | 1984 | 54 | NR | .21 | .50 | .84 |
| McKean (1990) | Educational Psychology Ph.D. Dissertations | 1988 | NA | NA | .17 | .54 | .80 |
| Rossi (1990) | Journal of Abnormal Psychology | 1982 | 49 | 1,289 | .16 | .56 | .84 |
| | Journal of Consulting and Clinical Psychology | 1982 | 78 | 2,231 | .18 | .58 | .83 |
| | Journal of Personality and Social Psychology | 1982 | 94 | 2,635 | .16 | .55 | .81 |
| Acklin, McDowell, & | Journal of Personality Assessment | 1975-1991 | 158 | NR | .13 | .56 | .85 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Orndoff (1992) | | | | | | | |
| | Journal of Consulting and Clinical Psychology | 1975-1991 | | | | | |
| | Journal of Clinical Psychology | 1975-1991 | | | | | |
| | Journal of Abnormal Psychology | 1975-1991 | | | | | |
| | Psychological Bulletin | 1975-1991 | | | | | |
| | American Journal of Psychiatry | 1975-1991 | | | | | |
| | Journal of Personality and Social Psychology | 1975-1991 | | | | | |
| Brown & Hale (1992) | Psychosomatics | 1989 | 24 | NR | .19 | .60 | .84 |
| Sanchez, Valera, Velandrino, & Marin (1992) | Anales de Psicologia | 1984-1991 | 16 | NR | .13 | .47 | .76 |
| Kosciulek (1993) | Vocational Evaluation and Work Adjustment Bulletin | 1989-1991 | 14 | NR | .14 | .56 | .84 |
| Kosciulek & Szymanski (1993) | Rehabilitation Counseling Bulletin | 1990-1991 | 32 | NR | .15 | .63 | .90 |
| | Rehabilitation Psychology | 1990 | | | | | |
| | Journal of Rehabilitation | 1990 | | | | | |
| | Journal of Applied Rehabilitation Counseling | 1990 | | | | | |
| | Rehabilitation Education | 1990 | | | | | |
| Mone, Meuller, & Mauland (1996) | Journal of Applied Psychology | 1992-94 | 30 | 100 | .35 | .82 | .95 |
| | Personnel Psychology | 1992-94 | 30 | 105 | .30 | .83 | .97 |
| | Organizational Behavior and Human Decision Process | 1992-94 | 30 | 113 | .17 | .60 | .87 |
| Clark-Carter (1997) | British Journal of Psychology | 1993-1994 | 54 | 1,090 | .20 | .60 | .82 |
| Dilullo (1998) | Journal for Research in Mathematics | 1976-1995 | NA | 81 | | .81 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Education | | | | | | |
| Valera, Sanchez, Marin, & Velandrino (1998) | Revista de Psicologia General y Aplicada | 1990-1992 | 89 | NR | .17 | .57 | .83 |
| Cady-Webster, Hevey, Huang, & Rossi (2000) | Psychology of Women Quarterly | 1996-1999 | 58 | 761 | .31 | .85 | .97 |
| Kazantzis (2000) | Psychotherapy Outcome Research | 1980-1998 | 27 | 32 | .11 | .44 | .71 |
| Whittington et al. (2000) | Memory Impairment in Parkinson's Disease | 1978-1997 | 46 | 1,360 | .20 | .63 | .85 |
| Bezeau & Graves (2001) | Journal of Clinical and Experimental Neuropsychology<br>Journal of International Neuropsychology Society<br>Neuropsychology | 1998-1999 | 66 | NR | NR | .451 | .785 |
| Maddock & Rossi (2001) | Journal of Studies on Alcohol | 1997 | 61 | 3,388 | .41 | .81 | .92 |
| | Health Psychology | 1997 | 56 | 2,429 | .34 | .74 | .92 |
| | Addictive Behaviors | 1997 | 70 | 2,449 | .34 | .75 | .90 |
| Kenna & Rossi (2002) | Experimental and Clinical Psychopharmacology | 1999-2000 | 48 | 619 | .12 | .36 | .59 |

*All truth passes through three stages.*
*First, it is ridiculed.*
*Second, it is violently opposed.*
*Third, it is accepted as being self-evident.*
*- Arthur Schopenhauer (1788-1860)*

# Chapter 3:

## A History of Effect Sizes

Over the years, the American Psychological Association (APA) has made a concerted effort in encouraging researchers to provide an indication of an effect size when reporting their statistical results (Hogarty & Kromrey, 2001). Effect size measures have been seen as a vital complement to tests of significance. Despite recent urgings for the consistent and methodical reporting of effect size indices, these measures are rarely found in published articles and do not appear to be standard practice (Kirk, 1996; Thompson & Snyder, 1997, 1998). Hogarty and Kromrey (2001) contend, "the reporting of effect sizes assists researchers in planning future research (i.e., the determination of sample size for subsequent experimentation) as well as facilitating comparison of results across studies through the use of meta-analytic techniques."

The current argument has influenced a number of editors to require effect size reporting. A total of 20 journals now require effect size reporting (Huberty, 2002). They are: (1) Career Development Quarterly, (2) Contemporary Educational Psychology, (3) Early Childhood Research Quarterly, (4) Educational and Psychological Measurement, (5) Exceptional Children, (6) Journal of Agricultural Education, (7) Journal of Applied Psychology, (8) Journal of Community Psychology, (9) Journal of Consulting & Clinical Psychology, (10) Journal of Counseling and Development, (11) Journal of Early Intervention, (12) Journal of Educational and Psychological Consultation, (13) Journal of Experimental Education, (14) Journal of Learning Disabilities, (15) Language Learning, (16) Measurement and Evaluation in Counseling and Development, (17) The Professional Educator, (18) Reading and Writing, (19) Research in Schools, and (20) Journal of Personality Assessment.

While the most common reporting of effect sizes is effect sizes as applied to univariate comparisons, there are effect size measures available for a broad range of statistics including, but not limited to: prediction methods, multiple regression, MANOVA, and proportion comparisons.

Correlation

One of the first indices established to examine the relationship between variables was the correlation. While its first use is under dispute (Cowles, 1989; Stigler, 1986), it was either developed by Sir Francis Galton (Hald, 1998) or by his cousin, Charles Darwin (Cowles, 1989). Whether it was developed and presented by Galton or Darwin first is difficult to determine, but it is evident that the discovery was made in the late 1800's. Soon after in 1892, Edgeworth used the symbol $\rho$ for the *coefficient of correlation*. Around 1896, Pearson used $r$ for the same concept. In 1905, Pearson developed the concept of the *correlation ratio*, $\eta$. In 1924, Fisher used Pearson's $\eta$ and derived a probability distribution for it in terms of the analysis of variance. Kelly (1935) adjusted this statistic and proposed $\varepsilon^2$.

Later, researchers made a connection between the effect size indices of $\eta^2$ and $\varepsilon^2$ and the analysis of variance (Peters & Van Voorbis, 1940).

Soon researchers sought to improve upon $\eta^2$ and reduce some of its estimation bias. After $\varepsilon^2$, Hays (1963) offered yet another solution the effect size index, est. $\omega^2$. This index estimates the strength of the relationship between the grouping variable and a dependent variable.

While correlations and other indices of relationship have been considered to examine effect size, researchers commonly square the correlation value to determine the percent of variance accounted for in the dependent variable by the independent variable. Cohen (1969) operationalized the shared variance and assigned small, medium, and large labels to $r^2$ values. Rosenthal and Rubin (1979) criticized these labels and later (1982) offered a solution. Their solution was the binomial effect size display (BESD).

If the relationship being examined contains two dichotomous variables, Yule's (1900) Q is the appropriate index. Other options are Pearson coefficient of mean square contingency, Pearson tetrachoric coefficient of correlation, and Tschuprow coefficient (Cowles, 1989). Cramer's (1946) C can be used in this situation and can also be used when comparing multiple proportions.

Group Differences

Cohen (1962) established one of the first indices to examine two group mean difference. His index is Cohen's d. Hays (1963) also contributed to this area with his $\delta$ and $\omega^2$. Over time, researchers sought to improve Cohen's d by selecting different standard deviations to be in the denominator. Cohen (1969) decided on pooled standard deviation for the denominator of his index while Glass (1976) proposed the standard deviation of the control group. Once again a researcher sought to reduce the bias in this estimator and developed a new index. Hedges (1981) developed g in this effort. Another alternative to d and g, is trimmed means or Winsorized variances (Yuen, 1974). Recently, researchers developed a "common language" (CL: McGraw & Wong, 1992) statistic that expresses the relative frequency with which a score from one distribution will be greater than a score sample for the second distribution.

Cohen (1962) also developed an index for multiple group comparisons, f. During that same year, Winer (1962) established an index for estimating the effect of the treatment, $\tau_j$. Cohen (1969) continued to develop effect size indices and actually proposed $\delta$ for a standardized mean difference when working with two or more groups and (1962) a simple difference in proportions ($|P_1 - P_2|$) when working with a dichotomous dependent variable.

Group Overlap Indices

When examining how much the groups overlap, the indices of choice stem from the work of Kelley (1920, 1923) and Tilton (1937). Tilton asserted that whenever a researcher is comparing means the results "should be supplemented whenever possible by an explicit measure of overlapping, such as the percentage of area common to the two distributions" (p. 657). After thirty years, researchers began to restate Tilton's original assertion (Alf & Abrahams, 1968; Dunnette, 1966).

Multivariable Effect Indices

Indices were also developed for research situations when multiple variables were used. Pearson and Lee (1897) introduced the concept of multiple correlation and Pearson (1914) extended this work to what he would call R (*coefficient of multiple correlation*). Cohen (1977) established $f^2$ as an effect size index. Cohen's $f^2$ is related to R in the following way:

$$f^2 = R^2 / (1 - R^2) \tag{3.1}$$

His index is considered a signal to noise ratio. Huberty (1994) sought to improve this index with an adjusted $R^2$ value.

Tatsuoko (1970) is credited with establishing the first multivariate effect size index (Huberty, 2002). The effect size index proposed for the MANOVA is:

$$\eta^2 = 1 - \Lambda \tag{3.2}$$

where $\Lambda$ refers to Wilk's (1932) MANOVA criterion. Similar to the adjustments made on the univariate versions of effect size, Tatsuoka (1973) offered corrections in estimation for the multivariate counterparts.

Effect Size Surveys

While effect size estimations have been around for over 100 years, seemingly few people have examined the magnitude of effects in research. Cohen (1962) made judgments based on his experience to what he dubbed small, medium, and large effects, but few people have surveyed the research to determine actual estimates of small, medium, and large effect sizes.

The earliest effect size survey was completed by Hamblin (1971) and appraised the magnitude of effects for the first here issues of American Sociological Review in 1961. He report average effect size (.107) in terms of explained variance (V). Brown (1975) examined the distribution of Pearson's correlation and R-squared in the American Educational Research Journal from 1970 to 1974. If one was to convert his findings to eta-squared, Brown found a mean effect size of .083. Craig, Eison, & Metze (1976) examined 62 articles from the Journal of Educational Psychology, the Journal of Comparative and Physiological Psychology, and the Journal of Personality and Social Psychology. For each article, a value of omega squared was calculated if it was not reported. Craig et al. (1976) did not report summary indices of fit for the articles that they surveyed. Cooper and Findley (1982) calculated for effect size indices (d, f, r, and w) for Social Psychology textbooks. They found 1.19, .45, .60, .48, and .26 for d, f (df=1), f (df>1), r, and w respectively. Haase, Waechter, & Solomon (1982) examined the research in the Journal of Counseling Psychology from 1970 to 1979. They found a median of .083 for eta-squared in their research. Rubin and Conway (1985) examined 10 journals and estimated the effect sizes for the research articles. They examined journals between 1981-1983 and found a median effect size of .130. Most recently, Thompson and Snyder (1998) examined the 1996 issues of the Journal of Counseling & Development. They found a mean PVA of .148 (SD = .134).

While effect sizes have continued to progress over the last 100 years, few researchers have estimated the average or median effect size in their area of interest (figure 3.1 presents a history of effect size). Meta-analytic procedures have introduced methods for determining average effect sizes for research areas, but in terms of verifying Cohen's small, medium, and large labels, that research has yet to be done.

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Insert Figure 3.1 here

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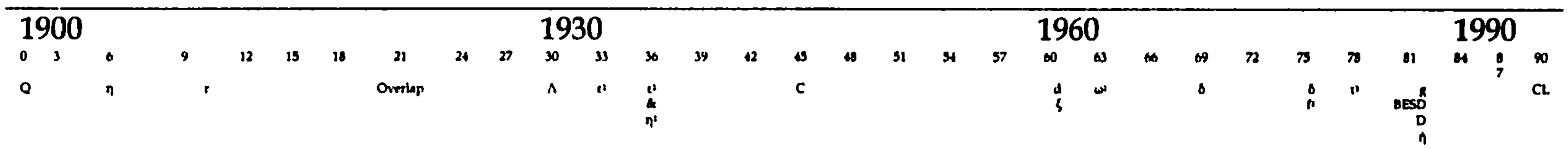
Figure 3.1

Historical Developments in Effect Size Measures (adapted from Huberty, 2002)



*Sometimes in the winter*
*you see things that*
*you can't see in any other season.*
*Billie Jean Ward*

# Chapter 4:
# Examining the Statistical Power and Effect Sizes in Three Psychological Journals

From the beginning of psychology, researchers have been evaluating hypotheses using statistical methods. Most commonly, researchers evaluate their hypotheses against the probability of making a Type I error. Over the last 100 years, individuals have attempted to persuade researchers to augment their findings with statistical power calculations, effect sizes, and confidence intervals (Cohen, 1965; Hayes, 1963; Thompson, 1997a, 1997b, 1999, 2002). Yet, these suggestions have been for the most part ignored (Thompson, 1999).

Part of the discussion concerning evaluating hypotheses involves the dispute concerning significance testing. The debate concerning the utility of Null Hypothesis Significance Testing (NHST) is not a new one. It has been examined, criticized, and supported (Berkson, 1938; Chow, 1996; Harlow et al., 1997; Hogben, 1957; Morrison & Henkel, 1970) since the first psychology textbooks presented the hybrid method. Some researchers insist that tests of statistical significance are not useful (Carver, 1978, 1993; Cohen, 1994; Hunter, 1997; Kirk, 1996; Schmidt, 1992).

Recently, the American Psychological Association (APA: 2001) has set forth additional guidelines for hypothesis testing in an effort to improve the current practices. They recommend, "take seriously the statistical power considerations associated with your test of hypotheses" (p. 24), and "to fully understand the importance of your findings, it is almost always necessary to include some index of effect size or strength of relationship in your results section" (p. 25). While some researchers feel that statistical power considerations and effect size measures should be mandated (Cohen, 1988; Thompson, 1996), other researchers disagree (Frick, 1999; Levin & Robinson, 1999; Robinson & Levin, 1997).

But what is statistical power? What is an index of effect size? Power is the probability of avoiding a type II error or failing to reject a false null (Cohen, 1988). Power is affected by a number of factors including some factors that are directly controlled by the researcher and some that are not. Among the factors that are controlled by the researcher are sample size, statistical test, research design, and the alpha level. The factor that is not controlled by the researcher is the effect size. An effect size is a measure of magnitude of difference. While significance testing tells the researcher that there is a significant difference, effect size lets the researcher know how much of a difference. Although power is affected by sample size, effect size indices are not. This allows comparisons between different studies' effect sizes, which are based on different sample sizes (Clark-Carter, 1997).

Several papers have been written tracing the beginning and historical developments of effect size measures (Dwyer, 1974; Glass & Hakstian, 1969; Maxwell, Camp, & Arvey, 1981; Huberty, 2002; Richardson, 1996).

Researchers have also presented articles offering admonitory notes on the interpretation of effect size measures (Mitchell & Hartmann, 1981; Muray & Dosser, 1987; O'Grady, 1982; Sechrest & Yeaton, 1982; Strube, 1988). Despite the efforts of many to provide information about effect size indices researchers fail to utilize them (Keselman et al., 1998; McNamara, 1978). Recently, Olejnik and Algina (2000) wrote an article, which provides descriptions and formulas for comparative studies effect size measures, and a symposium discussing the current status of effect size measures made recommendations to the field (Elmore, 2001; Huberty 2001).

While the history of effect size measures have been traced, statistical power continues to be ignored in the research whether it be tracing its roots or applying it to current research designs. Researchers have asked if statistical power studies have had any effect on the statistical power of the current research. Some have replied no (Sedlmeier & Gigerenzer, 1989). Cohen first assessed the statistical power of psychological research in 1962. Rossi (1990) followed up Cohen's study by examining psychological research twenty years later.

With all the current awareness of the issues surrounding statistical power and effect size measures, it would be reasonable to assume that both have impacted the current research. The present study is an opportunity to assess the present status of psychological research and ask, "Are we improving or just staying the same."

## Research Hypotheses

The general objective of this study is to replicate the Cohen (1962) and Rossi (1990) power surveys and to complete an effect size survey of the same articles. The research hypotheses are as follows:

$H_1$. As in Rossi's (1990) replication of Cohen's study, a slight increase in statistical power is anticipated.

$H_2$. In respect to the effect size findings, a medium effect size is anticipated. The medium effect size described by Cohen (1992) with the intentions that it would be "visible to the naked eye of a careful observer."

$H_3$. Low statistical power and infrequent reporting of effect size measures will be prevalent.

## Study One:
## Assessing the Statistical Power
## Of Three Psychological Journals

Cohen's (1962) original power survey has set the guidelines for the procedures used in statistical power surveys. His original systematic approach involved surveying all of the articles published in Journal of Abnormal and Social Psychology for the year 1960. He only included articles in which statistical tests were conducted and tests which examined the primary hypotheses. Rossi's (1990) follow-up power survey mimicked Cohen's procedure and analyzed all of the articles published in the Journal of

Abnormal Psychology, 1982, vol. 91; the Journal of Consulting and Clinical Psychology, 1982, vol. 50; and the Journal of Personality and Social Psychology, 1982, vol. 42. Both power surveys had difficulty determining the power of all the potential articles. Some articles did not report one or more of the required factors to calculate power (sample size, alpha level, and effect size). (Additional information considering the required elements for calculating statistical power by statistical analysis choice is presented in table 4.1).

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Insert Table 4.1 here

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Method

Selection of Articles: All articles published in the Journal of Consulting and Clinical Psychology, 2000, vol. 68, the Journal of Personality and Social Psychology, 2000, vol. 78, and the Journal of Abnormal Psychology, 2000, vol. 109 were eligible for inclusion.

Articles were included in the analyses if:

1. Statistical tests were reported
2. Power can be calculated for the statistical tests that were reported.

Selection of Statistical tests: In agreement with previously run power surveys, a distinction was made between major and peripheral statistical tests. In this research study, major tests examine the research hypotheses of the study. Peripheral tests will examine research questions that are not the main hypotheses of the study.

Calculating Statistical Power: The PASS software (NCSS: 2001) will be used to determine power level in conjunction with power programs developed by Rossi (1990).

The following decision rules were employed:

1. Where a between-subjects design was utilized and subsamples sizes were not available, the subsamples were treated as equal. By assuming equal subsamples, maximum power was given for the research design.
2. Two-tailed tests with an alpha level of .05 were assumed for all tests.
3. Where a within-subjects design was employed in t-tests and ANOVA, the correlation was assumed to be .5 as recommended by Cohen (1988) and Lipsey (1990).
4. When ANCOVA was used, the correlation was assumed to be .5 as recommended by Cohen (1988) and Lipsey (1990).
5. Statistical tests in which many assumptions were to be made and little research evidence supporting these assumptions were excluded (i.e. survival analysis, path analysis, logistic regression, hierarchical linear modeling, etc.). Table 4.2 presents the

frequencies of all statistical tests (as described by the researchers themselves) utilized to address primary hypotheses.

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Insert Table 4.2 here

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6. For methods in which small, medium, and large effect sizes have not been operationally defined, power will be calculated but not included in general results (i.e., logistic regression: small, medium, and large effect size values for the odds ratio have not be published).

Results

Description of Articles

A pool of 287 potential articles were examined for inclusion in the study (75 in the Journal of Personality and Social Psychology; JPSP, 119 in the Journal of Consulting and Clinical Psychology; JCCP, and 93 in the Journal of Abnormal Psychology; JAP). A total of 157 articles were included in the statistical power survey examining small, medium, and large effect sizes. An additional 21 articles were examined for the power of the structural equation models and meta-analytic surveys presented. A total of 10 articles did not report statistics at all (3 in JPSP and 7 in JCCP), and 99 contained statistics for the primary hypothesis for which power was not determined (i.e. factor analysis, logistic regression, hierarchical linear modeling). Table 4.3 presents a description of the articles included in the assessment of small, medium, and large effect sizes.

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Insert Table 4.3 here

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Assessing Small, Medium, and Large

Statistical power was calculated for the remaining 157 articles (45 in JPSP, 57 in JCCP, and 55 in JAP). The total number of statistical tests for which power was calculated for was 2,747 with a total of 22,705 power calculations (power was calculated for effects beyond the normal small, medium, and large effect sizes). The frequency of the statistical tests included in the statistical power survey are presented in table 4.4. Due to the limitation of current statistical power survey techniques, the sample is dominated by "traditional" statistical tests such as the t-test, Pearson's correlation, and the ANOVA.

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Insert Table 4.4 here

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Because the number of statistical tests included in an article varied greatly (from zero to over 100), the article was used as the unit of analysis. This equalized all articles and allowed them all to contribute equally to the power survey results. The determination for small, medium, and large was assessed by averaging across statistical tests (for which small, medium, and large was available). Statistical power for small, medium, and large effects was calculated using both Cohen's (1962) original estimates and his later (1977) definitions.

Comparing Cohen '62, Rossi '90, and the Current Study

Statistical power estimates for the 1962 definitions are presented in table 4.5. A slight increase in statistical power can be noted across all three levels. Each increase is statistically significant, small: $F$ (2, 445) = 6.681, $p<$ .01, two-tailed, $\eta^2 = .029$, medium: $F$ (2, 445) = 16.067, $p<$ .01, two-tailed, $\eta^2 =$ .067, and large: $F$ (2, 445) = 5.731, $p<$ .01, two-tailed, $\eta^2 = .025$. Follow-up t-test results are reported in table 4.6 and show significant changes in medium effects across the three studies. Statistical power is not statistically different for small and large effects between the 1990 study and the current study. Table 4.7 compares the percent of studies with statistical power less than .50 and .80 in the 1990 study and the current study.

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Insert Tables 4.5, 4.6, & 4.7 here

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Statistical power estimates for the 1977 definitions are presented in table 4.8. A slight increase in statistical power can be noted across all three levels of effect size. Each increase is statistically significant, small: $t$ (376) = 3.303, $p<$ .01, two-tailed, $\eta^2 = .028$, medium: $t$ (376) = 3.768, $p<$ .01, two-tailed,

$\eta^2 = .036$, and large: $t\ (376) = 3.883$, $p < .01$, two-tailed, $\eta^2 = .038$. Table 4.9 compares the statistical power of the three journals using the 1962 and 1977 effect size definitions. Table 4.10 and figures 4.1 to figure 4.7 present the average power for a variety of effect size levels by statistical test. The figures and table show a rapid increase in observed power for some statistics and a slow increase for other statistics.

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Insert Tables 4.8, 4.9, 4.10, & Figures 4.1 through 4.7 here

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Results of SEM and meta-analysis power

Of the 71 structural equation models presented in the articles, 70 reported the required information for computing statistical power. Power was estimated for exact, close, and loose fitting models (RMSEAs of .05, .075, and .10 respectively). Power was determined to be .055 for exact fitting models, .518 for close fitting models, and .697 for loose fitting models. Of the 5 meta-analytic surveys, none of the surveys provided sufficient information for the calculation of power.

## Discussion

As the aforementioned tables exhibit, statistical power has continued to increase slightly from Cohen's (1962) original survey and Rossi's (1990) follow up survey. While the change is statistically significant, is it meaningful? The effect sizes are fairly small (eta-squared around .03). The statistical power of for small effects on the whole is poor (mean = .206) while the average power for large effects (mean = .884) is sufficient. While the power for medium effects is increasing, it is still not sufficient. Currently, it appears that research on average has about a 65% chance of detecting a medium effect. In Cohen's study, he noted that with respect to medium effect sizes, 57% of all studies had a power of .50. Rossi noted that 38% of studies in his survey had power less than .50. In the current study, the number continues to drop (32.5%). At the current rate, it will take close to 120 years for all studies to have sufficient statistical power to detect medium effects.

Cohen (1988) recommended a statistical power level of .80 (or 80% of the time correctly rejecting a false null). Current research designs are only sufficient in approaching this suggestion when examining large effect sizes. Unfortunately, once again these findings are not encouraging for psychological scientists. Researchers seem to still be failing in terms of statistical power.

Most power surveys are based on Cohen's notion that the medium effect size is most prevalent in psychological research. The next study examines the effect sizes of the previously mentioned articles.

## Study Two:
## Assessing the Effects Size Measures
## Of Three Psychological Journals

While statistical power surveys are easily accessible, surveys of effect sizes are difficult to uncover. In the previous chapters, effect size surveys have been noted. Each survey examined the average effect size for a journal or topic area. The current survey is designed to assess the average effect size indices for a variety of measures. To be included for examination are: eta-squared, Cohen's *d*, *r* (when reported as an effect size measure), *r*-squared, and odds ratios.

## Method

Selection of Articles: All articles published in the Journal of Consulting and Clinical Psychology, 2000, vol. 68, the Journal of Personality and Social Psychology, 2000, vol. 78, and the Journal of Abnormal Psychology, 2000, vol. 109 were eligible for inclusion.

Calculating Effect Size : The PASS software (NCSS: 2001) will be used to determine effect size in conjunction with power programs developed by Rossi (1988, 1990). Additional calculations will be done by hand using the following formulas (in addition to the formulas noted in previous chapters):

For the one-way ANOVA:

$$\eta^2 = (k\text{-}1)F/((k\text{-}1)F + \text{N} - k) \quad (4.1)$$

where k is the number of groups. For the t-test:

$$\eta^2 = t^2/(t^2 + \text{df}) \quad (4.2)$$

where df is the degrees of freedom. For factorial designs:

(4.3) $$\eta^2 = SS_{effect}/SS_{total}$$

Articles will be included in the analyses if:

1. Statistical tests were reported
2. Effect Size can be calculated for the statistical tests that were reported

Selection of Statistical tests: A distinction was made between major and peripheral statistical tests. In this research study, major tests examine the research hypotheses of the study. Peripheral tests will examine research questions that are not the main hypotheses of the study. Only effect sizes for major tests will be examined.

The following decision rules were employed:

1. When sufficient information was not reported (i.e. no means, no standard deviation, F test result, t test result), effect size measure was not calculated.
2. When effect size measures were reported, values for major tests were recorded.
3. For statistical tests in which widely accepted effect size measures are not available, effect size will not be calculated (i.e. SEM).

## Results

### Description of Articles

A pool of 287 potential articles were examined for inclusion in the study (75 in the Journal of Personality and Social Psychology; JPSP, 119 in the Journal of Consulting and Clinical Psychology; JCCP, and 93 in the

Journal of Abnormal Psychology; JAP). A total of 103 articles were included in the examination of effect sizes (23 in JPSP; 42 in JCCP; 38 in JAP). Articles were excluded if the statistical tests did not lend themselves to effect size calculation or sufficient information was not present. Because the number of statistical tests included in an article varied greatly (from zero to over 100), the article was used as the unit of analysis. This equalized all articles and allowed them all to contribute equally to the effect size survey results.

Effect Size Survey Results

A total of 42 articles either presented information concerning eta-squared or provided information in which enabled calculation of the measure. A total of 1,661 effect size measures were examined. A mean effect size of .194 and a median of .145 were determined for eta-squared. Of the studies that reported r-squared, a mean effect size of .259 and a median of .120 was discovered. Of the articles which utilized r as an effect size measure, .343 was the mean and .325 was the median. Researchers who calculated an odds ratio had 3.21 and 1.67 for their mean and median respectively. In the articles utilizing Cohen's d for their effect size measure, the mean was .672 and the median was .476. Table 4.11 presents a summary of the effect size findings.

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Insert Table 4.11 here

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## Discussion

The results of the effect size survey are encouraging. While no definition of a small, medium, and large effect exists for the odds ratio, Cohen (1988) did offer definitions for Cohen's *d*, Pearson's r, and eta-squared. It seems that on average a medium to large effect is prevalent in the research (when examining the mean and medium effect size).

These findings need to be interpreted with caution. Currently the APA (2001) only suggests reporting effect sizes for statistically significant findings. This suggestion in itself biases the reporting of effect sizes. Of the entire selection of articles examined that reported effect sizes, effect sizes were not reported for statistical tests which were not significant. On the whole, even when effect size measures were reported, they were not interpreted in terms of the research being examined.

## General Discussion

The statistical power survey exhibited that the statistical power of current psychological research is slowly increasing while the effect size survey confirmed Cohen's (1988) previous assertion that the most prevalent effect size in psychology is the medium effect size. The disappointing finding of the power survey is that the majority of psychological research still has insufficient statistical power to assess the magnitude of effects that they are examining.

In an effort to assess whether the fault of the use of statistical power lay with the current introduction to statistics textbooks, a quick examination of 11 textbooks published from 1999-2001 was run. Each textbook was examined by reading the hypothesis testing sections and checking the index for references on statistical power and effect size measures. Almost half of the textbooks (5 out of 11) address statistical power. Additional textbooks addressed statistical power by only giving the definition and the chart used in chapter 1. Surprisingly, only a few textbooks discussed effect size measures with any substance (refer to table 4.12 for a summary).

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Insert Table 4.12 here

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It would seem that the field is at least moving towards the utilization of statistical power while effect size indexes are not getting as much attention. According the current study though, 30.7% of the studies examined reported using effect size measures while only 7% reported examining statistical power.

Suggestions for improvement

The analysis of advanced statistical methods such as logistic regression, HLM, SEM, and path analysis need to be addressed (especially when examining power surveys across topics). Statistical power survey methods need to be developed to examine longitudinal methods and other common statistical analysis techniques. The procedures of ANCOVA and repeated measures cannot be addressed across topic areas without causing detriment to some areas and benefiting others. It is difficult to make assumptions about these techniques that fit psychological research as a whole. Another suggestion for future statistical power surveys and effect size surveys would be to break down the articles by topic (e.g., PTSD, eating disorders, addiction).

After examining the data in the power survey and effect size survey, it seems evident that it is easiest for those who are running the analyses to compute statistical power and effect size indices. It is very hard for post publication calculation. To further psychological as a science, it is paramount that these calculations precede publication and are reported.

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Table 4.1

Required Information for Determining Power by Statistical Test

| Statistic | Required Elements | | | | | | |
|---|---|---|---|---|---|---|---|
| | *df* | $H_a$ | #IV | #DV | Corr | #Grp | Other |
| *Univariate* | | | | | | | |
| Nonparametric | | | | | | | |
| Chi-square | x | x | | | | | |
| Fisher's Exact Test | x | x | | | | | Prob. |
| t test | | | | | | | |
| Independent | | x | | | | | |
| Dependent | | x | | | | | |
| Correlation | | | | | | | |
| Bivariate/Part/Partial | | x | | | | | |
| Classical Regression | | | | | | | |
| Hierarchical | | x | x | x | | | |
| Stepwise | | x | x | x | | | |
| Specialized Regression | | | | | | | |
| HLM | | x | x | x | | | ICC |
| Logistic | | x | x | x | | | OR |
| ANOVA (ANCOVA) | | | | | | | |
| Oneway | x | x | | | | | |
| Factorial | x | x | | | | | |
| Repeated Measures | x | x | | | | | auto |
| *Multivariate* | | | | | | | |
| Factor Analysis | | | *Analysis not appropriate* | | | | |
| EFA/ CFA | | | *Analysis not appropriate* | | | | |
| Cluster Analysis | | | *Analysis not appropriate* | | | | |
| Multidimensional Scaling | | | *Analysis not appropriate* | | | | |
| MANOVA (MACOVA) | | | | | | | |
| Oneway | x | x | | x | | x | |
| Factorial | x | x | | x | | x | |
| Post hoc Univariate | x | x | | x | | x | |
| Repeated Measures | x | x | | x | x | x | |
| Discriminant Analysis | x | x | | x | | x | |
| Canonical R Analysis | x | x | x | x | | | |
| SEM | x | | | | | | |

Note: Alpha level, sample size, and effect size are a requirement for all of the aforementioned statistics. $H_a$ is the directional nature of the hypotheses (one- versus two-tailed).

Table 4.2
Frequencies of Statistics in Potential Articles for Power and Effect Size

Survey

| Statistic | Frequency | JPSP | JCCP | JAP |
|---|---|---|---|---|
| **ANOVA** | | | | |
| One-way | 58 | 17 | 19 | 22 |
| 2-way | 5 | 2 | 3 | 0 |
| 2-way, repeated measures | 4 | 2 | 2 | 0 |
| 3-Way | 4 | 0 | 2 | 2 |
| Between-within | 1 | 1 | 0 | 0 |
| Factorial | 8 | 2 | 2 | 4 |
| Hierarchical | 1 | 0 | 0 | 1 |
| Meta-analytic | 2 | 1 | 1 | 0 |
| Mixed factorial | 3 | 1 | 1 | 1 |
| Mixed | 7 | 1 | 1 | 5 |
| Repeated measures | 33 | 9 | 9 | 15 |
| Simple Effects | 1 | 0 | 0 | 1 |
| Split Plot | 3 | 1 | 2 | 0 |
| **ANCOVA** | | | | |
| One-way | 25 | 9 | 12 | 4 |
| 3-way | 1 | 1 | 0 | 0 |
| repeated measures | 10 | 4 | 3 | 3 |
| **Bootstraping** | 2 | 1 | 1 | 0 |
| **Box Test** | 1 | 0 | 1 | 0 |
| **Chi-square** | 39 | 13 | 13 | 13 |
| **Cluster Analysis** | 2 | 1 | 1 | 0 |
| Hierarchical | 3 | 1 | 1 | 1 |
| **Confirmatory Factor Analysis** | 5 | 2 | 2 | 1 |
| **Correlation** | 54 | 17 | 17 | 20 |
| polychoric | 2 | 0 | 1 | 1 |
| **Cost Analysis** | 2 | 1 | 1 | 0 |
| **Cox Proportional Hazard Model** | 5 | 2 | 2 | 1 |
| **Cross Lagged Panel** | 2 | 0 | 0 | 2 |
| **Descriptives** | 11 | 7 | 4 | 0 |
| **DFA** | 5 | 1 | 1 | 3 |
| **Factor Analysis** | 8 | 3 | 3 | 2 |
| **Fisher's Exact Probability** | 7 | 3 | 3 | 1 |
| **Fisher's Exact Z Transformation** | 2 | 1 | 1 | 0 |
| **GEE** | 1 | 0 | 0 | 1 |
| **Growth Curve Analysis** | 2 | 1 | 1 | 0 |
| **Hierarchical Linear Modeling** | 7 | 2 | 2 | 3 |

| | | | | |
|---|---|---|---|---|
| **Hierarchical Multiple Linear Regression** | 1 | 0 | 1 | 0 |
| **Hierarchical Regression** | 4 | 0 | 1 | 3 |
| **HITMAX** | 1 | 1 | 0 | 0 |
| **Hosmer-Lemeshow** | 1 | 0 | 0 | 1 |
| **Item Response Theory** | 1 | 1 | 0 | 0 |
| **K-group split plot multivariate analysis** | 2 | 0 | 2 | 0 |
| **Kruskal-Wallis** | 2 | 0 | 1 | 1 |
| **Linear Regression** | | | | |
| Standard | 1 | 0 | 0 | 1 |
| Hierarchical | 3 | 0 | 0 | 3 |
| **Log Linear** | 1 | 1 | 0 | 0 |
| **Logistic Regression** | | | | |
| Standard | 20 | 0 | 12 | 8 |
| Hierarchical | 3 | 0 | 3 | 0 |
| Ordinal | 1 | 0 | 0 | 1 |
| Polytomous | 1 | 0 | 1 | 0 |
| Stepwise | 1 | 0 | 1 | 0 |
| **Longitudinal Modeling** (mixed) | 2 | 0 | 1 | 1 |
| **Longitudinal Random Regression** | 1 | 0 | 1 | 0 |
| **MAMBAC** | 1 | 0 | 0 | 1 |
| **Mann Whitney U** | 1 | 0 | 0 | 1 |
| **MANOVA** | | | | |
| One-way | 12 | 1 | 7 | 4 |
| Mixed model | 3 | 1 | 1 | 1 |
| Repeated measures | 5 | 1 | 3 | 1 |
| Within subjects | 1 | 0 | 1 | 0 |
| **MANCOVA** | 2 | 0 | 2 | 0 |
| **MAXCOV** | 2 | 0 | 0 | 2 |
| **Mediational Analysis** | 8 | 3 | 4 | 1 |
| **Meta-analysis** | 5 | 2 | 3 | 0 |
| **Mixture Analysis** | 1 | 0 | 1 | 0 |
| **Multi Level Regression** | 1 | 0 | 0 | 1 |
| **Multidimensional Scaling** | 1 | 0 | 1 | 0 |
| **Multiple Regression** | | | | |
| Standard | 14 | 5 | 5 | 4 |
| Hierarchical | 10 | 1 | 6 | 3 |
| Stepwise | 3 | 0 | 2 | 1 |
| with Covariates | 1 | 0 | 1 | 0 |
| **Networks** | 1 | 0 | 1 | 0 |
| **Odds Ratio** | 2 | 0 | 2 | 0 |

| | | | | |
|---|---|---|---|---|
| **Path Analysis** | 8 | 4 | 3 | 1 |
| **Poisson Sampling Model** | 1 | 0 | 1 | 0 |
| **Principal Component Analysis** | 2 | 1 | 1 | 0 |
| **Profile Analysis** | 1 | 0 | 1 | 0 |
| **Proportional Hazards Analysis** | 1 | 0 | 0 | 1 |
| **Proportions** | 1 | 0 | 0 | 1 |
| **Random Coefficient Analysis** | 1 | 0 | 1 | 0 |
| **Receiver Operating Characteristic** | 1 | 0 | 1 | 0 |
| **Regression** | | | | |
| Regression | 9 | 1 | 7 | 1 |
| Moderated | 1 | 1 | 0 | 0 |
| Random Effects | 2 | 0 | 2 | 0 |
| Stepwise | 1 | 0 | 0 | 1 |
| **Reliable Change Index** | 1 | 0 | 1 | 0 |
| **ROC Analysis** | 1 | 0 | 1 | 0 |
| **Rom's Procedure** | 1 | 1 | 0 | 0 |
| **SEM** | 15 | 5 | 6 | 4 |
| **Survival Analysis** | 8 | 0 | 6 | 2 |
| **Taxometric** | 3 | 1 | 0 | 2 |
| **Trend Analysis** | 1 | 0 | 0 | 1 |
| **Trimmed Means** | 1 | 1 | 0 | 0 |
| **t-test** | 45 | 19 | 14 | 12 |
| **Yule's Y** | 1 | 0 | 1 | 0 |
| **z-score** | 1 | 0 | 0 | 1 |

Table 4.3

Description of Articles Included in Current Study

| | JPSP | JCCP | JAP | Total |
|---|---|---|---|---|
| **First Author** | | | | |
| Female | 13 (28.9) | 23 (40.4) | 23 (40.0) | 58 |
| Male | 26 (57.8) | 33 (57.9) | 25 (45.5) | 84 |
| Unknown | 6 (13.3) | 1 (1.8) | 8 (15.1) | 15 |
| **Mean Number of Authors** | 2.89 | 4.33 | 4.00 | 3.80 |
| **Median Number of Authors** | 3.00 | 4.00 | 4.00 | 3.00 |
| **Median Sample Size** (across studies) | 296 | 92 | 81 | 146 |
| Females | 133 | 36 | 39 | 57 |
| Males | 102 | 27.5 | 30 | 40 |
| **Mean Number of Experiments** | 3.0 | 1.02 | 1.13 | 1.62 |
| **Median Number of Experiments** | 3 | 1 | 1 | 1 |
| **Grant Funded** | | | | |
| Yes | 32 (71.1) | 46 (80.7) | 42 (76.4) | 120 |
| No | 13 (28.9) | 11 (19.3) | 11 (20.0) | 35 |
| **Presented at a Conference** | | | | |
| Yes | 8 (17.8) | 5 (8.8) | 6 (10.9) | 19 |
| No | 37 (82.2) | 52 (91.2) | 47 (85.5) | 136 |
| **Student Thesis or Dissertation** | | | | |
| Yes | 4 (8.9) | 5 (8.8) | 8 (14.5) | 17 |
| No | 41 (91.1) | 52 (91.2) | 45 (81.8) | 138 |
| **Used Alpha Correction Methods** | | | | |
| Yes | 1 (2.2) | 9 (15.8) | 7 (12.7) | 17 |
| No | 44 (97.8) | 47 (82.5) | 48 (87.3) | 139 |
| **Number of Articles without CI** | 44 (97.8) | 53 (93.0) | 50 (90.9) | 147 |
| **Number of Articles mentioning Power** | 1 (2.2) | 1 (1.8) | 4 (7.7) | 6 |
| **Calculated Effect Size** | | | | |
| Yes | 11 (24.4) | 23 (40.4) | 16 (29.1) | 50 |
| No | 34 (75.6) | 33 (57.9) | 39 (70.9) | 106 |
| **Number of Brief Reports** | 0 | 10 (17.5) | 12 (21.8) | 22 |

Note: Percentages in the parentheses.

Table 4.4

Frequency Distribution of Statistical Tests included in Power Survey

| Statistical Test | Frequency | Proportion |
| --- | --- | --- |
| Pearson Correlation | 1429 | .520 |
| ANOVA | 753 | .274 |
| t-test | 250 | .091 |
| ANCOVA | 120 | .043 |
| Chi-square | 87 | .031 |
| Multiple Regression | 56 | .020 |
| MANOVA | 52 | .018 |

Table 4.5

Average Power of Current Study in Comparison to Rossi (1990) and Cohen (1962) Based on the 1962 Effect Size Definitions

| Effect Size | Mean | SD | Median |
|---|---|---|---|
| 2002 Study (n=157) | | | |
| Small '62 | .278 | .238 | .186 |
| Medium '62 | .678 | .263 | .725 |
| Large '62 | .897 | .144 | .970 |
| Rossi (1990) (n=221) | | | |
| Small '62 | .240 | .171 | .184 |
| Medium '62 | .590 | .251 | .582 |
| Large '62 | .893 | .131 | .958 |
| Cohen (1962) (n=70) | | | |
| Small '62 | .18 | .08 | .17 |
| Medium '62 | .48 | .20 | .46 |
| Large '62 | .83 | .16 | .89 |

Table 4.6

Follow-up t-test Results Comparing the Current Study, Rossi (1990), and Cohen (1962)

| | Studies being compared | | Mean Difference | *t*-value | *p*<.05? |
|---|---|---|---|---|---|
| **Small Effect** | 2002 | 1990 | .038 | 1.807 | No |
| | | 1962 | .098 | 3.358 | Yes |
| | 1990 | 2002 | -.038 | 1.807 | No |
| | | 1962 | .060 | 2.836 | Yes |
| **Medium Effect** | 2002 | 1990 | .088 | 3.293 | Yes |
| | | 1962 | .198 | 5.614 | Yes |
| | 1990 | 2002 | -.088 | 3.293 | Yes |
| | | 1962 | .110 | 3.344 | Yes |
| **Large Effect** | 2002 | 1990 | .004 | .280 | No |
| | | 1962 | .067 | 3.217 | Yes |
| | 1990 | 2002 | -.004 | .280 | No |
| | | 1962 | .063 | 3.317 | Yes |

Table 4.7

Percentage of Studies with Power <.50 and <.80

| | Current Study | | 1990 Study | |
|---|---|---|---|---|
| Effect Size | <.50 | <.80 | <.50 | <.80 |
| Small | 91.1 | 96.2 | 98 | 99 |
| Medium | 32.5 | 68.2 | 46 | 84 |
| Large | 3.2 | 22.3 | 8 | 36 |

Table 4.8

Average Power of Current Study Compared to Rossi (1990) using 1977 Definitions

| Effect Size | Mean | SD | Median |
|---|---|---|---|
| 2002 Study (n=157) | | | |
| Small '77 | .206 | .194 | .139 |
| Medium '77 | .646 | .253 | .663 |
| Large '77 | .884 | .152 | .962 |
| Rossi (1990) (n=221) | | | |
| Small '77 | .153 | .117 | .121 |
| Medium '77 | .549 | .242 | .516 |
| Large '77 | .814 | .186 | .883 |

Table 4.9

Power and Effect Size Estimations by Journal

| | | Journal | | | |
|---|---|---|---|---|---|
| | | JPSP | JCCP | JAP | Total |
| **Power** | | | | | |
| Small '77 | Mean | .172 | .232 | .207 | .206 |
| | Median | .150 | .140 | .120 | .139 |
| | SD | .121 | .207 | .228 | .195 |
| Medium '77 | Mean | .626 | .686 | .620 | .646 |
| | Median | .654 | .709 | .600 | .663 |
| | SD | .221 | .263 | .266 | .253 |
| Large '77 | Mean | .885 | .897 | .869 | .884 |
| | Median | .950 | .970 | .955 | .962 |
| | SD | .129 | .160 | .162 | .152 |
| Small '62 | Mean | .261 | .300 | .270 | .278 |
| | Median | .176 | .235 | .180 | .186 |
| | SD | .207 | .257 | .244 | .238 |
| Medium '62 | Mean | .659 | .714 | .658 | .678 |
| | Median | .710 | .810 | .708 | .725 |
| | SD | .241 | .269 | .274 | .263 |
| Large '62 | Mean | .902 | .903 | .886 | .897 |
| | Median | .966 | .987 | .959 | .970 |
| | SD | .115 | .159 | .151 | .144 |
| **Effect Size** | | | | | |
| Eta-Squared | Mean | .195 | .220 | .181 | .194 |
| | Median | .192 | .179 | .142 | .154 |
| | SD | .121 | .167 | .154 | .147 |
| Odds Ratio | Mean | | 2.831 | 6.268 | 3.213 |
| | Median | | 2.209 | 6.268 | 2.209 |
| | SD | | 1.767 | 8.553 | 2.879 |
| R-squared | Mean | .274 | .242 | .261 | .259 |
| | Median | .273 | .150 | .247 | .176 |
| | SD | .229 | .193 | .210 | .204 |

Table 4.10

Average Power by Statistical Test

| | | Effect Size | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t-test | d= | **0.1** | **0.2** | **0.25** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** | **1.0** |
| | | .08 | .18 | .24 | .31 | .44 | .56 | .66 | .75 | .81 | .87 | .91 |
| ANOVA | f= | **0.1** | **0.125** | **0.2** | **0.25** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** |
| | | .14 | .20 | .40 | .54 | .68 | .85 | .94 | .97 | .98 | .99 | .99 |
| ANCOVA | f= | **0.1** | **0.125** | **0.2** | **0.25** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | |
| | | .18 | .26 | .55 | .73 | .84 | .95 | .98 | .99 | .99 | .99 | |
| Correlation | r= | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** | **0.6** | | | | | |
| | | .27 | .61 | .83 | .94 | .98 | .99 | | | | | |
| Multiple Regression | $R^2$= | **0** | **0.02** | **0.1** | **0.15** | **0.2** | **0.25** | **0.3** | **0.35** | **0.4** | | |
| | | .15 | .36 | .72 | .81 | .87 | .91 | .94 | .95 | .97 | | |
| Chi-square | w= | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** | **1.0** | |
| | | .47 | .66 | .81 | .91 | .97 | .99 | .99 | .99 | .99 | .99 | |
| MANOVA | $R^2$= | **0.02** | **0.05** | **0.1** | **0.15** | **0.2** | **0.25** | **0.3** | **0.35** | **0.4** | | |
| | | .54 | .81 | .91 | .93 | .93 | .94 | .94 | .94 | .94 | | |

Table 4.11

Description of the Average Effect Sizes in the 2002 Study

| | Effect Size Measure | | | | |
|---|---|---|---|---|---|
| | $\eta^2$ | $R^2$ | r | Odds Ratio | Cohen's d |
| Mean | .194 | .259 | .343 | 3.21 | .672 |
| Median | .145 | .120 | .325 | 1.67 | .476 |
| SD | .205 | .201 | .248 | 6.289 | .549 |
| Minimum | 0 | 0 | -.73 | 0 | -1.49 |
| Maximum | 1.02 | .944 | .89 | 55.38 | 3.88 |
| Percentiles | | | | | |
| 25th | .00933 | .00798 | .165 | 1.423 | .306 |
| 50th | .145 | .120 | .325 | 1.67 | .476 |
| 75th | .290 | .443 | .460 | 4.015 | .907 |
| 80th | .312 | .524 | .606 | 4.998 | .929 |
| Number of Studies | 42 | 30 | 7 | 18 | 18 |
| Number of Tests | 416 | 322 | 112 | 404 | 407 |

Table 4.12

Survey of Introduction to Statistic Textbooks published in the 2000 and the Coverage of Power and Effect Size Measures

| Textbook | Publisher | Power | Effect Size |
|---|---|---|---|
| Applied Statistics for the Behavioral Sciences | Houghton Mifflin | Yes | Yes |
| Essentials of Statistics | Brooks/Cole | No | No |
| Everyday Statistical Reasoning | Wadsworth | No | No |
| Statistical Analysis | Radius Press | Briefly | No |
| Statistics and Data Analysis | McGraw Hill | Yes | Yes |
| Statistics For People who (think they) Hate Statistics | Sage | Briefly | No |
| Statistics for the Behavioral and Social Sciences | Prentice Hall | Yes | Yes |
| Statistics for the Behavioral Sciences | Wadsworth | Yes | No |
| Statistics with Confidence | Sage | Yes | Yes |
| Student Friendly Statistics | Prentice Hall | Briefly | No |
| The Cartoon Guide to Statistics | Harper Perennial | Briefly | No |

Figure 4.1

Power curve for t test statistics included in the present study

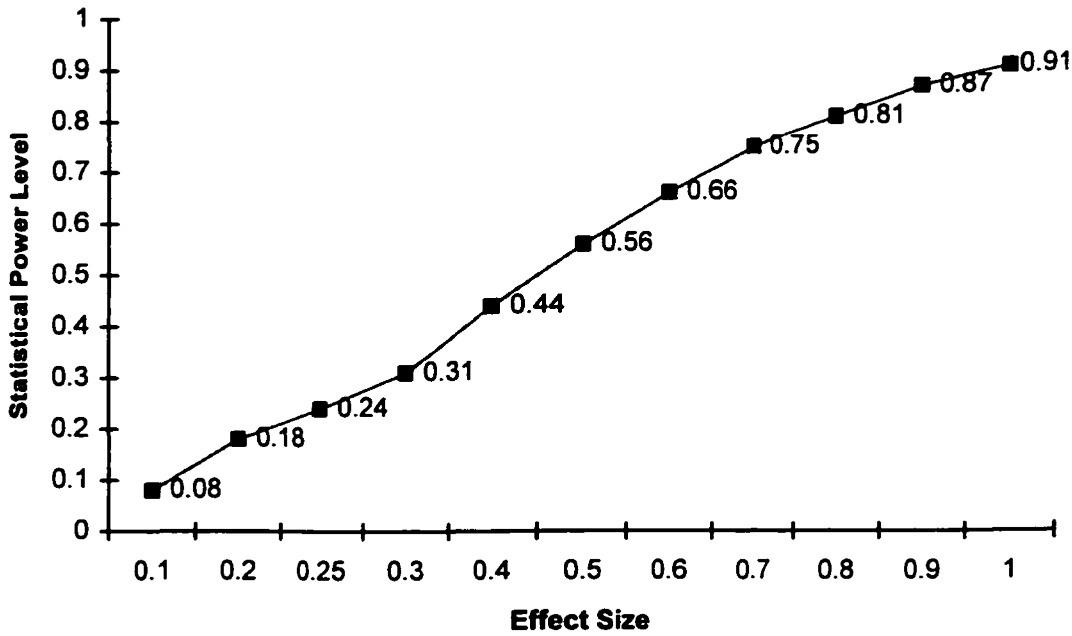


Figure 4.2

Power curve for ANOVA statistics included in the present study

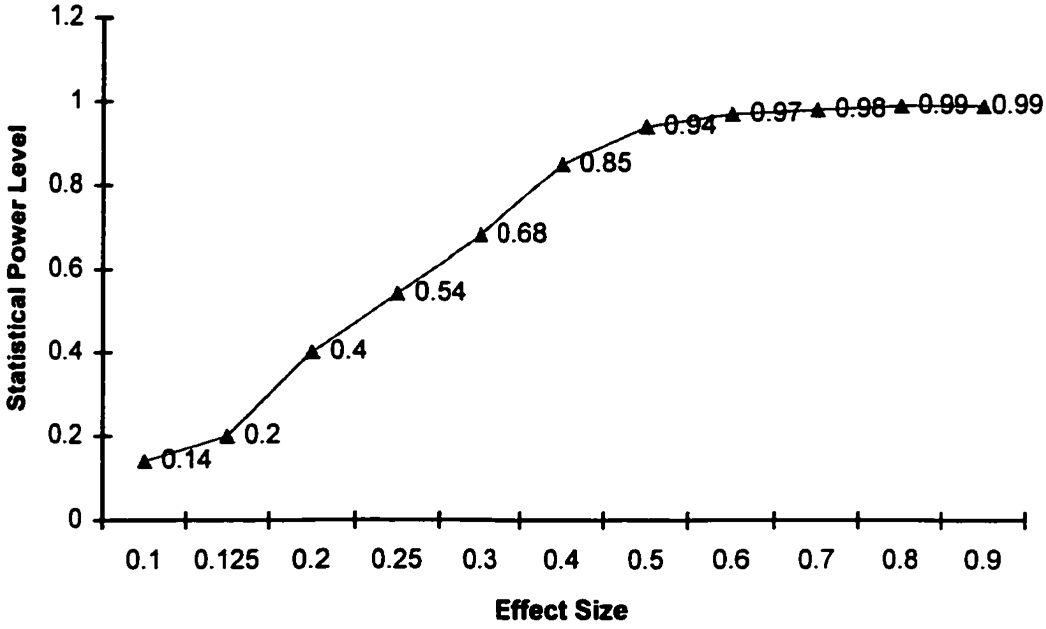


Figure 4.3

Power curve for ANCOVA statistics included in the present study

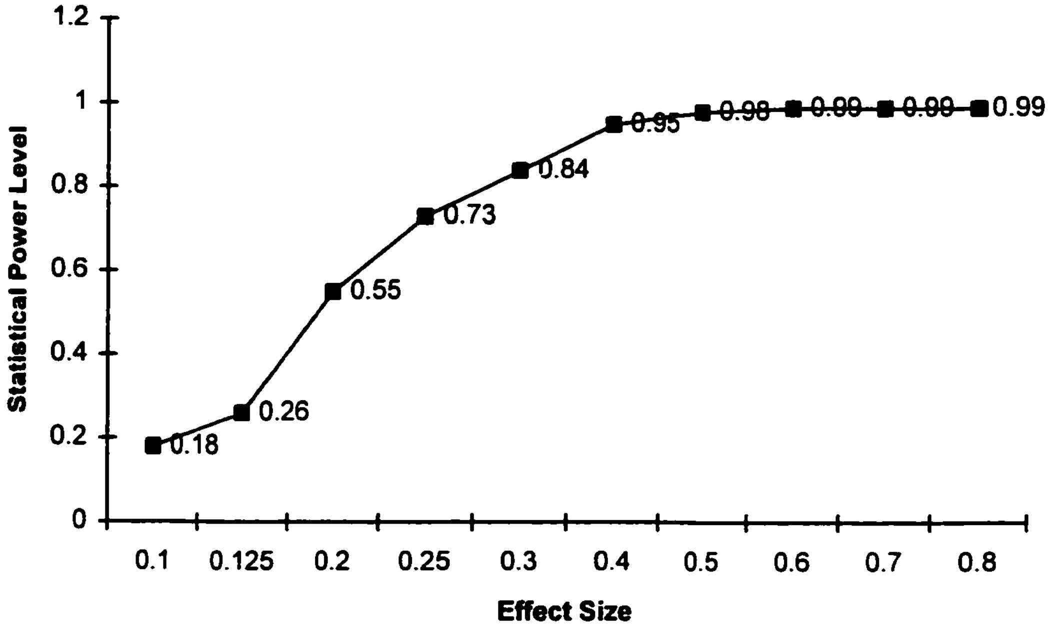


Figure 4.4

Power curve for correlation statistics included in the present study

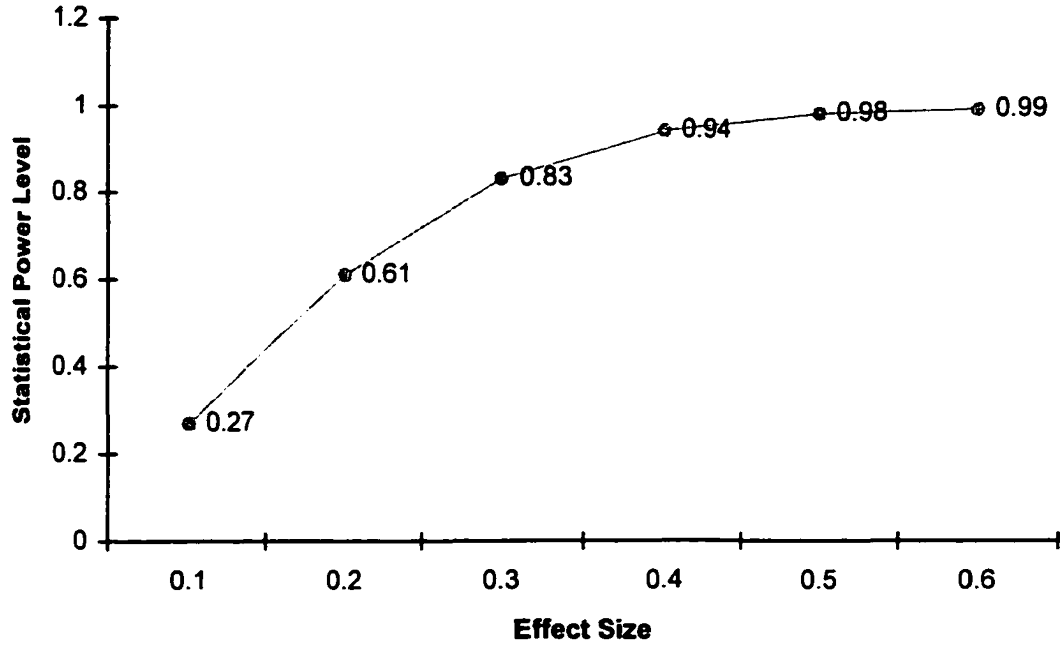


Figure 4.5

Power curve for multiple regression statistics included in the present study

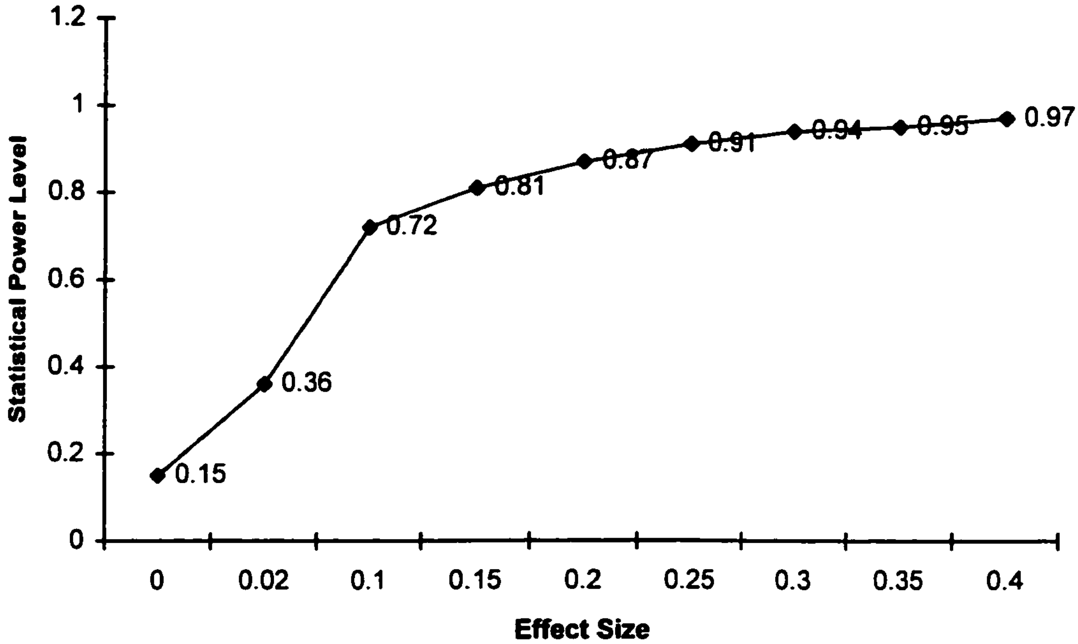


Figure 4.6

Power curve for chi-square statistics included in the present study

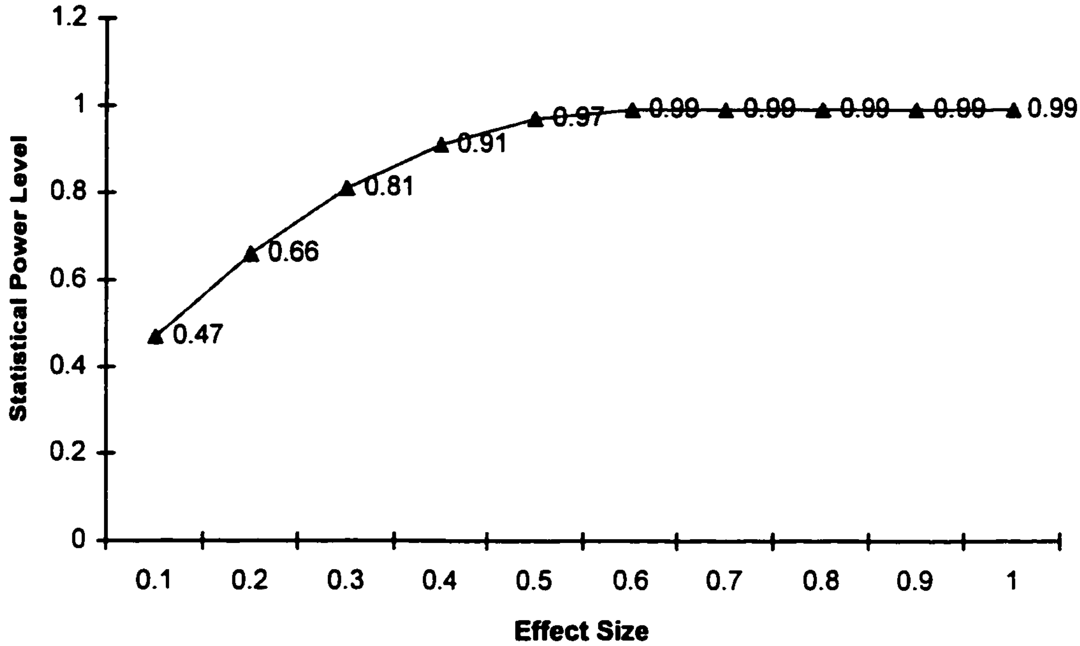
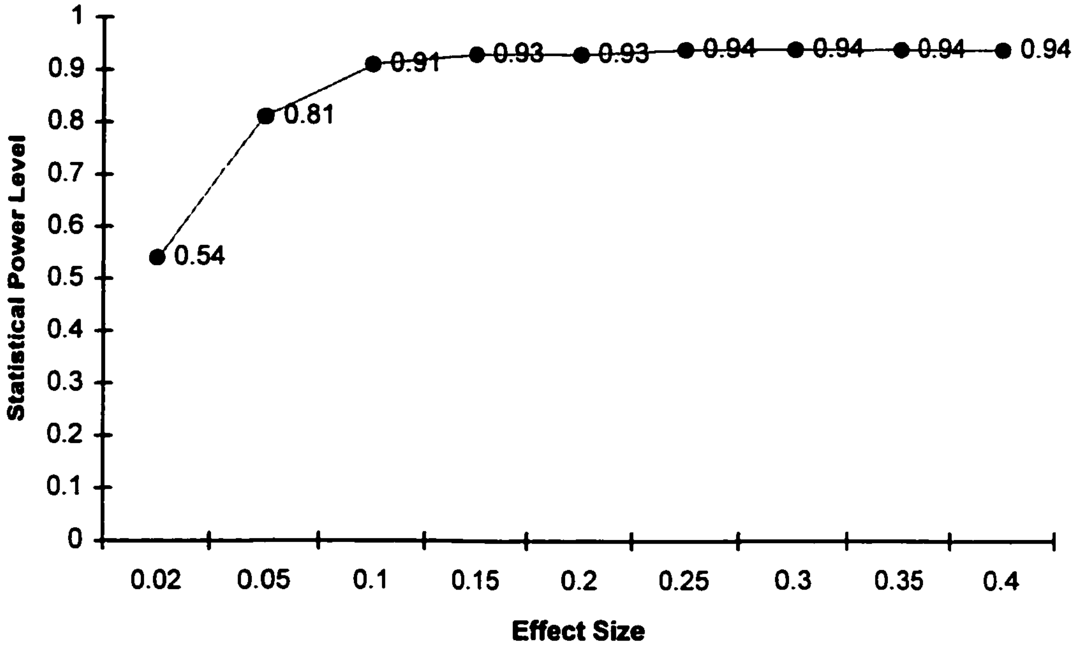


Figure 4.7

Power curve for MANOVA statistics included in the present study



*Where is the wisdom we have lost in knowledge?*
*Where is the knowledge we have lost in information?*
*T. S. Eliot (1888 - 1965)*

# Chapter 5:

## Summary of Findings

Statistical power analysis and effect size indices have been formulated in the past, applied in the current literature (on a limited basis), and will continue to evolve in future literature and research practices. While the practices of the past are being used in the current literature, for the both techniques to evolve to the next level, researchers need to conceptualize and utilize these techniques differently.

### Foundations of Statistical Power and Effect Size

Statistical power and effect size indices have a fairly short history. Both have evolved from their earlier forms to the current status of complementing null hypothesis significance testing practices. Statistical power is an extension of Neyman and Pearson's (1928a, 1928b, 1933a, 1933b) initial work in the area of significance testing. Some initial effect size indices predate Neyman and Pearson's work, for example Yule's (1900) work examining how different populations are or the magnitude of differences.

The pioneer in terms of statistical power in current psychological research is Jacob Cohen (1962, 1988). His initial statistical power survey set the guidelines for future surveys. Cohen (1962) established that power would be calculated with respect to three effect sizes (small, medium, and large), with respect to an alpha level of .05, assuming a two-tailed test, for statistical tests that are central to the primary hypotheses, and for statistical tests in which statistical power techniques are available. Cohen also established that the article would be the unit of analysis because some articles had multiple statistical tests while others had only a few tests.

Many researchers followed in Cohen's steps and surveyed psychological, communication, marketing, and many other types of journals to assess the statistical power in those fields. Other researchers extended Cohen's research and examined the statistical power of a specific research interest (i.e. research on the Rorschach, and research on psychotherapy treatment homework). These statistical power surveys were focused on the research interest and able to cross a spectrum of research journals.

Effect size research has not followed in the same path. Fewer researchers are concerned with surveying the literature to determine the status of effect sizes. Most researchers accept Cohen's initial recommendations for "small," "medium," and "large" effect sizes with out question while Cohen admitted that his definitions were based on his own experiences—no research. The few effect size surveys available do not address Cohen's definition nor posit their own definitions for small, medium, and large. It might seem logical that small, medium, and large may differ by research area or research interest, yet the research to confirm this assertion is not available.

Changing the whole system

One suggestion to problems with current research practices is to remove significance testing entirely. Statistical power and effect size measures were developed to complement the null hypothesis significance testing (NHST) message. If NHST was to be disbanded, it is proper to assume that at least statistical power would cease to exist. In terms of NHST, statistical power is the ability to discover a significant effect when a significant effect is present. If researchers are no longer testing for significant effect, determining statistical power is, in essence, meaningless.

While statistical power would vanish, effect size indices could still complement research findings. Instead of reporting that groups or treatments are different, effect size measures would indicate how much of a difference is present. Effect size measures would not state if the differences were "statistically" different, but indicate how much the groups differed.

Even as the disbandment of NHST has been suggested, it has not be broadly accepted, nor enforced. Despite the controversy, statistical power and effect size practices continue to evolve. Currently, methods are available to calculate statistical power for a variety of statistical techniques (i.e. correlation, t-test, ANOVA, ANCOVA, MANOVA, and SEM) and to calculate a variety of effect size measures (i.e. eta-squared, omega-squared, intraclass correlation, odds ratio, epsilon-squared, etc.). A plethora of statistical packages are available to calculate both statistical power (i.e.

GPOWER, SAS, and PASS) and effect size indices (i.e. SAS, SPSS, and EXCEL).

However, researchers fail to utilize and interpret their findings with regards to statistical power and effect size measures. The statistical programs are available and accessible, yet researchers seem to ignore the APA's (Wilkinson, 1999) requests to report both statistical power and effect size measures. The current study discovered that about 28% of the studies reported effect size indices while even fewer reported calculating statistical power. Of the studies that did report effect size indices, the vast majority did not interpret them. It seems that the current status of both statistical power and effect size indices is that they are under utilized and not understood.

Future/limitations

Because the field is not evolving to incorporate statistical power in to their pre-study practices and reporting and interpreting effect size measures in their post experiment process, it seems that statistical power surveys and effect size surveys may need to adapt. Using the current methods, statistical power surveys do not seem to impact the field (Sedlmeier & Gigerenzer, 1989). A broad power survey which exams a variety of research topics seems to diffuse its impact. Future statistical power surveys may become oriented to specific topic areas instead of incorporating a spectrum of topics. By researching the statistical power in certain areas (i.e. Post Traumatic Stress

Disorder), psychology researchers may be able to determine which areas are in need of more statistical power.

Statistical power surveys will also have to adapt in terms of incorporating more advanced statistical analysis techniques. While advanced statistical analysis techniques are becoming more prevalent in the literature, only preliminary statistical power methods have been developed for these techniques. In order to complete a statistical power survey on these methods, the researcher must not only make assumptions about effect sizes, but also other variables that influence statistical power. For example, in logistic regression, the researcher would have to make estimates for small, medium, and large for the odds ratio (currently there are no published studies which establish values for this) and the r-squared between the independent variables. This results in not 3 estimated of statistical power as in traditional power surveys but a matrix of possible outcomes. The researcher could estimate 3 levels for the odds ratios (small, medium, and large) and 3 levels for the r-squared (small, medium, and large) resulting in 9 possible values for power.

Whereas statistical power techniques will have to become more advanced, effect size indices will have to become more accessible. Statistical analysis computer programs provide some effect size indices commonly (i.e. odds ratios for logistic regression), but do display other effect size indices by default (i.e. eta-squared). It seems that to increase the use of effect size measures, computer programs will have to report effect size indices by default.

However, generating the effect size indices is only half of the problem. As researchers have stated previously, when effect size indices are being reported, they are rarely being interpreted (Thompson, 1997a, 1997b, 1999, 2002). Journal editors can require that researchers report the indices, but it seems nearly impossible to dictate that they interpret them. Institutions of higher education need to start addressing this issue in the introduction to statistics classes, conferences need to provide seminars training researchers in this skill, and articles need to be written explaining the steps in understanding, interpreting, and reporting effect size indices.

Statistical power and effect size indices have evolved from their initial inception. As the field of psychology continues to progress, these techniques need to continue to advance and the field needs to increase their awareness and understanding of these techniques. These techniques complement the statistical messages that we are already providing in the literature. They provide the punctuation to our statistical sentences and increase other investigators' understanding of our research.

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Appendix A:

Potential Articles in Statistical Power Survey and Effect Size Survey

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Addis, M. E. & Krasnow, A. D. (2000). A national survey of practicing psychologists' attitudes toward psychotherapy treatment manuals. Journal of Consulting & Clinical Psychology, 68(2) 331-339.

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