Individual Differences Research and Hearing Aid Outcomes

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ABSTRACT

This article provides a brief overview of the individual differences approach to research. This approach is first compared with the more familiar group-based approach to research. Following this comparison, some of the procedural and statistical issues central to individual differences research are noted. Ultimately, individual differences research has the potential to be of the greatest benefit to practicing clinicians; professionals who always deal with individual patients rather than the “average” or “typical” patient.

KEYWORDS: Hearing aids, outcomes, individual differences

Learning Outcomes: As a result of this activity, the participant will (1) compare and contrast typical group-based research and individual differences research; and (2) describe the unique procedural and statistical analysis features of individual differences research.

Interest in individual differences has had a long history in various aspects of psychology, including the areas of mental or cognitive abilities (e.g., Galton¹,² and Thurstone³) and personality (e.g., Cattell⁴,⁵). There was a time when researchers in the field of psychology were strongly divided over the superiority of group-based or individual differences-based research approaches.⁶,⁷ Today, both approaches to research peacefully coexist, with the study of individual differences continuing to blossom and develop. Thirty years ago, for instance, the International Society of the Study of Individual Differences was founded to further encourage and promote this approach to research. Historically, individual differences research was focused initially on behavioral measures that could be useful in identifying various “traits” or “abilities” of individuals. Genetic factors were long recognized as contributors to individual differences in such abilities and contemporary advancements in genetics have only increased interest in this area. Further, there have been efforts throughout the history of individual differences research to tie such individual differences in abilities to underlying anatomical or

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physiological differences, with the most recent such efforts focusing on the use of functional magnetic resonance imaging to identify structures underlying various aspects of cognition (e.g., Kanai and Rees). An interesting recent development in individual differences has been to focus on the “microstructure” of individual within-subject variability, such as within a given block of trials in a behavioral experiment, as a potential predictor of cognitive status in older adults (e.g., Ram et al).

With regard to the identification and study of various auditory abilities, early pioneering work in this area was performed by Karlin and Carroll. More recently, colleagues at Indiana University (IU) have developed and evaluated a battery of auditory discrimination tests to tap various auditory abilities. The focus in all of these studies of auditory abilities has been primarily on young, healthy, normal-hearing adults.

Spurred on by the focus on individual differences in auditory abilities by colleagues, a series of studies was conducted at IU with older adults, many having hearing loss typical for their age. Initially, the focus was on the ability to understand speech without individually tailored amplification and the identification of cognitive and auditory abilities that might predict individual differences in speech understanding ability among older adults (e.g., Humes et al). Two observations emerged from these studies: (1) despite using a variety of speech understanding measures (speech materials, test conditions, etc.), moderate to strong correlations were typically observed across these measures; and (2) audiometrically measured hearing loss, especially the average hearing thresholds at 1,000, 2,000, and 4,000 Hz, repeatedly emerged as the best predictor of individual differences in unaided speech understanding ability among older adults.

Over the past decade or so, the focus of our research at IU has turned to individual differences in aided speech understanding among older adults. The focus of this research was threefold: (1) what should be measured as hearing aid outcomes; (2) when should the outcomes be measured; and (3) how can individual differences in hearing aid outcomes be explained in older adults? Although we measured a wide range of outcomes in an attempt to identify the dimensions or facets of hearing aid outcome in general (questions 1 and 2), the greatest success in identifying underlying predictive factors (question 3) emerged for the outcome dimension of aided speech understanding ability (e.g., Humes; Humes and Krull).

The application of individual differences research to audiology in general, and to hearing aid outcomes in particular, is a relatively recent trend. To further prepare future audiology researchers for individual differences research, this introductory overview reviews some of the basic concepts, as well as procedural and statistical approaches, that are unique to the study of individual differences. Some of this general background information for this approach was reviewed in detail previously in Humes, and the reader is referred to this article for more in-depth coverage of some of the concepts presented briefly here.

**GROUP-BASED VERSUS INDIVIDUAL DIFFERENCE RESEARCH**

As noted, historically, in psychology there have been two somewhat independent approaches to research and experimentation: (1) group-based research and (2) individual differences research. To illustrate the fundamental difference between these two approaches, consider the schematic illustration in Fig. 1. In Fig. 1, individual differences research is shown for 10 subjects per condition or group and three conditions or groups.
data points are shown from subjects on a single dependent measure. The dependent measure could be the percent correct score on a standardized measure of speech understanding, for example, or a self-report measure of hearing aid benefit. A single independent variable is shown on the x-axis with three values for that variable. It could be an independent groups design with the groups representing three separate groups of individuals differing in the independent variable. For example, there could be three independent groups of adults differing in age (young, middle-aged, and older adults) or demographically similar groups who are treated differently (e.g., unaided, aided monaurally, and aided bilaterally). Another common example of this group-based design is to have all subjects receive all levels of the independent variable. This design is often referred to as a within-subject or repeated-measures design. As an example, the same aided-condition independent variable mentioned previously could be used here, with the same subjects tested unaided, with monaural hearing aids, and with hearing aids fitted bilaterally. There are advantages and disadvantages to the between-subject and within-subject variants of the group-based approaches to research, as well as special procedural considerations to minimize the influence of confounding variables interfering with the results (random selection and assignment of subjects for between-subjects designs, counterbalancing of order effects in within-subject designs, etc.). Used appropriately, either group-based approach can yield results that provide valuable information and shape the field of audiology.

In the end, however, the focus of the statistical analyses is on measures of central tendency and variance. The fundamental question is whether the independent variable has a real (unlikely to occur by chance) effect on the dependent variable; stated otherwise, do the groups or conditions differ “on average” from one another? Historically, the most common statistical tool used to address this question with one independent variable having three values (as in Fig. 1) has been to perform an analysis of variance. The general rationale behind this statistical tool can be illustrated by using the range of dependent measure values in Fig. 1 as a convenient easy-to-visualize analog of the “variance” to be analyzed. If we let the total range of scores across all subjects and conditions represent the between-group or between-condition variance and the range within each group or condition represent the within-group or within-condition variance, it is the ratio of these two ranges that could be used as a tool to determine whether there was a significant effect of the independent variable (x-axis) on the dependent variable (y-axis). (This is just a simple visual analogy to analysis of variance for illustration purposes only and does not represent the actual quantities used in the actual statistical calculations.) Note in Fig. 1, for example, that the ratio of the total range (17) to the within-group/condition range (9) is close to 2:1. If there were no effect of the independent variable on the dependent variable, on the other hand, then one would see three horizontal sets of data points such that the total and within-group/condition ranges are the same and the ratio would be smaller (closer to 1:1). Often, because it is the relative ratio of variances (ranges in this simple visual analogy) with the within-group variation of scores in the denominator, the only interest in this variance is that it be as small as possible thereby enhancing the likelihood of observing statistically significant effects of the independent variable on the dependent variable.

Let us suppose that the hypothetical data in Fig. 1 were obtained for a repeated-measures group design. That is, scores on the dependent measure were obtained from the same 10 subjects for three different conditions. Although it may be of interest to know the effect of the independent variable being manipulated on the dependent measure “on average,” this approach completely ignores individual differences among the 10 subjects. For example, perhaps the lowest performing subject in the first condition remains the lowest performing subject throughout and likewise for the highest-performing subject. What is it then about these two subjects that contributes to the observed individual differences such that one subject is consistently superior to others and one consistently inferior in performance? The answer to this question may be as or more important than whether there is an effect of $X$ on $Y$ “on average.” This may be especially important,
for example, in the context of clinical measurements as the audiologist is always dealing with the individual patient, not a group of patients. This notion is illustrated further by the hypothetical data in Fig. 2. These are the same hypothetical data points shown in Fig. 1, but now separate symbols and connecting lines have been added to uniquely identify each of the 10 subjects. This set of hypothetical individual data demonstrates that performance in condition two was strongly related to that in condition one, but that performance in condition three, although still related, was not as predictable from performance in condition two (or condition one). What is it about the subjects and the changes across conditions that elicited these unique individual response patterns? Consider again that the three conditions might be unaided, monaural amplification, and bilateral amplification for conditions one, two, and three, respectively. Although, from the group data (Fig. 1), it may be important to know that, “on average,” monaural amplification is superior to no amplification, and bilateral fits, “on average,” are better than monaural fits, the data in Fig. 2 clearly illustrate that this is not always the case. Some subjects show much larger gains when moving from monaural to binaural amplification whereas others show smaller gains or even decrements when doing so. Having identified these individual differences in performance, additional research can be conducted to better determine why these individual differences exist. Perhaps the mixed results regarding improvements when going from monaural (condition two) to bilateral (condition three) amplification might be found to be related to the degree of asymmetry of the hearing loss, subject age, prior hearing aid experience (unilateral or bilateral), and so on. If identified, such underlying predictive factors can prove to be of considerable value to the clinician working with individual patients. Clearly, as illustrated with Figs. 1 and 2, although the data are the same in both figures, the focus of individual differences research is not the same as group-based research.

Historically, just as analysis of variance has been the most commonly employed statistical tool to examine group or condition differences in group-based research, correlation coefficients are the most common statistical metric used in the examination of individual differences. Correlation coefficients range from a value of $-1$ to $+1$. The focus is on the covariation of data from the same subjects across conditions. As an illustration, the computed Pearson $r$ (parametric) correlation coefficient for the data in Fig. 2 is $+1.00$ from condition one to condition two and $+0.52$ from condition two to condition three.

SOME PROCEDURAL AND STATISTICAL ISSUES IN INDIVIDUAL DIFFERENCES RESEARCH

It could be safely assumed that most of what has been reported with regard to individual differences research in the area of hearing aid outcomes most likely made use of a group-based design to study the effects of the independent variable on the dependent variable(s) involved, then, subsequent to group-based statistical analyses, the study reported correlations to examine individual data. Syntheses of several such studies of unaided and aided speech understanding performance in older adults were provided recently by Akeroyd, Hougaard and Festen, and Humes and Dubno. Whereas probing individual differences in small or moderate-sized group designs is perfectly acceptable, especially in early stages of the exploration of individual differences, adherence to one
approach or the other may often result in procedural factors that may argue against the validity of such a late-stage redirection of research focus. As just one illustration of this, consider again a repeated-measures group design with the independent variable being amplification condition and the values of this independent variable being unaided, monaural, and bilateral. Because the biggest threats to the internal validity of repeated-measures designs typically have to do with the repetition of measurements, such as the negative effects of fatigue and inattention as well as the positive effects of practice and learning on performance, the experimenter often minimizes these potentially confounding factors by counterbalancing or randomizing the order of the conditions for each subject. In the end, some subjects complete testing with bilateral amplification first, some with bilateral amplification second, and some with bilateral amplification last; likewise for unaided listening and monaural amplification. This is an appropriate procedure for repeated-measures group-based research as it attempts to neutralize (not eliminate) the confounding effects of condition order on the dependent variable so as not to impact the actual effect of the independent variable on the dependent variable. In individual differences research, however, the focus is on the person, not the group. Counterbalancing controls for the potential bias of the group data, but, in the process, introduces a source of variation aside from the person or individual. Thus, in a true focus on individual differences, the sequence of testing will be fixed for all participants rather than randomized or counterbalanced. Of course, once the group-based research design has been executed and counterbalancing (or randomization) of order implemented, this can’t be undone for a subsequent late-stage transition to the analysis of individual differences. Whether the introduction of order-based variance confounds the variation among individuals and the interpretation of individual differences depends, in part, on the estimated magnitude of such order effects in a given study.

As noted, correlational analyses are at the heart of most statistical procedures used in individual differences research. Correlations also often serve as the “raw data” or input for most of the more sophisticated contemporary statistical procedures employed in individual differences research, such as factor analysis (e.g., Gorsuch) and structural equation modeling. Description of both of these more sophisticated data analysis methods is beyond the scope of this article, but a more detailed presentation on the application of factor analysis to hearing aid outcome measures can be found in Humes. The point to be made here is simply that the use of either of these approaches to data analysis typically requires many more subjects than common group-based research designs. This is due, in part, to the inclusion of many more variables than the small set of independent and dependent measures typically used in group-based research. For factor analysis, for example, it is recommended that there be at least 10 subjects for every variable included in the analysis, and there are often 10 to 20 variables measured, resulting in the need for at least 100 to 200 subjects in such cases. This is just a simple rule of thumb, however, and there are more appropriate ways to evaluate the validity of the factor analysis solution (see Gorsuch and Humes for application to hearing-aid outcomes). In general, even larger subject samples are needed for robust structural equation modeling.

When conducting individual differences research and relying on correlational approaches for data analysis, the reliability of the measures is critically important. For example, how does one interpret a correlation or multiple correlation (from multiple regression) of \( r = 0.5 \) between an independent (predictor) variable and a dependent variable. One can rely on the statistical significance of a correlation, but often, very small or low correlations are found to be significant in large study samples; as noted, large study samples are typically required in individual differences research. Another approach to interpreting the practical significance of the correlation is to square it; \( r^2 \) is often referred to as the coefficient of determination. Assuming \( r = 0.5 \), squaring this value (\( r^2 = 0.25 \)) indicates that 25% of the total variance in the dependent measure is captured by the predictor variable(s), but is this “good” or “bad”? Knowing the reliability or test-retest correlation for the measure can offer some
If the test-retest correlation is 0.9, for example, then it can be said that 81% of the variance in the data is systematic and the remaining 19% is random or error variance. One can only hope to explain or account for the systematic variance and not the error variance. That being the case, accounting for 25% of the variance with another variable explains approximately 31% (25% / 0.9) of the systematic variance, leaving about two-thirds of the systematic variance unexplained. If, on the other hand, the dependent measure is not as reliable and has a test-retest correlation of 0.7, then accounting for 25% of the total variance represents about half of the systematic variance (25% / 0.7) for which one could hope to account. At a minimum, the test-retest correlations of the measures used in the study of individual differences should be known and, hopefully, shown to be quite good (r ≥ 0.7, with r ≥ 0.9 often recommended for clinical tests).

Because large data sets are often required for the study of individual differences, the issue of how to address missing data also tends to arise frequently. A variety of approaches and tools are available to address this issue. When we were first employing factor analysis as a statistical tool to analyze individual differences in hearing aid outcome, common and widely acceptable approaches were to conservatively delete all of the subject’s data if any variables had missing values or to use the group mean to replace the missing individual data. Neither approach is desirable nor used frequently today. Most recently, we’ve made use of multiply imputed chained equations as a more robust and readily accessible approach to the replacement of missing data in large data sets designed for the examination of individual differences.

**SUMMARY**

This brief review of some of the issues in individual differences research is designed to make audiology researchers more aware of this approach and how it differs from the group-based approach to research with which audiology researchers are likely to be most familiar. Individual differences research has great potential for identifying unique profiles of hearing aid outcomes and in predicting those outcomes and profiles. Such information will likely prove to be of tremendous value to practicing clinicians; professionals most interested in helping individual patients under their care, rather than attaining a better understanding of the performance of the “typical” or “average” patient.

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