Using Synthetic Data in Communication Sciences and Disorders to Promote Transparency and Reproducibility

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# Abstract

**Purpose**: Reproducibility is a core principle of science and access to a study’s data is essential to reproduce its findings. However, data sharing is uncommon in the field of Communication Sciences and Disorders (CSD), often due to concerns related to privacy and disclosure risks. Synthetic data offers a potential solution to this barrier by generating artificial datasets that do not represent real individuals yet retain statistical properties and relationships from the original data. This study aimed to explore the feasibility and preliminary utility of synthetic data promote transparency and reproducibility in the field of CSD.

**Method**: Open datasets were obtained from previously published research within the American Speech-Language-Hearing Association ‘Big Nine’ domains (articulation, cognition, communication, fluency, hearing, language, social communication, voice and resonance, and swallowing) across a range of study outcomes and designs. Synthetic datasets were generated with the *synthpop* R package. General utility was assessed visually and with the standardized ratio of the propensity mean squared error (*S\_pMSE*). Specific utility assessed whether inferential relationships from the original data were preserved in the synthetic dataset by comparing model fit indices, coefficients, and *p*-values.

**Results**: Synthetic datasets maintained the direction of *p*-values in six out of the nine studies and effect size categorizations in five studies. In cases where synthetic datasets did not maintain 95% of the inferential or effect size results, the absolute mean difference between synthetic and original datasets was relatively low, suggesting that the distribution of results from synthetic datasets closely approximated the alpha or effect size categorization threshold.

**Conclusion**: Findings suggest that synthetic data can effectively maintain statistical properties and relationships across a wide range of non-hierarchical data commonly seen in the field of CSD. While some studies with fewer observations than recommended (i.e., n < 130) showed lower agreement and greater variability in *p*-values and effect size estimates, this was not consistently appreciated. Therefore, researchers who use synthetic data should assess its utility in preserving their results for their own data and use-case.

# Introduction

Transparency and openness are fundamental tenets of science, with computational reproducibility playing a key role in maintaining these values. Computational reproducibility refers to the ability to recreate a study’s results using the original data. Nowadays, the vast majority of scientific studies use some degree of computation in processing data, conducting descriptive or inferential statistics, and visualizing results. When these computations are reproducible, the transparency and confidence in findings are enhanced. Achieving computational reproducibility, however, requires authors to share their data. Both the National Institutes of Health and the National Science Foundation mandate data sharing and management plans to ensure that scientific data supporting a study is shared upon publication and aligns with FAIR (Findability, Accessibility, Interoperability, and Reuse) principles of digital assets (Watson et al., 2023; Wilkinson et al., 2016).

Providing open, publicly available data benefits scientists, funding bodies, and society at large by enabling researchers to verify results, generate new knowledge (e.g., meta-analyses, secondary analyses), develop hypotheses, and minimize redundant data collection (Chow et al., 2023). In this sense, sharing data promotes a cumulative and self-correcting science. Despite the clear benefits of open data and its growing adoption in other fields like psychology and the biobehavioral sciences (Quintana, 2020), only 26% of a sample of researchers in the field of Communication Sciences and Disorders (CSD) reported sharing their data publicly at least once (El Amin et al., 2023).

Understanding the nuances of data sharing requires a closer look at the different types of data generated throughout a research project’s life cycle. These include raw collected data, processed intermediate data, and final analysis data (Table 1). However, a common misconception is that open data refers solely to sharing raw data (e.g., audio recordings, videos, MRI data) (Pfeiffer et al., 2024). In reality, sharing intermediate or analysis data can also support reproducibility while reducing privacy and confidentiality concerns associated with sharing raw data. However, these different types of data offer varying levels of utility: sharing raw data enables maximum reproducibility and secondary research opportunities, while analysis data (although easier to share) primarily supports computational reproducibility.

Table 1: Description of types of data.

|  | Raw Data | Intermediate Data | Analysis Data |
| --- | --- | --- | --- |
| Description | Original, unmodified data collected from studies.  Also known as primary data, microdata, individual-level data. | Cleaned, de-identified, and processed data, used for creating the analysis data.  Also known as cleaned data, transactional data, processed data. | Final dataset containing variables used in statistical analyses.  Also known as derived data, result data, aggregate data. |
| **Examples** |  |  |  |
| Acoustic Data (Thompson et al., 2023) | Raw audio recordings. | Extracted formant data. | Dataset containing average vowel space area per speaker. |
| Swallowing Data (Curtis et al., 2023) | Video files from flexible endoscopic evaluations of swallowing. | Not applicable. | Dataset containing ratings of swallowing safety and efficiency. |
| Eye Tracking Data (Baron et al., 2023) | Eye movement recordings (gaze, saccades, fixations). | Cleaned data with merged fixations and removed artifacts. | Dataset containing summary of fixation durations, reading times, and target proportions. |
| Focus Group/Interview Data (Pfeiffer et al., 2024) | Audio recordings and transcripts. | De-identified transcripts. | Dataset containing coded categories and themes from qualitative analysis. |
| Survey Data (Riccardi, 2024) | Raw survey responses. | Cleaned and coded responses. | Dataset containing summary scores and frequencies of survey responses. |
| Assessment Tool Data (Pfeiffer & Landa, 2024) | Raw, unscored assessment protocols. | Scored protocols with calculated totals and subscales. | Dataset containing standard scores, confidence intervals, percentile ranks. |

Both individual and system-level barriers hinder data sharing, including a lack of time, knowledge, support from colleagues, and perceived incentives (Pfeiffer et al., 2024). Furthermore, each type of data comes with unique challenges regarding data sharing. For raw data, it is common that researchers often do not obtain consent to share data or cannot contact participants after data collection. Additionally, sharing de-identified raw or intermediate data may require additional approval from the institutional review board. Even when de-identification is possible, anonymized intermediate or analysis datasets can still carry re-identification risks, especially in small samples or vulnerable populations where indirect identifiers (e.g., gender, age, or race) may compromise participant confidentiality (Rocher et al., 2019). Therefore, although sharing de-identified analysis data is the minimum requirement for ensuring computational reproducibility and promoting cumulative science, concerns about privacy must be addressed when sharing sensitive data.

***Synthetic Data as an Approach to Promote Transparency and Reproducibility***

Synthetic data generation offers a promising solution to safeguarding participants’ privacy and confidentiality in publicly available datasets (Drechsler & Haensch, 2024; Rubin, 1993). This approach can be applied to a wide variety of data types (e.g., demographic information, outcome measures) and involves creating artificial datasets that do not represent real individuals, thereby significantly reducing the risk of disclosure. Importantly, synthetic data retains the statistical properties and relationships of the original data, enabling readers to evaluate key aspects of the study’s analysis workflow (e.g., data pre-processing, statistical modeling), reproduce study findings, explore datasets, and develop new questions or hypotheses. Synthetic data generation is widely used across medical research, industry, and government agencies, most notably by the United States Census Bureau (Jarmin et al., 2014). Although the concept of synthetic data methods was first proposed more than 30 years ago (Rubin, 1993), recent analytic and software developments have streamlined the process, making it easier and more efficient to generate high-quality synthetic data (Nowok et al., 2016).

The intended use of synthetic data influences the level of rigor and scrutiny required. For example, synthetic data can serve as a pedagogical tool to teach data analysis skills or novel statistical methods (Shepherd et al. 2017). In such cases, preserving general statistical properties is sufficient, even if precise relationships between variables are not fully maintained. Similarly, synthetic data accompanying publications can facilitate reproducible workflows to illustrate data pre-processing steps or statistical models without reproducing exact study results. However, higher standards are required when synthetic data is used for hypothesis testing, meta-analyses, or methodological development (Raab et al., 2017). In these scenarios, synthetic datasets must accurately preserve multivariable relationships to ensure their validity and utility.

Two main approaches are used to assess the utility of synthetic datasets: general and specific (Snoke et al., 2018). General utility evaluates whether the synthetic dataset maintains the overall statistical properties of the original dataset. This includes visual comparisons of univariate (e.g., bar charts, histograms) and bivariate joint distributions (e.g., scatterplots), as well as metrics to determine to what degree synthetic data is distinguishable from the original data (e.g., standardized propensity mean squared error; *S\_pMSE*). Specific utility assesses whether inferential relationships from the original dataset are preserved in the synthetic dataset by comparing model fit indices and coefficients.

***Application of Synthetic Data in Communication Sciences and Disorders***

Despite its potential to enhance data sharing in the field of CSD, synthetic data is not widely known or adopted in the field. Data commonly collected in CSD research poses unique challenges, including smaller sample sizes than are typically recommended for synthetic data generation and a wide range of study designs, outcomes, and analyses (Borders et al., 2022; Gaeta & Brydges, 2020). Moreover, reproducible workflows that detail important steps for data wrangle or statistical modeling are rarely provided in publications, further hindering transparency and reproducibility.

To address this gap, the present study aimed to explore the feasibility and preliminary utility of synthetic data generation in CSD. We applied synthetic data methods to open datasets from the ‘Big Nine’ American Speech-Language-Hearing Association (ASHA) domains and hypothesized that synthetic datasets would preserve both the statistical properties (general utility) and the inferential results (specific utility) of the original data. It’s important to recognize that synthetic data must be evaluated on a case-by-case basis and that the utility of the datasets included in this manuscript may not apply to one’s own dataset. To this end, the broad goal of the current investigation was to provide a proof-of-concept to the interested reader.

# Method

## Description of Original Datasets from ASHA ‘Big Nine’ Domains

A convenience sampling approach was used to identify publicly available datasets from previously published research articles related to the ‘Big Nine’ ASHA domains: swallowing (Curtis et al., 2023), articulation (Thompson et al., 2023), fluency (Elsherif et al., 2021), voice and resonance (Novotný et al., 2016), hearing (Battal et al., 2019), communication modalities (King et al., 2022), receptive and expressive language (Kearney et al., 2023; Robinaugh et al., 2024), cognitive aspects of communication (Clough et al., 2023), and social aspects of communication (Chanchaochai & Schwarz, 2023). Given the prevalence of single subject experimental designs in the field of CSD, an additional study was included to ensure adequate representation (Robinaugh et al., 2024), resulting in ten studies. These studies were classified by their study design, population, and statistical analysis (Table 2).

Table 2: Characteristics of included studies by ASHA domain.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Domain** | **Study Design** | **Sample Size** | **Population(s)** | **Analysis of Interest** | **Outcome Type(s)** | **Statistics** |
| Curtis et al. (2023) | Swallowing | Observational cohort study | 39 | Community-dwelling adults | Distribution of laryngeal vestibule residue ratings | Continuous | Descriptive |
| Thompson et al. (2023) | Articulation |  | 40 | Parkinson’s disease, amyotrophic lateral sclerosis, Huntington’s disease, cerebellar ataxia | Relationship between vowel space area and intelligibility | Continuous | Hierarchical linear regression |
| Elsherif et al. (2021) | Fluency | Between-group cross-sectional | 164 | Dyslexia, stuttering, neurotypical | Group difference in nonword repetition | Continuous | Independent t-test |
| Novotný et al. (2016) | Voice and resonance |  | 111 | Parkinson’s disease, Huntington’s disease, neurotypical | Relationship between overall perceptual rating and variability of nasality | Continuous | Pearson correlation |
| Battal et al. (2019) | Hearing |  | 34 | Congenitally blind, sighted | Group difference in auditory localization | Continuous | Linear mixed-effects model with 3-way interaction |
| King et al. (2022) | Communication modalities |  | 160 | Speech-language pathologists | Timepoint difference in lack of/limited internet and technology barriers | Ordinal | Chi-square |
| Kearney et al. (2023) | Receptive and expressive language |  | 34 | Brain tumor | Relationship between years of education and reading score | Continuous | Spearman’s rank correlation coefficient |
| Robinaugh et al. (2024) | Receptive and expressive language | Single-case experimental design | 1 | Primary progressive aphasia with a history of traumatic brain injury |  | Binary | Bayesian generalized mixed effects model |
| Clough et al. (2023) | Cognitive aspects of communication |  | 102 | Traumatic brain injury, neurotypical | Group x Condition interaction in emotion recognition accuracy | Binary | Generalized linear mixed-effects model with 3-way interaction |
| Chanchaochai & Schwarz (2023) | Social aspects of communication | Between-group cross-sectional | 96 | Autism spectrum disorder, neurotypical | Group difference in non-verbal IQ | Continuous | Analysis of Variance |

## It is important to note that not all research designs are represented due to the limited availability of public data in the field of CSD and the inherent challenge of including every possible study design. Instead, this approach was chosen to prioritize representation across all subfields to illustrate the application of synthetic data methods in CSD. To demonstrate the feasibility and preliminary utility of synthetic data, an analysis was chosen from each study and synthetic data was generated for those variables, as described below.

## Generation of Synthetic Datasets with the Synthpop Package

Synthetic data generation and statistical analyses were conducted in R version 4.2.1 (R Core Team, 2022). The *synthpop* R package (version 1.8.0) (Nowok et al., 2016) was used to generate synthetic data via complete conditional specification (Drechsler 2011). This method synthesizes one variable at a time: the first variable is generated by random sampling from the original dataset, and subsequent variables are synthesized conditionally based on previously synthesized variables. This stepwise approach captures relationships between variables incrementally rather than attempting to synthesize all relationships simultaneously.

For example, consider a dataset containing three variables: participant ID, age, and weight. The process would begin by synthesizing participant ID through random sampling from its observed distribution. Age would then be synthesized conditionally based on the synthetic participant ID values, with synthetic values drawn from predictions informed by the original data. Finally, weight would be synthesized conditionally on both participant ID and age, with synthetic values similarly sampled from predictions.

*Synthpop* inherently manages missing data and maintains relationships between missingness and other variables using a tree-based algorithm, specifically classification and regression trees (CART), for data synthesis (Nowok et al., 2016). Alternatively, users can select other tree-based methods, such as random forests, or parametric models like linear or logistic regression. This process resembles multiple imputation by chained equations (MICE) for handling missing data (van Buuren, 2018) but with a key distinction: instead of imputing only missing values, synthpop generates entirely synthetic data (Raghunathan, 2021), significantly reducing disclosure risk.

Nowok et al. (2016) provide an in-depth overview of the *synthpop* package’s features. Briefly, synthesis is largely automated using the syn() function. Users can customize various options, including the modeling approach, choice of predictors, order of synthesized variables, smoothing parameters for continuous variables to enhance privacy, and rules for maintaining logical relationships.

***Evaluation of General and Specific Utility***

In the present study, we aimed to explore the feasibility and preliminary utility of synthetic data to promote transparency and reproducibility in CSD. Utility was operationalized as general (does the synthetic data resemble the original data in its statistical properties and distribution?) and specific (is the inferential relationship between variables maintained?). To evaluate general utility, we visually compared univariate (e.g.., bar charts, histograms) and bivariate joint distributions (e.g., scatterplots) between the original and synthetic dataset, and evaluated the predicted probability that a record comes from the synthetic versus original data, known as the standardized propensity mean squared error (*S\_pMSE*). Standardized propensity scores closer to zero indicate greater general utility (typically with a standard deviation of one), where a value of zero indicates that the original and synthetic data are identical (Snoke et al., 2018). Notably, a value of zero is highly unlikely since synthetic data generation aims to achieve distributional similarity.

To assess specific utility, a statistical analysis was selected from each study and performed separately with the original and the synthetic data. Greater overlap in effect size or coefficient confidence intervals and similar *p*-value inferences (i.e., significant or non-significant) indicated greater specific utility. Since Curtis et al. (2023) examined median and interquartile ranges (IQR) instead of statistical models, only general utility was examined. The pre-registered analysis plan and corresponding deviations are publicly available on the Open Science Framework (<https://osf.io/vhgq2>).

# Results

### Swallowing

Curtis et al. (2023) examined normative reference values for swallowing outcomes during flexible endoscopic evaluations of swallowing among 39 non-dysphagic, community-dwelling adults. In this observational cohort study, participants were administered 15 swallowing trials that varied by bolus size, consistency, contrast agent, and swallowing instructions. A variety of swallowing outcomes were measured, including the amount of laryngeal vestibule residue rated with the Visual Analysis of Swallowing Efficiency and Safety. Median and interquartile ranges (IQR) were used to describe the distribution of laryngeal vestibule residue ratings.

##### Figure 1 here.

Descriptively, the synthetic dataset classified 64% of laryngeal vestibule ratings on thin liquid boluses as ‘absent’ (i.e., 0% residue) compared to 68% in the original dataset. In the synthetic dataset, the median value on thin liquids was 0.03 (IQR: 0.02 - 0.045) compared to 0.03 (IQR: 0.02 - 0.04) in the original dataset. 98.61% of extremely thick liquids were classified as having no laryngeal vestibule residue compared to 100% in the original dataset. A similar pattern was appreciated for regular solids (96.43% in synthetic vs. 100% in original dataset). When examined across 100 synthetic datasets, findings from the zero-inflated beta multilevel models indicate that 100% and 98% of synthetic datasets were not statistically significantly different than the original dataset for the zero-inflated and beta portions of the model, respectively (Table 4). Additionally, effect size categorizations were maintained for 100% of both zero-inflated and beta portions of the model.

### Study 2: Vowel Acoustics as Predictors of Speech Intelligibility in Dysarthria

Thompson et al. (2023) examined the relationship between vowel space area and speech intelligibility among 40 speakers with dysarthria of varying etiologies, including Parkinson’s disease, amyotrophic lateral sclerosis, Huntington’s disease, and cerebellar ataxia. A linear regression model revealed a statistically significant relationship between vowel space area and intelligibility (*p* < .001) with a Cohen’s *f* of 0.59, corresponding to a conventionally “large” effect size (Table 3).

Below we import the original dataset, wrangle the data, and generate a synthetic data set. The data wrangling steps include (1) importing the original dataset, (2) removing the reliability trials from the dataset, (3) removing a string character from the SpeakerID variable, and (4) selecting only the variables needed for the analysis.

# import original data  
articulation\_original\_data <- rio::import(  
 file = here::here("Data", "02\_Articulation", "data\_Acoustic Measures.csv")  
) |>  
 # Remove the reliability trials that have "\_rel" in the SpeakerID variable  
 dplyr::filter(  
 !grepl(  
 pattern = "\_rel",  
 x = SpeakerID  
 )) |>  
 # Selecting just the variables we need  
 dplyr::select(  
 SpeakerID, # ID  
 VSA\_b, # VSA in Bark  
 Int = Int\_OT # intelligibility (orthographic transcriptions)  
 )

Next, we generate a synthetic dataset with the syn() function, extract the dataset, and convert it to a dataframe. *Synthpop* provides a warning message that this dataset has fewer observations than recommended (> 130).

# generate synthetic dataset  
articulation\_synthetic\_dataset <- syn(articulation\_original\_data,  
 m = 1,  
 seed = 2024)

CAUTION: Your data set has fewer observations (40) than we advise.  
We suggest that there should be at least 130 observations  
(100 + 10 \* no. of variables used in modelling the data).  
Please check your synthetic data carefully with functions  
compare(), utility.tab(), and utility.gen().  
  
  
Variable(s): SpeakerID have been changed for synthesis from character to factor.  
  
Synthesis  
-----------  
 SpeakerID VSA\_b Int

# Extract the synthetic dataset and convert into a data frame  
articulation\_synthetic\_dataset <- as.data.frame(articulation\_synthetic\_dataset$syn)

Next, we compare the distributions for vowel space area and speech intelligibility between the synthetic and original dataset. Figure 2 suggests that while the synthetic data largely approximates the original dataset, there are several values that are oversampled in the synthetic dataset.

# Comparison of original and synthetic datasets with synthpop package  
articulation\_comparison <- compare(  
 articulation\_synthetic\_dataset, # synthetic dataset  
 articulation\_original\_data, # original dataset  
 vars = c("VSA\_b",  
 "Int"), # variables for comparison  
 stat = "counts", # Present the raw counts for each variable  
 cols = c("#62B6CB", "#1B4965") # Setting the colours in the plot  
)

##### Figure 2 here.

Findings from the 100 generated synthetic datasets indicate that 71% of datasets demonstrated the same inferential result (i.e., a statistically significant *p*-value). For the effect size, 57% of synthetic datasets maintained a ‘large’ effect size categorization.

### Results for Studies 3 - 9

Studies in the domains of fluency, voice and resonance, communication modalities, receptive and expressive language, and social aspects of communication demonstrated more than 95% *p*-value agreement between the original and synthetic datasets (Table 3). Among studies that demonstrated lower agreement, the absolute mean difference between the synthetic *p*-values and the original *p*-value was 0.05 (*SD* = 0.1) for articulation, 0.03 (*SD* = 0.04) for hearing, and 0.25 (*SD* = 0.28) for cognitive aspects of communication (Figure 3). For effect size categorization agreement, studies in the domains of fluency, hearing, communication modalities, and cognitive aspects of communication maintained the effect size categorization of the original study. Among studies that demonstrated lower effect size cateogrization agreement, the absolute mean difference between the effect size from synthetic datasets and the original study’s effect size was 0.19 (SD = 0.12) for articulation, 0.09 (*SD* = 0.07) for voice and resonance, 0.06 (*SD* = 0.05) for receptive and expressive language, and 0.21 (*SD* = 0.2) for social aspects of communication.

##### Figure 3 here.

##### Figure 4 here.

##### Table 4 here.

# Discussion

Although computational reproducibility is a core principle of science, data sharing is uncommon in CSD, partly due to concerns regarding disclosure risk (Pfeiffer et al., 2024). This study demonstrates the feasibility of synthetic datasets to promote transparency and reproducibility, while protecting participant confidentiality. Overall, synthetic data from selected studies demonstrated high general utility, preserving univariate and bivariate joint distributions. Specific utility, on the other hand, was maintained for studies that demonstrated non-hierarchical structures. Key findings and considerations for the implementation of synthetic data in CSD are outlined below.

One key finding is that lower agreement between synthetic and original datasets was not attributed to sample size, despite the *synthpop* package’s recommendation of a minimum of 130 observations for generating synthetic datasets (Nowok et al., 2016). For example, in the original study from the cognition domain, which included over 8,000 observations, only 35% of synthetic datasets maintained the same inferential result as the original dataset. Instead, specific utility of synthetic and original datasets was markedly reduced among data with a hierarchical structure. This is an important consideration since these datasets are common in the field. Other approaches to more accurately synthesize hierarchical data have been proposed and will require future investigation (Gauvin et al., 2021).

These findings highlight the importance of verifying the accuracy of synthetic datasets and providing these comparisons in supplemental manuscript materials. To ensure synthetic data quality, researchers should determine their intended purpose of data synthesis and assess general and/or specific utility to confirm that the synthetic dataset closely reproduces the distributional or statistical findings of the original analysis. If the synthetic dataset fails to sufficiently maintain these relationships, it should not be shared.

This study is not without limitations. It is important to recognize that synthetic data is inherently a proxy and cannot entirely preserve all statistical properties of the original dataset. Therefore, researchers should provide de-identified (or identifiable when ethical approval is obtained) data whenever possible, as well as evaluate the utility of the synthetic dataset in the context of their own study and data sharing goals. Finally, open data alone does not ensure computational reproducibility. Instead, both open data and accompanied code or syntax is required to reproduce analyses. In fact, recent research showed that a high percentage of findings from registered reports that provided open data were unable to be reproduced (Obels et al., 2020). Reproducible workflows in languages like R have been proposed and warrant consideration (Peikert et al., 2021).

Moving forward, larger systemic changes are likely necessary at both the organizational level (e.g., ASHA, societies) and within academic institutions to encourage appropriate data sharing. For example, doctoral programs should offer coursework that introduces these concepts and educates future researchers on best practices for data sharing. Fortunately, many resources are available for current researchers to familiarize themselves with these practices (Lewis, 2024). Additionally, institutions must incentivize data sharing and recognize open science efforts as valuable scholarly contributions. Although ASHA has introduced open science badges to acknowledge these efforts, it remains unclear if this is enough to encourage large-scale participation. Ultimately, a broader cultural shift is needed in the field - from the current individualistic, siloed approach to a more collaborative and pro-social view of science.

## Conclusions

This study assessed the utility of the *synthpop* package in R for generating synthetic data in situations where sharing original data poses risks of participant re-identification. Results suggest that synthetic data from non-hierarchical datasets can be effectively applied across various data types and research areas within the CSD field. Importantly, researchers using synthetic data should verify its accuracy in reproducing their original findings before sharing.

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# References

Battal, C., Occelli, V., Bertonati, G., Falagiarda, F., & Collignon, O. (2019, May 16). *Ubiquitous enhancement of spatial hearing in congenitally blind people*. <https://doi.org/10.31234/osf.io/veh7t>

Borders, J. C., Grande, A. A., & Troche, M. S. (2022). Statistical Power and Swallowing Rehabilitation Research: Current Landscape and Next Steps. *Dysphagia*. <https://doi.org/10.1007/s00455-022-10428-2>

Chanchaochai, N., & Schwarz, F. (2023). Difficulties with pronouns in autism: Experimental results from Thai children with autism. *Language Acquisition*, *0*(0), 1–38. <https://doi.org/10.1080/10489223.2023.2262457>

Chow, J. C., Sandbank, M., & Hampton, L. H. (2023). Guidance for Increasing Primary Study Inclusion and the Usability of Data in Meta-Analysis: A Reporting Tutorial. *Journal of Speech, Language, and Hearing Research*. <https://doi.org/10.1044/2023_JSLHR-22-00318>

Clough, S., Morrow, E., Mutlu, B., Turkstra, L., & Duff, M. C. (2023). Emotion recognition of faces and emoji in individuals with moderate-severe traumatic brain injury. *Brain Injury*, *37*(7), 596–610. <https://doi.org/10.1080/02699052.2023.2181401>

Curtis, J. A., Borders, J. C., Dakin, A. E., & Troche, M. S. (2023). Normative Reference Values for FEES and VASES: Preliminary Data From 39 Nondysphagic, Community-Dwelling Adults. *Journal of Speech, Language, and Hearing Research*. <https://doi.org/10.1044/2023_JSLHR-23-00132>

Drachen, T. M., Ellegaard, O., Larsen, A. V., & Dorch, S. B. F. (2016). Sharing data increases citations. *LIBER Quarterly: The Journal of the Association of European Research Libraries*, *26*(2, 2), 67–82. <https://doi.org/10.18352/lq.10149>

Drechsler, J., & Haensch, A.-C. (2024). 30 Years of Synthetic Data. *Statistical Science*, *39*(2), 221–242. <https://doi.org/10.1214/24-STS927>

Eisenhauer, J. G. (2021). Meta‐analysis and mega‐analysis: A simple introduction. *Teaching Statistics*, *43*(1), 21–27. <https://doi.org/10.1111/test.12242>

El Amin, M., Borders, J. C., Long, H. L., Keller, M. A., & Kearney, E. (2023). Open Science Practices in Communication Sciences and Disorders: A Survey. *Journal of Speech, Language, and Hearing Research*, *66*(6). <https://doi.org/10.1044/2022_JSLHR-22-00062>

Elsherif, M. M., Wheeldon, L. R., & Frisson, S. (2021). Do dyslexia and stuttering share a processing deficit? *Journal of Fluency Disorders*, *67*, 105827. <https://doi.org/10.1016/j.jfludis.2020.105827>

Gaeta, L., & Brydges, C. R. (2020). An Examination of Effect Sizes and Statistical Power in Speech, Language, and Hearing Research. *Journal of Speech, Language, and Hearing Research*, *63*(5), 1572–1580. <https://doi.org/10.1044/2020_JSLHR-19-00299>

Hothorn, T., Hornik, K., & Zeileis, A. (2006). Unbiased Recursive Partitioning: A Conditional Inference Framework. *Journal of Computational and Graphical Statistics*, *15*(3), 651–674. <https://doi.org/10.1198/106186006X133933>

Jarmin, R. S., Louis, T., & Miranda, J. (2014, February 1). *Expanding the Role of Synthetic Data at the U.S. Census Bureau* (SSRN Scholarly Paper No. 2408030). <https://doi.org/10.2139/ssrn.2408030>

Kearney, E., Brownsett, S. L., Copland, D. A., Drummond, K. J., Jeffree, R. L., Olson, S., Murton, E., Ong, B., Robinson, G. A., & Tolkacheva, V. (2023). Relationships between reading performance and regional spontaneous brain activity following surgical removal of primary left-hemisphere tumors: A resting-state fMRI study. *Neuropsychologia*, *188*, 108631. <https://www.sciencedirect.com/science/article/pii/S0028393223001653>

King, M., Ward, H., Soto, G., & Barrett, T. S. (2022). Supporting Emergent Bilinguals Who Use Augmentative and Alternative Communication and Their Families: Lessons in Telepractice From the COVID-19 Pandemic. *American Journal of Speech-Language Pathology*, *31*(5), 2004–2021. <https://doi.org/10.1044/2022_AJSLP-22-00003>

Lewis, C. (2024). *Data Management in Large-Scale Education Research*. CRC Press. <https://books.google.com/books?hl=en&lr=&id=z54LEQAAQBAJ&oi=fnd&pg=PT12&dq=Data+Management+in+Large-Scale+Education+Research&ots=6h09wWzI1A&sig=-Eq8b942JpPzrApSvO2M2y8MhCo>

Novotný, M., Rusz, J., Čmejla, R., Růžičková, H., Klempíř, J., & Růžička, E. (2016). Hypernasality associated with basal ganglia dysfunction: Evidence from Parkinson’s disease and Huntington’s disease. *PeerJ*, *4*, e2530. <https://doi.org/10.7717/peerj.2530>

Nowok, B., Raab, G. M., & Dibben, C. (2016). Synthpop: Bespoke Creation of Synthetic Data in R. *Journal of Statistical Software*, *74*(11). <https://doi.org/10.18637/jss.v074.i11>

Obels, P., Lakens, D., Coles, N. A., Gottfried, J., & Green, S. A. (2020). Analysis of Open Data and Computational Reproducibility in Registered Reports in Psychology. *Advances in Methods and Practices in Psychological Science*, *3*(2), 229–237. <https://doi.org/10.1177/2515245920918872>

Ohmann, C., Banzi, R., Canham, S., Battaglia, S., Matei, M., Ariyo, C., Becnel, L., Bierer, B., Bowers, S., Clivio, L., Dias, M., Druml, C., Faure, H., Fenner, M., Galvez, J., Ghersi, D., Gluud, C., Groves, T., Houston, P., … Demotes-Mainard, J. (2017). Sharing and reuse of individual participant data from clinical trials: Principles and recommendations. *BMJ Open*, *7*(12), e018647. <https://doi.org/10.1136/bmjopen-2017-018647>

Peikert, A., van Lissa, C. J., & Brandmaier, A. M. (2021). Reproducible Research in R: A Tutorial on How to Do the Same Thing More Than Once. *Psych*, *3*(4, 4), 836–867. <https://doi.org/10.3390/psych3040053>

Pfeiffer, D., Thompson, A., Ciullo, B., Hirsch, M. E., Amin, M. E., Ford, A., Riccardi, J. S., & Kearney, E. (2024, May 31). *1-800-Help-Me-With-Open-Science-Stuff: A Qualitative Examination of Open Science Practices in Communication Sciences and Disorders*. <https://doi.org/10.31219/osf.io/9kxa7>

Piwowar, H. A., Day, R. S., & Fridsma, D. B. (2007). Sharing Detailed Research Data Is Associated with Increased Citation Rate. *PLOS ONE*, *2*(3), e308. <https://doi.org/10.1371/journal.pone.0000308>

Piwowar, H. A., & Vision, T. J. (2013). Data reuse and the open data citation advantage. *PeerJ*, *1*, e175. <https://doi.org/10.7717/peerj.175>

Quintana, D. S. (2020). A synthetic dataset primer for the biobehavioural sciences to promote reproducibility and hypothesis generation. *eLife*, *9*, 1–12. <https://doi.org/10.7554/eLife.53275>

R Core Team. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. <https://www.R-project.org/>

Rocher, L., Hendrickx, J. M., & de Montjoye, Y.-A. (2019). Estimating the success of re-identifications in incomplete datasets using generative models. *Nature Communications*, *10*(1), 3069. <https://doi.org/10.1038/s41467-019-10933-3>

Rubin, D. B. (1993). Statistical disclosure limitation. *Journal of Official Statistics*, *9*, 462–468.

Soule MD, M. C., Beale BA, E. E., Suarez MD, L., Beach MD, S. R., Mastromauro MSW, L., Carol A., Celano MD, C. M., Moore BA, S. V., & Huffman MD, J. C. (2016). Understanding motivations to participate in an observational research study: Why do patients enroll? *Social Work in Health Care*, *55*(3), 231–246. <https://doi.org/10.1080/00981389.2015.1114064>

Stasinopoulos, D. M., & Rigby, R. A. (2007). Generalized additive models for location scale and shape (GAMLSS) in R. *Journal of Statistical Software*, *23*(7), 1–46.

Tedersoo, L., Küngas, R., Oras, E., Köster, K., Eenmaa, H., Leijen, Ä., Pedaste, M., Raju, M., Astapova, A., Lukner, H., Kogermann, K., & Sepp, T. (2021). Data sharing practices and data availability upon request differ across scientific disciplines. *Scientific Data*, *8*(1), 192. <https://doi.org/10.1038/s41597-021-00981-0>

Thompson, A., Hirsch, M. E., Lansford, K. L., & Kim, Y. (2023). Vowel Acoustics as Predictors of Speech Intelligibility in Dysarthria. *Journal of Speech, Language, and Hearing Research*, *66*, 3100–3114. <https://doi.org/10.1044/2022_JSLHR-22-00287>

Vazire, S., & Holcombe, A. O. (2022). Where Are the Self-Correcting Mechanisms in Science? *Review of General Psychology*, *26*(2), 212–223. <https://doi.org/10.1177/10892680211033912>

Watson, H., Gallifant, J., Lai, Y., Radunsky, A. P., Villanueva, C., Martinez, N., Gichoya, J., Huynh, U. K., & Celi, L. A. (2023). Delivering on NIH data sharing requirements: Avoiding Open Data in Appearance Only. *BMJ Health & Care Informatics*, *30*(1), e100771. <https://doi.org/10.1136/bmjhci-2023-100771>

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., … Yutani, H. (2019). Welcome to the Tidyverse. *Journal of Open Source Software*, *4*(43), 1686. <https://doi.org/10.21105/joss.01686>

Wilkinson, M. D., Dumontier, M., Aalbersberg, Ij. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., … Mons, B. (2016). The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, *3*(1), 160018. <https://doi.org/10.1038/sdata.2016.18>

Yu, Y., & Romero, D. M. (2024). Does the use of unusual combinations of datasets contribute to greater scientific impact? *Proceedings of the National Academy of Sciences*, *121*(41), e2402802121. <https://doi.org/10.1073/pnas.2402802121>

# Table and Figure Captions

Table 1: Description of types of data.

Table 2: Characteristics of included studies by ASHA domain.

Table 3: Effect size measures and interpretation by statistical test.

Table 4: Stability of synthetic datasets across ASHA domains.

Figure 1. Visualization of data distributions from synthetic and original data for Study #1 (Curtis et al., 2023).

*Caption*: Panel A displays the overall distribution of laryngeal vestibule residue. Panel B displays the frequency of values by bolus consistency.

Figure 2. Visualization of data distributions from synthetic and original data for Study #2 (Thompson et al., 2023).

*Caption*: Panel A displays the distribution of vowel space area and panel B displays the distribution of speech intelligibility.

Figure 3. Distribution of log-transformed *p*-values in synthetic datasets across ASHA domains.

*Caption*: Each panel displays the distribution of log-transformed *p*-values across 100 synthetic datasets for a given ASHA domain. The dashed line indicates the threshold for statistical significance from the original study. Shaded green areas indicate synthetic *p*-values that maintained the statistical inferential result of the original study. The mean difference and standard deviation of raw *p*-values compared to the *p*-value reported in the original study is shown below each panel’s title.

Figure 4. Distribution of effect sizes in synthetic datasets across ASHA domains.

*Caption*: Each panel displays the distribution of effect sizes across 100 synthetic datasets for a given ASHA domain. The dashed line indicates the effect size reported in the original study and the light blue shaded area indicates the range of the effect size categorization. The mean difference and standard deviation of the effect size compared to the result reported in the original study is shown below each panel’s title.

Figure 5. Decision tree for data sharing.