Variability and Confidence Intervals of Television Audience Estimates

BARC India
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Introduction

The goal of BARC India is to measure What India Watches™. This is an important task as, in the absence of measurement, there is no way of knowing what the Indian television population is choosing to view at any given moment – despite this being key information for programming, strategy and the buying and selling of television advertisement.

Since it is not possible to sample every individual, sample surveys become a key means of garnering information about a population. Using statistical and scientific methods, a sample survey is a power tool for creating a measure (i.e., an estimate) of an unknown feature of a population (i.e., a parameter). While survey samples are a robust method for developing statistical estimates, it is important to recognize that they can be subject to various errors and, as such, estimates should always be viewed simultaneously with measures of dispersion, such as the standard deviation or the relative error.

Dispersion of Statistical Estimates

Due to the underlying statistics, probabilities, and science, the average of many estimates will match the population parameter of interest. However, individual statistical estimates may vary to some degree from the population parameter. This is known as sampling error, which manifests itself when the behaviour of the sample does not perfectly match that of the population. Statistics and probability give us a mechanism to understand how this error may manifest across samples, and studying the distribution of possible errors (i.e., the dispersion), allows for the calculation of several measures of the dispersion allowing the statistician to understand the underlying precision of the audience estimate.

Precision and Accuracy

Accuracy and precision are often used as the means in which the quality of a survey is measured. These are sometimes also understood, or referred to as, validity and reliability. Both constructs refer to types of errors associated with the estimate of interest. Accuracy focuses on systematic errors in measurement – or biases. These could be biases due to incomplete sample frames (e.g., a measurement service may exclude households in rural India), biases due to technological limitations (e.g., an audio stream is required to capture an audio watermark), or processing errors. Precision focuses on the error from only observing a part (i.e., sample) of the population – often referred to as sampling error – where the sample does not perfectly represent the population. In certain cases, precision can be measured through the standard error. Estimates with smaller standard errors are more precise than those with larger standard errors.

These can be easily understood using the analogy of a dart board (Figure 1). Accuracy refers to how close the darts fall to the bullseye (i.e., the target), whereas precision refers to how consistent close the darts fall to one another. A darts player can be either accurate or precise, both accurate and precise, or neither accurate nor precise.

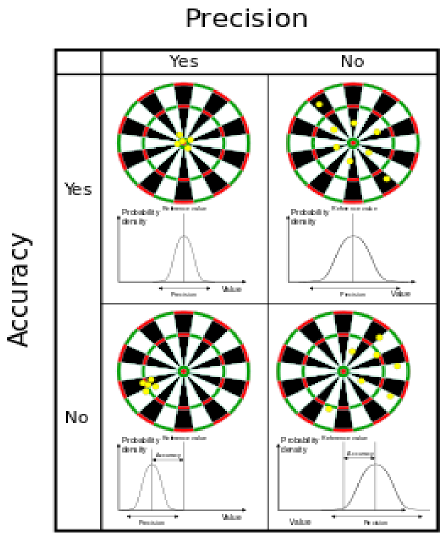

Figure 1. Accuracy vs. precision. By Arbeck [CC BY 4.0 (https://creativecommons.org/licenses/by/4.0)], from Wikimedia Commons.

Outside of technology and data production issues, accuracy is typically controlled through a strong sample design research methodology. Precision, on the other hand, is typically controlled through robust sampling methods such as probability sampling.

Probability Samples in Action

A probability sample is one in which: (a) every sampling unit in the sampling frame has a known probability of selection; and (b) the probability of selection for every sampling unit is greater than zero[1]. So, in the case of BARC India, a probability sample would be one where every television household in India has a known – and nonzero – chance of being selected for recruitment onto the BARC India television panel.

A probability sample is very different from a non-probability, or convenience, sample where only certain sections of the population are included. In these cases, it is often difficult to understand which segments of the population might be missing and therefore entirely possible that changes on the ground may not be reflected in the population. An example would be opt-in samples where individuals join a panel through unprompted choice. It is often impossible to know what the latent variables are surrounding the choice of joining the panel, and therefore, cannot be determined how that sample might change reflective to the ground. In this example, opt-in could be through downloading a particular application on a smartphone. If the appeal of the downloaded application is tied to a systematic bias, the sample may not behave in the same way as the general Indian population.

[1] Goodman, R., & Kish, L. (1950). Controlled selection – A technique in probability sampling. *Journal of the American Statistical Association, 45*(251), 350-372.

In its purest form, sampling can be administered through a process known as *Simple Random Sampling (SRS)* where every sampling unit, or address, has an equal probability of selection. Of the approximately 210 million television households in India, every household would have a probability of being selected for recruitment equal to roughly 1/210 million – or 0.000000048%.

The goal of sampling is to select a sample that is representative of the population. BARC India, therefore, aims to have a panel which is a microcosm of India. Unfortunately, random samples can lead to errors in which the sample selected does not align with the population. This deviation is what is known as sampling error. This phenomenon can be illustrated through an example where a sample of four cards is randomly drawn from a deck of cards to estimate the percentage of Clubs within the deck. In this example, an ideal sample would have precisely one Club – leading to an estimate of 25%, or 13 of the 52 cards. However, this will only happen for 43.9% of the time (Table 1).

Table 1
Probability of Drawing Clubs in a Four Card Hand

Number of Clubs	Probability
0	30.4%
1	43.9%
2	21.3%
3	4.1%
4	0.3%
Total	*100.0%*

A probability sample like this brings two significant advantages:

a. The most probable outcome is the correct outcome, a hand with a single Club – occurring 43.9% of the time; and
b. Due to the known probabilities, we can mathematically calculate a confidence interval around any of the possible estimates – allowing us some insight into the precision of our estimate.

In the above example, our expected value – or most likely outcome – is a hand with a single club. In this case, our estimate matches perfectly with the population – ¼ of the deck being Clubs. While this perfect case is only expected to happen 43.9% of the time, we see that in 30.4% + 43.9% + 21.3% = 95.6% of the time, the resulting four card hand either perfectly matches the population (i.e., one Club), or only over- or under-states by a single Club. Deviances greater than one card (i.e., 3 or 4 Clubs in a hand) occur less than 1 out of 20 times.

Sampling accuracy can be improved (i.e., reduce sampling error) by employing sophisticated sampling processes and techniques such as stratification. In the case of stratification, the population is split into non-overlapping segments (i.e., strata) before sampling. These segments should have some degree of homogeneity within while having some degree of heterogeneity between segments. A random sample is then chosen from each segment.

To illustrate this, we can use the following example. Table 2 shows a scenario where we would like to sample from three classrooms in a school to estimate the proportion of Males within the school. Despite the school being 50% Male and 50% Female, the Male/Female ratio varies dramatically between classrooms. Two approaches could be taken: (a) the school could be sampled as a single unit; or (b) the school could be stratified by classroom with a sample being taken from each class.

Table 2
School Population by Class and Sex

Count (Column%)	Classroom A	Classroom B	Classroom C	Total
Males	5 (25.0)	10 (50.0)	15 (75.0)	30 (50.0)
Females	15 (75.0)	10 (50.0)	5 (25.0)	30 (50.0)
Total	20 (100.0)	20 (100.0)	20 (100.0)	60 (100.0)

A sample of six is drawn two different ways.

1. In the first approach, all six are sampled from the overall pool of sixty students – in other words, a *Simple Random Sample* is drawn.
2. In the second approach, two are sampled from each class of 20. This latter procedure is known as *Stratified Random Sampling*.

It is observed that the likelihood of obtaining an entirely representative sample (i.e., 3 out of the 6 sampled being male) is higher in the Stratified Random Sample approach (Table 3). The likelihood of more extreme samples (i.e., the number of males being 0, 1, 5, or 6) also decreases by 5.0 percentage points. The result is a reduction in the variability of the samples, with the variance in possible outcomes reducing by 16.7% (i.e., decreases from a variance of 1.5 to 1.25). This phenomenon is well visualized by comparing the two probability distributions (Figure *2*).

Table 3
Probability of various outcomes for the number of males sampled in a sample of six

Number of Males in Sample	Approach 1: Simple Random Sampling	Approach 2: Stratified Random Sampling	Difference in Probability (pp)
0	1.6%	0.9%	-0.7
1	9.4%	7.6%	-1.8
2	23.4%	24.1%	+0.7
3	31.3%	34.8%	+3.5
4	23.4%	24.1%	+0.7
5	9.4%	7.6%	-1.8
6	1.6%	0.9%	-0.7
Total	*100.0%*	*100.0%*	*0.0%*

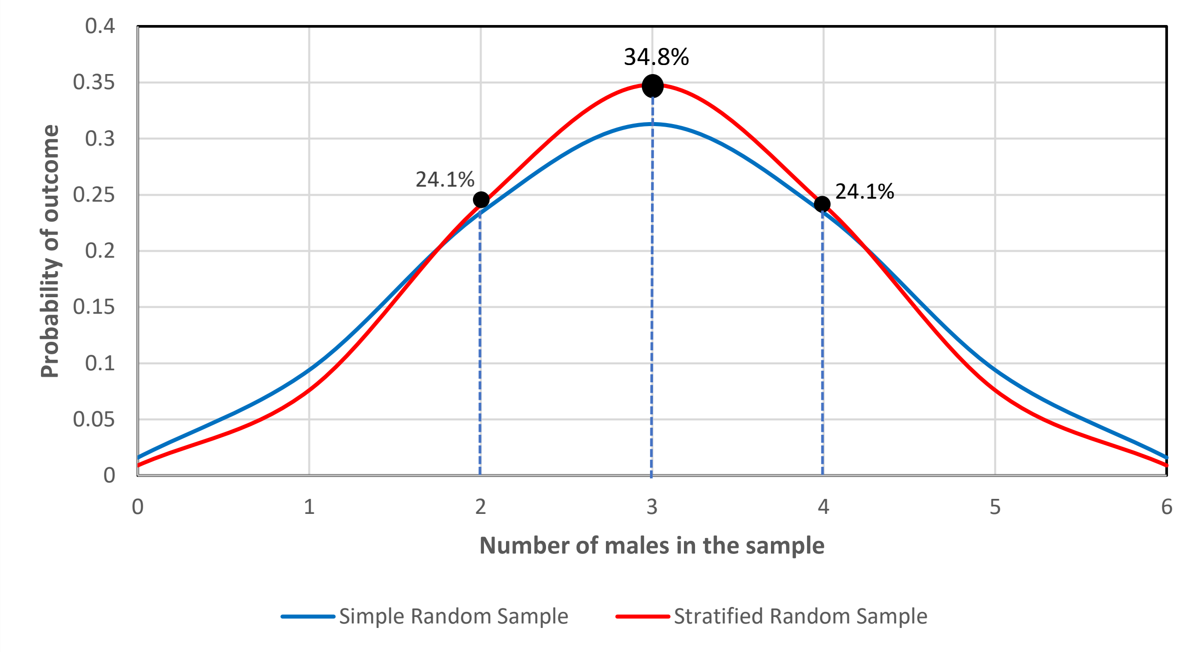

Figure 2. Probability distributions of sample outcomes by sampling approach.

As is demonstrated in the example above, Stratified Random Sampling scores over Simple Random Sampling. Therefore, by stratifying the sample, one can better control the possible sample outcomes, thereby ensuring a higher likelihood of a more representative sample and lower relative errors associated with the audience estimates. To capitalize on this phenomenon, BARC India utilizes a sophisticated sample design and sampling procedure for the management of their television viewing panel. BARC India stratifies the panel against three primary control variables and four secondary control variables (Table 4). These seven variables have been shown to be those most closely correlated with television viewing behaviour.

Table 4
BARC India stratification variables

Primary Control Variable	Secondary Control Variables
• State Group • Town Class • NCCS	• Household size • Languages spoken at home & Language most often spoken at home • Education of the highest educated individual in the household • Mode of signal reception (MOSR)

By controlling the sampling processes in such a way, BARC India can increase the likelihood that the panel remains representative of the Indian TV owing population – thereby minimizing variability and improving the precision of television audience estimates. The panel sampling procedures and panel representativeness has been audited by Centre d'Étude des Supports de Publicité (CESP) France, a global audit company specializing in audience measurement and research audits and has found the processes to be at least on par, if not exceeding global standards.

Measures of Dispersion

There are several useful measures of dispersion which enable a Statistician to understand the underlying precision of a statistical estimate. Each measure provides its own advantage, and the choice of measure is dependent on the Statistician's preference, and their end goal. A few of these important measures are further described in this section.

Standard Error. The Standard Error (SE) of an estimate is the standard deviation (σ) of the possible results that could occur from every possible sample permutation which could have been drawn. It provides and understanding of how the various possible samples would differ from one another. Since audience estimates are largely assumed to be normally distributed, it is generally understood that 68.2% of estimates will lie within one SE from the mean, or expected value, and 95.4% would lie within two SEs from mean (Figure 3).

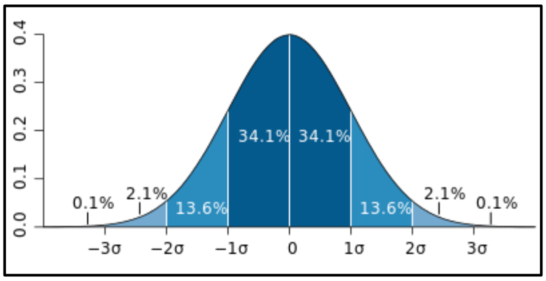

Figure 3. Standard deviation diagram. By M. W. Toews [CC BY 2.5 Generic], from Wikimedia Commons.

For a relative audience estimate calculated from a Simple Random Sample (SRS), the formula for the SE is quite simple (Equation 1, Equation 2), provided that the sample size is known. This formula, however, becomes much more complex and sophisticated under complex multi-stage sampling processes such as those used by BARC India. Typically, it requires advanced statistical formulas or complex algorithms such as Bootstrapping.

$$\boldsymbol{SE}\{\boldsymbol{Rat}\%\} = \sqrt{\frac{\boldsymbol{Rat}\%\times(\mathbf{1}-\boldsymbol{Rat}\%)}{\boldsymbol{n}}}$$

Equation 1. Formula for the SE of a Rat% estimate under SRS.

$$\boldsymbol{SE}\{\boldsymbol{Rch}\%\} = \sqrt{\frac{\boldsymbol{Rch}\%\times(\mathbf{1}-\boldsymbol{Rch}\%)}{\boldsymbol{n}}}$$

Equation 2. Formula for the SE of a Rch% estimate under SRS.

Margin of Error. The possible distance between an estimate and expected value of the estimates follows a probability distribution (Figure 3). We can therefore view the Margin of Error (ME) as expected possible error at a certain confidence level. For example, knowing that 68.2% of estimates will lie within one SE of the expected value, the corresponding ME at a 68.2% confidence level is the SE itself. In its simplest form, the ME at a particular confidence level α is the SE multiplied by a corresponding factor for that confidence level (Equation 3). These factors are known as z-scores (Table 5).

$$\boldsymbol{ME}_{\boldsymbol{\alpha}} = \boldsymbol{z}_{\boldsymbol{\alpha}} \times \boldsymbol{SE}$$

Equation 3. Formula for ME.

Table 5

MEs at various confidence levels

Confidence Level	z-score	ME
68%	1.00	1.00 x SE
90%	1.64	1.64 x SE
95%	1.96	1.96 x SE
99%	2.58	2.58 x SE

Relative Error. The Relative Error (RE) is simply the ME expressed as a percentage of the audience estimate itself (Equation 3). Sometimes this can also be known as the Coefficient of Variation (CV).

$$\boldsymbol{RE = \frac{ME}{Estimate}}$$

Equation 3. Formula for RE.

Since the economic value of a channel or program is often tied to its audience estimate, a relative measure helps the Statistician understand the possible variation with respect to the economic value of the channel. For example, two channels may have similar MEs, but if there is a large difference between the size of their audience estimates, the ME will represent a greater variability of the audience for the smaller channel.

This can be illustrated with an example of two programs. Program A has an Average Minute Audience (AMA) in thousands of 639, and Program B has an AMA('000) of 74. Both programs carry a ME of 25. It is easy to see that while the MEs are the same for both programs, the RE for Program B is larger (Table 6). This is important to understand as it suggests that the variation may have a greater economic impact on the Program with the smaller audience if variability is not taken into consideration.

Table 6

Comparison of REs of two programs with similar MEs			
Program	AMA (A)	ME (B)	RE (B)/(A)
A	639	25	3.9%
B	74	25	33.8%

It is also important to understand that the relative error tends to increase as audience estimates are analyzed at more granular levels. For example, a Hindi GEC channel might have a reach of 10% at an all-India level which carries a RE of 1%. However, as this data starts to be analyzed at more granular levels, the RE starts to increase (Figure 4).

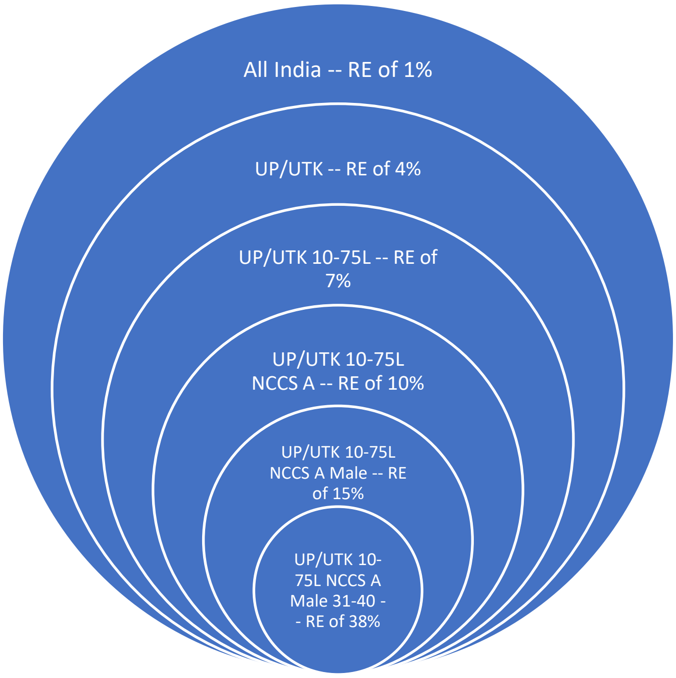

Figure 4. Relative Errors associated with a Rat% of a Hindi GEC channel.

Confidence Intervals. The Confidence Interval (CI) is the range of possible values for the unknown parameter (i.e., television audience) being estimated. Like ME, the CI carries a confidence level. In scientific terms, the confidence level is the theoretical long-run frequency of CIs which will contain the true parameter. In more simplistic terms, the confidence level is the probability that the CI contains the true parameter. Therefore, a 95% CI can be viewed as the range in which the true value will lie 19 out of 20 times.

Since the ME already factors the confidence level, the CI can be simply expressed in relation to the ME (Equation 4).

$$\boldsymbol{CI_{\alpha} = estimate \pm ME_{\alpha}}$$

Equation 4. Formula for CI.

For example, consider a TV program with an audience of 1 TVR and a ME of 0.25 at a 90% confidence level. This suggests that the actual rating is expected to lie between 1 – 0.25 and 1 + 0.25, or 0.75 and 1.25, with a probability of 90% (Figure 5).

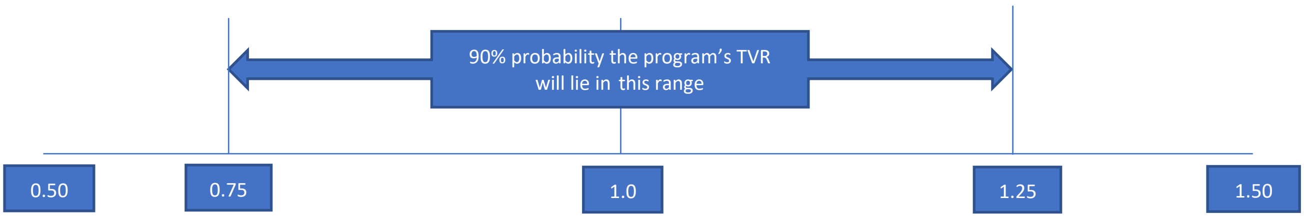

Figure 5. Example of a 90% confidence interval for a program with a TRP of 1.

Understanding the Dispersion of BARC India Television Audience Estimates

Given the importance of understanding the potential variability around a particular audience estimate, BARC India has two key resources for the users of its data. These are explained in detail in this section. End users of BARC's data are always encouraged to consider the associated variability in conjunction with any single audience estimate.

Margin of Error in YUMI

As part of BARC India's constant endeavor to empower its subscribers with an authentic and an accurate representation of What India Watches™, effective retrospectively in YUMI as part of the upgrade implemented 25 June 2021, YUMI subscribers have access to ME figures for the Rat% and Reach% audience estimates. This is another step in BARC's ongoing journey of raising the bar to enable the industry with sharper data-driven decision-making tools.

The availability of Margin of Error (expressed at a specific Confidence Interval) within YUMI gives a better understanding of the precision of the audience estimates. ME is only available within the Time-band Report for either a specific channel or group of channels (virtual or user-defined) for any defined market/time-band.

This upgrade helps improve the effectiveness in media planning by giving advertisers better visibility into the actual performance of their media investments relative to their goals. This in turn will lead to even more informed decisions.

Tables 7 and 8 provide a demonstration of the two metrics – ME and CI.

Table 7
Illustrative sample #1. TG: Maharashtra 2+.

Channel	Measure	Avg. Value	Margin of Error (90% CI)	90% Confidence Interval Lower Bound	90% Confidence Interval Upper Bound	Relative Error
Total TV	Rch%	71.90%	0.6759%	71.23%	72.58%	0.94%
Total TV	Rat%	13.55%	0.2213%	13.33%	13.77%	1.63%
Channel A	Rch%	9.33%	0.4559%	8.88%	9.79%	4.88%
Channel A	Rat%	0.47%	0.0321%	0.44%	0.51%	6.77%
Channel A, 9p-11p	Rch%	3.41%	0.2571%	3.15%	3.66%	7.55%
Channel A, 9p-11p	Rat%	0.90%	0.0866%	0.81%	0.99%	9.62%
Channel A, B, C, D	Rch%	21.78%	0.6322%	21.15%	22.41%	2.90%
Channel A, B, C, D	Rat%	1.31%	0.0540%	1.26%	1.36%	4.12%
Channel E	Rch%	7.63%	0.3768%	7.26%	8.01%	4.94%
Channel E	Rat%	0.12%	0.0100%	0.11%	0.13%	8.43%
Channel E, 7p-8p	Rch%	3.84%	0.1511%	3.69%	3.99%	3.93%
Channel E, 7p-8p	Rat%	0.26%	0.0370%	0.22%	0.30%	14.26%
Channel E, F, G, H, J	Rch%	13.53%	0.5063%	13.02%	14.03%	3.74%
Channel E, F, G, H, J	Rat%	0.35%	0.0223%	0.33%	0.38%	6.30%

Table 8
Illustrative sample #2. TG: Assam M22+ AB.

Channel	Measure	Avg. Value	Margin of Error (90% CI)	90% Confidence Interval Lower Bound	90% Confidence Interval Upper Bound	Relative Error
Total TV	Rch%	70.84%	4.0281%	66.81%	74.86%	5.69%
Total TV	Rat%	10.43%	1.1208%	9.31%	11.55%	10.75%
Channel A	Rch%	10.66%	2.9132%	7.75%	13.58%	27.32%
Channel A	Rat%	0.48%	0.2152%	0.27%	0.70%	44.67%
Channel A, 9p-11p	Rch%	3.64%	1.7718%	1.87%	5.41%	48.66%
Channel A, 9p-11p	Rat%	0.88%	0.5571%	0.32%	1.44%	63.34%
Channel A, B, C, D	Rch%	21.28%	3.7814%	17.50%	25.06%	17.77%
Channel A, B, C, D	Rat%	1.24%	0.3578%	0.88%	1.59%	28.93%
Channel E	Rch%	7.73%	2.5964%	5.14%	10.33%	33.58%
Channel E	Rat%	0.09%	0.0596%	0.04%	0.15%	62.90%
Channel E, 7p-8p	Rch%	1.47%	1.1328%	0.34%	2.61%	76.84%
Channel E, 7p-8p	Rat%	0.27%	0.2916%	0.00%	0.56%	107.47%
Channel E, F, G, H, J	Rch%	16.06%	3.3718%	12.69%	19.43%	21.00%
Channel E, F, G, H, J	Rat%	0.40%	0.1541%	0.25%	0.56%	38.39%

Relative Error Tables

BARC has published an extensive White Paper on REs on its website at https://barcindia.co.in/whitepaper/barc-india-relative-error-whitepaper.pdf

This paper covers many key topics including:

- Sampling and Data Collection
- Relative Error
- Factors affecting Relative Error
- Why is Relative Error important?
- Tables for understanding the Relative Error of various audience estimates

Users of BARC's data are encouraged to download and read the aforementioned paper in conjunction with this paper.