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Cover Letter

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Science at the heart of medicine

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Re: "Using the Race Model Inequality to quantify behavioral multisensory integration effects."

Dear Dr. Berard,

We are pleased to resubmit our manuscript entitled: "Using the Race Model Inequality to quantify behavioral multisensory integration effects" as a PubMed-indexed video article to the *Journal of Visualized Experiments*.

As per the editorial team's request, we now include specific figures detailing each step of our experimental protocol. Additionally, we have uploaded all requested supplemental files.

The authors have participated in the research reported, have seen and approved the final version of the manuscript, and have agreed to be an author of the paper. All authors of this paper certify that any affiliations with or involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the manuscript.

Should you have any additional questions, please feel free to contact me.

Respectfully submitted,

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TITLE:

Using the Race Model Inequality to Quantify Behavioral Multisensory Integration Effects

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KEYWORDS:
multisensory integration; sensorimotor integration; Race Model Inequality; Redundant Signals Effect; aging

SHORT ABSTRACT:
The current study aims to provide a step-by-step tutorial for calculating the magnitude of multisensory integration effects in an effort to facilitate the production of translational research studies across diverse clinical populations.

LONG ABSTRACT:
Multisensory integration research investigates how the brain processes simultaneous sensory information. Research on animals (mainly cats and primates) and humans reveal that intact multisensory integration is crucial for functioning in the real world, including both cognitive and physical activities. Much of the research conducted over the past several decades documents multisensory integration effects using diverse psychophysical, electrophysiological, and neuroimaging techniques. While its presence has been reported, the methods used to determine the magnitude of multisensory integration effects varies and typically faces much criticism. In what follows, limitations of previous behavioral studies are outlined and a step-by-step tutorial for calculating the magnitude of multisensory integration effects using robust probability models is provided.

INTRODUCTION:
Interactions across sensory systems are essential for everyday functions. While multisensory integration effects are measured across a wide array of populations using assorted sensory combinations and different neuroscience approaches [including but not limited to the psychophysical, electrophysiological, and neuroimaging methodologies][1-9], currently a gold standard for quantifying multisensory integration is lacking. Given that multisensory experiments

typically contains a behavioral component, reaction time (RT) data is often examined to determine the existence of a well-known phenomenon called the redundant signals effect[10]. As its name suggests, simultaneous sensory signals provide redundant information, which typically yield quicker RTs. Race and co-activation models are used to explain the above mentioned redundant signals effect[11]. Under race models, the unisensory signal that is processed the fastest is the winner of the race and is responsible for producing the behavioral response. However, evidence for co-activation occurs when responses to multisensory stimuli are quicker than what race models predict.

Earlier versions of the race model are inherently controversial[12,13] as they are referred to by some as overly conservative[14,15] and purportedly contain limitations regarding the independence between the constituent unisensory detection times inherent in the multisensory condition[16]. In an effort to address some of these limitations, Colonius & Diederich[16] developed a more conventional race model test:

$$\mathrm{P}(\mathrm{RT}_{\mathrm{AB}} \leq t) - \min\left[\mathrm{P}(\mathrm{RT}_{\mathrm{A}} \leq t) + \mathrm{P}(\mathrm{RT}_{\mathrm{B}} \leq t), 1\right],$$

where the cumulative distribution frequencies (CDFs) of the unisensory conditions (e.g., A & B; with an upper limit of one) are compared to the CDF of the simultaneous multisensory condition (e.g., AB) for any given latency (t)[11,16,17]. In general, a CDF determines how often an RT occurs, within a given range of RTs, divided by the total number of stimulus presentations (i.e., trials). If the CDF of the actual multisensory condition $[\mathrm{P}(\mathrm{RT}_{\mathrm{AB}} \leq t)]$ is less than or equal to the predicted CDF derived from the unisensory conditions

$$\left[\min\left(\mathrm{P}(\mathrm{RT}_{\mathrm{A}} \leq t) + \mathrm{P}(\mathrm{RT}_{\mathrm{B}} \leq t), 1\right)\right],$$

then the race model is accepted and there is no evidence for sensory integration. However, when the multisensory CDF is greater than the predicted CDF derived from the unisensory conditions, the race model is rejected. Rejection of the race model indicates that multisensory interactions from redundant sensory sources combined in a non-linear manner, resulting in a speeding up of RTs (e.g., RT facilitation) to multisensory stimuli.

One main hurdle that multisensory researchers face is how to best quantify integration effects. For instance, in the case of the most basic behavioral multisensory paradigm, where participants are asked to perform a simple reaction time task, information regarding accuracy and speed is collected. Such multisensory data can be used at the face-value or manipulated using various mathematical applications including but not limited to Maximum Likelihood Estimation[18,19], CDFs[11], and various other statistical approaches. The majority of our previous multisensory studies employed both quantitative and probabilistic approaches where multisensory integrative effects were calculated by 1) subtracting the mean reaction time (RT) to a multisensory event from the mean reaction time (RT) to the shortest unisensory event, and 2) by employing CDFs to determine whether RT facilitation resulted from synergistic interactions facilitated by redundant sensory information[8,20-23]. However, the former methodology was likely not sensitive to the individual differences in integrative processes and researchers have since posited that the later

methodology (i.e., CDFs) may provide a better proxy for quantifying multisensory integrative effects[24].

Gondan and Minakata recently published a tutorial on how to accurately test the Race Model Inequality (RMI) since researchers all too often make countless errors during the acquisition and pre-processing stages of RT data collection and preparation[25]. First, the authors posit that is unfavorable to apply data trimming procedures where certain *a priori* minimum and maximum RT limits are set. They recommend that slow and omitted responses be set to infinity, rather than excluded. Second, given that the RMI may be violated at any latency, multiple t-tests are often used to test the RMI at different time points (i.e., quantiles); unfortunately, this practice leads to the increased Type I error and substantially reduced statistical power. To avoid these issues, it is recommended that the RMI be tested over one specific time range. Some researchers have suggested that it makes sense to test the fastest quartile of responses (0-25%)[26] or some pre-identified windows (i.e., 10-25%)[24,27] as multisensory integration effects are typically observed during that time interval; however, we argue that the percentile range to be tested must be dictated by the actual dataset (see **Protocol Section 5**). The problem with relying on published data from young adults or computer simulations is that older adults manifest very different RT distributions, likely due to the age-related declines in sensory systems. Race model significance testing should only be tested over violated portions (positive values) of group-averaged difference wave between actual and predicted CDFs from the study cohort.

To this end, a protective effect of multisensory integration in healthy older adults using the conventional test of the race model[16] and the principles set forth by Gondan and colleagues[25] has been demonstrated. In fact, greater magnitude of visual-somatosensory RMI (a proxy for multisensory integration) was found to be linked to better balance performance, lower probability of incident falls and increased spatial gait performance[28,29].

The objective of the current experiment is to provide researchers with a step-by-step tutorial to calculate the magnitude of multisensory integration effects using the RMI, to facilitate the increased production of diverse translational research studies across many different clinical populations. Note that data presented in the current study are from recently published visual-somatosensory experiments conducted on healthy older adults[28,29], but this methodology can be applied to various cohorts across many different experimental designs, utilizing a wide-array of multisensory combinations.

PROTOCOL:

All participants provided written informed consent to the experimental procedures, which were approved by the institutional review board of the Albert Einstein College of Medicine.

1. Participant Recruitment, Inclusion Criteria, and Consent

1.1. Recruit a relatively large cohort of English-speaking individuals who can ambulate independently and are free of significant sensory loss; active neurological or psychiatric disorders that interfere with experimental evaluations; and current/future medical procedures that affect

mobility.

1.2. Ensure that each participant can successfully complete a sensory screening exam, where visual, auditory, and somatosensory acuity are formally tested to confirm study appropriateness.

1.2.1. Use the Snellen eye chart to ensure that bilateral visual acuity is better than or equal to 20/100.

1.2.2. Use a tone-emitting otoscope to ensure that participants are at a minimum able to hear a 2,000 Hz tone at 25 dB[30].

1.2.3. Determine whether participants maintain a diagnosis of clinical neuropathy and whether it interferes with the ability to feel the experimental somatosensory stimulation[21,28,29].

1.2.4. If the participant is unable to meet these minimum sensory requirements, do not include them in the study.

1.3. Exclude older adults with dementia by implementing cut-scores from reliable screening instruments such as the AD8 Dementia Screening Interview cutoff score ≥2 [31,32]; and the Memory Impairment Screen MIS; cutoff score < 5[33].

1.4. Have participants provide written informed consent to the experimental procedures (approved by a local institutional review board) if willing to participate.

2. Experimental Design

2.1. Use stimulus presentation software to program a simple reaction time experiment with three experimental conditions: visual (V) alone, somatosensory (S) alone, and simultaneous visual-somatosensory (VS). Inform participants to respond to each sensory stimulus, regardless of the condition, as quickly as possible. See supplementary files for an example of a VS simple RT task (**Supplementary File 1**).

2.1.1. Use a stimulus generator with three control boxes (30.48 mm × 20.32 mm × 12.70 mm) and plastic housing for stimulators. The left and right control boxes contain bilateral blue light emitting diodes (LEDs; 15.88 cm diameter) that illuminate for visual stimulation and bilateral motors with 0.8 G vibration amplitude that vibrate for somatosensory stimulation (equivalent to a cell-phone vibration)[22,23,28].

2.1.2. Ensure that stimulus generators provide both unisensory (visual OR somatosensory alone), as well as multisensory (simultaneous visual AND somatosensory) stimulation. Place a center dummy control box equidistant (28 cm) from the left and right control boxes described in 2.1.1. and affix a visual target sticker (central circle of 0.4 cm diameter) to serve as the fixation point.

2.1.3. Connect the stimulus generator to the experimental computer via the parallel port which allows the direct control for each stimulator.

2.1.4. Program the stimulus presentation software to send transistor-transistor-logic (TTL, 5 V) pulses to the trigger stimulus generators on and off directly via the parallel port. Set the stimulus presentation time to 100 ms in duration.

2.2. In the stimulus presentation software, program a minimum of 3 experimental blocks each consisting of 45 trials (15 trials of each stimulus condition presented in random order) for a total of 135 stimulus presentations for this simple reaction time experiment.

2.3. Vary the inter-stimulus-interval randomly between 1 and 3 s to prevent anticipatory effects. Alternatively, insert catch trials where the stimulus parameters are the same as above, but the TTL pulse is not sent, thus no visual or somatosensory stimulation occurs and, therefore, no response is expected.

2.4. Allow participants up to 2000 ms to respond to any given stimulus condition. If no response is detected within the 2000 ms response period, ensure that the stimulus presentation software advance to the next trial automatically.

NOTE: This response window cut-off is arbitrary but necessary to keep the total experimental time to a minimum; note that longer RTs will be set to infinity regardless.

2.5. Separate the three experimental blocks by programming 20-s breaks in the stimulus presentation software to reduce the potential fatigue and increase concentration span. Ensure each subsequent block starts immediately after the 20-s break concludes.

2.6. Program written instructions to appear on the visual display (monitor of the experimental computer). The exact instructions are provided in the supplemental material. Ask the participant to start the experiment by pushing the response pad with their right foot when ready to commence. Once the stimulus parameters are programmed, the stimulus presentation software creates a script that is to be run on each participant.

2.7. Provide participant ID and session number in order to run the experimental script. Once the experiment is completed, a unique behavioral data log is produced for each participant (see **Supplementary File 2** for a sample Eprime 2.0 output file).

3. Apparatus & Task

3.1. Have participants sit upright and comfortably rest hands upon the left and right control boxes.

3.1.1. Strategically place index fingers over the vibratory motors mounted to the back of the control box, and thumbs on the front of the control box, under the LED to not block the LED (see **Figure 1**).

3.1.2. Ensure that the somatosensory stimuli are inaudible by providing participants with headphones over which continuous white noise is played at a comfortable level (typically 65-75 dBs).

3.2. Instruct participants to respond to all stimuli as quickly as possible.

3.2.1. Ask participants to use a foot-pedal located under the right foot as the response pad and to use the fingers as needed to accept somatosensory stimulation (see **Figure 1**).

3.3. Calculate the performance accuracy by stimulus condition.

3.3.1. Instruct participants to respond to each of the experimental stimuli (45 per condition) as quickly as possible.

3.3.2. Divide the number of accurately detected stimuli per condition over 45 (total number of trials per condition) to obtain measures of performance accuracy for visual, somatosensory, and VS conditions, respectively.

4. Race Model Inequality Data Preparation (Individual Level)

4.1. Determine whether an individual's behavioral performance is valid.

4.1.1. Exclude participants that are not able to attain an accuracy of 70% correct or greater on any one stimulus condition[21,22,28]. As the participant's performance accuracy on a simple reaction time task decreases, so does the reliability of the individual's data.

4.1.2. Consider trials inaccurate (omitted) if a participant fails to respond to a stimulus within the set response time period and set corresponding RT to infinity rather than excluding the trial from the analysis[25,28].

NOTE: In previous studies, the group-averaged (n=289) stimulus detection was 96% across all conditions, and over 90 % of the population had detection rates above 90% for all conditions[28].

4.1.3. Do not employ data-trimming procedures that delete very slow RTs as this will bias the distribution of RT data.[25] Ensure RTs that are clearly outliers are set to infinity. See supplementary file depicting alterations in CDFs based on data-trimming procedures and inclusion of slow RTs (**Supplementary File 3**).

4.2. Organize the RT Data.

4.2.1. Sort RT data in ascending order by the experimental condition. Place visual, somatosensory, and VS conditions in separate columns of sorted RT data. Ensure each row represents one trial and each cell represents the actual RT (or infinity in the case of omitted or slow trials).

4.3. Bin the RT Data.

4.3.1. Identify the fastest RT (to whichever condition- orange ellipse) and the slowest RT (to whichever condition-red ellipse). Subtract the slowest RT from the fastest (e.g., 740 ms – 237 ms) in order to calculate the individual's RT range (503ms; blue ellipse) across ALL test conditions.

4.3.2. Bin RT data from the 0% (fastest RT = 237 in this example) to the 100% (or slowest RT = 740 in this example) in 5% increments by taking the fastest RT and gradually adding 5% of the RT range identified in 4.3.1 until 100% of the RT data is accounted for (see **Table 2**). This will result in 21-time bins.

NOTE: Table 1 demonstrates how to calculate an individual's RT Range. In **Table 2** - 1%ile is only included in worksheet just for illustrative purposes.

4.4. Calculate the Cumulative Distribution Frequency (CDF) for the experimental conditions.

4.4.1. Using spreadsheet software, use a "FREQUENCY" function $=$ $\mathrm{FREQUENCY}\,(\mathrm{array1}, \mathrm{array2})$ / total_#_of_trials (black ellipse **Figure 2a**) where array1 equals the actual RTs for one of the experimental condition and array2 equals the 21 quantized RTs bins calculated in Step 4.3, divided by the total number of trials (45) per condition. This is illustrated in **Figure 2a.**

4.4.2. Repeat this function for the other two experimental conditions (**Figures 2b-2c**) so as to populate frequencies (or probability (P)) of an RT occurring within each of the 21 quantized time bins, for each of the three experimental conditions.

4.4.3. Next, create the cumulative distribution frequency (CDF) by summing the running total of probabilities across the quantized bins (0%, 0+5%, 0+5+10%, 0+5+10+15%, etc.) for each of three experimental conditions. For example, in the cumulative probability column for the Soma condition (column AE), the cumulative probability for the 95%ile range (cell AE22) is the summation of the probability values in cells Z3:Z23 (see **Figure 3**).

4.5. Actual vs. Predicted CDFs.

4.5.1. Ensure that the CDF of the multisensory condition represents the **actual** CDF (see **Figure 4** column AF and plotted purple trace). To calculate the **predicted** CDF (column AG), sum the two unisensory CDFs (with an upper limit set to 1). Use = $\mathrm{MIN}(\mathrm{CDF1} + \mathrm{CDF2}, 1)$ across each one of the 21 quantized time bins (see **Figure 5**). Start at the 0th percentile (bin 1) and continue all the way down to the 100th percentile (bin 21).

4.6. Conduct the Test of the Race Model Inequality (RMI).

4.6.1. Subtract the **predicted** CDF (calculated in 4.5.2.) from the **actual** CDF for each of the 21 quantized time bins to obtain the difference values (column AH; see **Figure 6**).

4.6.2. Plot these 21 values as a line graph, where the x-axis represents each one of the quantized time bins (column AC) and the y-axis represents the probability difference between the actual and predicted CDFs (column AH; **Figure 7** (black trace).

4.6.3. Check for positive values at any latency (i.e., quantiles) which indicate the integration of the unisensory stimuli and reflect a violation of the RMI (see the green highlighted portion of difference wave from 0.00 – 0.10 in **Figure 7**).

5. Quantification of the Multisensory Effect (Group Level).

5.1. Group-average the individual RMI data (differences between **predicted** CDF and the **actual** CDF for each of the 21-time bins; step 4.6.1- column AH) across all participants. Use a spreadsheet software for doing this by assigning individuals to rows and time bins as columns. In a new spreadsheet, place the 21 values calculated in 4.6.1 in individual rows (1 row per participant), and average values within time bins to create one group-averaged difference waveform.

5.2. Plot the group average 21 values as a line graph, where the x-axis represents each one of the quantized time bins and the y-axis represents the probability difference between CDFs.

5.3. Visually inspect and document the violated portion of the group-averaged difference wave (i.e., positive values).

5.4. Run Gondan's RMI permutation test (R script available as a free download)[26] to determine whether there is a statistically significant violation of the RMI over the positive values identified in step 5.3.

5.4.1. Organize the data in one text file where the first column is named "Obs" for Observer (e.g., participant ID), the second column is named "Cond" for stimulus condition (V, S, or VS) and the third column is named "RT" for actual RT or "Inf" if set to infinity.

5.4.2. Open the software, identify which time bins are to be tested (based on the positive time bins identified in 5.3), and enter the text file name created in 5.4.1.

5.4.3. Run the test by calling up the script. The results will provide a *t*max value, 95% criterion, and p-value which will be instrumental in determining whether a significant violation of the Race Model exists.

5.5. Calculate the area-under-the-curve (AUC) for each individual after establishing the

significantly violated percentile bins in step 5.3. AUC will serve as the magnitude of multisensory integration (or the independent variable). To calculate AUC use participant 1's data as an example, for percentile bins 0.00 - 0.15 depicted in **Figures 8a-d**).

5.5.1. Sum the CDF difference value at time bin 1 (1st time positive value) with the CDF difference value of time bin 2 (next positive value) and then divide by two (see **Figure 8a**). Repeat step 5.3.1. for each consecutive pair of time bins containing positive values (see **Figure 8b-8c**).

5.5.2. Sum the results obtained from steps 5.5.1 - 5.5.2. to generate the total AUC of the CDF difference wave during the violated percentile range (e.g., 0.00 – 0.15 in **Figure 8d**).

NOTE: AUC is a continuous measure and one AUC value is present for each individual for the violated portion of the RMI (Figure 8d red ellipse = participant 1's AUC = 0.13). AUC can be used as an independent variable representing 'magnitude of VS integration' which can later be tested to predict important clinical outcome measures (see also[28,29]).

5.6. Assign multisensory integration classification groups based on the number of violated percentile bins (values greater than zero highlighted in gray in **Table 3**) during the significantly violated percentile range identified above in step 5.3. Looking at **Table 3** (percentile bins 0.00 – 0.15): Participant 1 has positive values for 2 out of 4 bins; Participant 2 has positive values for 4 out of 4 bins; and Participant 3 has positive values for 0 out of 4 bins.

5.6.1. Operationalize a classification system based on the number of violated percentile bins (values greater than zero for 0, 1, 2, or 3 bins) during the 0-10th percentile. One potential classification definition is depicted below in **Figure 9**, which was adapted from recently published data presented by Mahoney and Verghese[29].

REPRESENTATIVE RESULTS:

The purpose of this study was to provide a step-by-step tutorial of a methodical approach to quantify the magnitude of VS integration effects, to foster the publication of new multisensory studies using similar experimental designs and setups (see **Figure 1**). Screenshots of each step and calculation needed to derive magnitude of multisensory integration effects, as measured by RMI AUC, are delineated above and illustrated in **Figures 2-8**.

Figure 9 demonstrates a group-averaged violation (dashed trace) occurring over the 0-10% percentile range for a sample of 333 older adults (see also[29]). Here, the total number of positive values (0, 1, 2, or 3) for those 3 quantiles (0.00 – 0.10) determines which multisensory classification group a person is assigned (deficient, poor, good, or superior) respectively. Here, the total number of positive values (0, 1, 2, or 3) for those 3 quantiles (0.00 – 0.10).

As depicted in **Figure 9**, group-averaged results demonstrate a significant race model violation over the fastest tenth of all response times[26]. While this group-averaged difference waveform suggests that on average older adults demonstrate significant race model violation (i.e.,

multisensory integration effects), we argue that this is not a one size fits all model. Rather, the individual's AUC under the violated time period (0-10%ile) provides a better proxy of assessing the individual's magnitude of VS integration, as differential integration patterns have been documented [20-23, 28,29]. Once calculated, the individual magnitude of VS integration can serve as a continuous predictor of important outcomes in various clinical populations.

We recommend implementing a classification system, perhaps based on the number of violated percentile bins (values greater than zero) during the group-averaged RMI violation period, as a means of depicting inherent differential integration patterns. Classification of data in this manner will reveal a clear degradation of race model violation by multisensory integration classification group.

FIGURE AND TABLE LEGENDS:

Figure 1: Experimental apparatus. Using a foot pedal located under the right foot as a response pad, participants were asked to respond to unisensory and multisensory stimuli as quickly as possible. This figure has been reprinted with permission[22,28,29].

Figure 2: Calculating the frequency of an RT occurring within a specified range of RTs for each experimental condition. a) Visual (V); b) Somatosensory (S); and c) Visual-Somatosensory (VS).

Figure 3: Creating the cumulative distribution frequency for the experimental conditions. This figure depicts the summation of the cumulative probability at the 95%ile bin for the Soma (S) condition.

Figure 4: Plotting the Actual CDF (VS condition; purple trace) as a function of quantile.

Figure 5: Calculating the Predicted CDF. Sum the CDFs of the two unisensory CDFs while including an upper limit = 1 for each of the quantiles from 0.00 to 1.00.

Figure 6: Create the Race Model Inequality (RMI). Subtract the CDF of the predicted CDF from the actual CDF for each quantile.

Figure 7: Plot the individual RMI values. The x-axis represents each of the 21 quantiles (column AC) and the y-axis represents the probability difference between CDFs (column AH). The green highlighted portion of the RMI depicts the positive or violated portion of the waveform, indicative of multisensory integration.

Figure 8: Calculating an individual's Area-Under-the-Curve (AUC). a) Sum the CDF difference value at quantile 1 (0.00) with the CDF difference value of quantile 2 (0.05) and then divide by two to create a measure of AUC from 0.00 – 0.05. b-c) Repeat step a) for each consecutive pair of quantiles (e.g., 0.05 - 0.10 and 0.10 – 0.15) to attain the AUC for each quantile range. d) Sum the AUC for each time bin range to obtain the total AUC for the entire time bin window identified in 5.3. Note this example includes a wider quantile range (0.00 – 0.15) for illustrative purposes

only.

Figure 9: Race Model Inequality: Overall and by Group Classification. The group-averaged difference between actual and predicted CDFs over the trajectory of all quantiles is represented by the dashed trace. The solid traces represent each of the four multisensory integration classifications defined above based on the number of violated quantile bins. This adapted figure has been reprinted with permission[29].

Supplementary File 1: Sample Simple Reaction Time Paradigm programmed in Eprime 2.0.

Supplementary File 2: Sample RT data behavioral data output from Eprime 2.0.

Supplementary File 3: Sample RMI data with and without outliers and omitted trials.

Table 1. Individual Descriptive Statistics by Condition and Calculation of RT Range.

Table 2. Example of how to bin RT data based on RT range.

Table 3. Example of AUC calculation & Identification of # of violated quantiles (grey shaded area).

DISCUSSION:

The goal of the current study was to detail the process behind the establishment of a robust multisensory integration phenotype. Here, we provide the necessary and critical steps required to acquire multisensory integration effects that can be utilized to predict important cognitive and motor outcomes relying on similar neural circuitry. Our overall objective was to provide a step-by-step tutorial for calculating the magnitude of multisensory integration in an effort to facilitate innovative and novel translational multisensory studies across diverse clinical populations and age-ranges.

As stated above and outlined by Gondan and colleagues, it is very important to preserve the individual's RT dataset[25,28]. That is, avoid data-trimming procedures that omit very slow RTs given its inherent bias on the RT distribution;[25] instead, set omitted and slow RTs to infinity. This step is critical and failure to abide by these simple rules will lead to the development of inaccurate multisensory integration results. Additionally, race model significance testing should only be tested over group-averaged violated portions of the RMI identified in the study cohort (i.e., not a priori specified windows).

In terms of limitations, the current experimental design was based on data from a simple reaction time task to bilateral stimuli that were presented to the same location and at precisely the same time. We recognize that several adaptations to the current experimental design can be made depending upon various hypotheses that researchers are interested in examining. We utilize this study as a launching pad towards documenting robust MSI effects in aging but recognize that

implementation of various experimental adaptations (e.g., different bi- and even tri-sensory combinations, varied stimulus presentation onsets times, and differential magnitude of stimulus intensity) will provide a wealth of incremental information regarding this multisensory phenomenon.

We have implemented the above approach to demonstrate significant associations between the magnitude of visual-somatosensory integration with balance[28] and incident falls[28], where older adults with greater multisensory integration abilities manifest better balance performance and less the incident falls. Similarly, we demonstrate that the magnitude of visual-somatosensory integration was a strong predictor of spatial aspects of gait[29], where individuals with worse visual-somatosensory integration demonstrated slower gait speed, shorter strides, and increased double support. In the future, this methodology should be used to uncover the relationship of MSI with other important clinical outcomes like cognitive status, and aid in the identification of critical functional and structural multisensory integrative neural networks in aging and other clinical populations.

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DISCLOSURES:

There are no conflicts of interest to report and the authors have nothing to disclose.

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Figure 1.

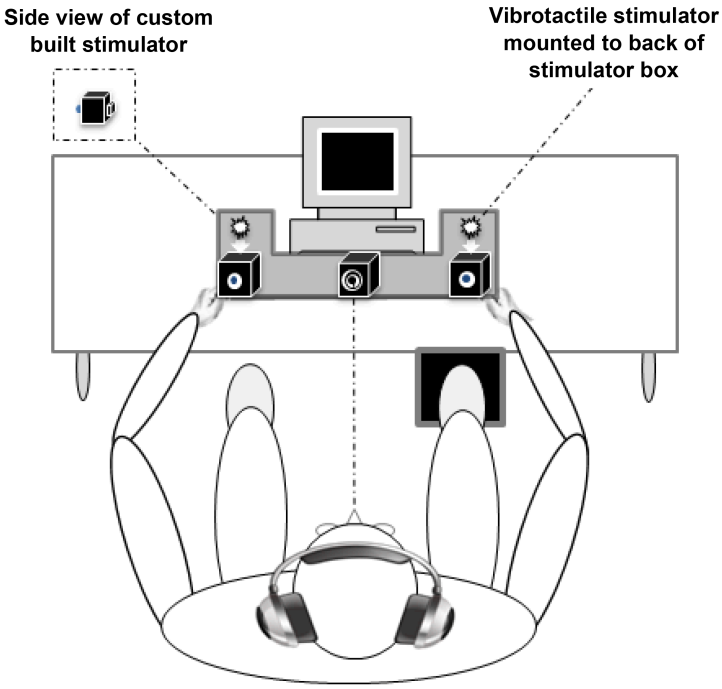

Figure 2.

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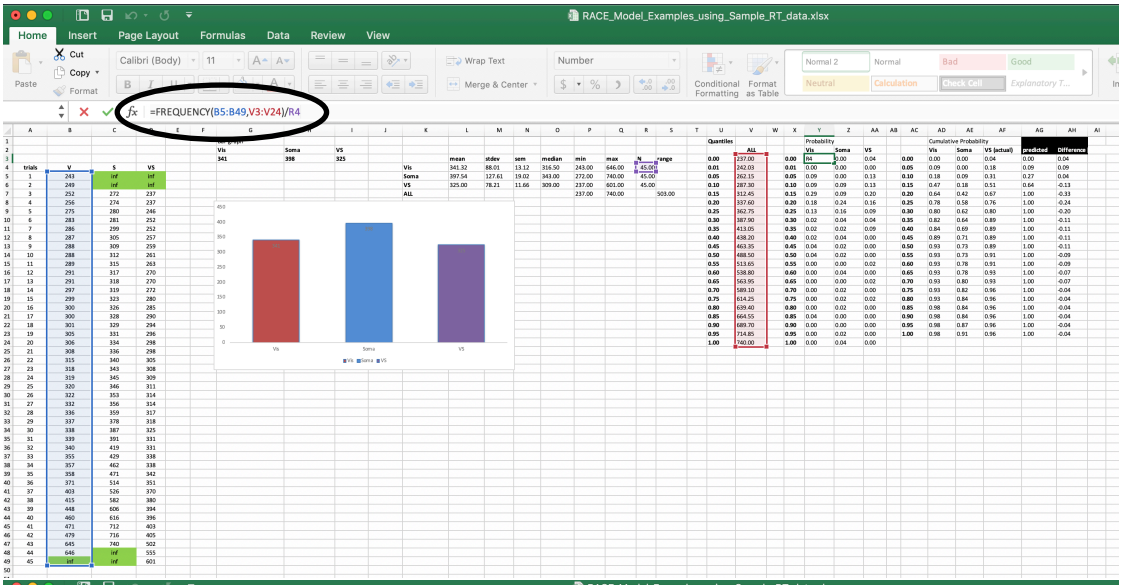

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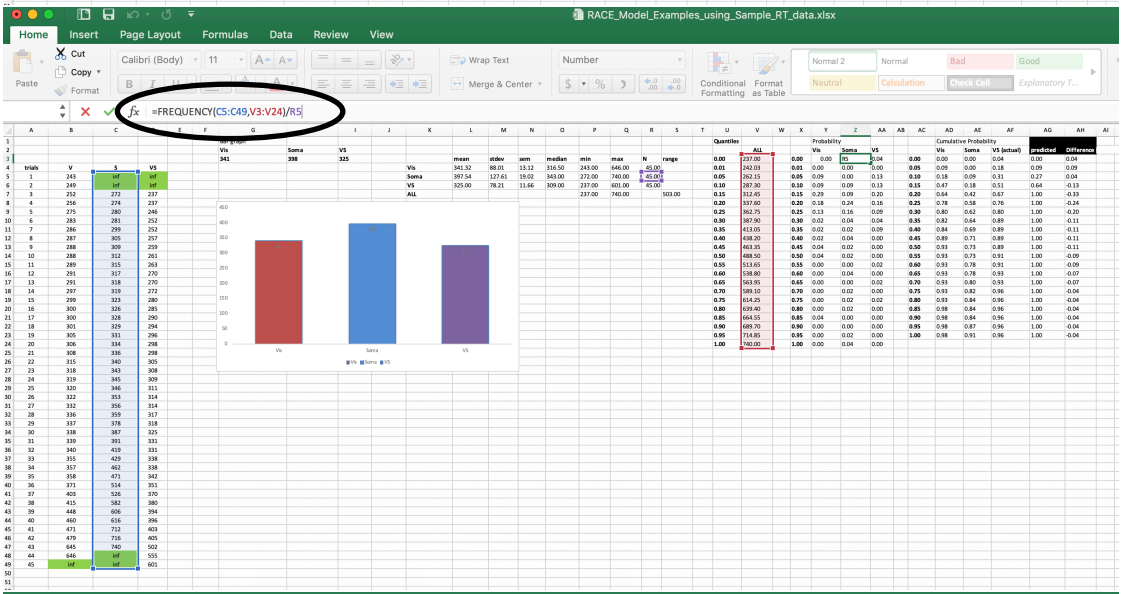

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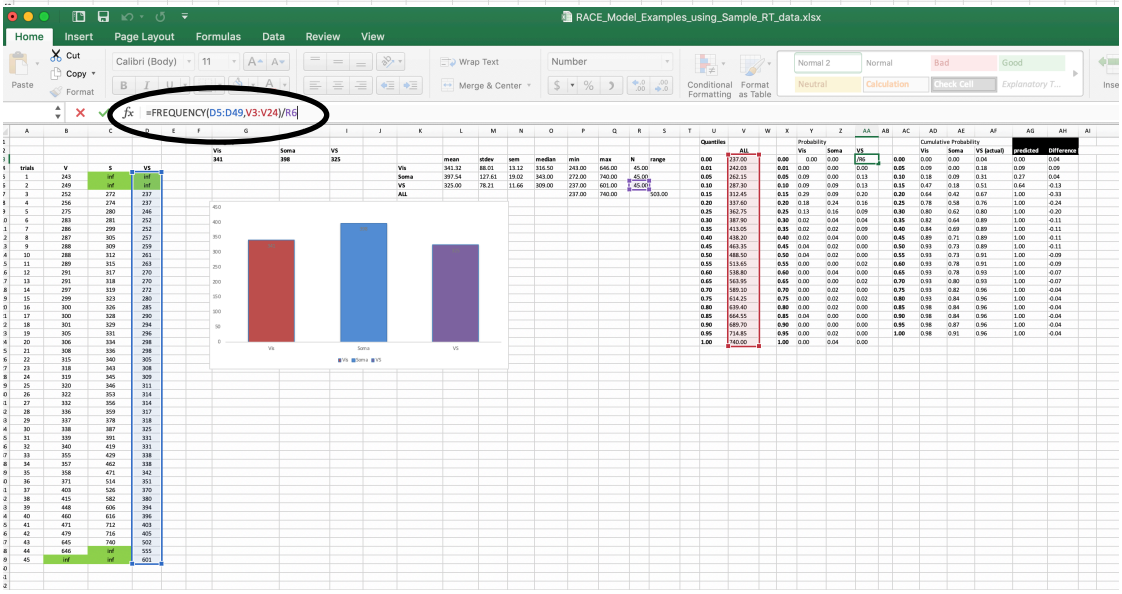


Figure 3.

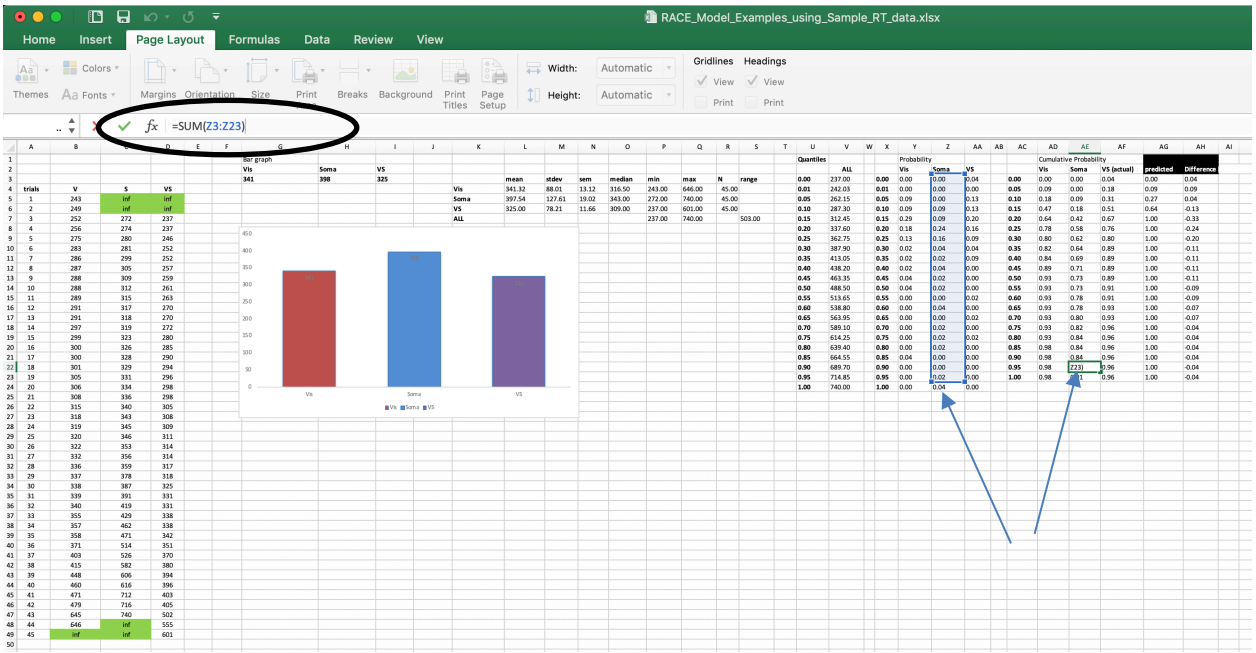
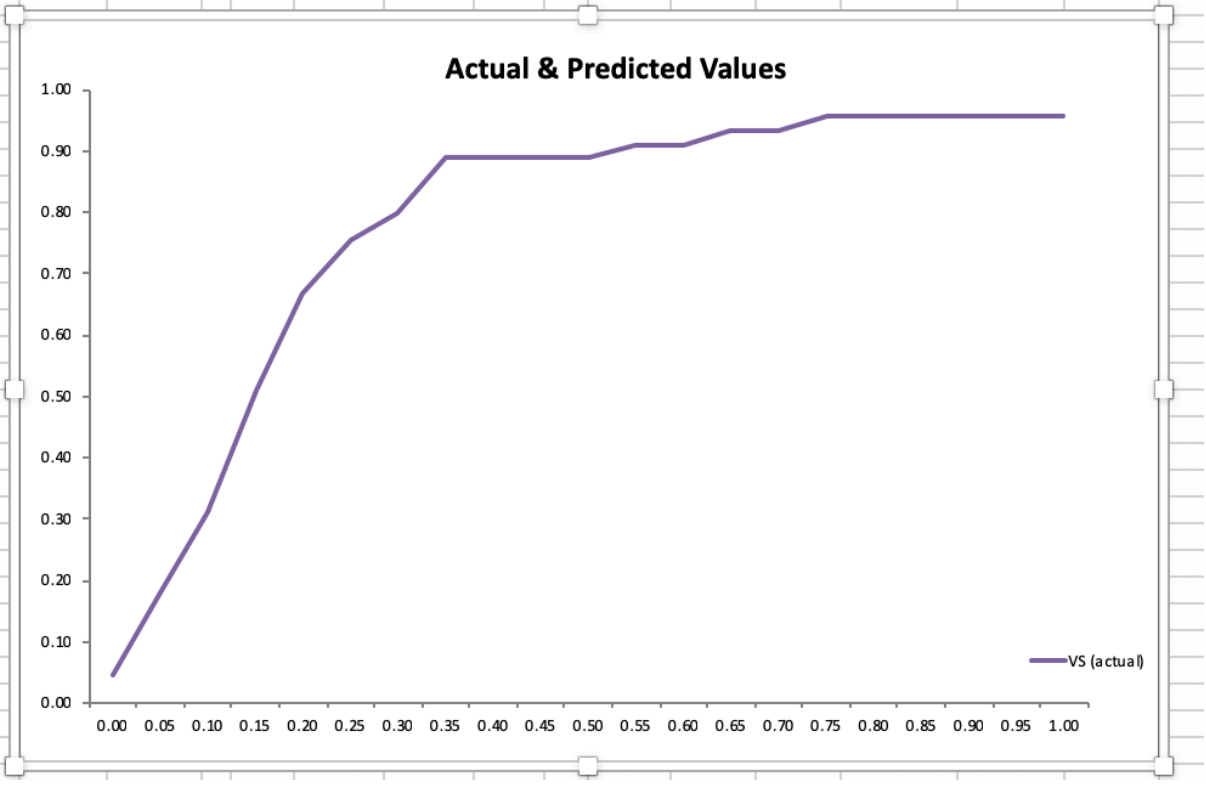


Figure 4

	Quantiles			Probability				Cumulative Probability				
		ALL		Vis	Soma	VS		Vis	Soma	VS (actual)	predicted	Difference
	0.00	237.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.04
	0.01	242.03	0.01	0.00	0.00	0.00	0.05	0.09	0.00	0.18	0.09	0.09
	0.05	262.15	0.05	0.09	0.00	0.13	0.10	0.18	0.09	0.31	0.27	0.04
	0.10	287.30	0.10	0.09	0.09	0.13	0.15	0.47	0.18	0.51	0.64	-0.13
	0.15	312.45	0.15	0.29	0.09	0.20	0.20	0.64	0.42	0.67	1.00	-0.33
	0.20	337.60	0.20	0.18	0.24	0.16	0.25	0.78	0.58	0.76	1.00	-0.24
	0.25	362.75	0.25	0.13	0.16	0.09	0.30	0.80	0.62	0.80	1.00	-0.20
	0.30	387.90	0.30	0.02	0.04	0.04	0.35	0.82	0.64	0.89	1.00	-0.11
	0.35	413.05	0.35	0.02	0.02	0.09	0.40	0.84	0.69	0.89	1.00	-0.11
	0.40	438.20	0.40	0.02	0.04	0.00	0.45	0.89	0.71	0.89	1.00	-0.11
	0.45	463.35	0.45	0.04	0.02	0.00	0.50	0.93	0.73	0.89	1.00	-0.11
	0.50	488.50	0.50	0.04	0.02	0.00	0.55	0.93	0.73	0.91	1.00	-0.09
	0.55	513.65	0.55	0.00	0.00	0.02	0.60	0.93	0.78	0.91	1.00	-0.09
	0.60	538.80	0.60	0.00	0.04	0.00	0.65	0.93	0.78	0.93	1.00	-0.07
	0.65	563.95	0.65	0.00	0.00	0.02	0.70	0.93	0.80	0.93	1.00	-0.07
	0.70	589.10	0.70	0.00	0.02	0.00	0.75	0.93	0.82	0.96	1.00	-0.04
	0.75	614.25	0.75	0.00	0.02	0.02	0.80	0.93	0.84	0.96	1.00	-0.04
	0.80	639.40	0.80	0.00	0.02	0.00	0.85	0.98	0.84	0.96	1.00	-0.04
	0.85	664.55	0.85	0.04	0.00	0.00	0.90	0.98	0.84	0.96	1.00	-0.04
	0.90	689.70	0.90	0.00	0.00	0.00	0.95	0.98	0.87	0.96	1.00	-0.04
	0.95	714.85	0.95	0.00	0.02	0.00	1.00	0.98	0.91	0.96	1.00	-0.04
	1.00	740.00	1.00	0.00	0.04	0.00						



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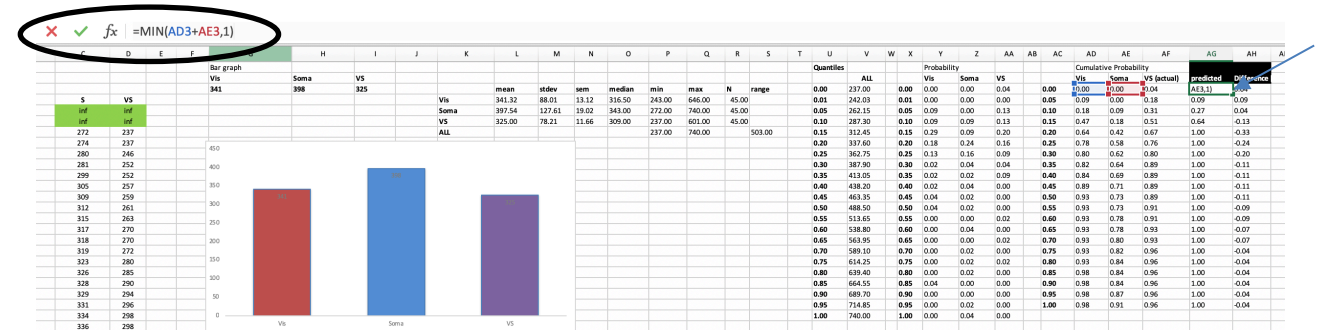

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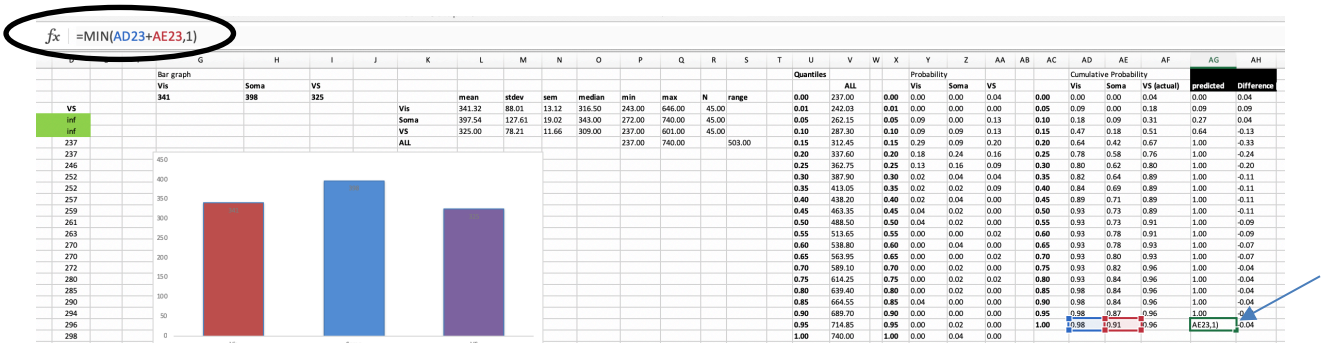


Figure 6.

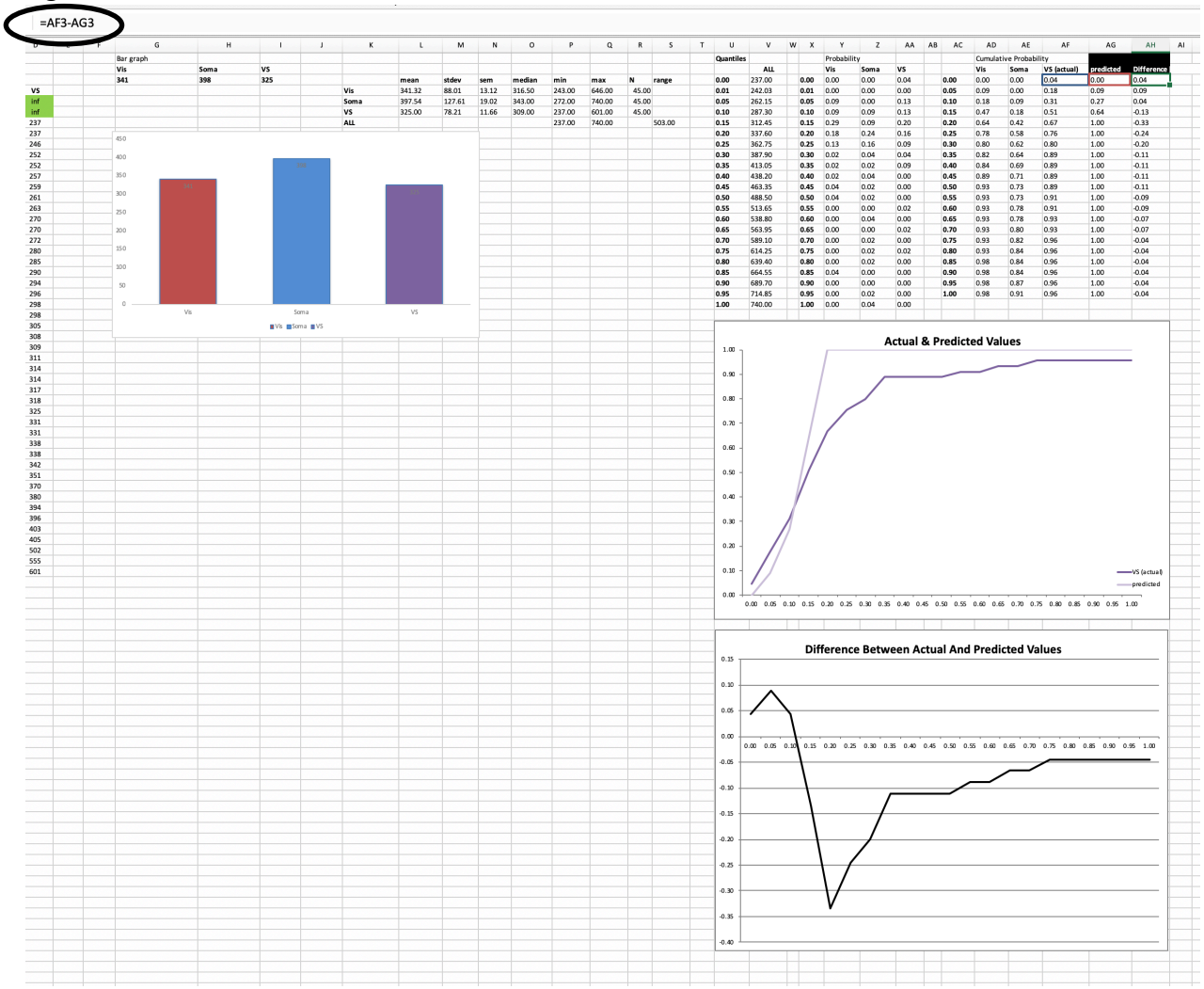


Figure 7.

U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
Quantiles				Probability					Cumulative Probability				
	ALL			Vis	Soma	VS			Vis	Soma	VS (actual)	predicted	Difference
0.00	237.00		0.00	0.00	0.00	0.04		0.00	0.00	0.00	0.04	0.00	0.04
0.01	242.03		0.01	0.00	0.00	0.00		0.05	0.09	0.00	0.18	0.09	0.09
0.05	262.15		0.05	0.09	0.00	0.13		0.10	0.18	0.09	0.31	0.27	0.04
0.10	287.30		0.10	0.09	0.09	0.13		0.15	0.47	0.18	0.51	0.64	-0.13
0.15	312.45		0.15	0.29	0.09	0.20		0.20	0.64	0.42	0.67	1.00	-0.33
0.20	337.60		0.20	0.18	0.24	0.16		0.25	0.78	0.58	0.76	1.00	-0.24
0.25	362.75		0.25	0.13	0.16	0.09		0.30	0.80	0.62	0.80	1.00	-0.20
0.30	387.90		0.30	0.02	0.04	0.04		0.35	0.82	0.64	0.89	1.00	-0.11
0.35	413.05		0.35	0.02	0.02	0.09		0.40	0.84	0.69	0.89	1.00	-0.11
0.40	438.20		0.40	0.02	0.04	0.00		0.45	0.89	0.71	0.89	1.00	-0.11
0.45	463.35		0.45	0.04	0.02	0.00		0.50	0.93	0.73	0.89	1.00	-0.11
0.50	488.50		0.50	0.04	0.02	0.00		0.55	0.93	0.73	0.91	1.00	-0.09
0.55	513.65		0.55	0.00	0.00	0.02		0.60	0.93	0.78	0.91	1.00	-0.09
0.60	538.80		0.60	0.00	0.04	0.00		0.65	0.93	0.78	0.93	1.00	-0.07
0.65	563.95		0.65	0.00	0.00	0.02		0.70	0.93	0.80	0.93	1.00	-0.07
0.70	589.10		0.70	0.00	0.02	0.00		0.75	0.93	0.82	0.96	1.00	-0.04
0.75	614.25		0.75	0.00	0.02	0.02		0.80	0.93	0.84	0.96	1.00	-0.04
0.80	639.40		0.80	0.00	0.02	0.00		0.85	0.98	0.84	0.96	1.00	-0.04
0.85	664.55		0.85	0.04	0.00	0.00		0.90	0.98	0.84	0.96	1.00	-0.04
0.90	689.70		0.90	0.00	0.00	0.00		0.95	0.98	0.87	0.96	1.00	-0.04
0.95	714.85		0.95	0.00	0.02	0.00		1.00	0.98	0.91	0.96	1.00	-0.04
1.00	740.00		1.00	0.00	0.04	0.00							

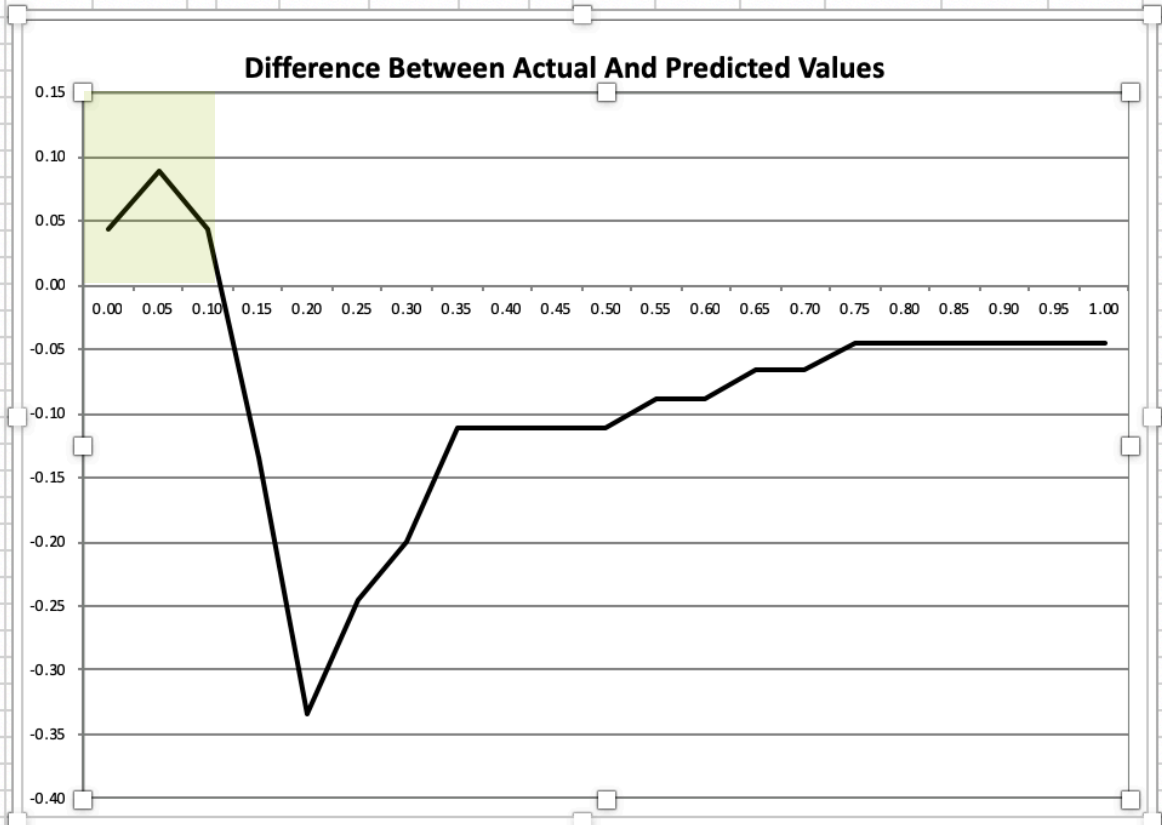
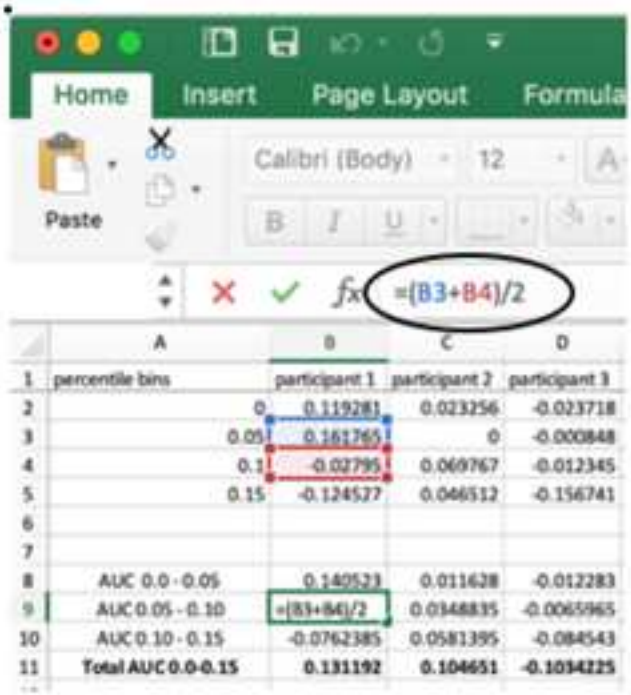


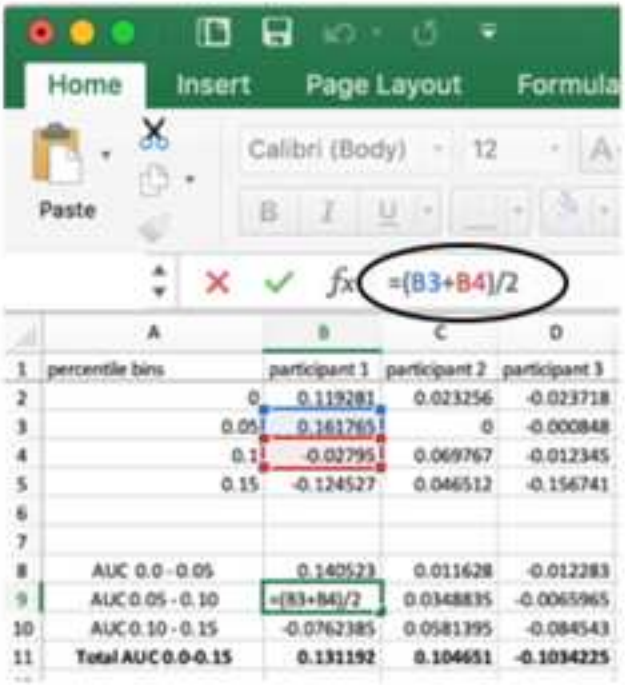
Figure 8

a.



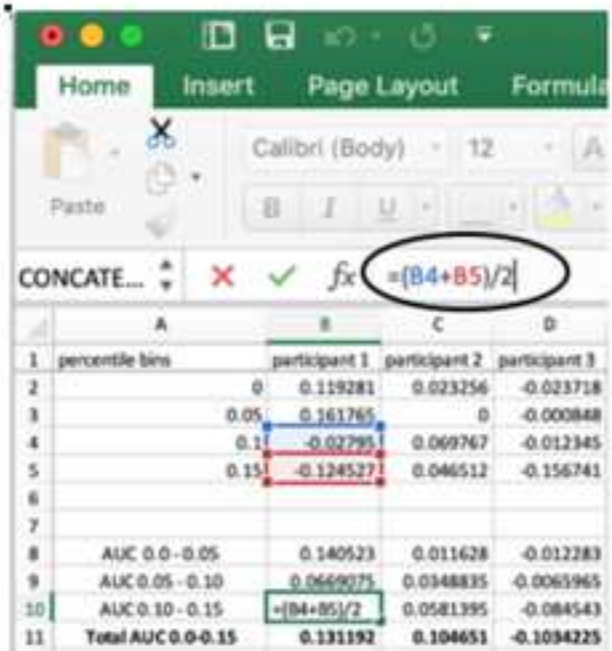
	A	B	C	D
1	percentile bins	participant 1	participant 2	participant 3
2	0	0.119281	0.023256	-0.023718
3	0.05	0.161765	0	-0.000848
4	0.1	-0.02795	0.069767	-0.012345
5	0.15	-0.124527	0.046512	-0.156741
6				
7				
8	AUC 0.0 - 0.05	0.140523	0.011628	-0.012283
9	AUC 0.05 - 0.10	=(B3+B4)/2	0.0348835	-0.0065965
10	AUC 0.10 - 0.15	-0.0762385	0.0581395	-0.084543
11	**Total AUC 0.0-0.15**	**0.131192**	**0.104651**	**-0.1034225**

b.



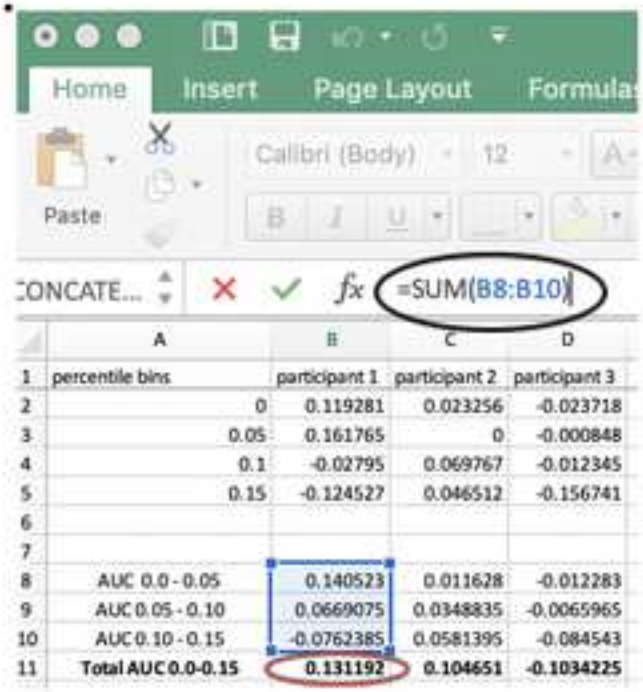
	A	B	C	D
1	percentile bins	participant 1	participant 2	participant 3
2	0	0.119281	0.023256	-0.023718
3	0.05	0.161765	0	-0.000848
4	0.1	-0.02795	0.069767	-0.012345
5	0.15	-0.124527	0.046512	-0.156741
6				
7				
8	AUC 0.0 - 0.05	0.140523	0.011628	-0.012283
9	AUC 0.05 - 0.10	=(B3+B4)/2	0.0348835	-0.0065965
10	AUC 0.10 - 0.15	-0.0762385	0.0581395	-0.084543
11	**Total AUC 0.0-0.15**	**0.131192**	**0.104651**	**-0.1034225**

c.



	A	B	C	D
1	percentile bins	participant 1	participant 2	participant 3
2	0	0.119281	0.023256	-0.023718
3	0.05	0.161765	0	-0.000848
4	0.1	-0.02795	0.069767	-0.012345
5	0.15	-0.124527	0.046512	-0.156741
6				
7				
8	AUC 0.0 - 0.05	0.140523	0.011628	-0.012283
9	AUC 0.05 - 0.10	0.0669075	0.0348835	-0.0065965
10	AUC 0.10 - 0.15	=(B4+B5)/2	0.0581395	-0.084543
11	**Total AUC 0.0-0.15**	**0.131192**	**0.104651**	**-0.1034225**

d.



	A	B	C	D
1	percentile bins	participant 1	participant 2	participant 3
2	0	0.119281	0.023256	-0.023718
3	0.05	0.161765	0	-0.000848
4	0.1	-0.02795	0.069767	-0.012345
5	0.15	-0.124527	0.046512	-0.156741
6				
7				
8	AUC 0.0 - 0.05	0.140523	0.011628	-0.012283
9	AUC 0.05 - 0.10	0.0669075	0.0348835	-0.0065965
10	AUC 0.10 - 0.15	-0.0762385	0.0581395	-0.084543
11	**Total AUC 0.0-0.15**	**0.131192**	**0.104651**	**-0.1034225**

Figure 9.

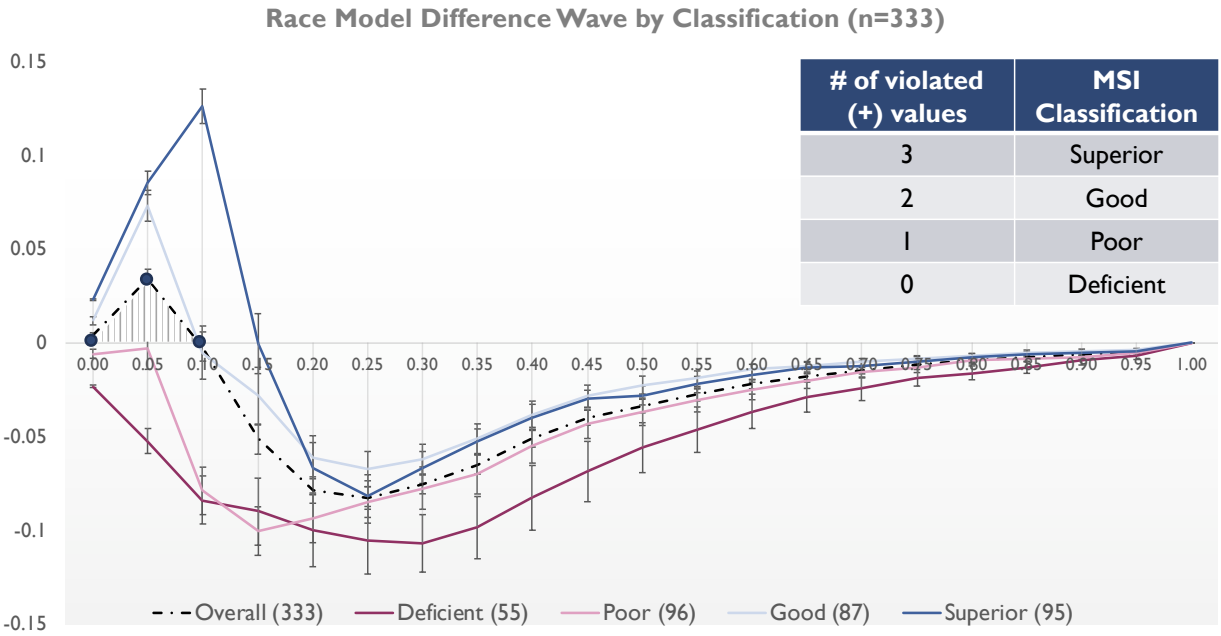


Table 1. Individual Descriptive Statistics by Condition and Range Calculation

	mean	stdev	sem	median	min
Visual Alone	341.32	88.01	13.12	316.5	243
Soma Alone	397.54	127.61	19.02	343	272
VS	325	78.21	11.66	309	237
ALL					237

max	N	range
646	45	
740	45	
601	45	
740		503

Table 2. Example of how to bin RT data based on RT range*

Quantiles:	Calculate Range:	Result:
0	fastest RT (237)	237
0.01	237+0.01*(503)	242.03
0.05	237+0.05*(503)	262.15
0.1	237+0.1*(503)	287.3
0.15	237+0.15*(503)	312.45
0.2	237+0.2*(503)	337.6
0.25	237+0.25*(503)	362.75
0.3	237+0.3*(503)	387.9
0.35	237+0.35*(503)	413.05
0.4	237+0.4*(503)	438.2
0.45	237+0.45*(503)	463.35
0.5	237+0.5*(503)	488.5
0.55	237+0.55*(503)	513.65
0.6	237+0.6*(503)	538.8
0.65	237+0.65*(503)	563.95
0.7	237+0.7*(503)	589.1
0.75	237+0.75*(503)	614.25
0.8	237+0.8*(503)	639.4
0.85	237+0.85*(503)	664.55
0.9	237+0.9*(503)	689.7
0.95	237+0.95*(503)	714.85
1	237+1*(503)	740 (longest RT)

*Note 1%ile is included in worksheet for illustrative purposes only.

Table 3. Identification of # of violated quantiles

Percentile bins	Participant 1	Participant 2	Participant 3
0	0.12	0.02	-0.02
0.05	0.16	0.00	0.00
0.1	-0.03	0.07	-0.01
0.15	-0.12	0.05	-0.16
AUC 0.0 - 0.05	0.14	0.01	-0.01
AUC 0.05 - 0.10	0.07	0.03	-0.01
AUC 0.10 - 0.15	-0.08	0.06	-0.08
Total AUC 0.0-0.15	**0.13**	**0.10**	**-0.10**

Table of Materials

Click here to access/download;Table of Materials;JoVE_Table_of_Materials-updated.xlsx

Name of Material/Equipment	Company	Catalog Number	Comments/Description
stimulus generator	Zenometrics, LLC; Peekskill, NY, USA	n/a	custom-built
Excel	Microsoft Corporation		spreadsheet program
Eprime	Psychology Software Tools (PST)		stimulus presentation software

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February 11th, 2019

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Re: JoVE59575R2 - "Using the Race Model Inequality to quantify behavioral multisensory integration effects."

Dear Dr. Berard,

We would like to thank the editor and the external reviewers for the comprehensive and thoughtful review of the above referenced manuscript. The central critics raised in the decision letter were requests for additional clarifications, as well as formatting changes to be consistent with the journal's requirements. We appreciate the opportunity to address each of the key criticisms raised by the reviewers and the Editor. Below, please find responses to the specific comments raised in the decision letter. As requested, revisions are marked using Track Changes. We include a few questions for you in **bold** font, and am certain that we can work together to address these comments in the final version of the manuscript and video.

Editorial Comments:

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.
   ⇒ Done

2. Please define all abbreviations during the first-time use.
   ⇒ Done

3. Please remove all commercial language from your manuscript and use generic terms instead. All commercial products should be sufficiently referenced in the Table of Materials and Reagents. For example: Eprime software, Excel, etc
   ⇒ Done

4. Please include an ethics statement before the numbered protocol steps, indicating that your protocol follows the guidelines of your institution's human research ethics committee.

⇒ Done

5. Please use insert equation feature for all the equations used in the manuscript.
   ⇒ Done

6. For the protocol section, please revise the text to avoid the use of any personal pronouns in the protocol (e.g., "we", "you", "our" etc.).
   ⇒ Done

7. Please ensure that all text in the protocol section is written in the imperative tense as if telling someone how to do the technique (e.g., “Do this,” “Ensure that,” etc.). The actions should be described in the imperative tense in complete sentences wherever possible.
   ⇒ Done

8. Avoid usage of phrases such as “could be,” “should be,” and “would be” throughout the Protocol. Any text that cannot be written in the imperative tense may be added as a “Note.” However, notes should be concise and used sparingly.
   ⇒ Done

9. The Protocol should contain only action items that direct the reader to do something.
   ⇒ Done

10. The Protocol should be made up almost entirely of discrete steps without large paragraphs of text between sections.
    ⇒ There are no paragraphs of text, only multilevel lists with action items that provide clarity of procedures.

11. Please leave a single line space between all the numbered step, substep and Notes in the protocol section.
    ⇒ Done

12. Software steps must be more explicitly explained ('click', 'select', etc.). Please add more specific details (e.g. button clicks for software actions, numerical values for settings, scripts etc.). Please include all the custom scripts generated for the experiment as supplemental files.
    ⇒ Done

13. Please add more details to your protocol steps. Please ensure you answer the “how” question, i.e., how is the step performed? Please ensure that the protocol should be specific with respect to your experiment and should be written in a stepwise manner as if you are describing someone how to perform your experiment with all necessary details.
    ⇒ Done

14. 2.1.1.: What kind of stimulus is generated?
    ⇒ The stimuli are 100ms blue flashes from illuminated LEDS (visual stimulus) and 100ms 0.8G vibrations (somatosensory stimulus) that are presented in isolation for unisensory stimuli and simultaneously for multisensory stimuli. There are a total of three experimental conditions (visual, somatosensory, and visual-somatosensory). We have improved this section for clarity in the revised manuscript.

15. 2.1.2: How do you do so?
    ⇒ The devices are connected to a network control center, which allowed direct control for each device through the testing computer's parallel port. The devices were cycled on and off at precise predetermined intervals in any combination. A TTL (transistor-transistor-logic, 5 V, duration 100ms) pulse was used to trigger the visual and somatosensory stimuli through E-Prime 2.0 software. We have improved this section for clarity.

16. 2.1.3: This step needs clarity.
    ⇒ We have added a few additional sub-steps to improve the clarity of the entire Experimental Design section (#2).

17. 2.2: What kind of experiment is performed? Please explain. What kind of 135 stimuli are generated and how? Do you perform any button clicks? Do you run any scripts? Please include details.
    ⇒ As requested, we now provide additional information regarding the experiment (Simple Reaction Test) and associated task in the revised manuscript.

18. 2.3: How? Do you perform any button clicks for the same? What is the blank catch trial? How do you perform the same?
    ⇒ We have revised this section as requested to answer these questions.

19. 3.3: This needs more clarity.
    ⇒ Revised as requested to improve clarity.

20. 4..1.1.: what is the reason of excluding the participants? Will this not have an impact on the result?
    ⇒ Including participants with unreliable data greatly alters the end result. As mentioned, we employ a cutoff of 70% performance accuracy on all of our multisensory studies to exclude participants with unreliable responses and provide numerous citations to support that established cutoff. There are a number of instances where participants miss trials – it could be that they did not push hard enough for their response to register, that they made two responses very quickly and neither registered, they experienced an attentional disruption, neuropathy interfered with the sensation of foot pedal, or perhaps they just needed to stretch their legs… Nevertheless, if 70% accuracy cannot be obtained on this simple reaction time test, then it is likely that their data are no longer valid and therefore these participant should not included in the study.

21. 4.1.2: So, you present 135 stimuli, How many times should they fail per block? This step needs explicit details.
    ⇒ Technically they shouldn't fail at all, as the task is very simple. But given the above list of non-exhaustive reasons why one might miss a response, it does happen occasionally. In previous studies, the group-averaged (n=289) stimulus detection was 96% across all conditions, and over 90 % of the population had detection rates above 90% for all three conditions. Older adults often perform very-well, which is precisely why participants with poor accuracy levels should not be included. 70% is our established cut-off score, but as mentioned above, on average our seniors only miss about 3 – 4 trials per condition.

22. 4.2.1: No mention of sensory condition before in the above steps. So, the stimulus had different sensory conditions?
    ⇒ Sorry, sensory condition = experimental condition defined in 2.1 as "three experimental

conditions: visual (V) alone, somatosensory (S) alone, and simultaneous visual-somatosensory (VS)." We have revised this term back to "experimental condition" for consistency.

23. 4.3.2: How do you perform the binning? Do you use any software, scripts etc?
    ⇒ Yes, this is automated in Excel and preciously why I provided the equations and steps in the manuscript. I figured with the video, we will use screenshots to display the actual equations and show exactly how things like the range and binning procedures are calculated.

24. 5.1: How?
    ⇒ We now include specific steps on how to create the group-averaged difference waveform in the revised manuscript.

25. 5.2: How do you run this test? What is the output? Please include the script as a supplemental file.
    ⇒ This test is run in R. Gondan and colleagues have made the script available (for free) on their website. The output provides a *t*max value, 95% criterion, and p-value which is instrumental in determining whether a significant violation of the Race Model exists.

26. 5.3, 5.4: How is this done?
    ⇒ This is done by performing steps 5.5.1-5.5.3. We have clarified this in the revised manuscript.

27. There is a 10-page limit for the Protocol, but there is a 2.75-page limit for filmable content. Please highlight 2.75 pages or less of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, i.e., the steps that should be visualized to tell the most cohesive story of the Protocol.
    ⇒ Done

28. Please expand the Representative Results in the context of the technique you have described, e.g., how do these results show the technique, suggestions about how to analyze the outcome, etc. The paragraph text should refer to all of the figures. Data from both successful and sub-optimal experiments can be included.
    ⇒ Done

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    ⇒ Please note that *Frontiers* publications are published under CC BY 4.0 License; therefore, there is no need to request specific permission for reproducibility and researchers are free to re-use published material as long as license terms are followed. We now include an updated figure caption for Figure 2 clearly listing the proper citations. We have written permission to reproduce Figure 1, first published in *Multisensory Research*, however, this figure has recently been reproduced in *JGMS* and *Frontiers*. ***Frontiers* is not an issue, but Dr. Berard should I seek additional approval from *JGMS* as well?**

30. As we are a methods journal, please revise the Discussion to explicitly cover the following in detail in 3-6 paragraphs with citations:
    - Critical steps within the protocol

- Any modifications and troubleshooting of the technique
- Any limitations of the technique
- The significance with respect to existing methods
- Any future applications of the technique

⇒ We have completely revised the discussion section to address the above bullet points.

31. Please expand the journal titles in the reference section.
    ⇒ Done. Sorry terms list in Endnote needed to be updated.

32. Please complete the materials table. All commercial software should be listed here as well.
    ⇒ Done

Reviewer Comments:

Reviewer #1

This paper is to accompany a video depicting an approach to quantifying multisensory integration that should be transferable to many different research settings and experimental designs.

1. This is not so much a concern as perhaps a lack of familiarity with this format, but it is fairly difficult to follow the calculation methods without a visual depiction of the spreadsheet; it seems like the methods are very clearly described and will be easy to follow with video screenshots of the steps being completed in real time. As a reader trying to imagine using this technique on my own data, I also wonder if it could be useful to demonstrate specifically how this approach leads to measurably different results than other approaches (e.g. how would the final curves differ if slow response trials are excluded rather than RT set to infinity? what happens if you pre-select the fastest quartile rather than allow the dataset to dictate percentile range?
    ⇒ This a great comment and we have many great visuals of what happens to the difference curves when these outliers are included. The main problem here is to do with the fact that the entire CDF is predicated on the RT range. If most RTs are falling between let's say 150 and 650ms – then the range is about 500ms. The longest RT sets the upper limit of the range, so if even one long RT of let's say 1650ms is included, the range just increased from 500ms to 1500ms, by including that one outlier RT. Thus, the entire CDF is skewed and the shape of the subsequent RMI curve is significantly altered. **I am happy to provide examples of this either in the video or as a supplementary figure and can work with Dr. Berard to adequately display this in either the article, movie, or both.**
    ⇒ The advantage of using a data-driven approach is that only the time bins that have positive (violated) time bins in the study cohort are included in the independent measure, thus minimizing error. While it is commonplace to just test the fastest quartile, unfortunately datasets do not follow a one-size-fits all model. Kiesel et al 2007 posit that 'race model violations most likely occur during first quartile' – but they use computer simulations to determine which time bins should be examined. The problem with relying on such simulations is that older adults maintain completely different RT distributions relative to young adults or computer simulated results. Rather than naïvely setting an *a priori* test window for race model significance testing, we recommend that researcher be informed of the actual violated portion of their group-averaged difference wave (identified under new step 5.3 of this tutorial) and subject data from only that window to further statistical testing. If you look at Figure 2, why would anyone want to include the negative (non-violated) portion of the difference wave (percentile bins .15 - .25) to further

testing → these time points do not violate the race model inequality and thus, there is no reason to include them to determine whether the violation is significant (new step 5.4).

2. page 2 line 83 "RMI" is an abbreviation for race model inequality? spell it out the first time.
   ⇒ Yes, we have rectified that oversight.

3. page 4 Experimental design - redundant wording in 2.1.3 and 2.3 could be edited for clarity?
   ⇒ Revised as requested.

Reviewer #2

1. Ad 4.1.1.: the 70% criterion of excluding participants may depend on the population (age, health status) and seems too liberal for "normal" (student) populations.
   ⇒ Great comment. We agree that this cutoff may be too liberal for student populations, but require utilization of it here given inclusion of an elderly cohort with potential sensory, motor, and cognitive limitations (see response to Editorial Comments 20-21). Note that some empirical cut is necessary to maintain reliability, and this cutoff can be tailored on a study-by-study basis depending upon the population being examined.

2. Check this new reference for (individual data) race model tests:
   Lombardi, L., D' Alessandro, and Colonius, H. (2018). A new nonparametric procedure to evaluate the race model inequality. Behavior Research Methods https://doi.org/10.3758/s13428-018-1170-0
   ⇒ Thank you.

3. line147: remove "is placed"
   ⇒ Done

Reviewer #3

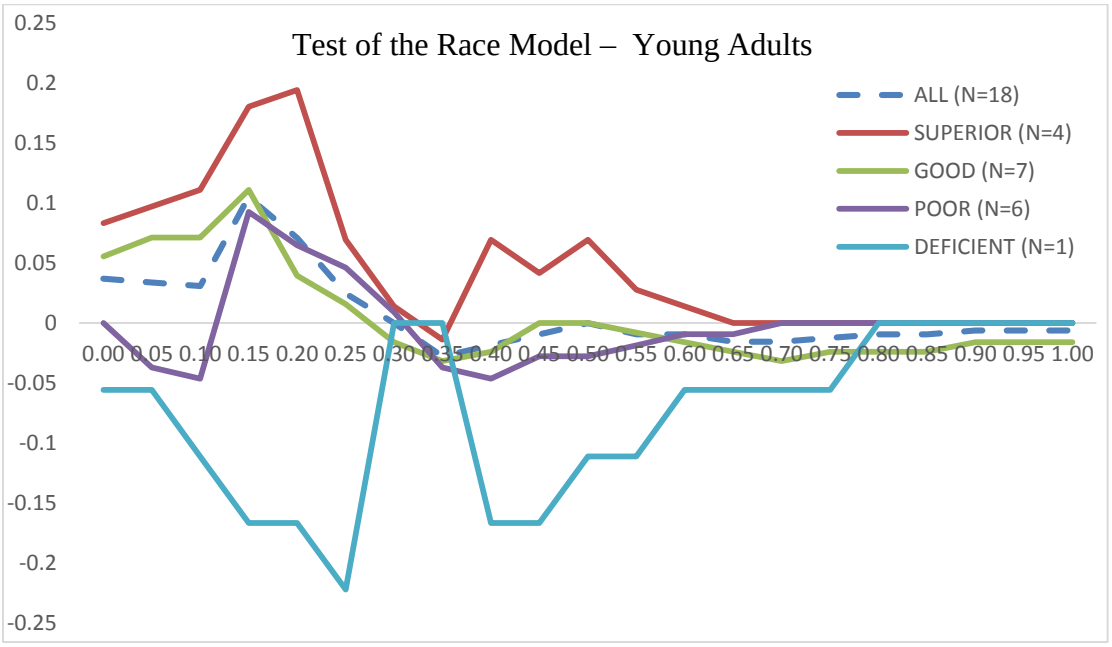
The authors present a method for conducting a visual-tactile integration experiment and for analysing the level of integration according to violation of the race model inequality. The manuscript is well written and the methods will certainly be of use to other researchers who wish to conduct multisensory experiments with a reaction time component. However, there are a number of issues with using the test of the race model as a measure of the extent of integration, such as race model violation being biased towards individuals with slower unisensory reaction times (i.e. a floor/ceiling effect; see Major Concerns below). Although this is a major concern, there are a number of a priori and post-hoc techniques which can be implemented to avoid these biases, which the authors should include in their manuscript/video presentation. This will ensure that their analysis technique and interpretation, as well as future experiments that wish to exploit this analysis technique, are not affected by floor/ceiling effects. There are a few other minor concerns and typographical errors (see Minor Concerns), but I am happy to recommend this methodology for publication and for a video presentation if all concerns are addressed.

1. Page 3, lines 78-81 - This point is correct. However, Couth et al 2017 were also critical of the use of race models as a way of determining enhanced integration, where race model violation is biased towards individuals who have slower unisensory RTs. That is, a greater room for improvement for slower participants gives the impression of greater race model violation (i.e. a floor effect). Conversely, young participants purportedly show less/no integration (i.e. race model violation) than older (e.g.; Laurienti et

al 2006; Peiffer et al 2007; Hugenschmidt et al 2009; Mahoney et al 2011; Couth et al 2017), but this is probably due to young adults having faster unisensory RTs, thus limiting the amount of race model violation that can be observed (i.e. a ceiling effect), rather than them integrating less than older adults. Based on your interpretation of less race model = 'poorer/deficient' integration, this would mean that young adults are also poorer integrators, which would be detrimental for balance etc. That is unless you can show more race model violation for young adults compared to older with the new method of analysis that you present here?

⇒ In these studies, regardless of age, both groups demonstrate a RT speeding from uni- to multisensory stimuli (e.g., a MSI effect). The proportion of RT change from unisensory to multisensory may be greater in olds vs. youngs for various reasons including but not limited to alterations in sensory, cognitive, and/or motor functioning associated with increasing age that younger adults are not subjected to yet. This is one reason why I do not recommend comparisons of young to old adults because there are so many unanswered questions regarding multisensory integration processes in aging alone.

⇒ It is unlikely that all young individuals would be deficient integrators. In support, our 2011 paper reveals that younger adults demonstrate larger RMI than older adults for the auditory-somatosensory (AS) and auditory-visual (AV) conditions, while older adults demonstrate larger RMI than younger adults for the visual-somatosensory (VS) condition. To further address this comment, we reanalyzed the AS data from the 18 young individuals presented in the 2011 published manuscript and processed it using the methodology described in the current tutorial. The results demonstrate similar patterns of differential integration (see below figure) where some individuals have larger race violations (red and green traces) than average (blue dashed trace), while others have smaller race violations (purple and cyan traces) than average. While the young adults demonstrate differential MSI effects, larger scale studies are needed to verify this effect. Further, notice the average RTs by condition (A=auditory, S= somatosensory, and AS= auditory-somatosensory) for these 18 younger adults, there does not seem to be large RT differences between superior and poor integrators; providing further evidence for the fact that that the entire distribution of valid RTs (not just average) should be taking into consideration when assessing magnitude of multisensory integration.



RTs	A	S	AS
ALL (N=18)	334	371	266
SUPERIOR	306	359	230
GOOD	380	372	291
POOR	307	373	253
DEFICIENT	286	405	310

⇒ The premise behind the past decade of our work has been to demonstrate that older adults manifest differential integration patterns. These differences are 'washed-out' when one simply group averages race model difference waves across very small cohorts. If we apply the step-by-step approach documented in the current tutorial to younger individuals, similar patterns of superior to deficient integration exist, and further their AUC would likely be associated with some motor outcome (perhaps not balance as it unlikely that young adults wouldn't be able to stand on one leg for 30 seconds), but maybe gait speed or postural sway. The effects may not be as dramatic, especially if young adults are at 'ceiling' on these tasks – but note that the average RTs to the multisensory AS condition in youngs does not increase linearly from superior to deficient integrator status and further highlights the notion of differential integration patterns, regardless of chronological age.

⇒ Nevertheless, all of the above listed young *vs.* old research studies contained very small n's (18-30 individuals per group) and most (bar ours & Couth) solely investigated AV integration. Each study maintained different criteria for data trimming processes and only Couth discussed differential integration patterns that were identified in our 2014/2015 papers.

⇒ Unfortunately, at this point this remains an understudied area where further research is clearly warranted. However, this tutorial is timely so as to insure utilization of standardized methodological approaches and data preparation procedures for easy comparisons of multisensory integration effects across different age groups and/or clinical populations.

2. In line with the point above; based on previous research, there could be ways of setting up the experiment or transforming the data to avoid extremes in unisensory RTs and misinterpreting enhanced race model violation (i.e. more integration) e.g. Holmes et al 2009 The Principle of Inverse Effectiveness in Multisensory Integration: Some Statistical Considerations. I think that it is important that these potential shortcomings are acknowledged somewhere (maybe in the methods or discussion), along with the other general criticisms of the race model (as per point 3 of the minor concerns below; page 3, lines 53-54). In this case, it is important for the authors to emphasize how their method addresses these potential confounds and how researchers might want to set up their experiment/analyses to avoid these problems.
   ⇒ We now include this important point in the revised manuscript.

3. Page 2, line 29 - research isn't limited to adults e.g. Gori et al 2008. Suggest to say 'humans' more generally.
   ⇒ Done

4. Page 3, line 46 - redundant signalS effect.
   ⇒ Done

5. Page 3, lines 53-54 - expand on point "purportedly contain limitations regarding independence between unisensory systems" (see suggestions in Major concerns)
    ⇒ Done

6. Page 3, line 62 – then
    ⇒ Done

7. Page 4, line 106 - experimental designs
    ⇒ Done

8. Page 5, line 135 - remove '1.5'
    ⇒ Done

9. Page 5, point 2.1.1/ point 3.1 - what is the benefit of having bilateral vs unilateral stimulation? Could perhaps comment on its utility for investigating spatial separation of stimuli? e.g. Mahoney et al 2014 Does stimulus location really matter; Couth et al 2015 Investigating the spatial and temporal modulation of visuotactile interactions in older adults; Poliakoff et al 2006 Vision and touch in ageing: crossmodal selective attention and visuotactile spatial interactions etc. Worth mentioning either here and/or in the last paragraph of the discussion where you suggests adaptations of the experimental design (e.g. Page 8, lines 290-292).
    ⇒ This is a great point but unfortunately it is beyond the scope of the current experiment as many different experimental manipulations can be implemented and unfortunately space limitations do not afford the opportunity to discuss all experimental adaptations.

10. Page 5, point 2.4 - Allow participants up to 2000ms. Why? This seems counterintuitive as you argue that slow responses should not be omitted (as per Gondan and Minakata). Perhaps state why there needs to be some limit placed on this?
    ⇒ We now include a comment about this in section 2.4. Note that participants need ample time to respond and while the opportunity to make a slow RT is inherent in the design, the long RTs are never omitted, they are set to infinity. There is a good reason for dropping very long RTs that are not consistent with the individual's RT profile (see response to Reviewer #1, comment 1).

11. Page 5, point 3.2 - Could the tactile stimuli provide auditory cues which could enhance RTs? This could be the case depending on what type of vibrotactile stimulator researchers use. If so, you could recommend using headphones playing white noise to drown out these unwanted auditory cues.
    ⇒ Yes, 100% correct. We always employ headphones with white noise - it seems that statement was inadvertently left out here. Thank you for noticing!

12. Page 5, point 3.2.1 - Which foot? Dominant?
    ⇒ We use right foot and now provide this information.

13. Pages 5-6, point 4 - Does not explain why the "percentile range to be tested should be dictated by the actual dataset" rather than 0-25% bins, as suggested earlier on page 3, lines 93-49. In fact, you do not see any race model violation beyond 15% percentile (Figure 2), so perhaps there is nothing wrong with looking within a certain range of bins (as suggested by Kiesel et al 2007 Systematic biases and Type I error accumulation in tests of the race model inequality).

⇒ Please see response to Review 1 comment 1 (second bullet). We now include a further explanation in the revised manuscript to address this.

14. Page 7, point 5.2 - expand on this. How does it work? What is the interpretation?
    ⇒ Done

15. Page 7, point 5.3 - Really nice (and unique?) way of looking at the amount of race model violation. Suggest that the authors emphasize this as part of their USP.
    ⇒ Great idea, thank you.

16. Page 7, point 5.3.1/5.3.2 - What if there is only one bin that significantly violates RMI, and not consecutive bins? Are these still included in the analysis or ignored?
    ⇒ We have added more information on the classification system in new section 5.6. The index is based just on the number of violated (positive >0) points, regardless of whether they are consecutive.

17. Page 7, point 5.4 - Need to quantify and give an example e.g. are individuals classed as 'race model violators' if they have a positive difference for just one bin, or does this need to be 2,3,4 etc.? Rather than looking at time bins, could you set a certain AUC value to assign multisensory classification?
    ⇒ See response to comment 16. While AUC value can be used to assign a multisensory classification, the classification system is merely used for descriptive purposes as it highlights the degradation of magnitude of MSI as classification category decreases. We recommend using AUC as a continuous measure of magnitude of multisensory effects and as a predictor of other outcome measures and include this point in the revised manuscript.

18. Page 7, point 5.5?? - explain how AUC could be used to compare between different groups (e.g. old vs young) or to look at the relationship with other measures e.g. balance, gait, sensory acuity etc. as per Mahoney et al 2018a;b.
    ⇒ Done

19. Page 8, line 293 - "stimulus presentation onset times can be varied"
    ⇒ Done

20. Figure 1 - what is the purpose of the computer monitor? Does it give some instructions and/or some sort of visual feedback for the participant? Need to explain in section 2/3
    ⇒ Done.

21. Figure 2 - use colour example to discern groups more easily
    ⇒ **This can be provided if Dr. Berard deems it necessary.**

    ⇒ **Additionally, Dr. Berard, can you please advise which files should be uploaded as supplementary. From the comments, I gathered that the following could be useful, but not sure if these should ALL be included:**

        i. **Excel spreadsheet with RMI equations**
            1. **Also can show multiple, perhaps with and without data-trimming procedures or with and without inclusion of slow RTs**

ii. **R script for Gondan's test of the Race Model – although I refer the reader to the citation where these are available**
iii. **Eprime 2.0 experimental paradigm and behavioral output**
iv. **Any other additional files?**

Again, we would like to express our sincere appreciation for the constructive review of our manuscript. We hope that this revision addresses all of the concerns raised by the reviewers and that you will find our revised manuscript suitable for publication in *Journal of Visualized Experiments*.

Respectfully submitted,

Jeannette R. Mahoney, Ph.D.
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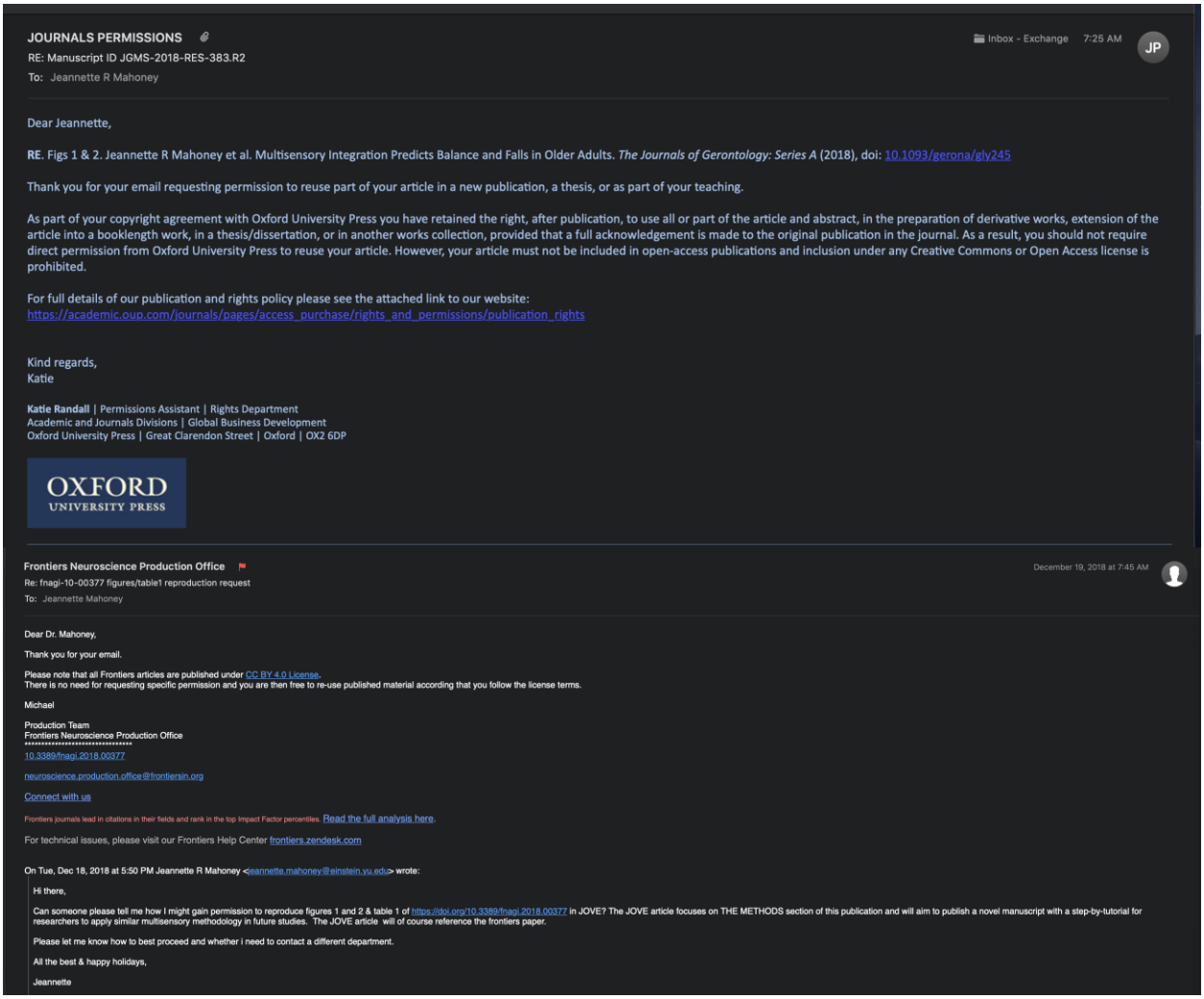
Albert Einstein College of Medicine
1225 Morris Park Avenue, Room 316G
Bronx, New York 10461
T#: 718-430-3809; F#: 718-430-3829
Jeannette.Mahoney@einstein.yu.edu



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RE: Manuscript ID JGMS-2018-RES-383.R2

To: Jeannette R Mahoney

Inbox - Exchange 7:25 AM

JP

Dear Jeannette,

RE. Figs 1 & 2. Jeannette R Mahoney et al. Multisensory Integration Predicts Balance and Falls in Older Adults. *The Journals of Gerontology: Series A* (2018), doi: 10.1093/gerona/gly245

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To: Jeannette Mahoney

December 19, 2018 at 7:45 AM

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Michael

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On Tue, Dec 18, 2018 at 5:50 PM Jeannette R Mahoney <jeannette.mahoney@einstein.yu.edu> wrote:

> Hi there,
>
> Can someone please tell me how I might gain permission to reproduce figures 1 and 2 & table 1 of https://doi.org/10.3389/fnagi.2018.00377 in JOVE? The JOVE article focuses on THE METHODS section of this publication and will aim to publish a novel manuscript with a step-by-tutorial for researchers to apply similar multisensory methodology in future studies. The JOVE article will of course reference the frontiers paper.
>
> Please let me know how to best proceed and whether i need to contact a different department.
>
> All the best & happy holidays,
>
> Jeannette

BRILL

Leiden, 9/12/18

Dear Jaennette,

Hereby Koninklijke Brill N.V. grants you permission to reprint Figure 1 (Experimental apparatus) which originally appeared in *Visual–Somatosensory Integration is Linked to Physical Activity Level in Older Adults*, Mahoney, Jeannette R. and Dumas, Kristina and Holtzer, Roee, Multisensory Research, 28, 11-29 (2015) for reuse in upcoming journal article, free of charge. Based on the assumption that the text will be typeset anew and with proper reference.

Yours sincerely,

BRILL
Isadora Lyra
Rights & Permissions coordinator

Bar graph
Vis
369

trials	V	S	VS
1	243	0	0
2	249	0	0
3	252	272	237
4	256	274	237
5	275	280	246
6	283	281	252
7	286	299	252
8	287	305	257
9	288	309	259
10	288	312	261
11	289	315	263
12	291	317	270
13	291	318	270
14	297	319	272
15	299	323	280
16	300	326	285
17	300	328	290
18	301	329	294
19	305	331	296
20	306	334	298
21	308	336	298
22	315	340	305
23	318	343	308
24	319	345	309
25	320	346	311
26	322	353	314
27	332	356	314
28	336	359	317
29	337	378	318
30	338	387	325
31	339	391	331
32	340	419	331
33	355	429	338
34	357	462	338
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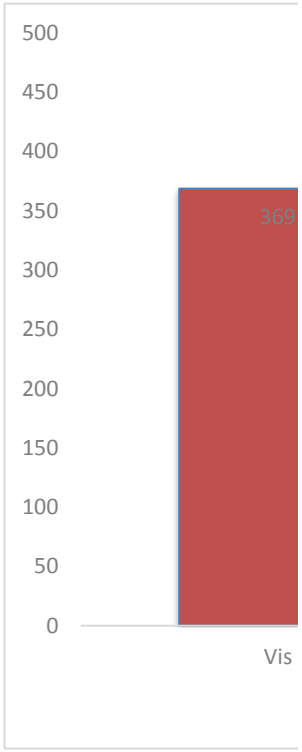
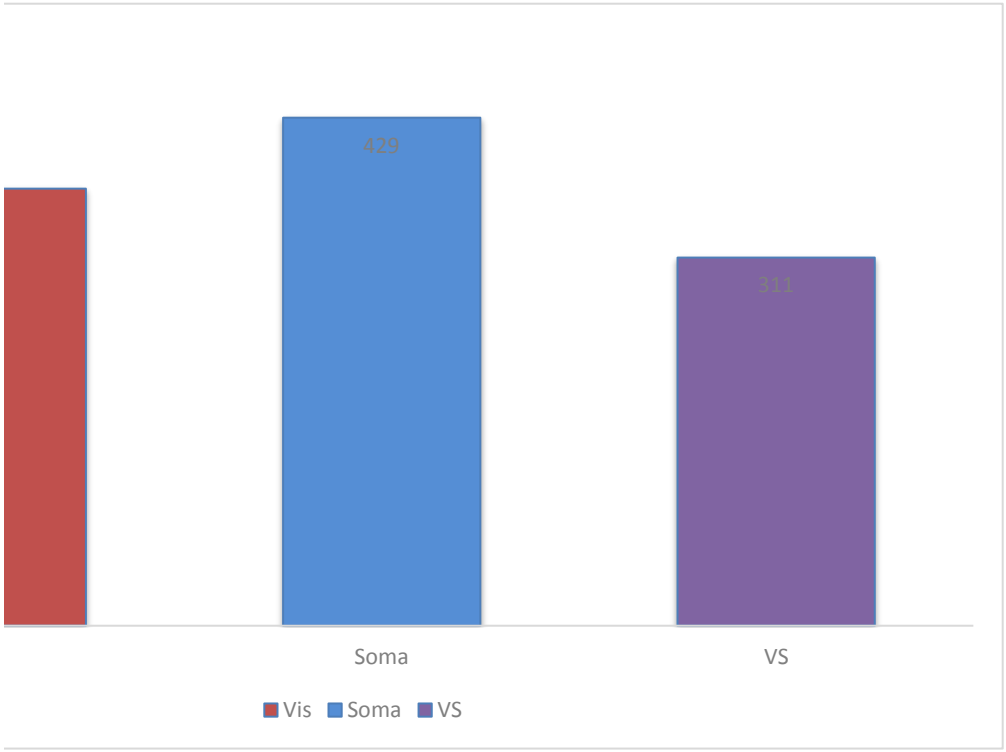
37	403	526	370
38	415	582	380
39	448	606	394
40	460	616	396

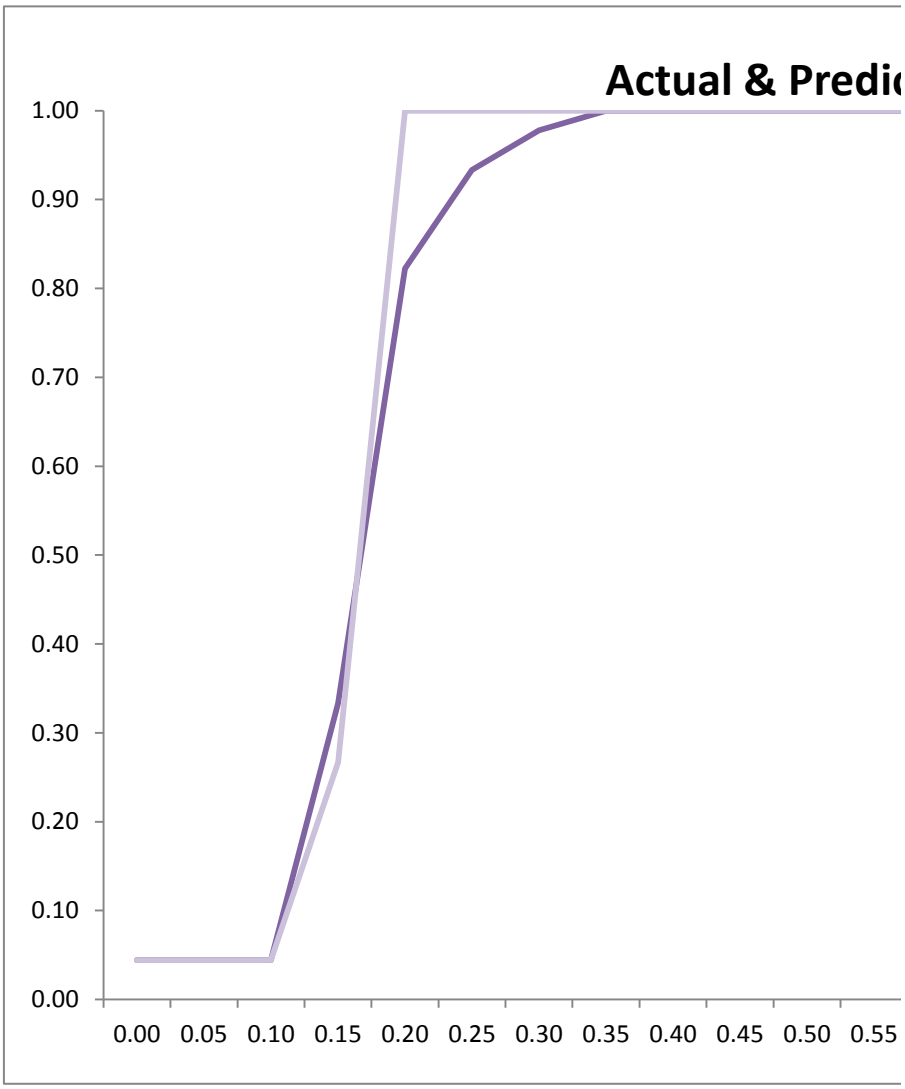


41	471	712	403
42	479	716	405
43	645	740	502
44	646	1094	555
45	1574	1893	601

Soma	VS
429	311

	mean	stdev	sem	median
Vis	368.71	203.31	30.31	318.00
Soma	428.58	287.84	42.91	343.00
VS	310.56	102.11	15.22	308.00
ALL				




Actual & Predi
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min	max	N	range
243.00	1574.00	45.00	
0.00	1893.00	45.00	
0.00	601.00	45.00	
0.00	1893.00		1893.00

Quantiles		Probability			
	ALL		Vis	Soma	VS
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0.01	18.93	**0.01**	0.00	0.00	0.00
0.05	94.65	**0.05**	0.00	0.00	0.00
0.10	189.30	**0.10**	0.00	0.00	0.00
0.15	283.95	**0.15**	0.13	0.09	0.29
0.20	378.60	**0.20**	0.67	0.51	0.49
0.25	473.25	**0.25**	0.11	0.13	0.11
0.30	567.90	**0.30**	0.02	0.04	0.04
0.35	662.55	**0.35**	0.04	0.07	0.02
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0.45	851.85	**0.45**	0.00	0.00	0.00
0.50	946.50	**0.50**	0.00	0.00	0.00
0.55	1041.15	**0.55**	0.00	0.00	0.00
0.60	1135.80	**0.60**	0.00	0.02	0.00
0.65	1230.45	**0.65**	0.00	0.00	0.00
0.70	1325.10	**0.70**	0.00	0.00	0.00
0.75	1419.75	**0.75**	0.00	0.00	0.00
0.80	1514.40	**0.80**	0.00	0.00	0.00
0.85	1609.05	**0.85**	0.02	0.00	0.00
0.90	1703.70	**0.90**	0.00	0.00	0.00
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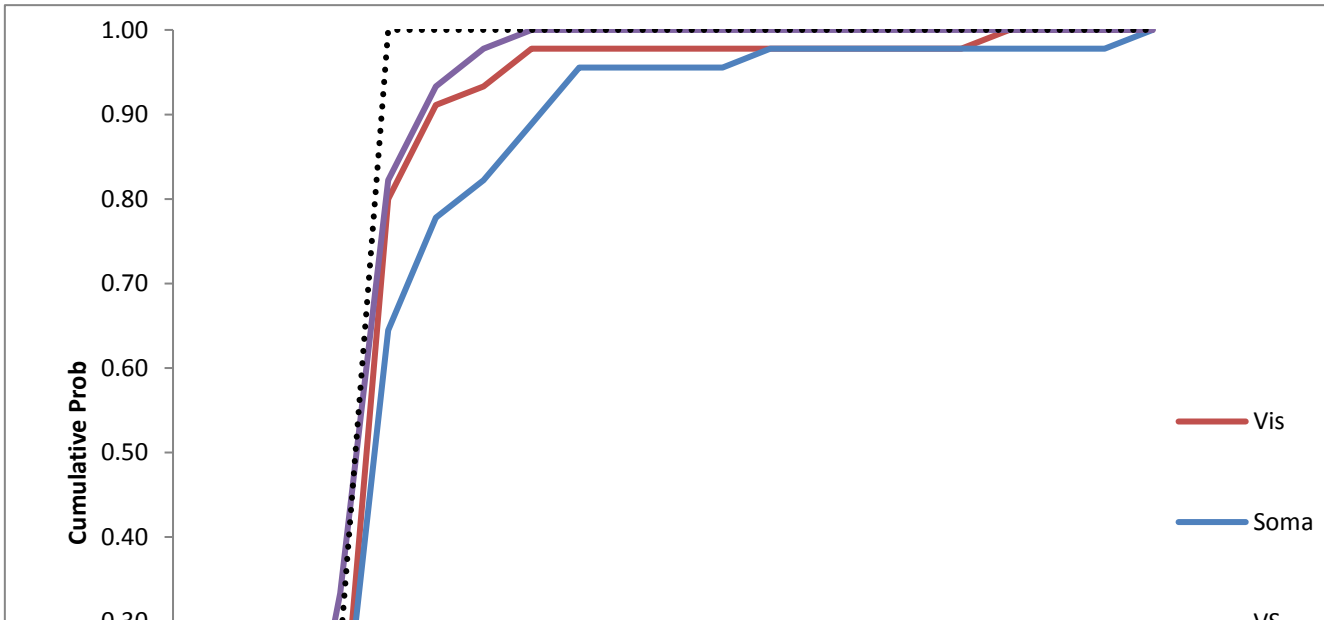

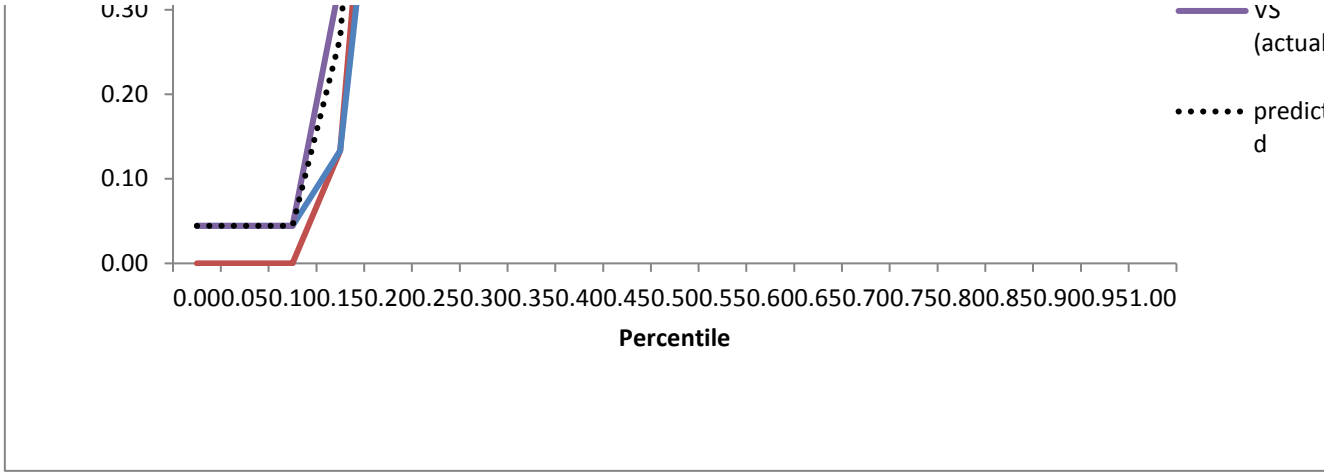
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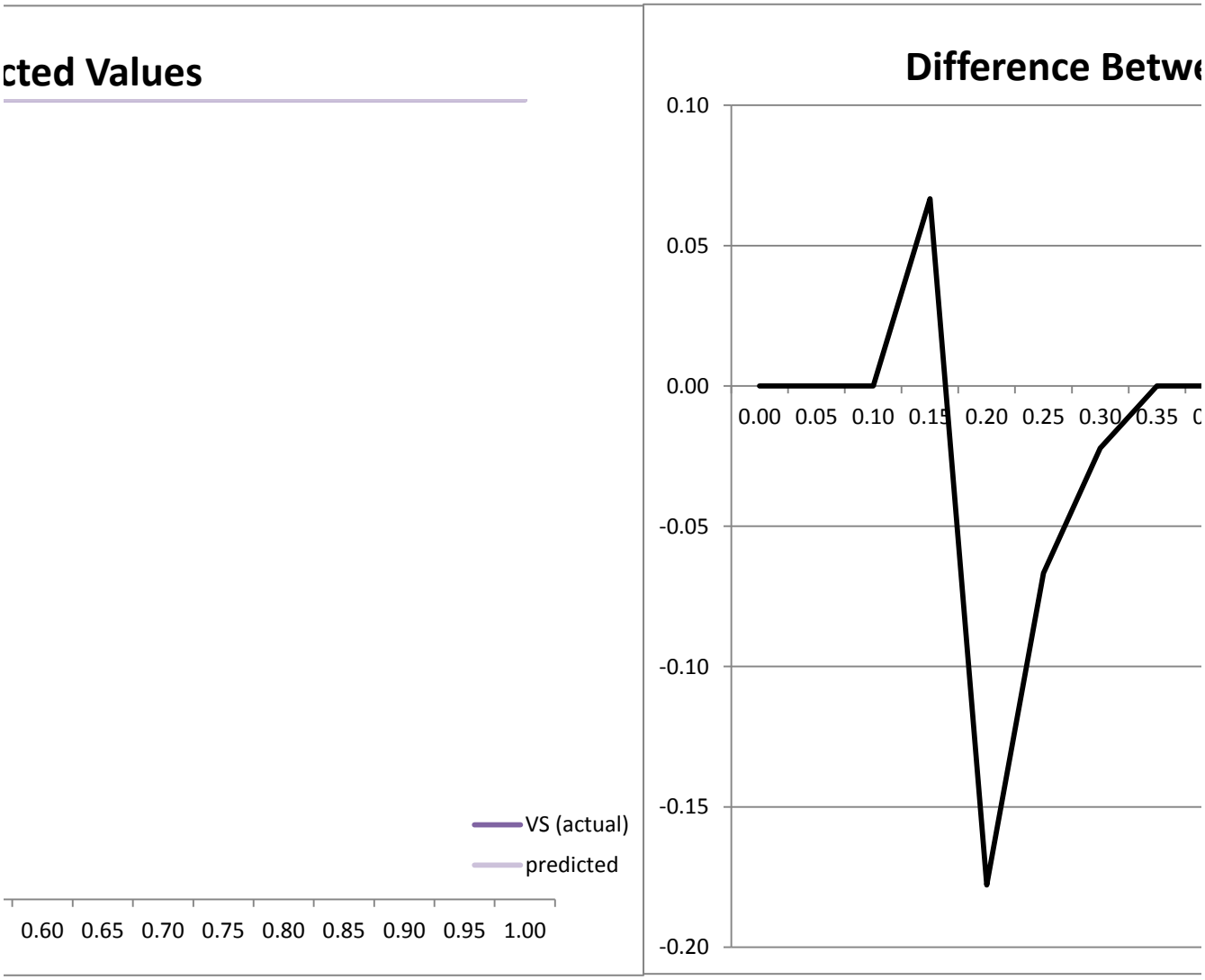
Percentile
VS (actual)
predicted


cted Values
VS (actual)
predicted
0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
Difference Betwe
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-0.05
-0.10
-0.15
-0.20
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35

	Cumulative Probability				
	Vis	**Soma**	**VS (actual)**	**predicted**	**Difference**
0.00	0.00	0.04	0.04	0.04	0.00
0.05	0.00	0.04	0.04	0.04	0.00
0.10	0.00	0.04	0.04	0.04	0.00
0.15	0.13	0.13	0.33	0.27	0.07
0.20	0.80	0.64	0.82	1.00	-0.18
0.25	0.91	0.78	0.93	1.00	-0.07
0.30	0.93	0.82	0.98	1.00	-0.02
0.35	0.98	0.89	1.00	1.00	0.00
0.40	0.98	0.96	1.00	1.00	0.00
0.45	0.98	0.96	1.00	1.00	0.00
0.50	0.98	0.96	1.00	1.00	0.00
0.55	0.98	0.96	1.00	1.00	0.00
0.60	0.98	0.98	1.00	1.00	0.00
0.65	0.98	0.98	1.00	1.00	0.00
0.70	0.98	0.98	1.00	1.00	0.00
0.75	0.98	0.98	1.00	1.00	0.00
0.80	0.98	0.98	1.00	1.00	0.00
0.85	1.00	0.98	1.00	1.00	0.00
0.90	1.00	0.98	1.00	1.00	0.00
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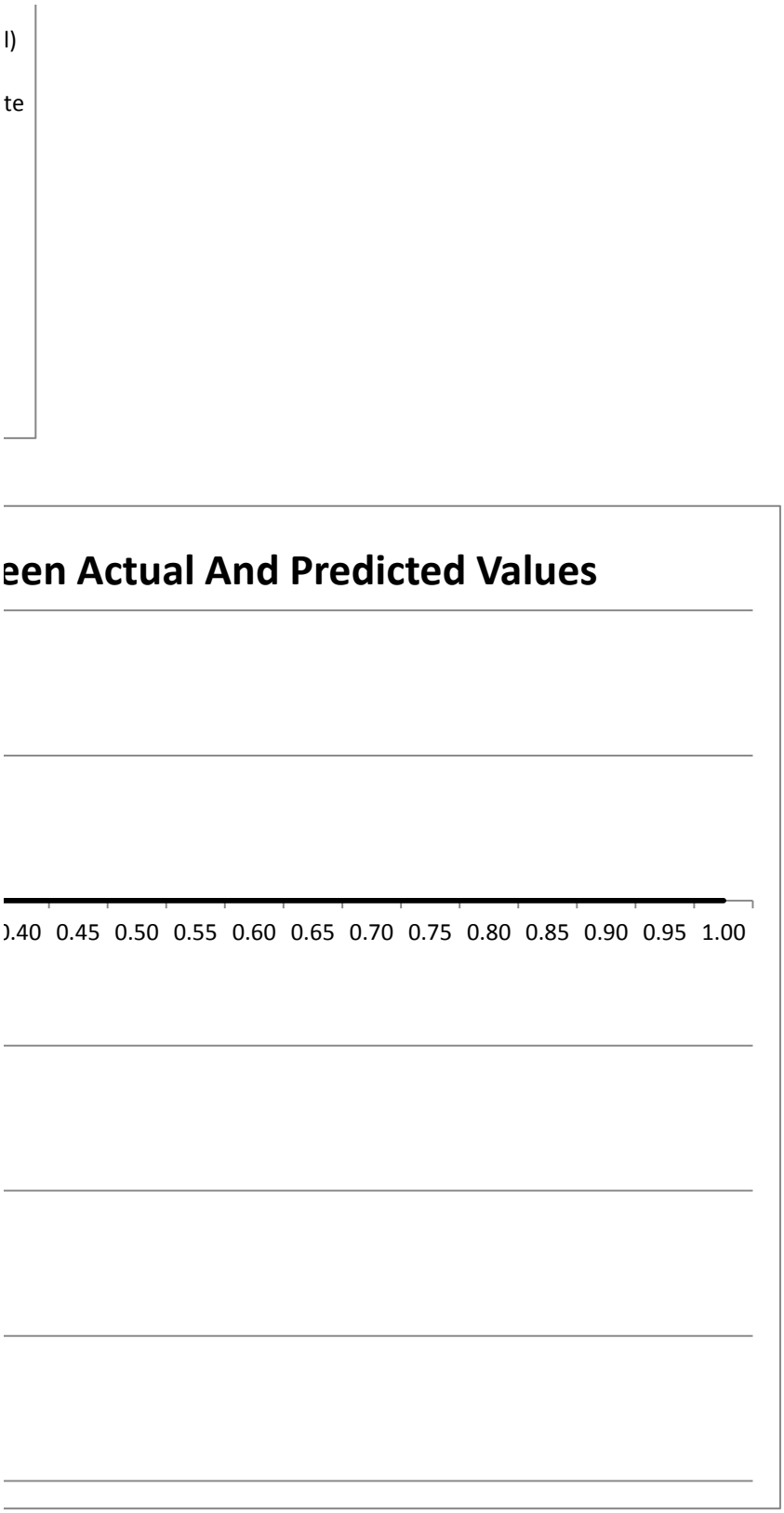
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Bar graph
Vis
369

trials	V	S	VS
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13	291	318	270
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25	320	346	311
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27	332	356	314
28	336	359	317
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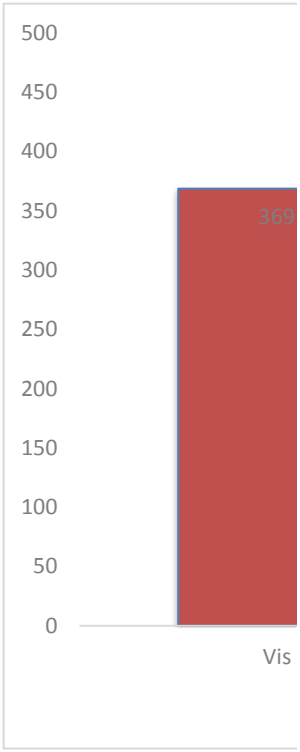
40	460	616	396



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43	645	740	502
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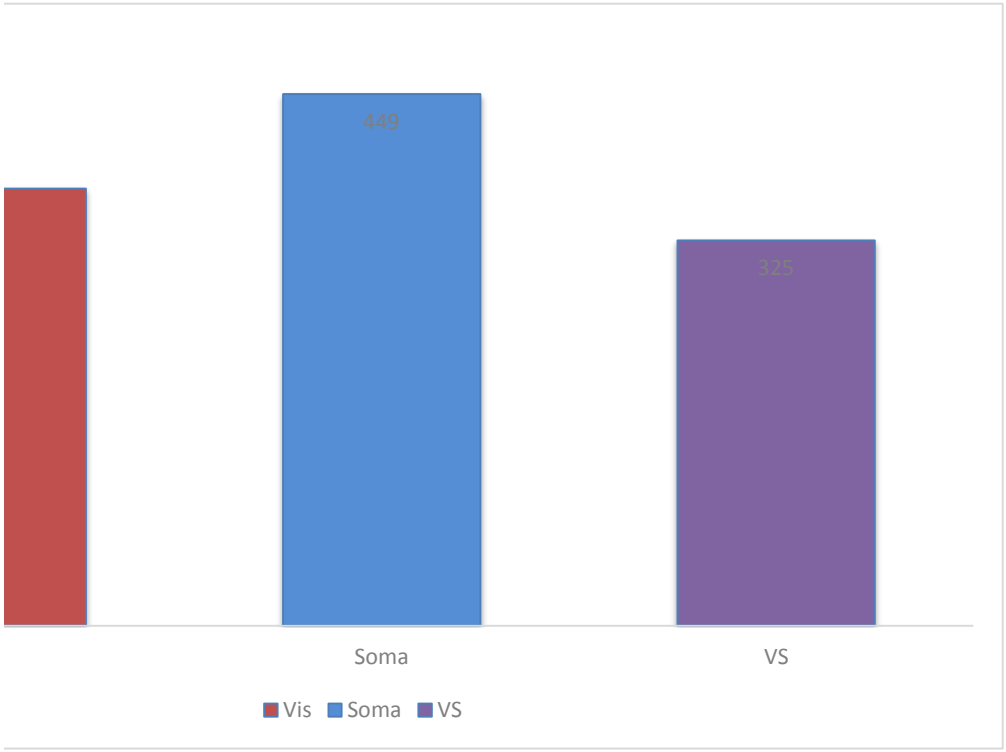
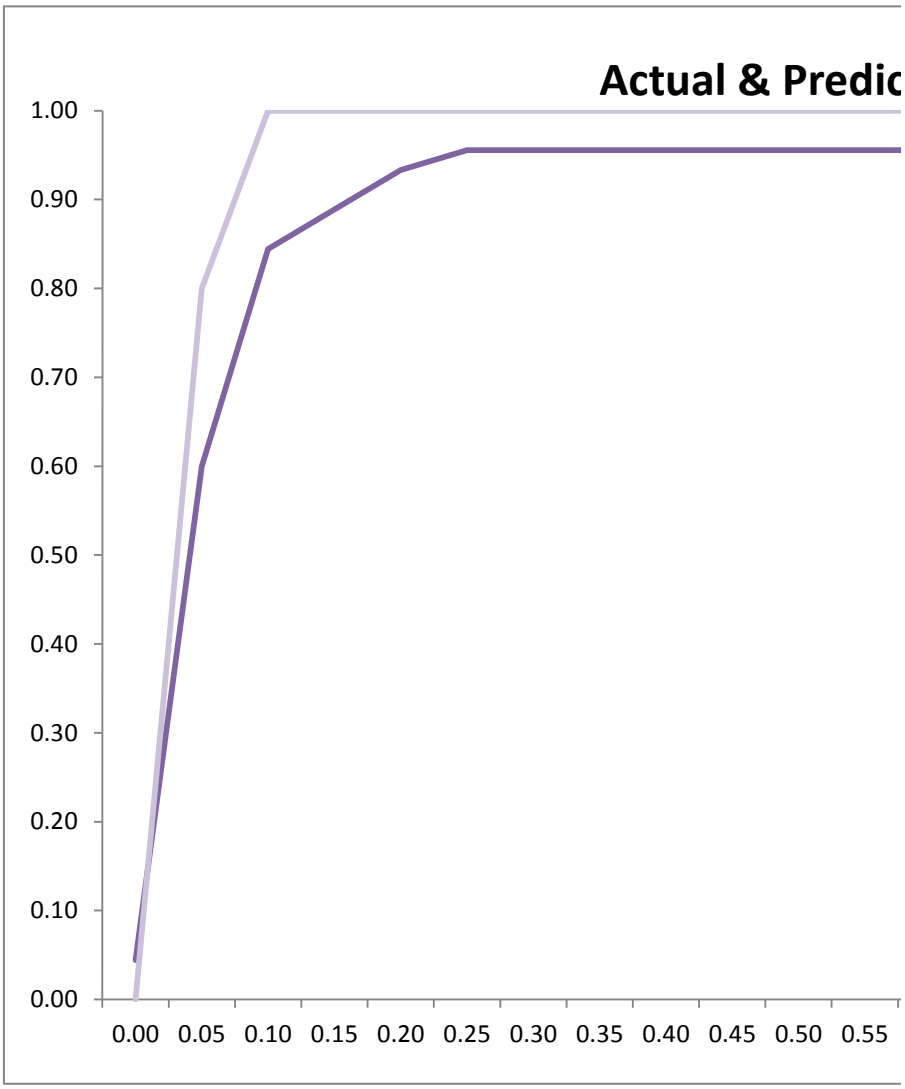
45	1574	1893	601

Soma	VS
449	325

	mean	stdev	sem	median
Vis	368.71	203.31	30.31	318.00
Soma	448.51	278.65	41.54	345.00
VS	325.00	78.21	11.66	309.00
ALL				




Actual & Predic
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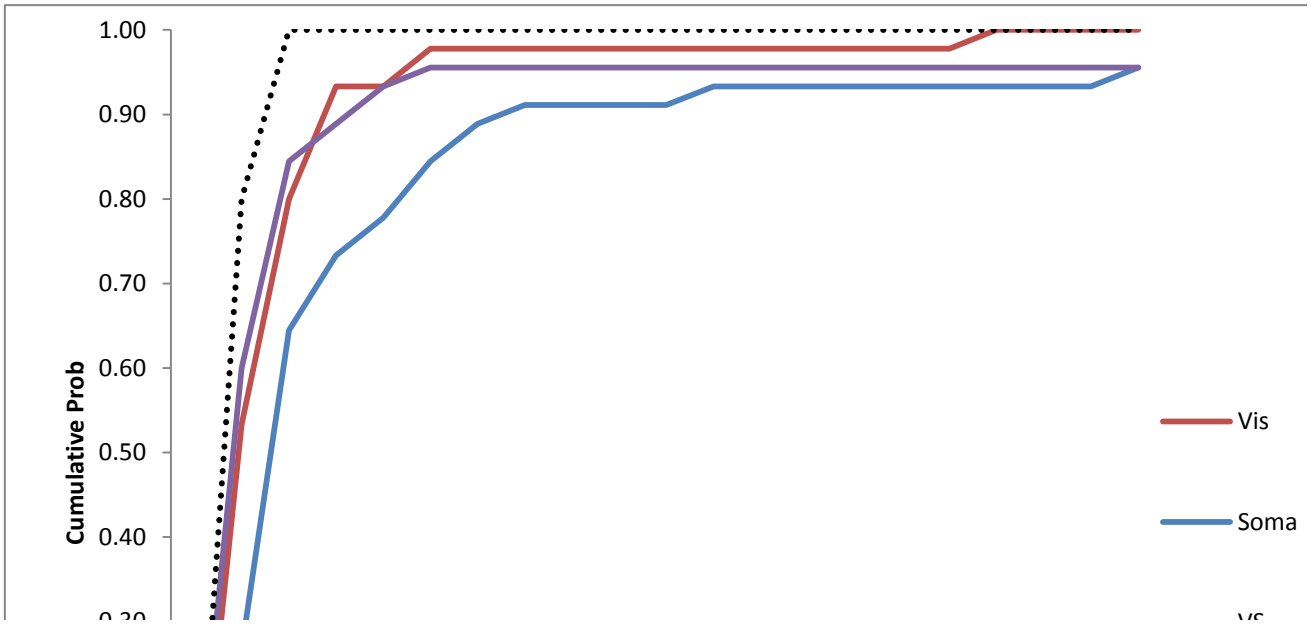
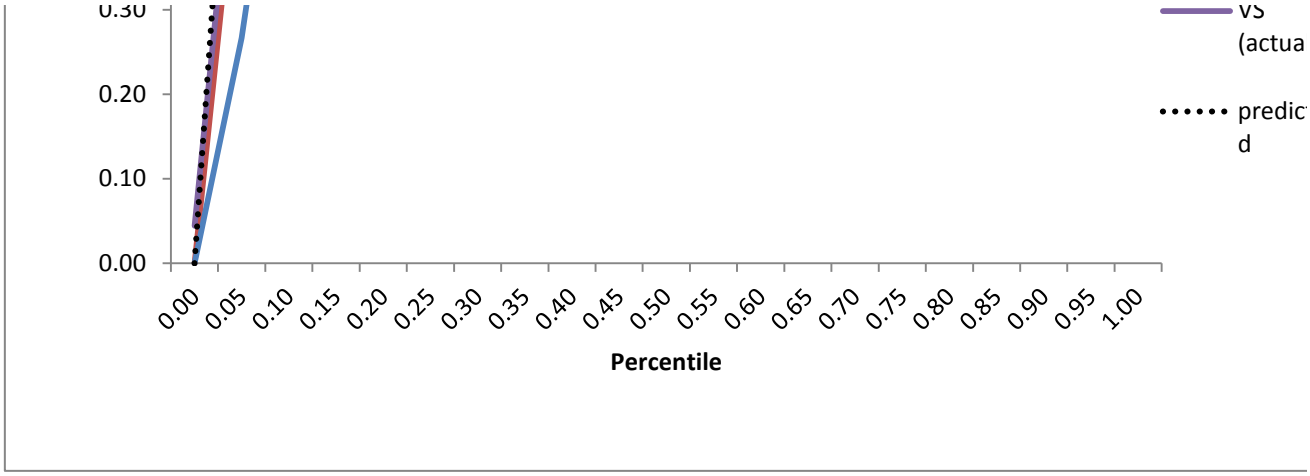
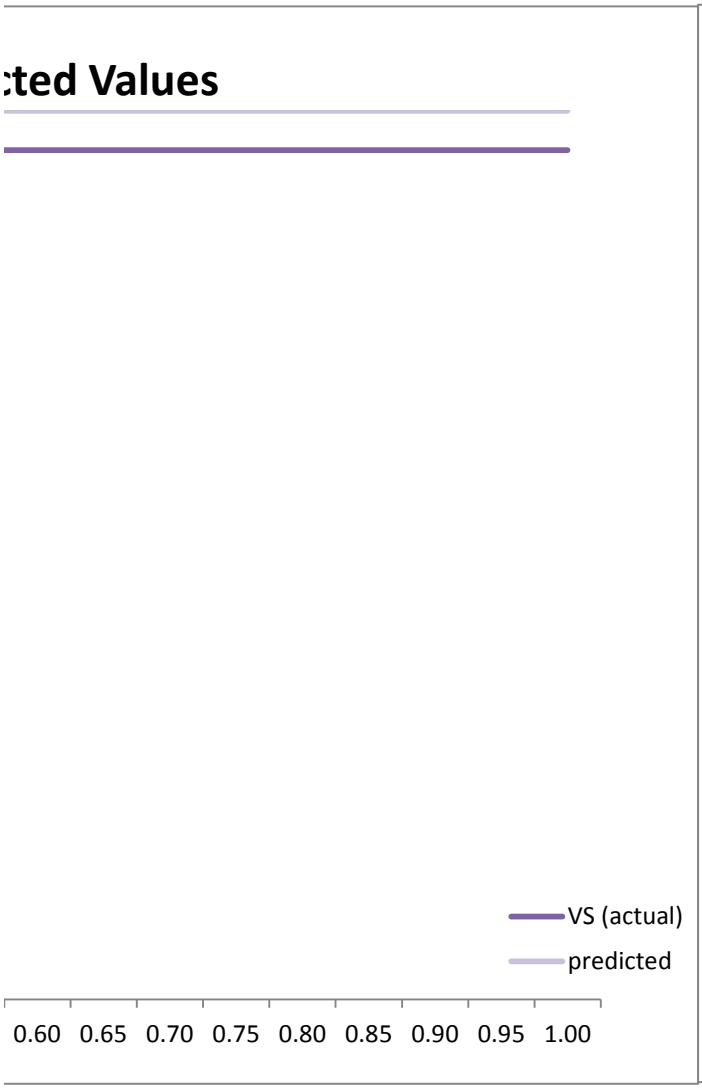
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55

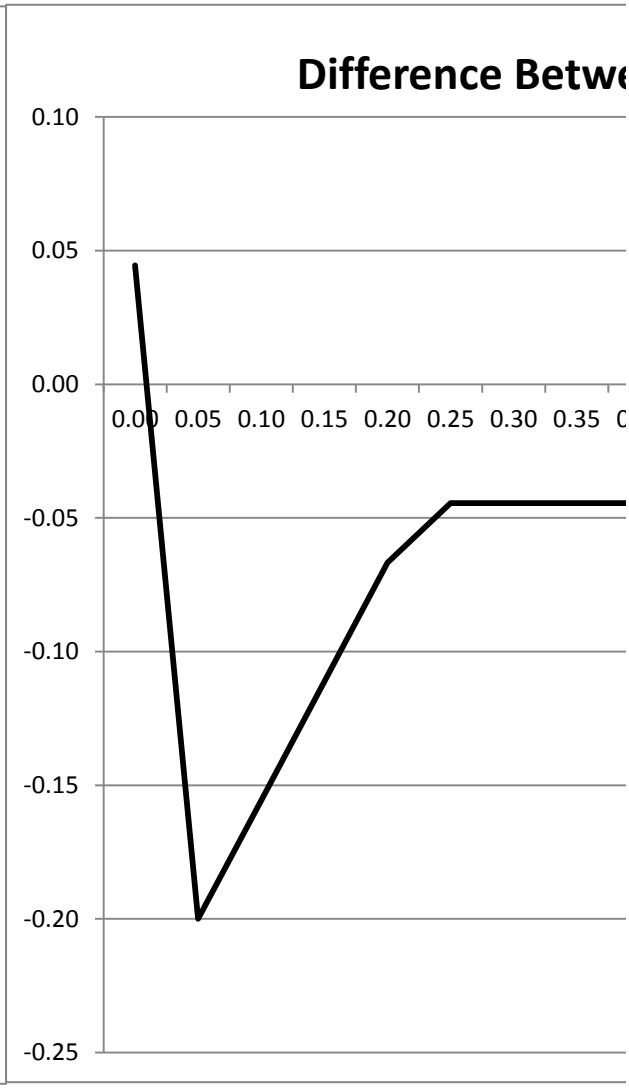
min	max	N	range
243.00	1574.00	45.00	
272.00	1893.00	45.00	
237.00	601.00	45.00	
237.00	1893.00		1656.00

Quantiles		Probability			
	ALL		Vis	Soma	VS
0.00	237.00	**0.00**	0.00	0.00	0.04
0.01	253.56	**0.01**	0.07	0.00	0.07
0.05	319.80	**0.05**	0.47	0.27	0.49
0.10	402.60	**0.10**	0.27	0.38	0.24
0.15	485.40	**0.15**	0.13	0.09	0.04
0.20	568.20	**0.20**	0.00	0.04	0.04
0.25	651.00	**0.25**	0.04	0.07	0.02
0.30	733.80	**0.30**	0.00	0.04	0.00
0.35	816.60	**0.35**	0.00	0.02	0.00
0.40	899.40	**0.40**	0.00	0.00	0.00
0.45	982.20	**0.45**	0.00	0.00	0.00
0.50	1065.00	**0.50**	0.00	0.00	0.00
0.55	1147.80	**0.55**	0.00	0.02	0.00
0.60	1230.60	**0.60**	0.00	0.00	0.00
0.65	1313.40	**0.65**	0.00	0.00	0.00
0.70	1396.20	**0.70**	0.00	0.00	0.00
0.75	1479.00	**0.75**	0.00	0.00	0.00
0.80	1561.80	**0.80**	0.00	0.00	0.00
0.85	1644.60	**0.85**	0.02	0.00	0.00
0.90	1727.40	**0.90**	0.00	0.00	0.00
0.95	1810.20	**0.95**	0.00	0.00	0.00
1.00	1893.00	**1.00**	0.00	0.02	0.00

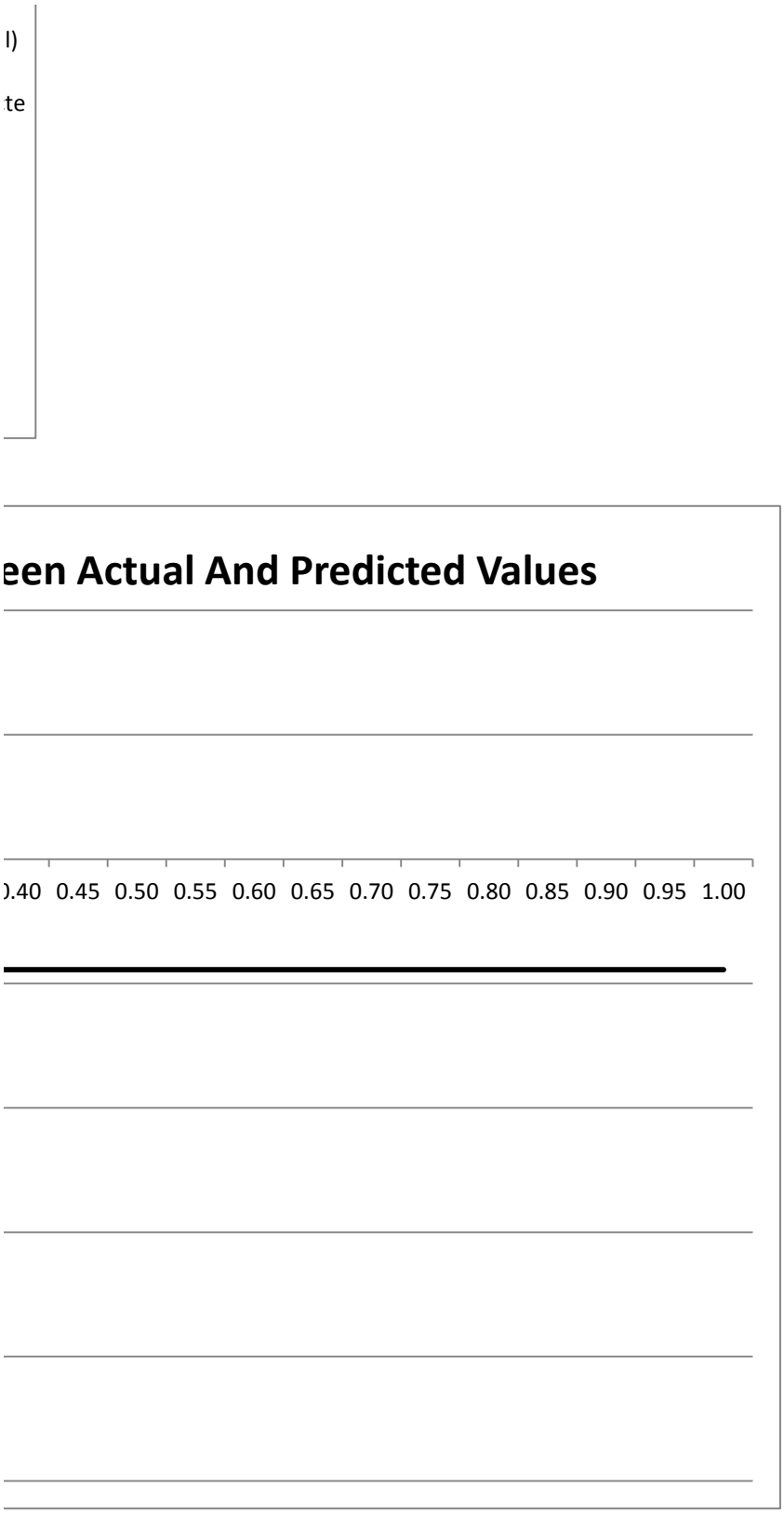



0.30
0.20
0.10
0.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
Percentile
VS (actua
predic d


cted Values
VS (actual)
predicted
0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00

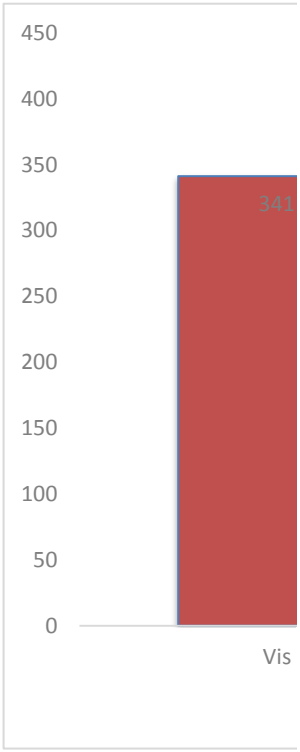

Difference Betwe
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35

	Cumulative Probability				
	Vis	**Soma**	**VS (actual)**	**predicted**	**Difference**
0.00	0.00	0.00	0.04	0.00	0.04
0.05	0.53	0.27	0.60	0.80	-0.20
0.10	0.80	0.64	0.84	1.00	-0.16
0.15	0.93	0.73	0.89	1.00	-0.11
0.20	0.93	0.78	0.93	1.00	-0.07
0.25	0.98	0.84	0.96	1.00	-0.04
0.30	0.98	0.89	0.96	1.00	-0.04
0.35	0.98	0.91	0.96	1.00	-0.04
0.40	0.98	0.91	0.96	1.00	-0.04
0.45	0.98	0.91	0.96	1.00	-0.04
0.50	0.98	0.91	0.96	1.00	-0.04
0.55	0.98	0.93	0.96	1.00	-0.04
0.60	0.98	0.93	0.96	1.00	-0.04
0.65	0.98	0.93	0.96	1.00	-0.04
0.70	0.98	0.93	0.96	1.00	-0.04
0.75	0.98	0.93	0.96	1.00	-0.04
0.80	0.98	0.93	0.96	1.00	-0.04
0.85	1.00	0.93	0.96	1.00	-0.04
0.90	1.00	0.93	0.96	1.00	-0.04
0.95	1.00	0.93	0.96	1.00	-0.04
1.00	1.00	0.96	0.96	1.00	-0.04


l)
te
een Actual And Predicted Values
.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00

Bar graph
Vis
341

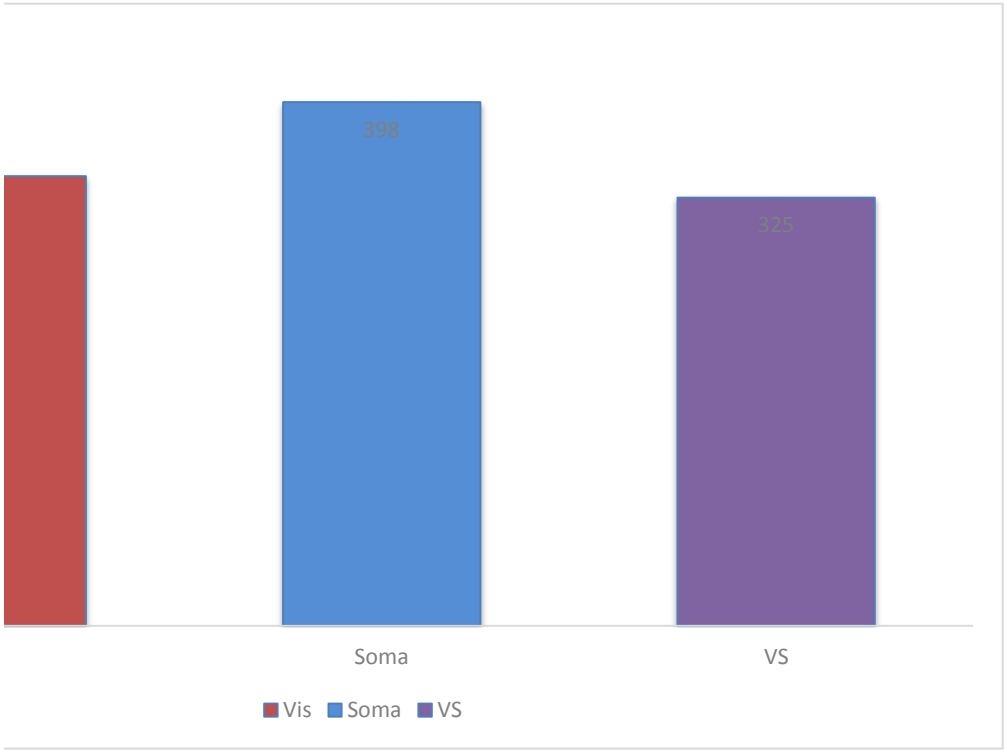
trials	V	S	VS
1	243	Inf	Inf
2	249	Inf	Inf
3	252	272	237
4	256	274	237
5	275	280	246
6	283	281	252
7	286	299	252
8	287	305	257
9	288	309	259
10	288	312	261
11	289	315	263
12	291	317	270
13	291	318	270
14	297	319	272
15	299	323	280
16	300	326	285
17	300	328	290
18	301	329	294
19	305	331	296
20	306	334	298
21	308	336	298
22	315	340	305
23	318	343	308
24	319	345	309
25	320	346	311
26	322	353	314
27	332	356	314
28	336	359	317
29	337	378	318
30	338	387	325
31	339	391	331
32	340	419	331
33	355	429	338
34	357	462	338
35	358	471	342
36	371	514	351
37	403	526	370
38	415	582	380
39	448	606	394
40	460	616	396

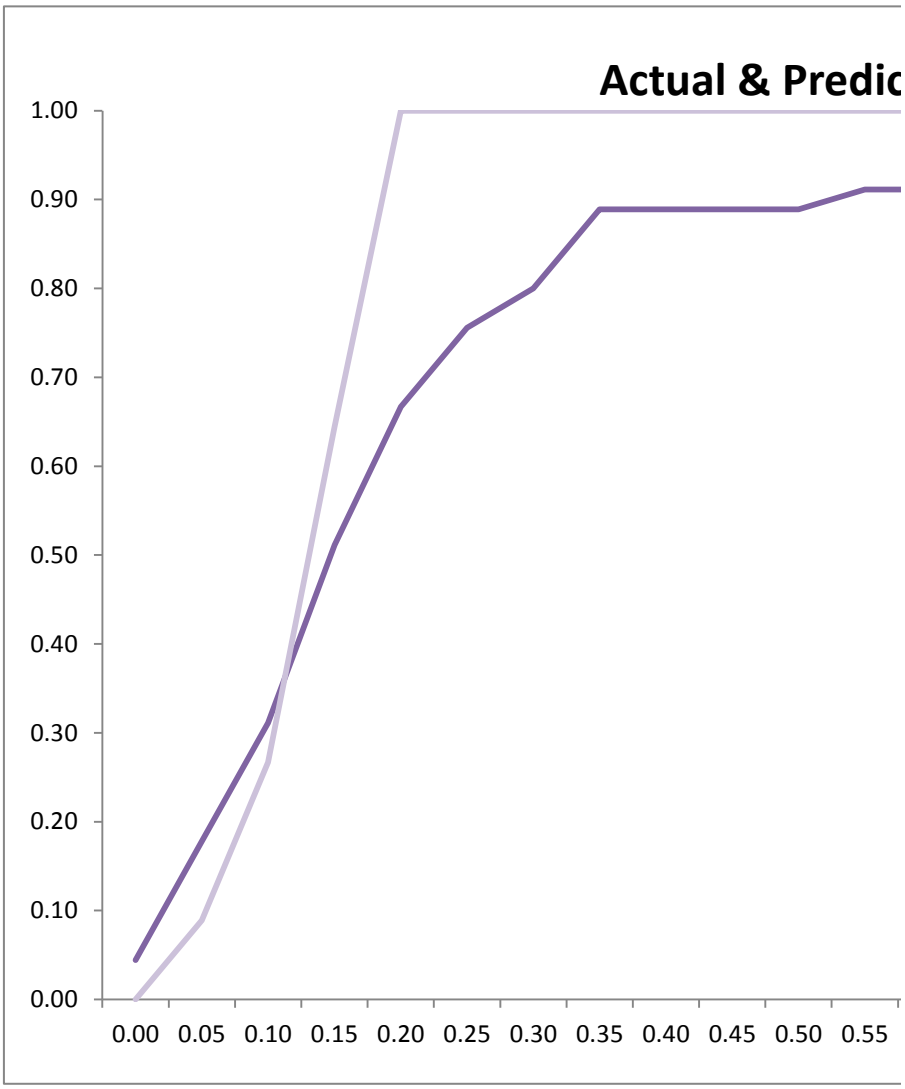


41	471	712	403
42	479	716	405
43	645	740	502
44	646	Inf	555
45	Inf	Inf	601

Soma	VS
398	325

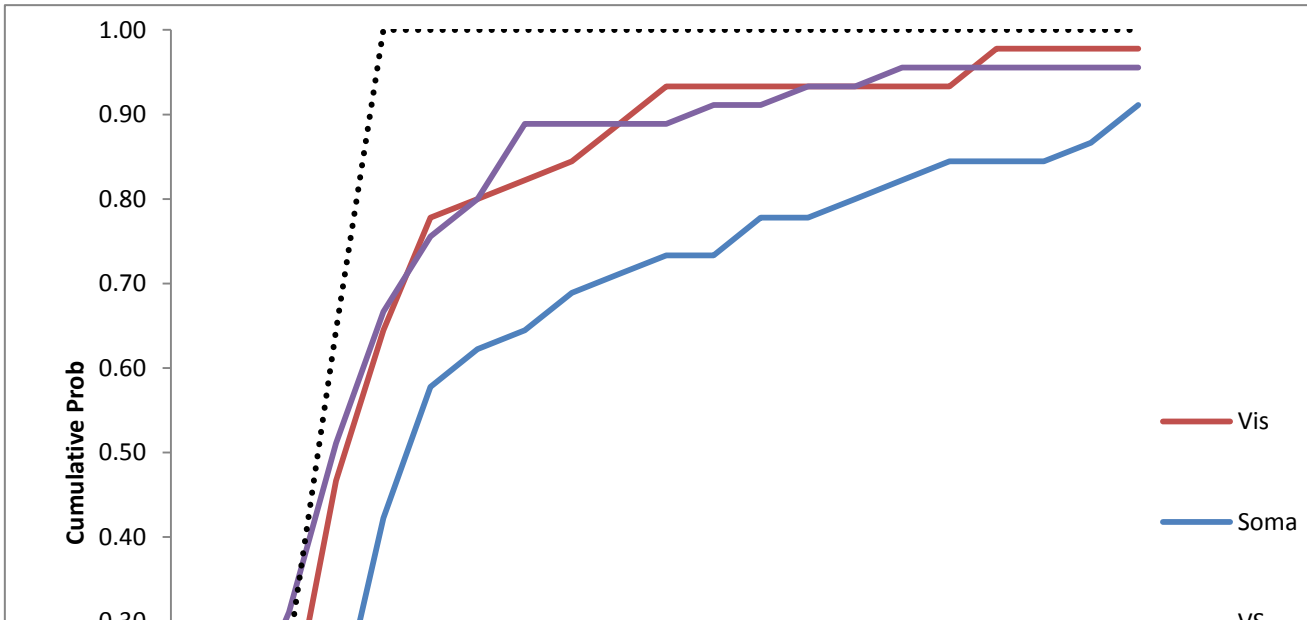
	mean	stdev	sem	median
Vis	341.32	88.01	13.12	316.50
Soma	397.54	127.61	19.02	343.00
VS	325.00	78.21	11.66	309.00
ALL				

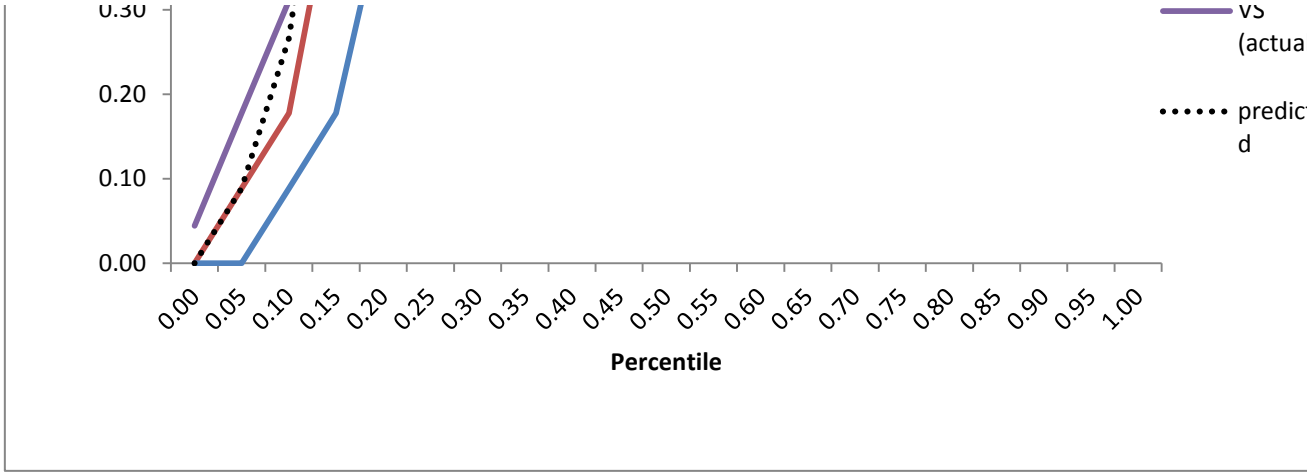


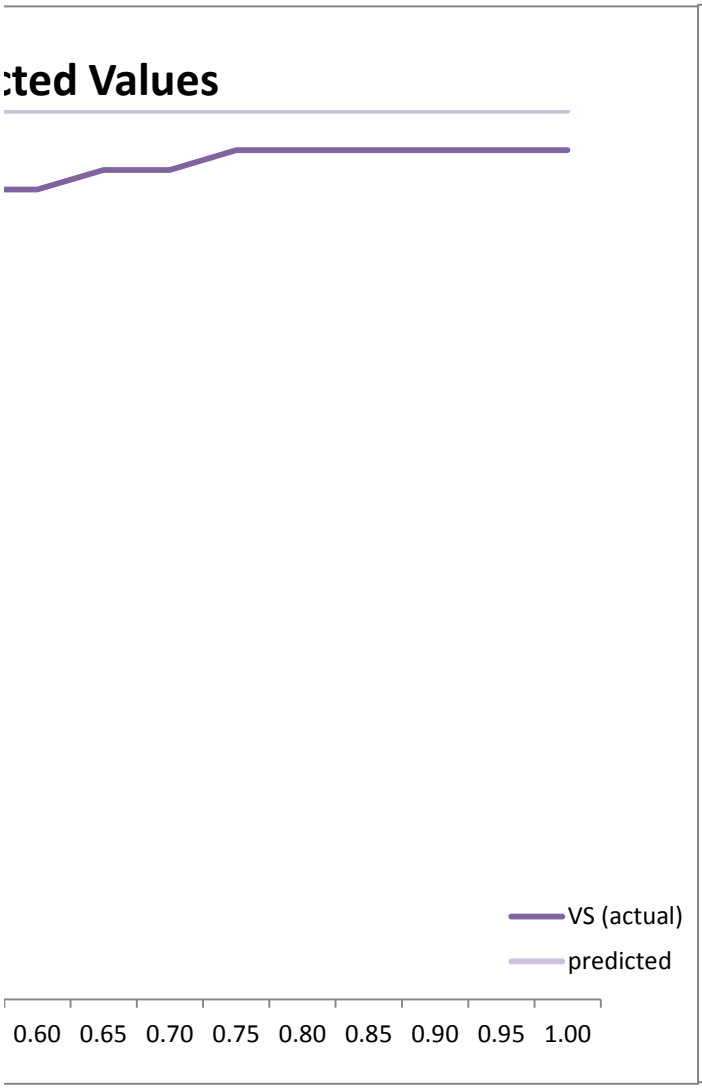

Actual & Predic
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55

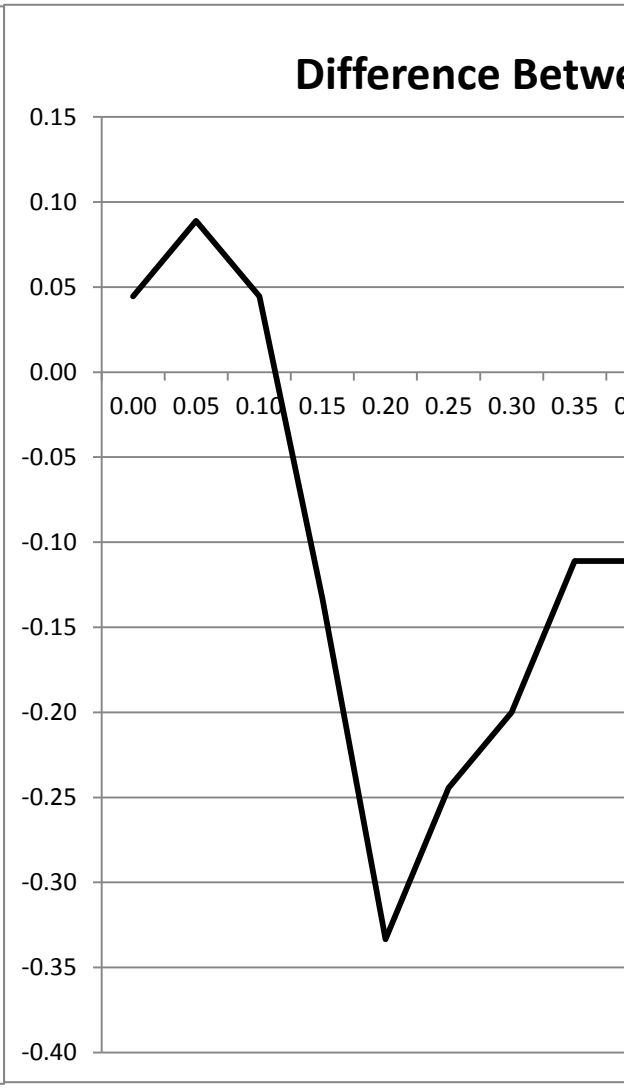
min	max	N	range
243.00	646.00	45.00	
272.00	740.00	45.00	
237.00	601.00	45.00	
237.00	740.00		503.00

Quantiles		Probability			
	ALL		Vis	Soma	VS
0.00	237.00	**0.00**	0.00	0.00	0.04
0.01	242.03	**0.01**	0.00	0.00	0.00
0.05	262.15	**0.05**	0.09	0.00	0.13
0.10	287.30	**0.10**	0.09	0.09	0.13
0.15	312.45	**0.15**	0.29	0.09	0.20
0.20	337.60	**0.20**	0.18	0.24	0.16
0.25	362.75	**0.25**	0.13	0.16	0.09
0.30	387.90	**0.30**	0.02	0.04	0.04
0.35	413.05	**0.35**	0.02	0.02	0.09
0.40	438.20	**0.40**	0.02	0.04	0.00
0.45	463.35	**0.45**	0.04	0.02	0.00
0.50	488.50	**0.50**	0.04	0.02	0.00
0.55	513.65	**0.55**	0.00	0.00	0.02
0.60	538.80	**0.60**	0.00	0.04	0.00
0.65	563.95	**0.65**	0.00	0.00	0.02
0.70	589.10	**0.70**	0.00	0.02	0.00
0.75	614.25	**0.75**	0.00	0.02	0.02
0.80	639.40	**0.80**	0.00	0.02	0.00
0.85	664.55	**0.85**	0.04	0.00	0.00
0.90	689.70	**0.90**	0.00	0.00	0.00
0.95	714.85	**0.95**	0.00	0.02	0.00
1.00	740.00	**1.00**	0.00	0.04	0.00




0.30
0.20
0.10
0.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
Percentile
VS (actua
predic d


cted Values
VS (actual)
predicted
0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00


Difference Betwe
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35

	Cumulative Probability				
	Vis	**Soma**	**VS (actual)**	**predicted**	**Difference**
0.00	0.00	0.00	0.04	0.00	0.04
0.05	0.09	0.00	0.18	0.09	0.09
0.10	0.18	0.09	0.31	0.27	0.04
0.15	0.47	0.18	0.51	0.64	-0.13
0.20	0.64	0.42	0.67	1.00	-0.33
0.25	0.78	0.58	0.76	1.00	-0.24
0.30	0.80	0.62	0.80	1.00	-0.20
0.35	0.82	0.64	0.89	1.00	-0.11
0.40	0.84	0.69	0.89	1.00	-0.11
0.45	0.89	0.71	0.89	1.00	-0.11
0.50	0.93	0.73	0.89	1.00	-0.11
0.55	0.93	0.73	0.91	1.00	-0.09
0.60	0.93	0.78	0.91	1.00	-0.09
0.65	0.93	0.78	0.93	1.00	-0.07
0.70	0.93	0.80	0.93	1.00	-0.07
0.75	0.93	0.82	0.96	1.00	-0.04
0.80	0.93	0.84	0.96	1.00	-0.04
0.85	0.98	0.84	0.96	1.00	-0.04
0.90	0.98	0.84	0.96	1.00	-0.04
0.95	0.98	0.87	0.96	1.00	-0.04
1.00	0.98	0.91	0.96	1.00	-0.04

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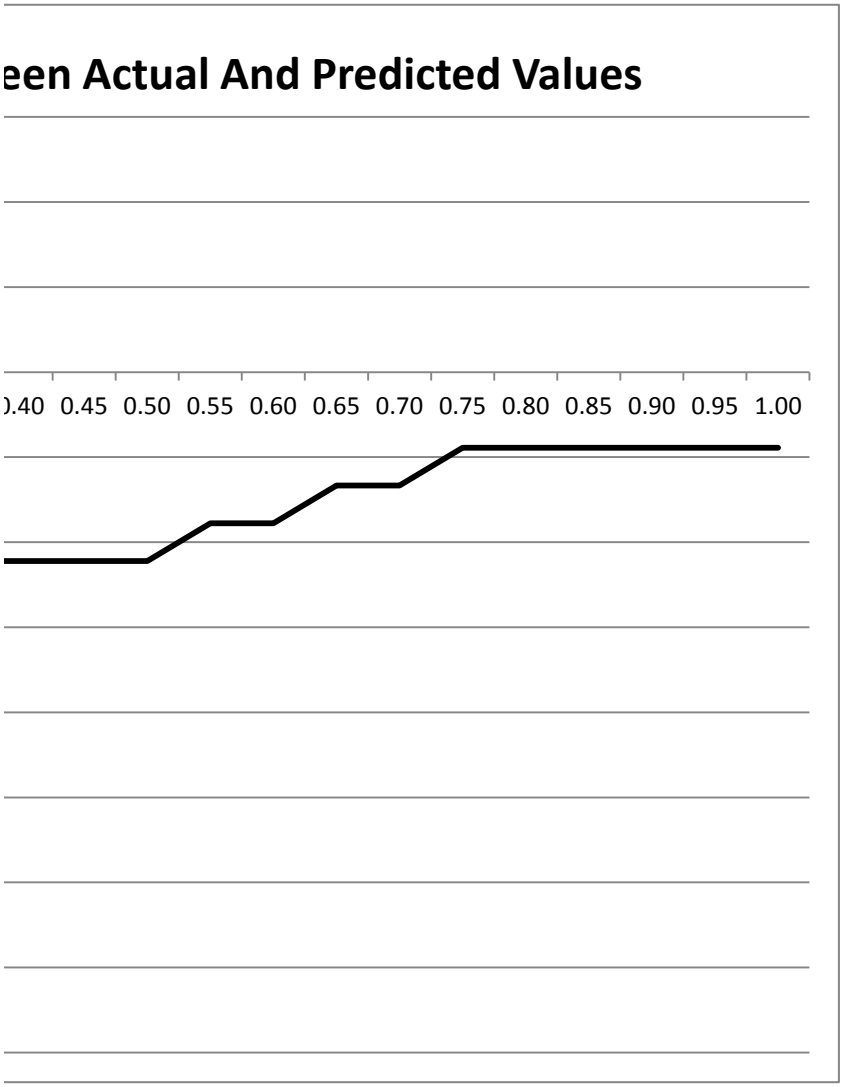
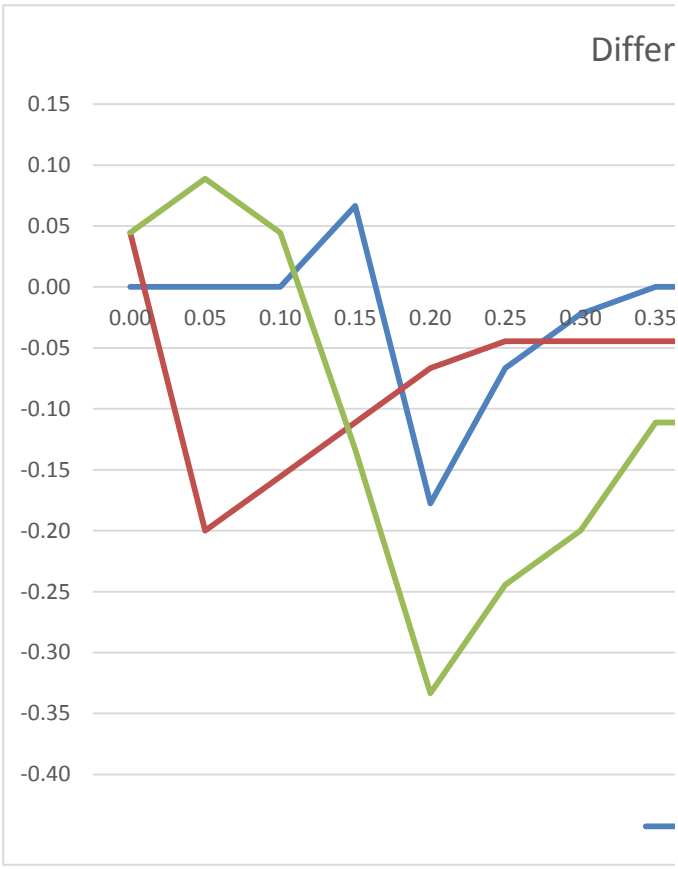

een Actual And Predicted Values
0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00

	1.00	2.00	3.00
0.00	0.00	0.04	0.04
0.05	0.00	-0.20	0.09
0.10	0.00	-0.16	0.04
0.15	0.07	-0.11	-0.13
0.20	-0.18	-0.07	-0.33
0.25	-0.07	-0.04	-0.24
0.30	-0.02	-0.04	-0.20
0.35	0.00	-0.04	-0.11
0.40	0.00	-0.04	-0.11
0.45	0.00	-0.04	-0.11
0.50	0.00	-0.04	-0.11
0.55	0.00	-0.04	-0.09
0.60	0.00	-0.04	-0.09
0.65	0.00	-0.04	-0.07
0.70	0.00	-0.04	-0.07
0.75	0.00	-0.04	-0.04
0.80	0.00	-0.04	-0.04
0.85	0.00	-0.04	-0.04
0.90	0.00	-0.04	-0.04
0.95	0.00	-0.04	-0.04
1.00	0.00	-0.04	-0.04




ence Waves By Example
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
2.00
3.00

Analysis name:
Column conditions: TrialName
Row conditions: Block1, Block2, Block3
Statistics: Response.RT:Mean
Filters: None
Data file:
File does not have data alterations.

S#
Wave

Response.RT:Mean by Block1, Block2, Block3 and TrialName						
Block1	**Block2**	**Block3**	**Stats**	**SomaCue_D**	**VSCue_D**	**VizCue_D**
NULL	NULL	1	Mean Response.RT			219.00
NULL	NULL	2	Mean Response.RT			379.00
NULL	NULL	3	Mean Response.RT			220.00
NULL	NULL	4	Mean Response.RT			152.00
NULL	NULL	5	Mean Response.RT			183.00
NULL	NULL	6	Mean Response.RT			191.00
NULL	NULL	7	Mean Response.RT			206.00
NULL	NULL	8	Mean Response.RT			175.00
NULL	NULL	9	Mean Response.RT			199.00
NULL	NULL	10	Mean Response.RT			187.00
NULL	NULL	11	Mean Response.RT			218.00
NULL	NULL	12	Mean Response.RT			237.00
NULL	NULL	13	Mean Response.RT			191.00
NULL	NULL	14	Mean Response.RT			149.00
NULL	NULL	15	Mean Response.RT			188.00
NULL	NULL	16	Mean Response.RT	229.00		
NULL	NULL	17	Mean Response.RT	180.00		
NULL	NULL	18	Mean Response.RT	243.00		
NULL	NULL	19	Mean Response.RT	253.00		
NULL	NULL	20	Mean Response.RT	287.00		
NULL	NULL	21	Mean Response.RT	278.00		
NULL	NULL	22	Mean Response.RT	259.00		
NULL	NULL	23	Mean Response.RT	172.00		
NULL	NULL	24	Mean Response.RT	205.00		
NULL	NULL	25	Mean Response.RT	640.00		
NULL	NULL	26	Mean Response.RT	223.00		
NULL	NULL	27	Mean Response.RT	181.00		
NULL	NULL	28	Mean Response.RT	256.00		
NULL	NULL	29	Mean Response.RT	228.00		
NULL	NULL	30	Mean Response.RT	226.00		
NULL	NULL	31	Mean Response.RT		170.00	
NULL	NULL	32	Mean Response.RT		196.00	
NULL	NULL	33	Mean Response.RT		137.00	
NULL	NULL	34	Mean Response.RT		218.00	
NULL	NULL	35	Mean Response.RT		159.00	
NULL	NULL	36	Mean Response.RT		163.00	

NULL	NULL	37	Mean Response.RT		208.00	
NULL	NULL	38	Mean Response.RT		198.00	
NULL	NULL	39	Mean Response.RT		231.00	
NULL	NULL	40	Mean Response.RT		231.00	
NULL	NULL	41	Mean Response.RT		157.00	
NULL	NULL	42	Mean Response.RT		280.00	
NULL	NULL	43	Mean Response.RT		214.00	
NULL	NULL	44	Mean Response.RT		152.00	
NULL	NULL	45	Mean Response.RT		137.00	
NULL	1	NULL	Mean Response.RT			240.00
NULL	2	NULL	Mean Response.RT			255.00
NULL	3	NULL	Mean Response.RT			208.00
NULL	4	NULL	Mean Response.RT			197.00
NULL	5	NULL	Mean Response.RT			201.00
NULL	6	NULL	Mean Response.RT			143.00
NULL	7	NULL	Mean Response.RT			238.00
NULL	8	NULL	Mean Response.RT			546.00
NULL	9	NULL	Mean Response.RT			239.00
NULL	10	NULL	Mean Response.RT			215.00
NULL	11	NULL	Mean Response.RT			188.00
NULL	12	NULL	Mean Response.RT			315.00
NULL	13	NULL	Mean Response.RT			205.00
NULL	14	NULL	Mean Response.RT			189.00
NULL	15	NULL	Mean Response.RT			236.00
NULL	16	NULL	Mean Response.RT	219.00		
NULL	17	NULL	Mean Response.RT	0.00		
NULL	18	NULL	Mean Response.RT	319.00		
NULL	19	NULL	Mean Response.RT	217.00		
NULL	20	NULL	Mean Response.RT	245.00		
NULL	21	NULL	Mean Response.RT	199.00		
NULL	22	NULL	Mean Response.RT	0.00		
NULL	23	NULL	Mean Response.RT	240.00		
NULL	24	NULL	Mean Response.RT	209.00		
NULL	25	NULL	Mean Response.RT	218.00		
NULL	26	NULL	Mean Response.RT	362.00		
NULL	27	NULL	Mean Response.RT	215.00		
NULL	28	NULL	Mean Response.RT	236.00		
NULL	29	NULL	Mean Response.RT	612.00		
NULL	30	NULL	Mean Response.RT	329.00		
NULL	31	NULL	Mean Response.RT		172.00	
NULL	32	NULL	Mean Response.RT		0.00	
NULL	33	NULL	Mean Response.RT		161.00	
NULL	34	NULL	Mean Response.RT		501.00	
NULL	35	NULL	Mean Response.RT		190.00	
NULL	36	NULL	Mean Response.RT		251.00	
NULL	37	NULL	Mean Response.RT		217.00	
NULL	38	NULL	Mean Response.RT		305.00	

NULL	39	NULL	Mean Response.RT		198.00	
NULL	40	NULL	Mean Response.RT		146.00	
NULL	41	NULL	Mean Response.RT		214.00	
NULL	42	NULL	Mean Response.RT		238.00	
NULL	43	NULL	Mean Response.RT		211.00	
NULL	44	NULL	Mean Response.RT		152.00	
NULL	45	NULL	Mean Response.RT		180.00	
1	NULL	NULL	Mean Response.RT			360.00
2	NULL	NULL	Mean Response.RT			200.00
3	NULL	NULL	Mean Response.RT			257.00
4	NULL	NULL	Mean Response.RT			200.00
5	NULL	NULL	Mean Response.RT			156.00
6	NULL	NULL	Mean Response.RT			545.00
7	NULL	NULL	Mean Response.RT			271.00
8	NULL	NULL	Mean Response.RT			258.00
9	NULL	NULL	Mean Response.RT			303.00
10	NULL	NULL	Mean Response.RT			232.00
11	NULL	NULL	Mean Response.RT			1474.00
12	NULL	NULL	Mean Response.RT			371.00
13	NULL	NULL	Mean Response.RT			348.00
14	NULL	NULL	Mean Response.RT			186.00
15	NULL	NULL	Mean Response.RT			222.00
16	NULL	NULL	Mean Response.RT	426.00		
17	NULL	NULL	Mean Response.RT	994.00		
18	NULL	NULL	Mean Response.RT	212.00		
19	NULL	NULL	Mean Response.RT	1793.00		
20	NULL	NULL	Mean Response.RT	291.00		
21	NULL	NULL	Mean Response.RT	616.00		
22	NULL	NULL	Mean Response.RT	246.00		
23	NULL	NULL	Mean Response.RT	506.00		
24	NULL	NULL	Mean Response.RT	234.00		
25	NULL	NULL	Mean Response.RT	516.00		
26	NULL	NULL	Mean Response.RT	371.00		
27	NULL	NULL	Mean Response.RT	414.00		
28	NULL	NULL	Mean Response.RT	174.00		
29	NULL	NULL	Mean Response.RT	231.00		
30	NULL	NULL	Mean Response.RT	482.00		
31	NULL	NULL	Mean Response.RT		270.00	
32	NULL	NULL	Mean Response.RT		402.00	
33	NULL	NULL	Mean Response.RT		185.00	
34	NULL	NULL	Mean Response.RT		296.00	
35	NULL	NULL	Mean Response.RT		209.00	
36	NULL	NULL	Mean Response.RT		194.00	
37	NULL	NULL	Mean Response.RT		303.00	
38	NULL	NULL	Mean Response.RT		238.00	
39	NULL	NULL	Mean Response.RT		455.00	
40	NULL	NULL	Mean Response.RT		225.00	

41	NULL	NULL	Mean Response.RT	170.00
42	NULL	NULL	Mean Response.RT	242.00
43	NULL	NULL	Mean Response.RT	0.00
44	NULL	NULL	Mean Response.RT	205.00
45	NULL	NULL	Mean Response.RT	294.00

sorted RTs in ascending order by condition

add stimulus presenta

	V	S	VS
1	143	0	0
2	149	0	0
3	152	172	137
4	156	174	137
5	175	180	146
6	183	181	152
7	186	199	152
8	187	205	157
9	188	209	159
10	188	212	161
11	189	215	163
12	191	217	170
13	191	218	170
14	197	219	172
15	199	223	180
16	200	226	185
17	200	228	190
18	201	229	194
19	205	231	196
20	206	234	198
21	208	236	198
22	215	240	205
23	218	243	208
24	219	245	209
25	220	246	211
26	222	253	214
27	232	256	214
28	236	259	217
29	237	278	218
30	238	287	225
31	239	291	231
32	240	319	231
33	255	329	238
34	257	362	238
35	258	371	242

	V	S
1	**243**	**Inf**
2	**249**	**Inf**
3	**252**	**272**
4	**256**	**274**
5	**275**	**280**
6	**283**	**281**
7	**286**	**299**
8	**287**	**305**
9	**288**	**309**
10	**288**	**312**
11	**289**	**315**
12	**291**	**317**
13	**291**	**318**
14	**297**	**319**
15	**299**	**323**
16	**300**	**326**
17	**300**	**328**
18	**301**	**329**
19	**305**	**331**
20	**306**	**334**
21	**308**	**336**
22	**315**	**340**
23	**318**	**343**
24	**319**	**345**
25	**320**	**346**
26	**322**	**353**
27	**332**	**356**
28	**336**	**359**
29	**337**	**378**
30	**338**	**387**
31	**339**	**391**
32	**340**	**419**
33	**355**	**429**
34	**357**	**462**
35	**358**	**471**

36	271	414	251	**36**	**371**	**514**
37	303	426	270	**37**	**403**	**526**
38	315	482	280	**38**	**415**	**582**
39	348	506	294	**39**	**448**	**606**
40	360	516	296	**40**	**460**	**616**
41	371	612	303	**41**	**471**	**712**
42	379	616	305	**42**	**479**	**716**
43	545	640	402	**43**	**645**	**740**
44	546	994	455	**44**	**646**	**1094**
45	1474	1793	501	**45**	**1574**	**1893**

	V	S	VS
ACCURATE TRIAL COUNT	**45**	**43**	**43**
ACCURACY	**1.00**	**0.96**	**0.96**

ıtion time (+100ms) and change omitted trials (0) to Inf

VS
Inf
Inf
237
237
246
252
252
257
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263
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380
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502
555
601

Supplemental File 3

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Supplemental Coding Files

sample_eprime_behave_data.edat2

Eprime experiment codes