Comparison of Statistical Methods to Calculate an Audiovisual Temporal Binding Window

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Introduction

The human brain is evolutionarily designed to integrate inputs from different sensory modalities in order to make sense of the world around us. Appropriate multisensory integration underlies proper development of critical skills including motor coordination and language (1,2).

Temporal Binding Window: The time within which the brain perceives the synchrony or asynchrony of multiple sensory stimuli (eg hearing the sound of someone's voice and seeing the movement of their lips) is known as the temporal binding window (TBW). A wider TBW has been demonstrated in individuals with disorders such as autism and can result in asynchronous events being perceived as synchronous more so than for typically developing (TD) individuals (3,4,5).

TBW Statistics: The established method of TBW estimation calculates the area of the Gaussian curve below the 75% time within the maximum baseline value. This excluded participants whose TBWs were not estimable as their modeled curves were not within the criterion.

Significance of Proposed Method: Our proposed method determines the TBW corresponding to the intersection of a vertical line where 75% of the curve area is contained and intersects the curve enabling the inclusion of participant data that would otherwise have been excluded thus providing a more accurate description of the full range of TBWs.

Simultaneity Judgment Task

Procedure: Participants were seated in a sound isolation booth approximately 60cm from a computer monitor.

Stimuli:

- Visual **-** white circle briefly flashed on a solid black background
- Auditory – a short tone was delivered via headphones that was either in synch with the brief flash of the white circle or was heard at various stimulus offset asynchronies (SOAs) ranging from 10-500ms either preceding the presentation of the circle or occurring after the circle was flashed on the monitor.

Task: Identify whether the circle and tone were presented synchronously or asynchronously via keyboard button-press of number 1 or 2 respectively

Length: ~10 minutes for 380 presentations of various SOAs

Participants

Autism Group:

- age 13-26 years old with clinical diagnosis of Autism, Asperger's Syndrome, or Pervasive Developmental Disorder-not otherwise specified

Typically developing (TD) Control Group:

- age 11-28 years old screened for a history of neurological disorders including autism

Screening Criteria: native English speakers, self-reported normal hearing and vision or wore corrective lenses.

Statistics: Participants were matched ($p>0.05$) for age, handedness and IQ (WASI-II Perceptual Reasoning)

IRB Compliance: Informed consent was obtained based on the procedures approved by the West Virginia University Institutional Review Board. All participants were paid for their time.

Figure 1. Comparable Visual & Statistical TBW Estimations

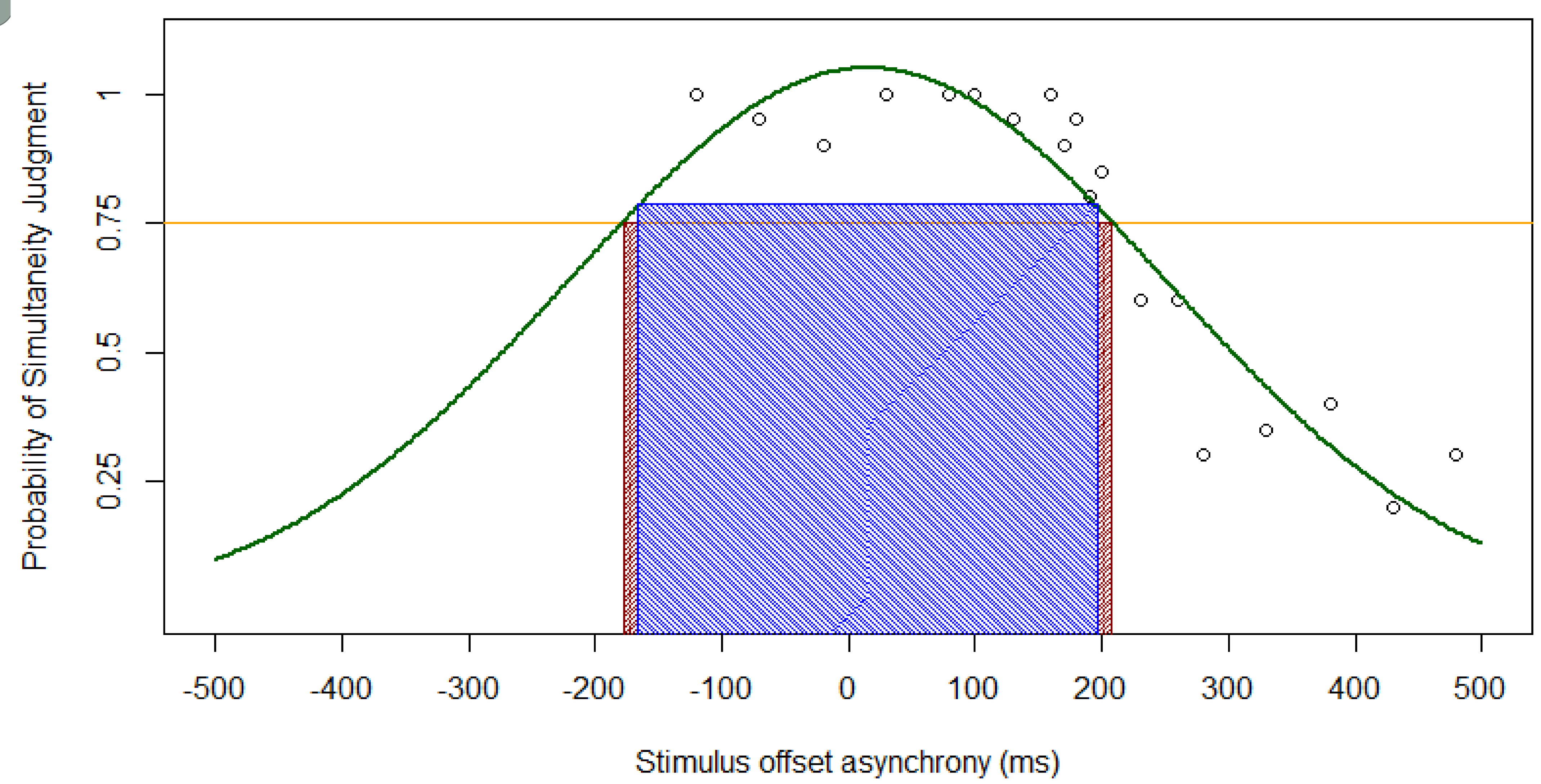

Figure 1. The TBW (blue shaded area) represents the area that is measured by the statistical method of estimation. The TBW (red shaded area), that is overlapped by the statistical TBW (blue shaded area) represents the area measured by the visual method of estimation.

Table 1. Average TBW Estimate (Matched Obs.)

	Visual	p-value*	Statistical	p-value*
Autism	357.67	0.1929	431.76	0.0876
TD	284.20		271.95	

* Wilcoxon Rank Sum Test

Table 1. The sample size of each TBW average by group is a one to one match of participants who have estimable TBWs utilizing each method (Visual & Statistical: Autism, N = 20; TD, N = 24). This table illustrates the validity of the proposed statistical method to replicate the conclusion derived from the standard visual method of estimation

Table 2. Average TBW Estimates (Complete Obs.)

	Visual	p-value*	Statistical	p-value*
Autism	357.67	0.1929	560.96	0.007**
TD	284.20		284.67	

* Wilcoxon Rank Sum Test ** Significant at the 0.05 level

Figure 2. Limitation of Visual TBW Estimation

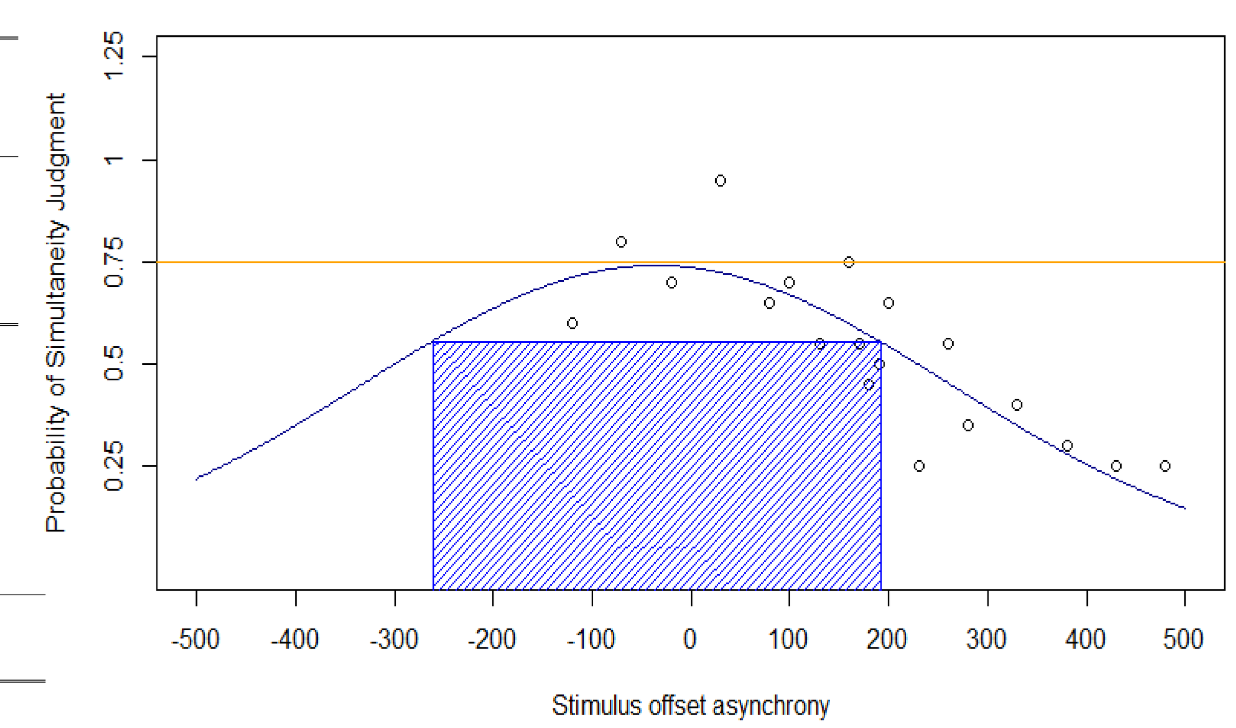

Figure 2. The TBW (Blue) represents the area that is measured by the statistical method of estimation. The visual method of TBW calculation is not determined as the predicted curve does not cross the threshold for interpretation.

Table 2. After incorporating the previously unreported TBW estimates into the statistical TBW average, by group, a statistical difference between group TBW's is calculated. The updated sample sizes are: Visual - Autism, N = 20; TD, N = 24; Statistical - Autism, N = 26; TD, N = 26

Conclusions

The statistical method produces comparable results when only incorporating participants that have a TBW estimable by both methods (Table 1). This allows for further justification to include the TBW estimates of the statistical method into the analysis, as it performs statistically comparable to the previously accepted visual method. Advantages of including these previously unincorporated participants include: increased sample size, inclusion of clinically significant participants (Visual outliers consisted of primarily participants with autism), potentially establishes criteria to identify autistic participants that do not have a previous diagnosis. The clinical application of including participants that have statistically estimable TBW's can not be overstated, as this often includes participants with non neuro typical diagnoses.

Curve Estimation

From the 380 observations for each participant, the probability of simultaneity judgment is calculated for each interval of the assessment. These endpoints correspond to the probability that the participant incorrectly classified the event as synchronous. Window size estimation was made after estimating Gaussian curves that best fit the endpoints calculated for each participant. The Gaussian function has the following form:

$$f(x) = \frac{1}{\sqrt{2B\pi}} e^{-\frac{(x-A)^2}{2B}}$$

With parameters A, as the position of the center, or mean of the curve, and B, as the standard deviation. Estimations of the mean and standard deviation have been made using this function; similarly, an estimation of the 75% temporal binding window has been made from the Gaussian curve that best fit the data. Although multiple methods were initially tested, ultimately, the Gaussian curves have been estimated by simulating, and selecting the curve that best fits the observed data.

Standard TBW Estimation

The accepted practice for calculating the TBW of participants relies on the observance of an estimated simultaneity mean greater than 75%. The value of this window was set as the breadth of the distribution (in ms) at which individual participants reported simultaneity at, or above, 75%. This level was chosen because it represents half the distance between the 50% level and each individual's highest likelihood of reporting simultaneity.

Proposed TBW Estimation

A statistical method has been developed to approximate the TBW that first estimates that area of the predicted Gaussian curve and identifies the probability of simultaneity judgement that 75% of the area of the curve is contained by. The intersection with the predicted curve and the identified probability of simultaneity judgement form the area in which the TBW is calculated.

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