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# How Audio and Visual Cues Combine to Discriminate Tempo of Swing Groove Drumming

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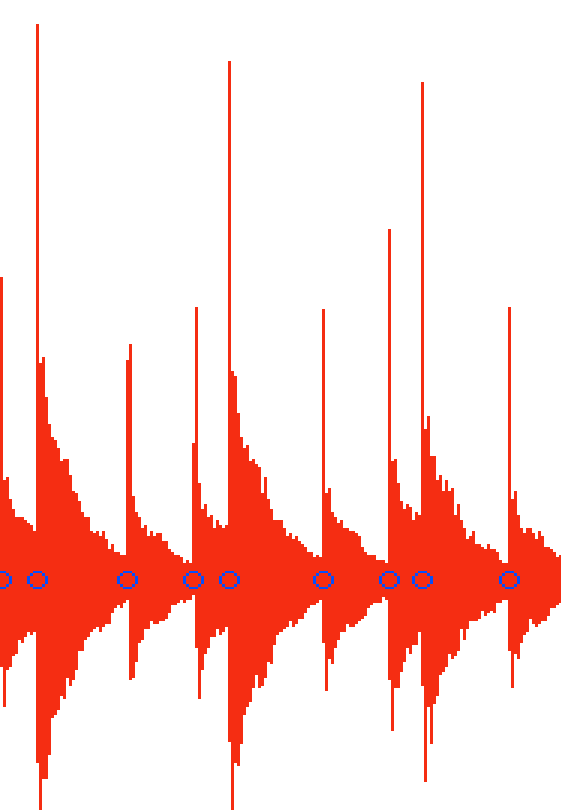
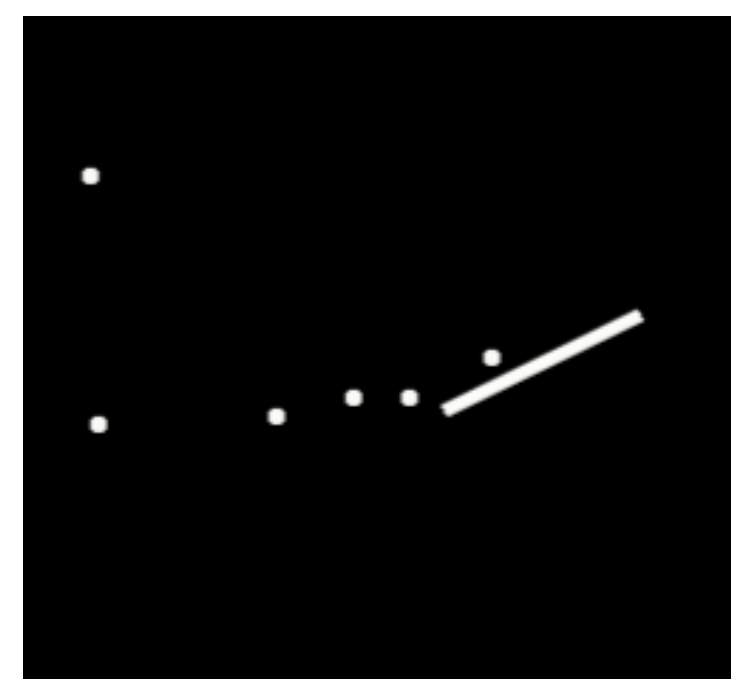
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## Introduction

- Studies show that when multiple sources of sensory information about a single environmental property are available, more precise estimates of that property can be formed by combining the different sources.
- For physical dimensions such as object size (Ernst & Banks, 2002), surface slant (Knill & Saunders, 2003) and object location (Alais & Burr, 2004), studies show that humans integrate different sensory sources in a statistically optimal fashion.
- According to these models, to maximize the precision of the combined estimate, each cue must be weighted in proportion to its reliability.
- **We investigated the integration of auditory and visual cues for a more complex physical property: beat tempo.**

## Stimulus Production

- Stimuli were created from 3D motion capture data (240Hz) of a drummer who was asked to perform swing groove drumming at 90BPM.
- This movement data was converted into a visual point-light display (60Hz) with points at the shoulder, elbow, wrist, hand and two drumstick points.
- Sounds were obtained by simulation of the first 25 modes of a circular membrane (Rocchesso & Avanzini, 2004). Parameters for the sound model were the physical parameters of the membrane and the time and impact velocity of a strike taken from the motion capture data.
- To create a standard stimulus a segment containing 9 drum impacts was chosen and found to be 97BPM. Comparison stimuli were created by multiplying the time of impact and total duration to produce 6 tempi above and 6 below the standard in 2BPM increments.



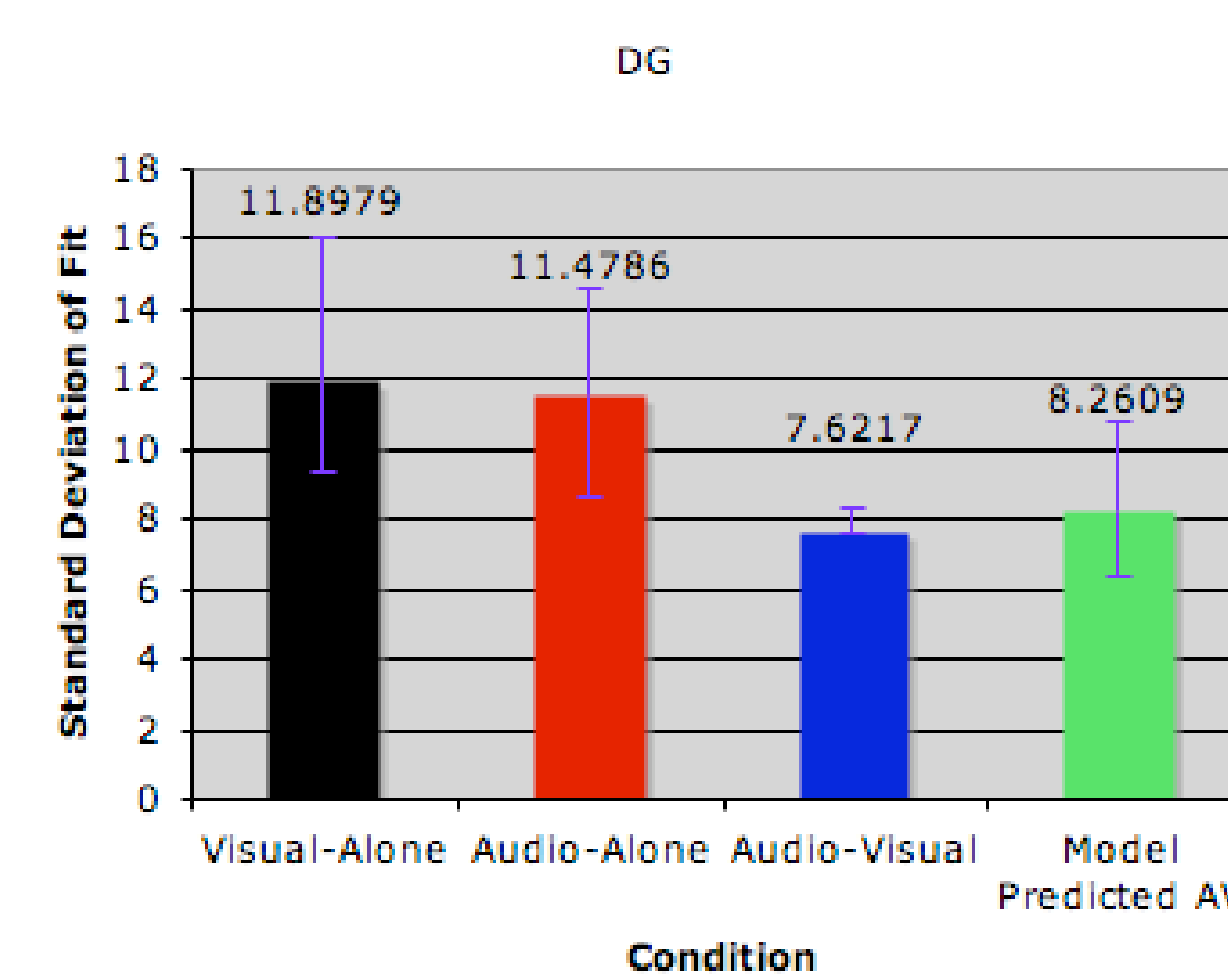
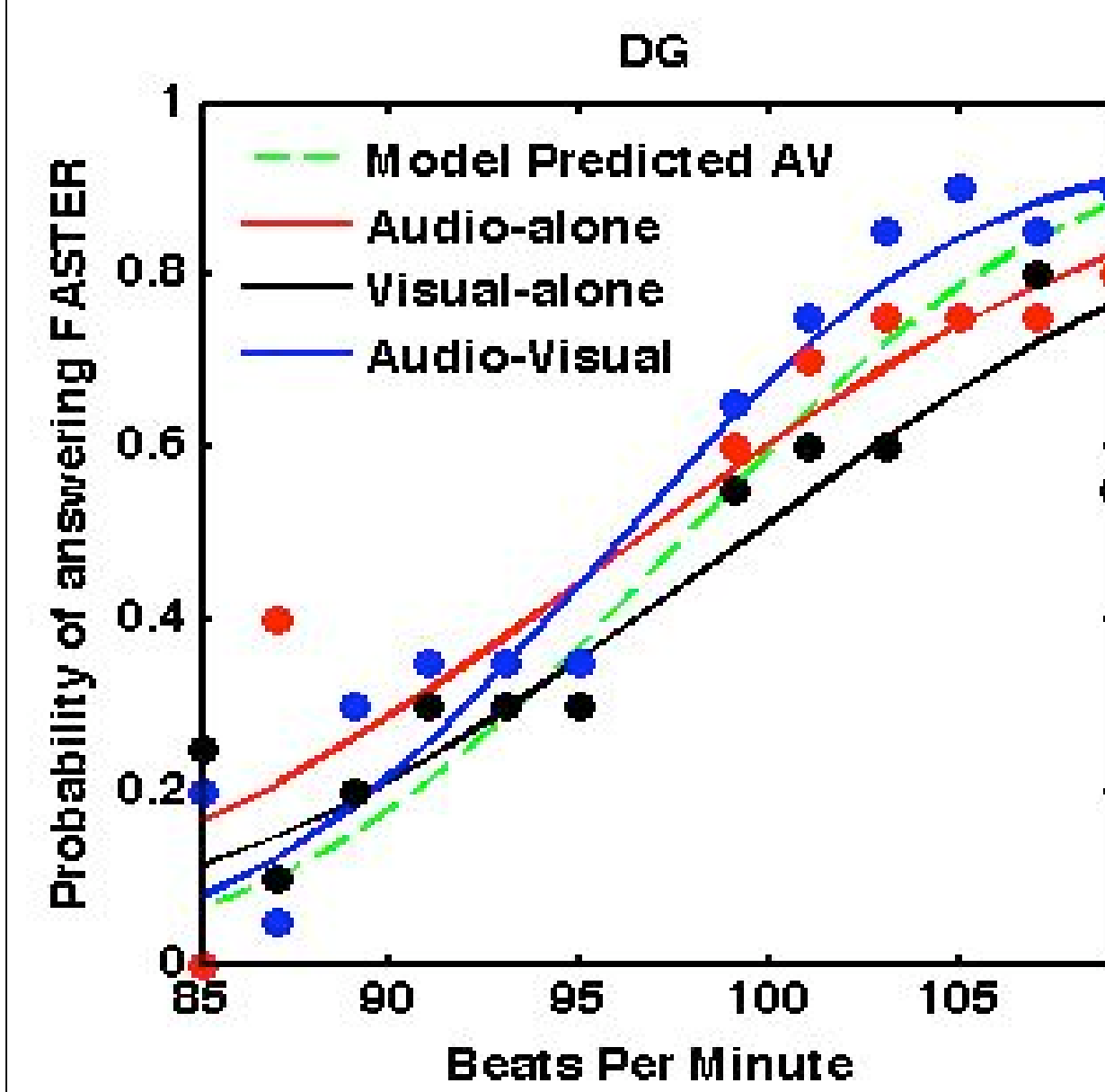
Example audio-wave

## Methods

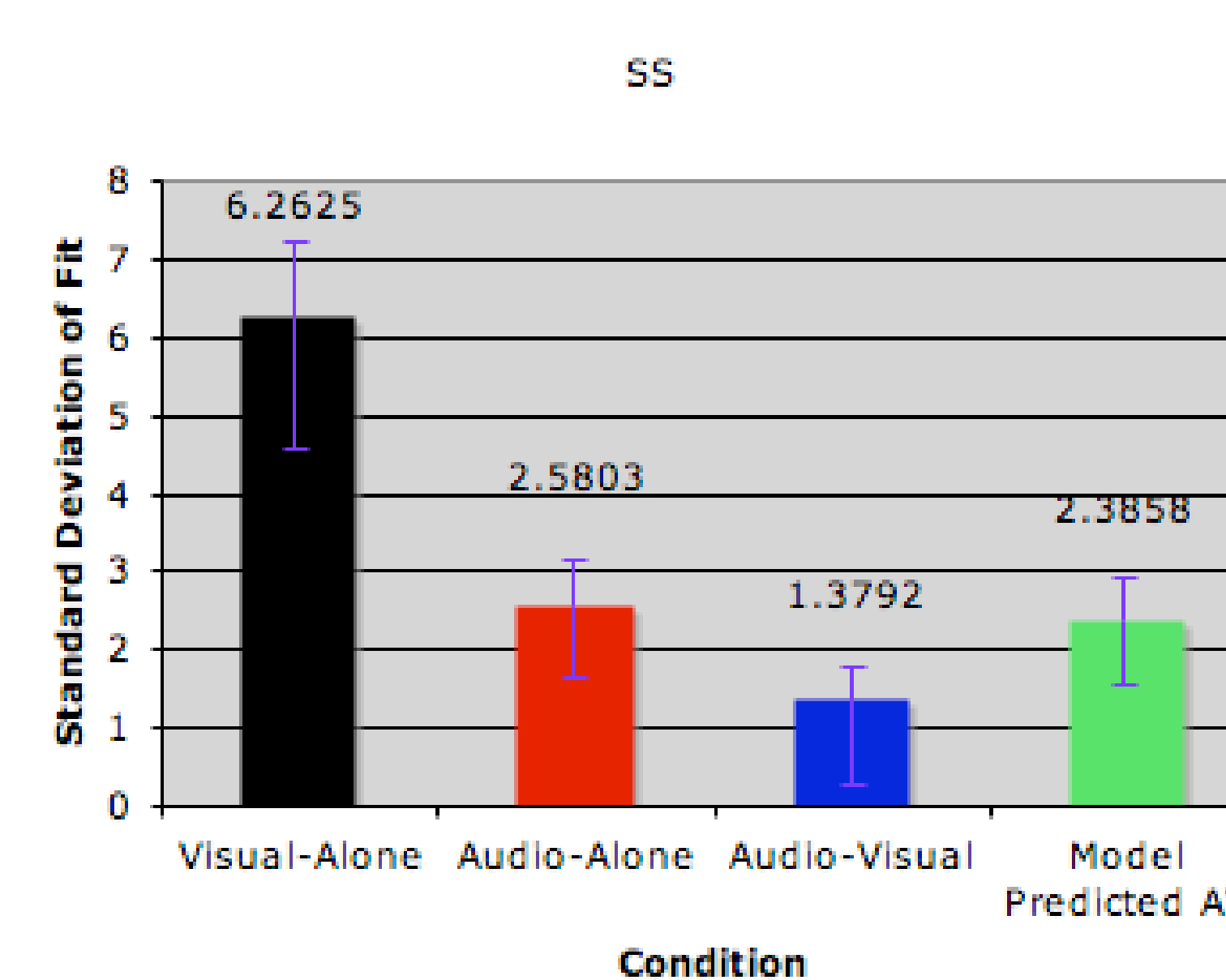
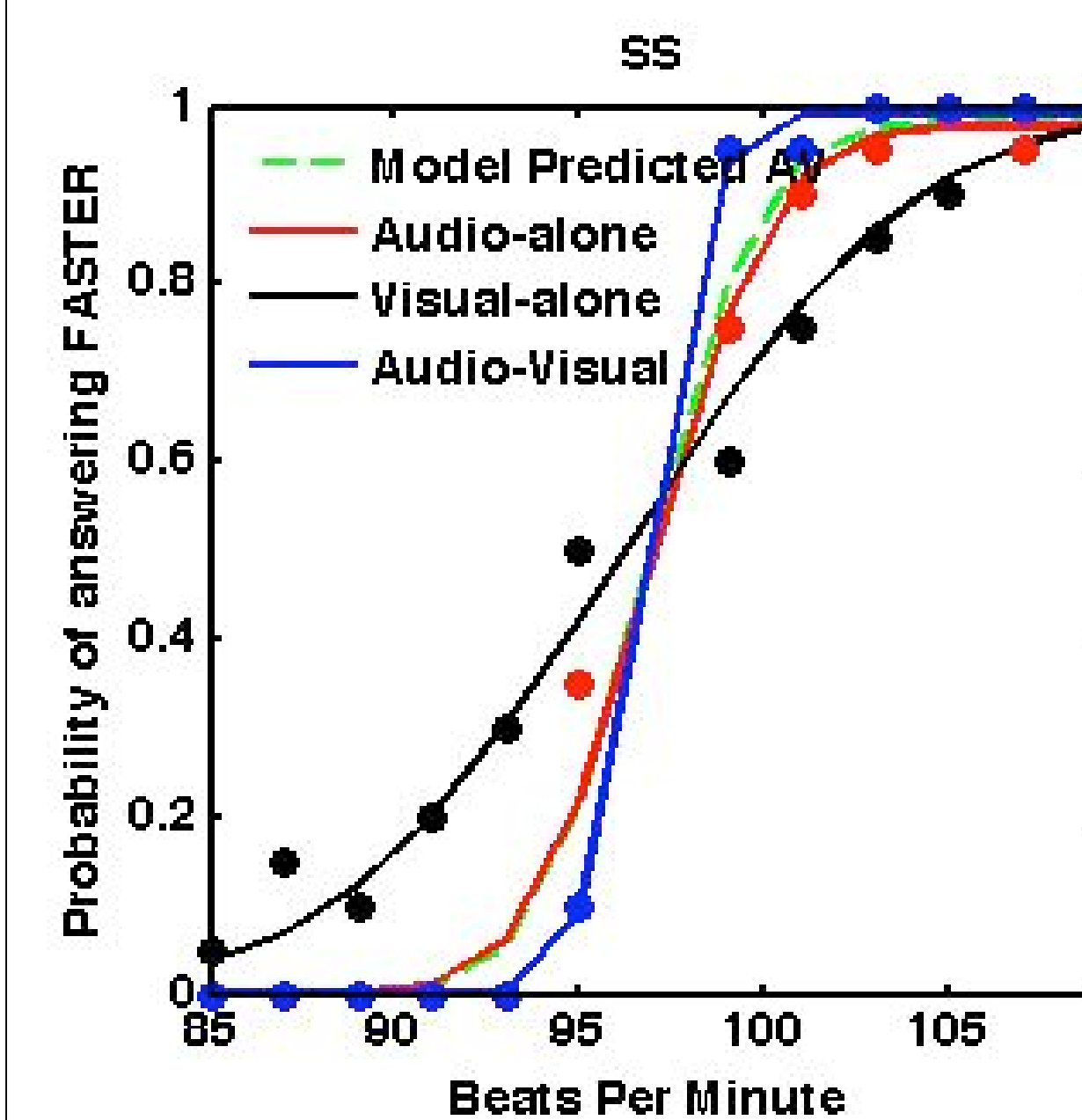
- 3 conditions: Audio-alone(A), Visual-alone(V), Audio-Visual(AV).
- 2IFC design with a random trial-by-trial allocation of which interval contained the standard stimulus.
- 7 novices and 1 expert drummer completed 2 one hour sessions on different days. Each session contained 3 blocks, one for each condition with 10 repetitions of each standard/comparison pair (e.g. 97 vs 85BPM).
- 240 trials per person, 20 trials per data point.
- Participants were asked to indicate which of the two intervals contained the faster drumming tempo.
- The model predicted fits are based on Ernst & Banks (2002).

## Examples of Novice Results

- Standard deviations are taken from the best fitting cumulative gaussian functions, with lower standard deviations indicating better performance.

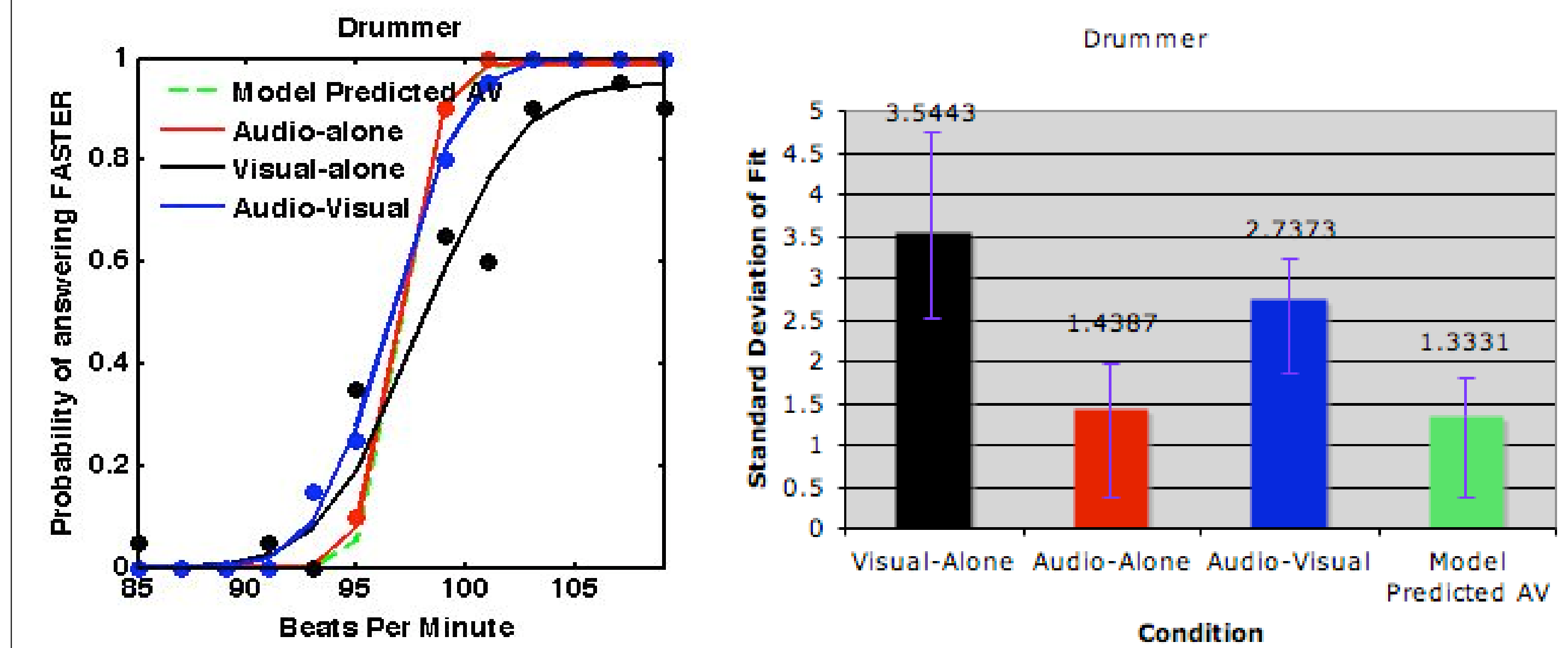


- For participant DG, the AV confidence intervals only overlap with the model predicted confidence intervals.



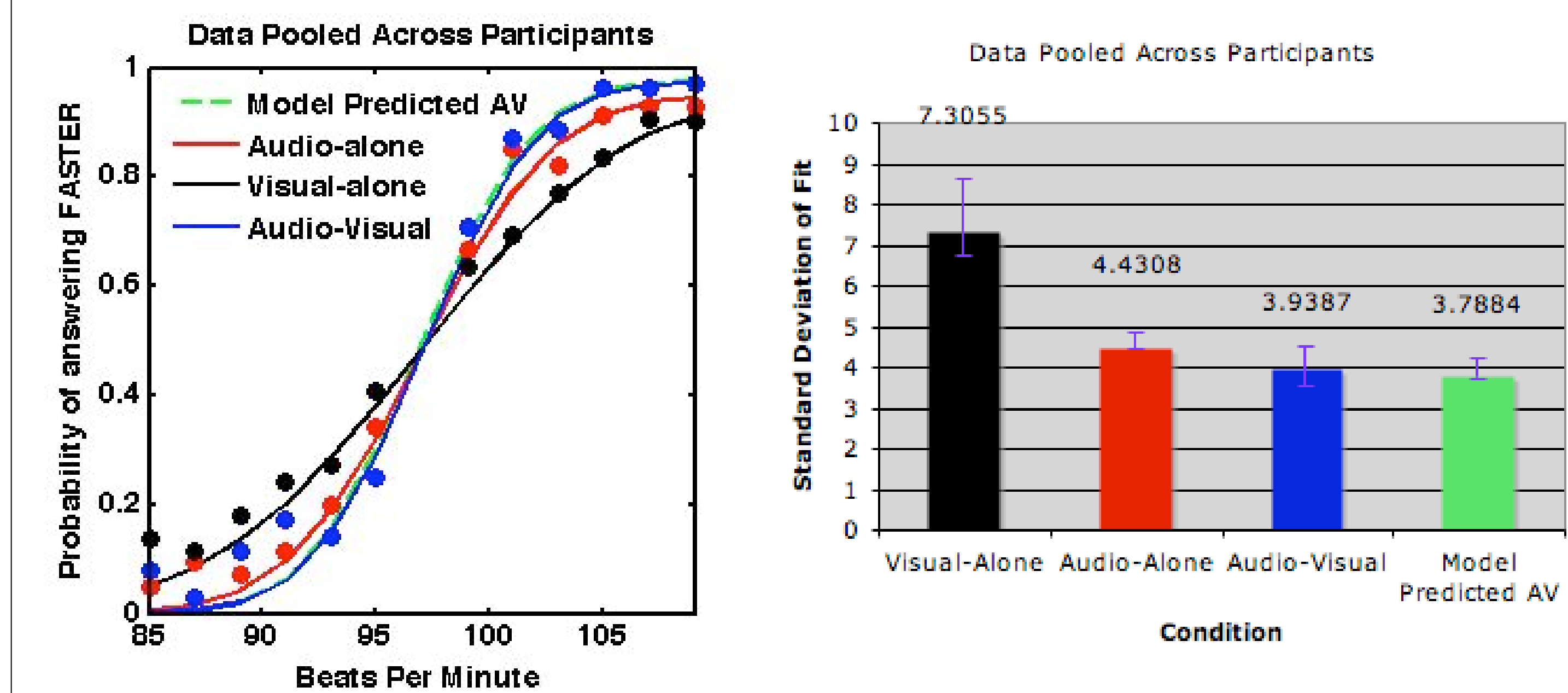
- For participant SS, the AV confidence intervals overlap with both the A and model predicted confidence intervals.

## Drummer Results



- For the drummer, the AV confidence intervals overlap with both the V and A confidence intervals but not the model predicted confidence intervals.

## Average Novice Results



- On average, the AV confidence intervals overlap with both the A and model predicted confidence intervals.

## Conclusions

- There are considerable individual differences in performance on each condition of the task and on the relationship between observed and model predicted results on the AV condition.
- On average combined AV standard deviations are within the model predicted standard deviations.
- However, it is not possible to draw strong conclusions as to whether the cues are being combined in a statistically optimal manner because it is still possible that only the most reliable single cue is being utilised.

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