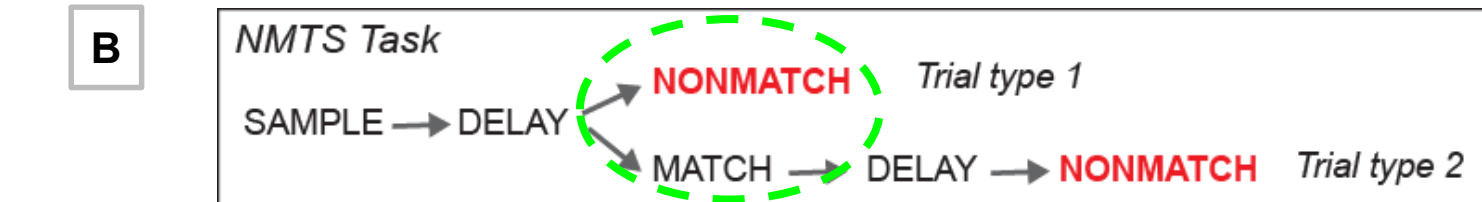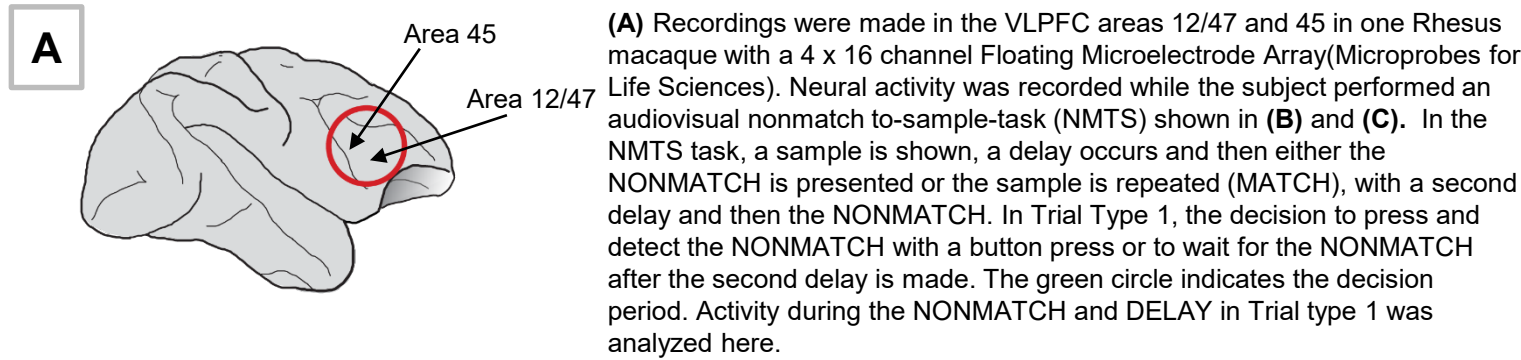# Contextual Modulation in Primate Ventrolateral Prefrontal Neurons during Audiovisual Task-switching

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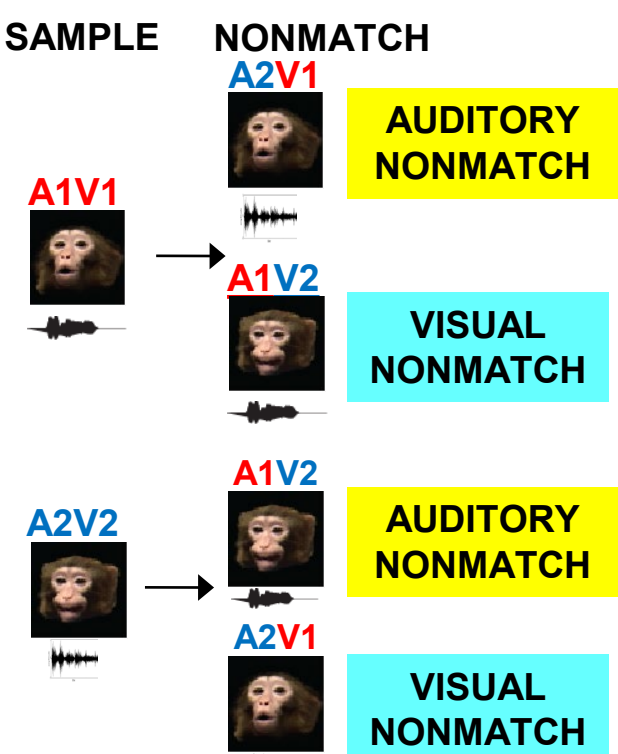
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INTRODUCTION

During audiovisual communication, attention may focus on facial cues, vocal information, or rapidly switch between modalities in order to extract time-varying information accurately. Previous studies indicate that neuronal activity is often increased to attended features of a stimulus, while studies of task related attention have described attention-related suppression of neuronal activity. In addition, behavioral studies of modality-selective attention indicate subjects respond quicker and more accurately for targets in the expected modality. Neurons in the primate VLPFC are involved in the perception, integration and remembering of faces and their corresponding vocalizations (Romanski & Sharma, 2023). In this study we recorded VLPFC neurons during an Audiovisual (AV) attention shifting task. A block of the typical modality-changing Auditory and Visual, nonmatch to sample task which we have used before (Hwang and Romanski, 2015) was conducted, followed by (or preceded by) blocks of an Auditory-detect-only NMTS version of the task and a Visual-detect-only task. We compared performance and neural activity across these three blocks (called Random A+V, Unimodal A and V). Our preliminary results demonstrate a clear increase in neuronal activity during Delay and Nonmatch period of the task during the single modality blocks compared to activity during the Randomized AV task.

METHODS

(A) Recordings were made in the VLPFC areas 12/47 and 45 in one Rhesus macaque with a 4 x 16 channel Floating Microelectrode Array(Microprobes for Life Sciences). Neural activity was recorded while the subject performed an audiovisual nonmatch to-sample-task (NMTS) shown in **(B)** and **(C)**. In the NMTS task, a sample is shown, a delay occurs and then either the NONMATCH is presented or the sample is repeated (MATCH), with a second delay and then the NONMATCH. In Trial Type 1, the decision to press and detect the NONMATCH with a button press or to wait for the NONMATCH after the second delay is made. The green circle indicates the decision period. Activity during the NONMATCH and DELAY in Trial type 1 was analyzed here.
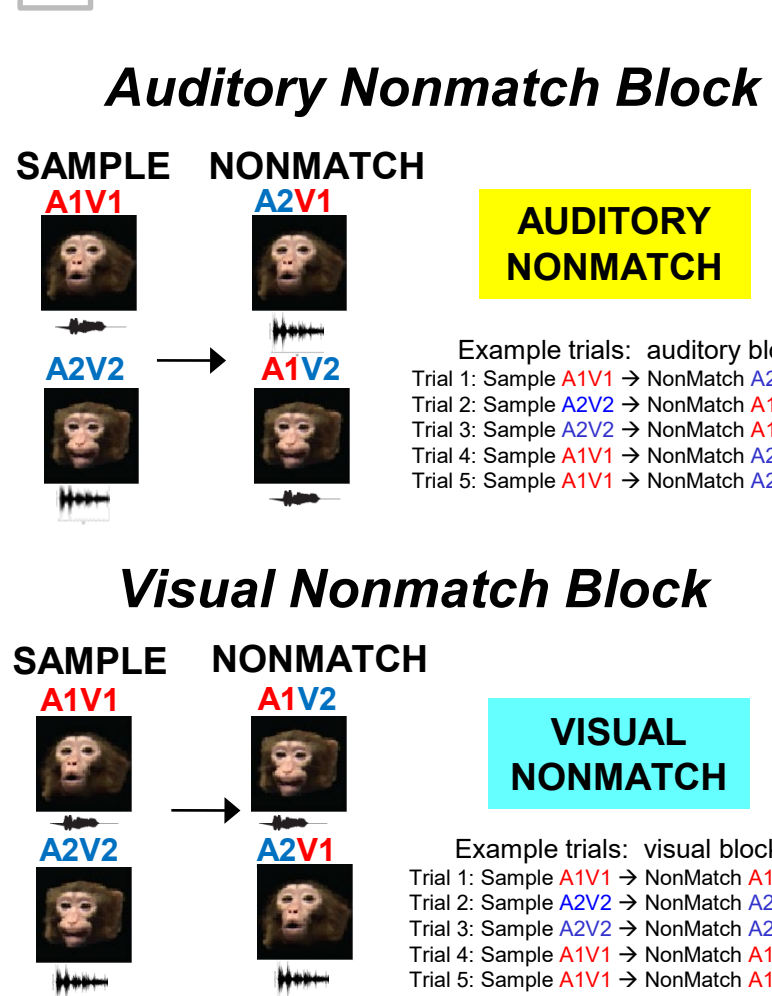

We presented the NMTS task as an **Auditory + Visual Randomized block (C)** or a **Unimodal Auditory or Unimodal Visual Block** as in **(D)**. In the randomized A+V block, the SAMPLE audiovisual movie was presented and either the face or vocalization component of the movie stimulus mismatched during the NONMATCH. The mismatched auditory (vocalization) or visual stimulus (face video) component varied randomly from trial to trial. In the Unimodal blocks, the sample audiovisual movie was presented and only one modality component was presented as the mismatch for a block of trials. As shown in **(D)** every trial was an auditory mismatch in the Unimodal Auditory Block and every trial was a visual (face) mismatch in the Unimodal Visual block. For all blocks, the occurrence of the NONMATCH was unpredictable since in 50% of trials the NONMATCH occurred as the second stimulus and in 50% of trials the sample was repeated and the NONMMATCH occurred as the third stimulus **(B)**.
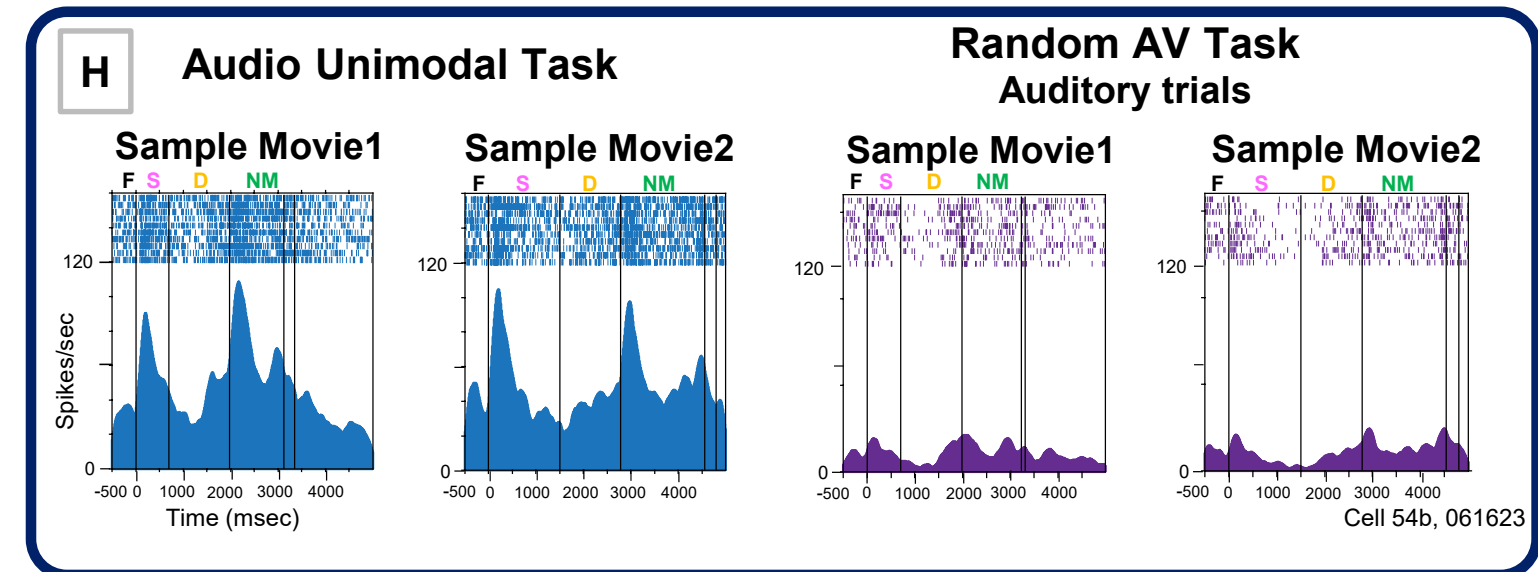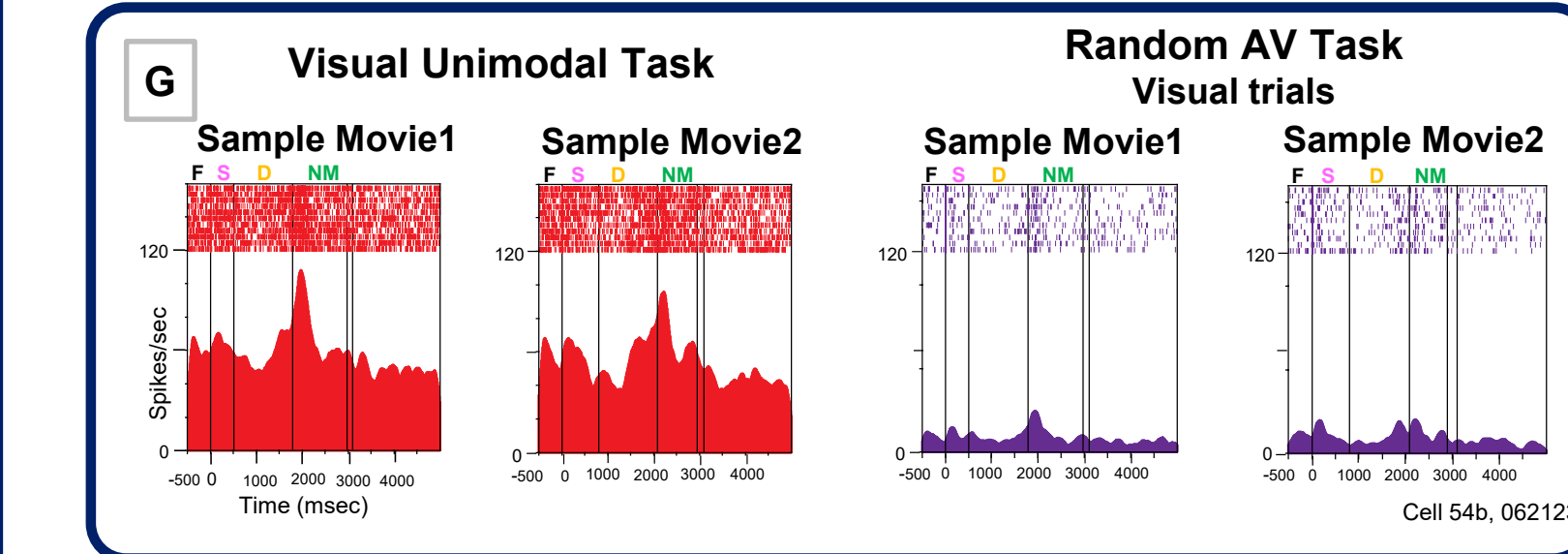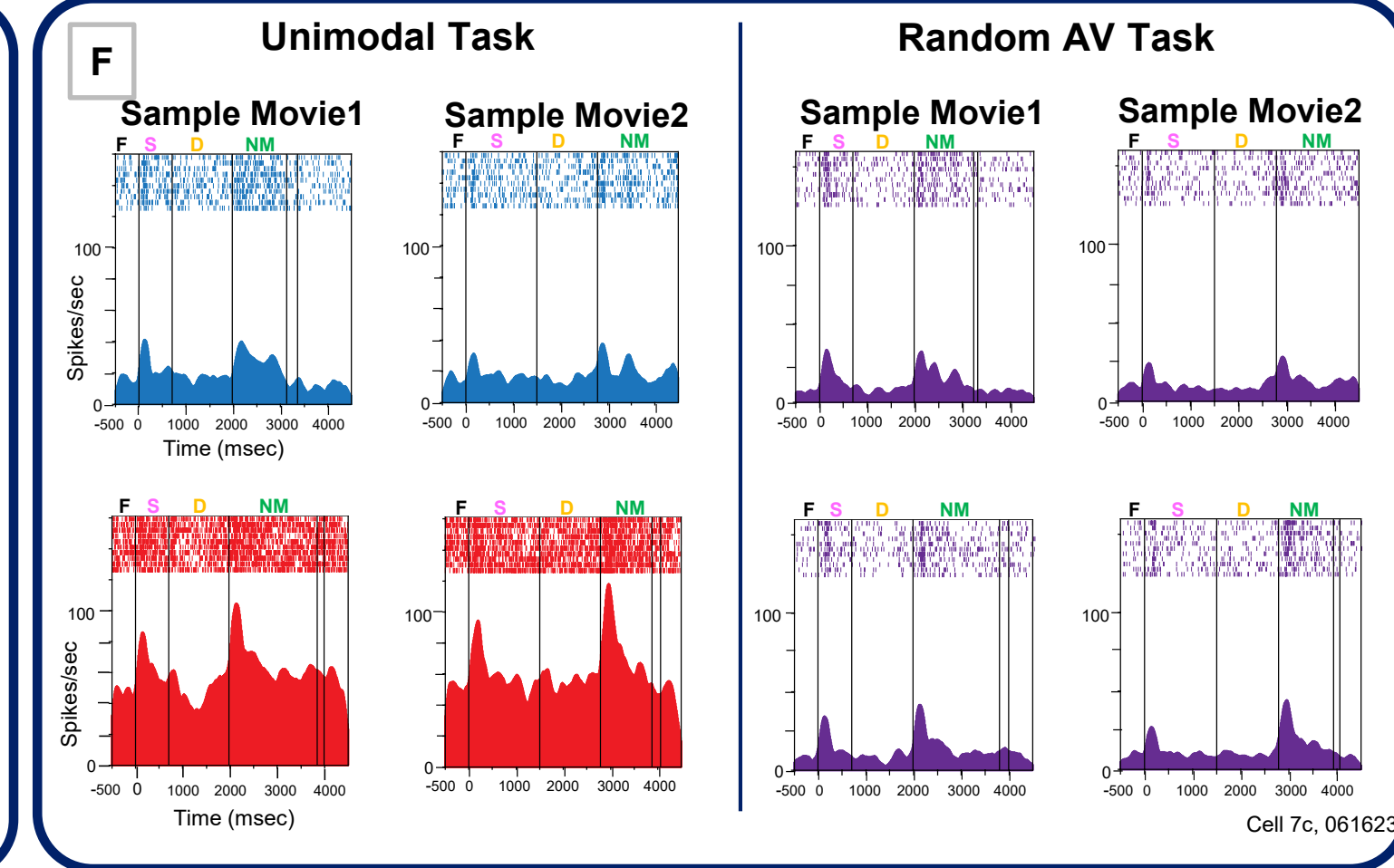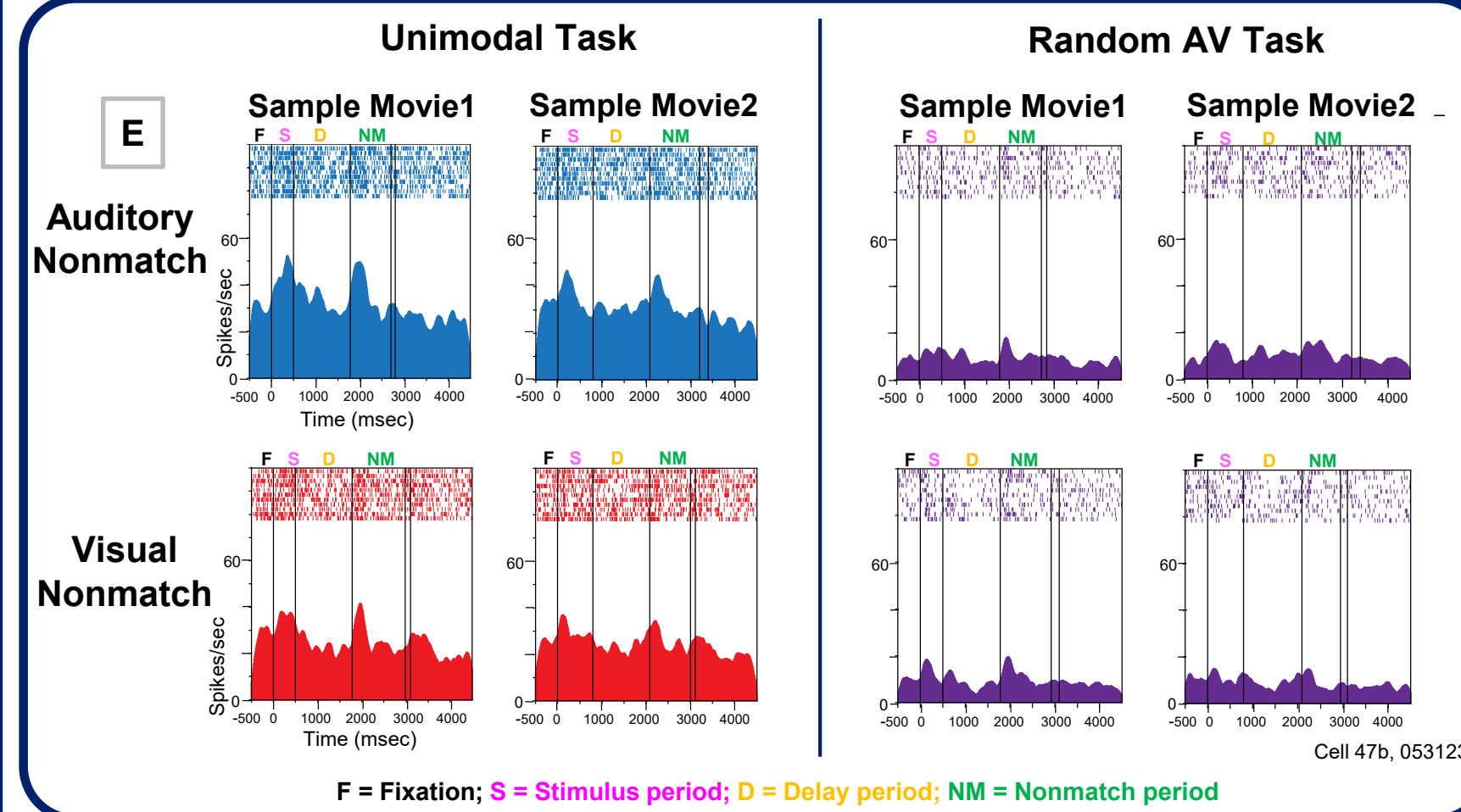
RANDOMIZED A + V Block

Example trials: randomized block:
Trial 1: Sample A1V1 → Auditory NonMatch (A2V1)
Trial 2: Sample A2V2→ Auditory NonMatch (A1V2)
Trial 3: Sample A2V2→ Auditory NonMatch (A1V2)
Trial 4: Sample A1V1 → Visual NonMatch (A1V2)
Trial 5: Sample A1V1 → Visual NonMatch (A1V2)

UNIMODAL TASK

Auditory Nonmatch Block

Example trials: auditory block:
Trial 1: Sample A1V1 → NonMatch A2V1
Trial 2: Sample A2V2 → NonMatch A1V2
Trial 3: Sample A2V2 → NonMatch A1V2
Trial 4: Sample A1V1 → NonMatch A2V1
Trial 5: Sample A1V1 → NonMatch A2V1

Visual Nonmatch Block

Example trials: visual block:
Trial 1: Sample A1V1 → NonMatch A1V2
Trial 2: Sample A2V2 → NonMatch A1V2
Trial 3: Sample A2V2 → NonMatch A1V2
Trial 4: Sample A1V1 → NonMatch A1V2
Trial 5: Sample A1V1 → NonMatch A1V2

RESULTS

F = Fixation; S = Stimulus period; D = Delay period; NM = Nonmatch period

Cell 47b, 053123

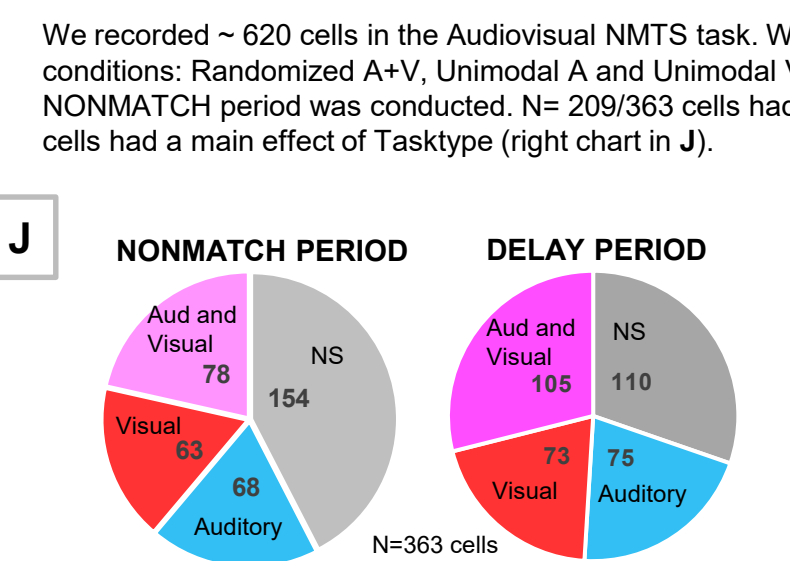Cell 7c, 061623

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Neural activity from 4 single units during the NMTS tasks are shown (**E – H**). In all 4 cells the mean firing rate during the unimodal nonmatch period was significantly greater than the same modality trials when presented in a randomized A+V task. In **E** and **F** the cells were recorded during performance of the NMTS task in the randomized A+V block, the visual unimodal and the unimodal auditory block. For Cell **E** there was a significant increase in firing in the NONMATCH period in the unimodal auditory (blue) compared with the auditory trials in the randomized A+V block; and there was a significant increase (P< 0.001) in the unimodal visual block compared with the same visual discrimination when it was presented in the A+V random block (p< 0.001). For cell **F**, the unimodal visual block of trials were significantly different from the same visual stimuli in the random A+V task (p< 0.0001). The same was true for the auditory unimodal block compared to the auditory trials in the randomized A+V block although the mean firing rate in the visual trials was greater than the auditory. Panels **G** and **H** show the same unit recorded on two different days with only one unimodal task. In **G**, the increased firing rate during the nonmatch period of the unimodal visual task block was significantly different from the randomized A+V task block and in **H**, the response during the nonmatch period of the auditory unimodal task block was significantly greater than the nonmatch period in the randomized A+V task block. Abbreviations as in Panel **E**.
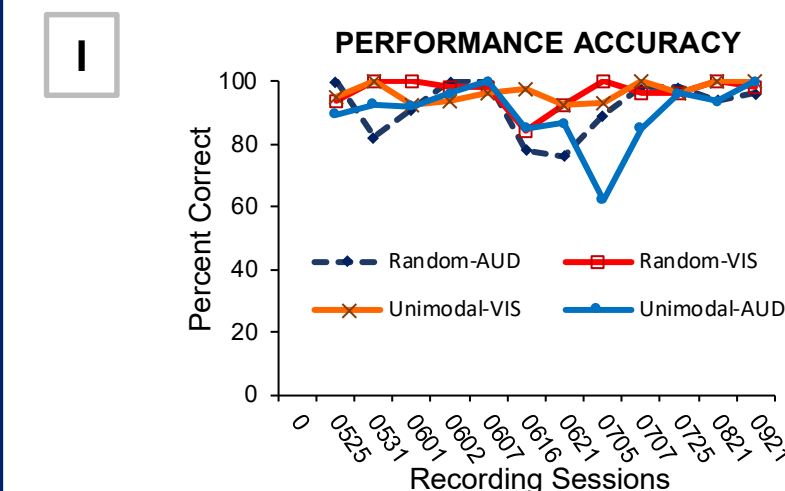

PERFORMANCE AND REACTION TIME

Performance in the AV-NMTS task was high due to the long term training of the subject shown in **(I)**. Paired T-tests of the performance in the Random-AV presented auditory trials were not significantly different from the Unimodal Auditory trials. Performance in the visual Random AV and Unimodal Visual trials were also not different. Analysis of the reaction time (not shown) also did not show any differences in the Random-AV trials and the Unimodal Trials.

We recorded ~ 620 cells in the Audiovisual NMTS task. We determined that N= 363 cells were significantly different from baseline firing, and had been tested in all three conditions: Randomized A+V, Unimodal A and Unimodal V. A one-way ANOVA of the effect of Tasktype (Random, Unimodal) on the neural response during the NONMATCH period was conducted. N= 209/363 cells had a main effect of Tasktype shown in (**J**). We also examined the DELAY period by Tasktype and found that 253 cells had a main effect of Tasktype (right chart in **J**).

(**J**) Proportion of cells with significantly different responses in the unimodal tasks compared to the randomized A+V task for the NONMATCH period and the DELAY period.
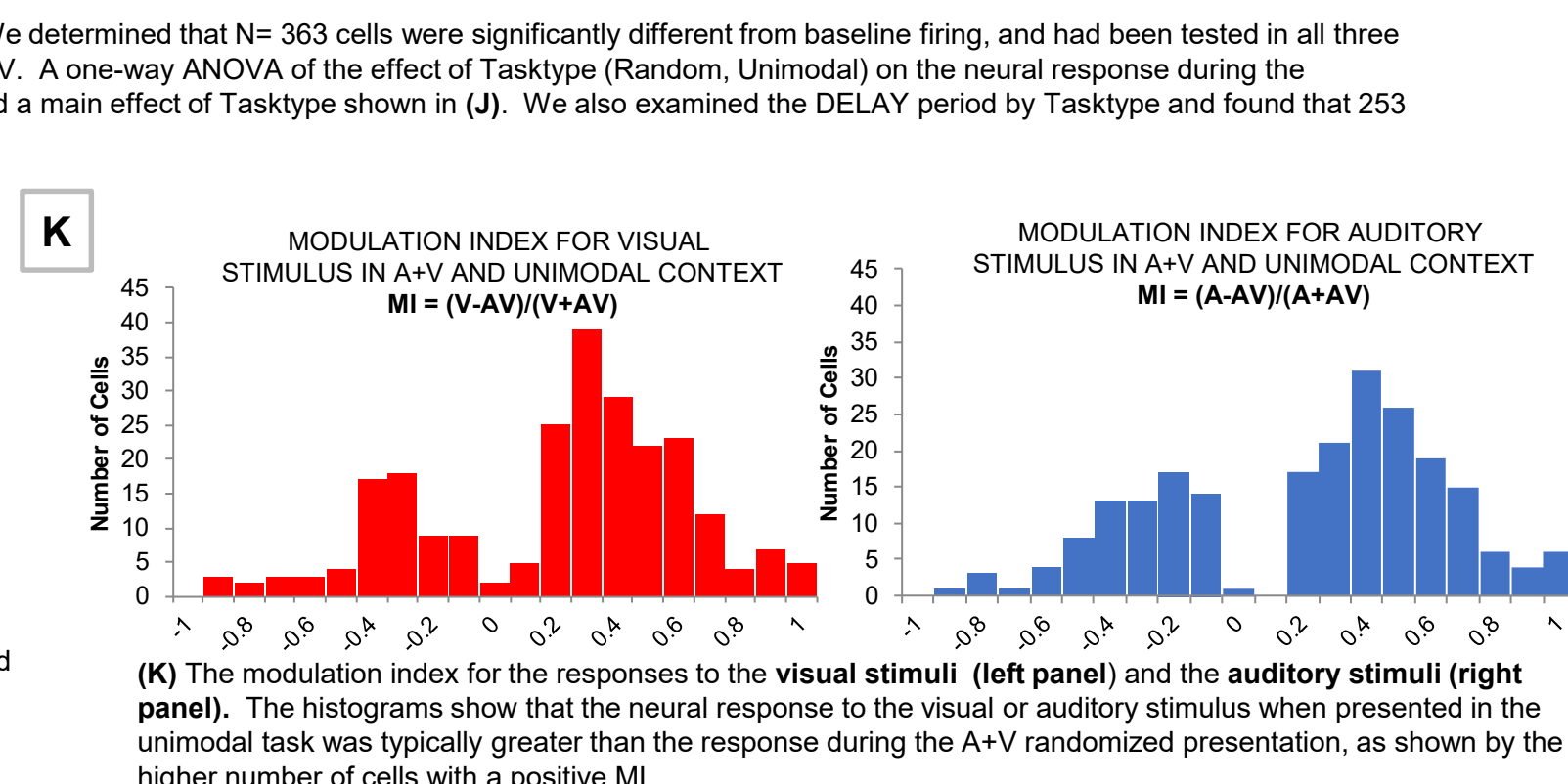
(**K**) The modulation index for the responses to the **visual stimuli (left panel)** and the **auditory stimuli (right panel)**. The histograms show that the neural response to the visual or auditory stimulus when presented in the unimodal task was typically greater than the response during the A+V randomized presentation, as shown by the higher number of cells with a positive MI.

CONCLUSIONS

- Response magnitude in VLPFC was higher during the unimodal discrimination task compared to the randomized A+V task, regardless of the modality or the specific sample stimulus. The decrease in activity in the cross-modal task has been referred to as attention suppression.

- The emergence of an increase in activity across all periods of the easier, unimodal task is likely due to a change in behavioral state, which will be addressed in future analyses.

- Recordings were conducted with chronic arrays which allow for longitudinal population and ensemble analyses in future studies.

- The use of a cross-modal attention task provides a way to "spotlight" the specific auditory or visual component of an audiovisual communication expression during working memory. This spotlight may also provide a means to understand the neuronal changes which underlie face and vocal integration.