Effects of face and motion stimuli on auditory processing in the ventrolateral prefrontal cortex

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Introduction

❑ Previous studies have shown that integration of sensory information from multiple sources may enhance accuracy and speed of responses, compared to performance using unimodal cues.

❑ It has been suggested that multisensory integration is also advantageous to neural signal transmission since it may reduce the variability of signals and increase the rate of information transfer.

❑ Studies in our laboratory and others have shown that some single cells in the primate ventrolateral prefrontal cortex (VLPFC) may respond preferentially to face stimuli or vocalizations while others are multisensory and respond to combined face and vocalization stimuli (O'Scalaidhe et al., 1997; Romanski et l., 2005; Sugihara et al., 2006).

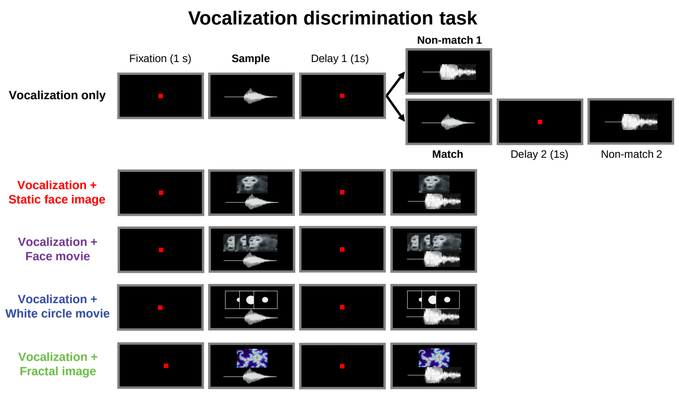
❑ To examine the effect of face-vocalization integration, we trained non-human primates to perform a vocalization discrimination task with and without accompanying visual stimuli and recorded single-neuron activity from VLPFC, where multisensory neurons have been previously recorded.

Methods

❑ **Non-match to Sample Vocalization Discrimination Task**

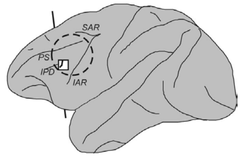
- Species-specific vocalizations and corresponding face stimuli from our home colony were used as stimuli.
- The subject was required to press a button when the vocalization non-match occurred. Correct presses were rewarded with a drop of juice.
- In some trials the sample was repeated and then a non-match stimulus occurred while in other trials the non-match occurred immediately after the sample.
- The trial conditions included a VOCALIZATION ONLY condition and 4 conditions where different types of visual stimuli accompanied the vocalization. These visual stimuli were irrelevant to the task.

Vocalization discrimination task



❑ **Single-neuron recording**

- The recording cylinder was placed over the lateral prefrontal cortex (areas 12, 45 and 46).
- Single-neuron activity was discriminated and isolated using a signal processing system (Pentusa system, Tucker-Davis Technology, FL).



Results

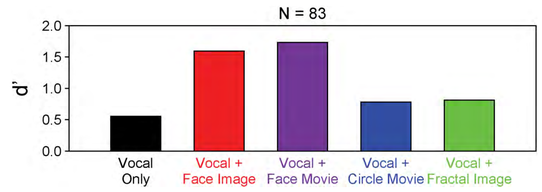
❑ **Visual Influences on Behavioral Performance**

- Signal detection theory was used to analyze behavior.

  Hit rate = P(press | non-match 1)
  Miss rate = P(no press | non-match 1)
  Correct rejection rate = P(no press | match)
  False alarm rate = P(press | match)

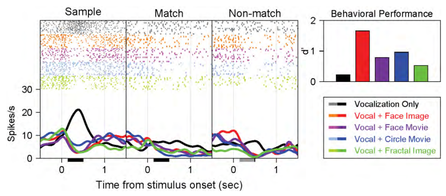
- d' was computed as an index of the response accuracy.

  d' = Z(Hit rate) – Z(False alarm)
  ex) d' = Z(0.5) – Z(0.5) = 0
  d' = Z(0.9) – Z(0.1) = 2.56
  d' = Z(0.99) – Z(0.01) = 4.65

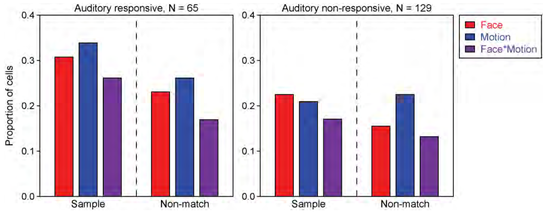


- Accuracy was higher when vocalizations were presented with visual stimuli. Furthermore, accuracy was highest when static or dynamic face stimuli were presented with the vocalizations.

❑ **Visual Influences on Neuronal activity in Prefrontal Cortex**



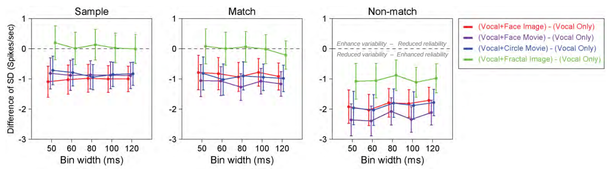
- This example neurons showed a dramatic effect of visual stimuli on auditory processing. The response to a vocalization was completely suppressed when visual stimuli were presented with the vocalizations.



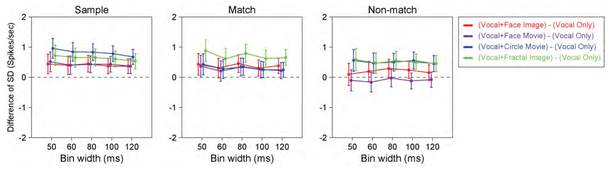
- A paired t-test performed on the VOCALIZATION ONLY condition indicated whether a neurons was auditory responsive. We then examined the effect of FACE and MOTION stimuli on neural responses with a 2-way ANOVA.
- Neurons which are responsive to vocalizations may be more likely to be affected by accompanying face stimuli, compared to auditory non-responsive cells.

❑ **Visual Influences on Response Reliability**

- Auditory responsive cells

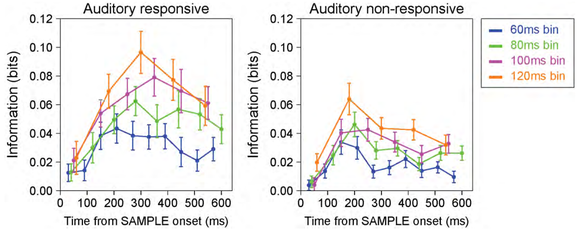


- Auditory non-responsive cells



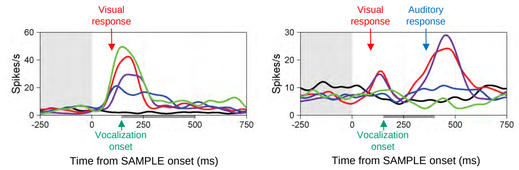
- The variability of neural responses was quantified by computing the standard deviations of spike counts in each time window across trials and averaging them across subsequent time windows. Then, the variability of the vocalization only trials was subtracted from all other conditions.
- We found that variability was decreased in the auditory responsive cells when the vocalization was presented with visual stimuli, compared to the vocalization only condition.
- In the auditory non-responsive cells, such a decrease was not observed.

❑ **Information Coding of Visual Stimuli**

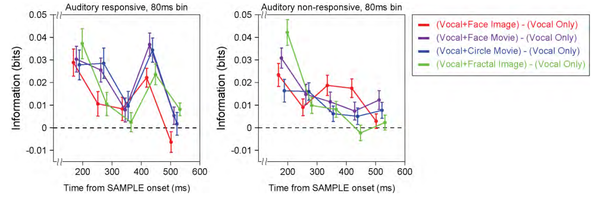


- To examine how much information about the accompanying visual stimuli was transmitted, mutual information between neural responses and visual stimuli was computed for time bins of several different sizes.
- The maximum information transfer occurred between 200ms and 350ms in auditory responsive cells, whereas it occurred earlier in auditory non-responsive cells.
- In our stimuli, the visual component has an earlier onset than the lagging auditory stimulus (107ms – 194ms after visual onset). It seemed that visual processing signals might be delayed or prolonged by the processing of the lagging auditory component of the audiovisual stimulus.

❑ **Visual Influences on Auditory Information Coding**



- In our audiovisual stimuli, the auditory components (vocalizations) were preceded by the visual components. Therefore, neural responses to the auditory components also should occur later.



- Information about the auditory component of the audiovisual stimulus conveyed during the sample presentation was computed by using the envelope of vocalizations as a feature.
- Compared to the vocalization only condition, information gain in the conditions in which visual stimuli were also presented was high between 320ms and 540ms, especially in auditory responsive cells. This time course is similar to that shown for the neural response example above.

Conclusions

1. Visual stimuli, such as faces, accompanying vocalizations can affect the behavioral performance of discrimination and the neural responses of cells in the lateral prefrontal cortex, even when they are not relevant to task performance.
2. Neural responses of auditory responsive cells were more reliable when vocalizations were presented with visual stimuli. However, such an effect was not observed for non-auditory non-responsive cells.
3. Mutual Information, which was computed by using the envelope of each vocalization as a feature, was increased when the vocalizations were presented with visual stimuli, and the gain was higher in auditory responsive cells.
4. Integration of vocalizations with accompanying visual stimuli may contribute to behavioral performance by reducing the variability and increasing the information of neural responses.

Acknowledgments

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