Processing of Expression and Identity in Audiovisual Communication Stimuli by Ventral Prefrontal and Amygdala Neurons

SFN 2023
#96.27/ GG17

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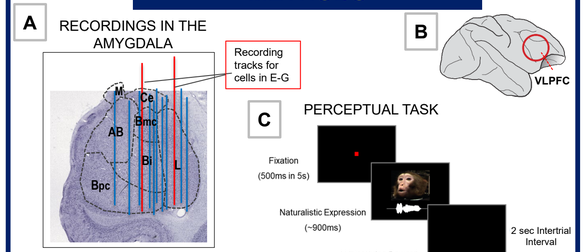
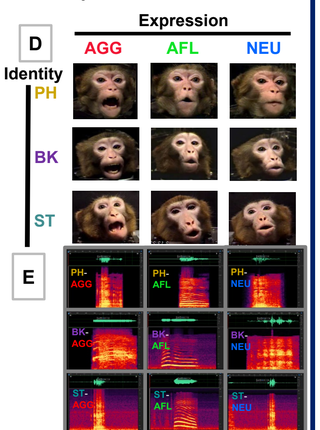
INTRODUCTION

We extract information about identity and expression from faces and vocal stimuli in our everyday social exchanges, via a network of brain regions including temporal and prefrontal areas. While many studies utilize static face images, we have investigated the processing and integration of face and vocal information using naturalistic videos. In a previous study (Sharma et al., J. Neuroscience, in press), we determined that while decoding of expression and identity from single unit firing rates rendered poor accuracy, decoding accuracy of expression and identity increased with increasing size of neuronal populations. In addition, decoding of identity occurred earlier and was more accurate than that of expression. In the present study, the same task and stimuli were used to investigate single unit and population encoding of identity and expression type from neurons in the **amygdala** while macaques attended to naturalistic expressions from various conspecifics. Results from the amygdala are compared with our findings in the VLPFC.

METHODS



(A) Recordings in the amygdala were made in one rhesus macaque with 32 channel Plexon V-probes over 5 recording sessions, who performed the same task as in our previous study of VLPFC **(B)** Recordings in the VLPFC areas 12/47 and 45 were made in 2 rhesus macaques with either chronically implanted multielectrode arrays or V-probes. **(C)** Neural activity was recorded while subjects performed a perceptual task, in which they attended to pseudorandomly presented audiovisual movies of expressions from 3 unfamiliar conspecifics (mean stimulus duration = 900ms) for a minimum of 10 repetitions of each of the 9 stimuli presented in a testing block.

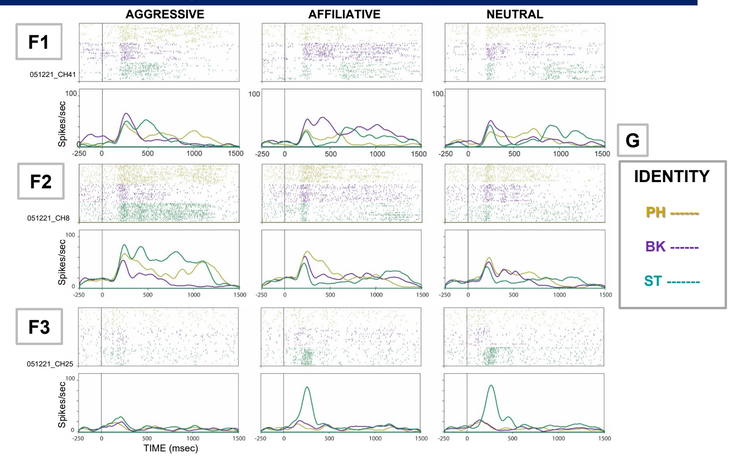


(D) Species-Specific Vocalization Movie Stimuli: Shown are still frames from the macaque vocalization movies used in one testing stimulus set. The 9 stimuli are 3 different vocalizations performed by 3 individual macaques (2 male, 1 female). The 3 vocalization types included: an aggressive (**AGG**, bark, scream); an affiliative (**AFL**, coo) and a neutral (**NEU**, grunt). The subjects were unfamiliar with all stimulus "actors". **(E)** The associated spectrograms of each vocalization in the (D) stimulus set.

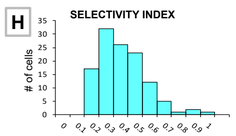
Neuronal Recordings:
Single units were identified through offline manual spike sorting from wideband and were analyzed for their selectivity for specific stimuli, identities, or expressions. Additional single unit and population level analyses were done using MATLAB and R.

RESULTS

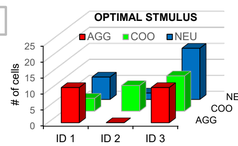
Single Neuron Responses



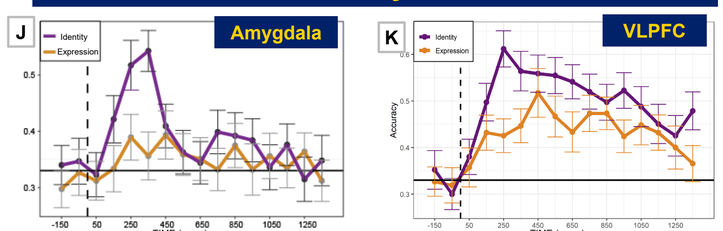
(F1,2,3) Three examples of single units (neurons) recorded simultaneously from the amygdala from two v-probes are displayed as rasters (above) and spike density functions (below, colored lines). Each column shows the neural responses to the same expression and colors indicate the response to the identity of the stimulus (**D, G**). Stimulus onset occurred at time 0. The duration of the video stimulus varied from ~500 – 1100 msec. **(F1)**, depicts a neuron with an increased and heterogenous response for each stimulus. The neuron in **(F2)**, also had a significant increase for all stimuli, with the greatest magnitude for the AGG expression (left column) of ID ST (green). In contrast, the cell in **F3**, had a selective response for the affiliative (middle) and neutral (right column) expressions by actor ST (green). Neurons were analyzed with a 2-way ANOVA (ID, EXP). All three neurons in **F1, F2, F3,** had an interaction of ID and EXP ($p < 0.01$) and main effects of ID and EXP ($p < 0.01$).



(H). A Selectivity Index was calculated across the 9 stimuli in the 118 responsive cells. From the distribution, most cells were not highly selective (mean SI = 0.36). **(I)** The stimulus which had the highest mean firing rate is shown for the responsive cells tested with set 1 (N=70).

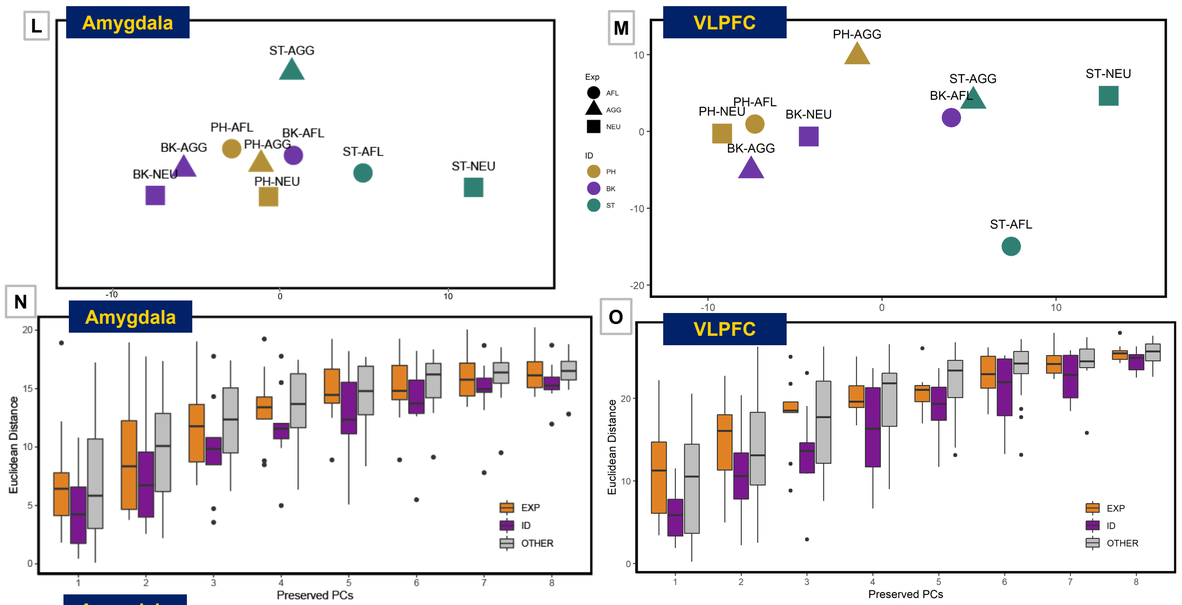


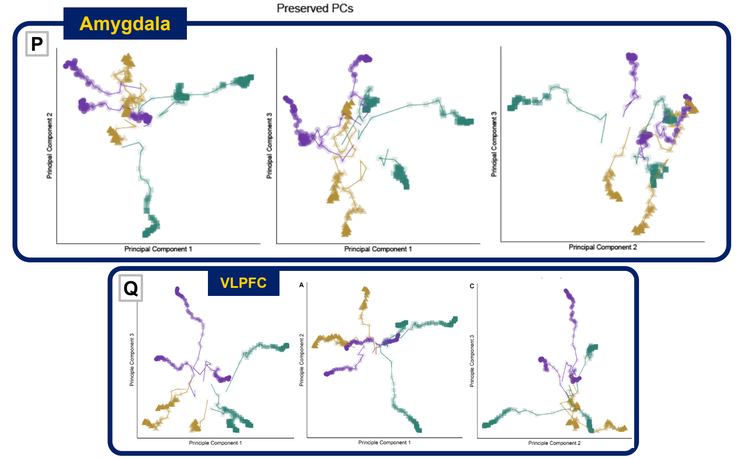
Information about Identity is Represented Early and More Robustly in Both Areas



Single units were combined into pseudopopulations of various sizes, randomizing trial and specific units at a given population size, and these population responses were used to decode the conspecific identity or expression type (Mean vector correlation, 2 CV, 50 Reps). Population level information contained sufficient information to accurately decode both variables, particularly identity. The decoding of identity and expression was explored across time, using 200ms time bins across the response period using 118 single units in the amygdala **(J)** and 285 units in VLPFC **(K)**. Dots represent the mean decoding accuracy of 50 iterations at 2-fold CV for a given time bin and variable of interest. Errors bars represent the 95% confidence interval of the mean. Peak decoding of identity was higher and occurred earlier than that for expression for both the amygdala and VLPFC. In VLPFC, the mean decoding accuracy for identity was greater than expression for al bins after stimulus onset while decoding accuracy for identity in the amygdala peaked and then decreased.

Identity Structures the Population Activity of the Amygdala and VLPFC





(L) PCA visualization of 118 neuron responses in the amygdala in (**L**) and 285 response in VLPFC (**M**) to each stimulus show separable regions of the response space for each identity in the set. **(N,O)** PCA dimensions 1-8 were progressively retained and distances between identities, between expressions, and between mismatches of identity and expression were measured in all 8 dimensions. For both amygdala **(N)** and VLPFC **(O)**, in each set of retained dimensions, distances between identities were smaller than those between expressions and mismatches. ANOVA revealed a significant effect of identity (and dimension) on distance, but not expression (multiple regression, Tukey HSD post-hoc). **(P, Q)** "Firework" plot tracking the position of population neural responses across the response period. Firing rates were calculated for increasing intervals of time from 50ms-1500ms and transformed into the final PCA space. Earlier periods (0-100ms) are more transparent than later (0-1200ms) and lines are drawn through the trajectory of each population response overtime. Responses to the same identities follow similar trajectories across time, in the population response space. 3 views of reconstructed PC spaces for combinations of PC 1, PC 2, and PC 3 are shown.

CONCLUSIONS

- **Single neurons, though responsive to audiovisual expression stimuli, were not particularly selective.**
- **Identity is a critical variable in the population activity of brain regions beyond the temporal cortex that interpret social information. The population response spaces of the amygdala and VLPFC are primarily shaped by identity.**
- **Both regions show early and robust information regarding identity, suggesting that subsequent neural activity may be predicated upon identity information from the temporal cortex.**
- **The accurate decoding of expression may require neurons that are responsive to dynamic visual and auditory features and/or neurons that integrate activity over time. In contrast to VLPFC neurons, amygdala neural activity had a more transient representation of identity suggesting a time scale of activity that is shorter than the length of a typical expression.**
- **Identity is correlated with a variety of other categorical features (sex, age, social status). It is possible that VLPFC and amygdala populations are optimally responsive to different underlying features that have high correlation with identity.**

ACKNOWLEDGEMENTS

NIH R01 MH121009-02 (KMG), NIH F30 MH122048 (KKS), NIH R01 DC04845 (LMR), NIH R21 DC016419 (LMR), University of Rochester (UofR) Center for Visual Sciences, UofR Schmitt Program for Integrative Neuroscience, and the UofR Medical Scientist Training Program. We would like to acknowledge John Housel, Archer Bowman, Lizzie Hillier, and Derek O'Neill for their help with recordings.