

## Supplementary Information

**Table.** List of PFC functions.

PFC Functions		Area	
Cognition	Decision	Value encoding	ORB <sup>1</sup> , ACA <sup>2</sup> , MOs <sup>3</sup>
		Outcome expectancy	ORB <sup>4</sup> , ACA <sup>5</sup>
		Confidence	ORB <sup>6</sup>
	Learning	Outcome representation	ORB <sup>7</sup> , ACA <sup>8</sup> , AI <sup>9</sup>
		Prediction error	ORB <sup>10</sup> , ACA <sup>11</sup>
		Task state representation	ORB <sup>12</sup> , ACA <sup>13</sup>
		Habitual learning	PL <sup>14</sup> , ILA <sup>14-16</sup>
	Attention		ORB <sup>17</sup> , ACA <sup>18</sup> , AI <sup>19</sup>
	Perception	Multisensory integration	AI <sup>20</sup>
		Modulation	ORB <sup>21</sup> , ACA <sup>22</sup> , MOs <sup>23</sup>
Memory	Short-term memory	mPFC <sup>24</sup> , MOs <sup>25</sup> , PL <sup>26</sup> , ILA <sup>26</sup>	
Emotion	Fear	Fear expression	PL <sup>27</sup>
		Fear extinction	ILA <sup>27,28</sup>
	Pain		AI <sup>19</sup>
	Anxiety		PL <sup>29</sup> , ILA <sup>29</sup>
Motor	Motor planning		MOs <sup>30</sup>
	Motor learning		MOs <sup>31</sup>

### Reference

- 1 Kuwabara, M., Kang, N., Holy, T. E. & Padoa-Schioppa, C. Neural mechanisms of economic choices in mice. *Elife* **9**, doi:10.7554/eLife.49669 (2020).
- 2 Seo, H. & Lee, D. Temporal filtering of reward signals in the dorsal anterior cingulate cortex during a mixed-strategy game. *J Neurosci* **27**, 8366-8377, doi:10.1523/JNEUROSCI.2369-07.2007 (2007).
- 3 Sul, J. H., Jo, S., Lee, D. & Jung, M. W. Role of rodent secondary motor cortex in value-based action selection. *Nat Neurosci* **14**, 1202-1208, doi:10.1038/nn.2881 (2011).
- 4 Riceberg, J. S. & Shapiro, M. L. Orbitofrontal Cortex Signals Expected Outcomes with Predictive Codes When Stable Contingencies Promote the Integration of Reward History. *J Neurosci* **37**, 2010-2021, doi:10.1523/JNEUROSCI.2951-16.2016 (2017).
- 5 Shidara, M. & Richmond, B. J. Anterior cingulate: single neuronal signals related to degree of reward expectancy. *Science* **296**, 1709-1711, doi:10.1126/science.1069504 (2002).
- 6 Kepecs, A., Uchida, N., Zariwala, H. A. & Mainen, Z. F. Neural correlates, computation and behavioural impact of decision confidence. *Nature* **455**, 227-231, doi:10.1038/nature07200 (2008).
- 7 Hirokawa, J., Vaughan, A., Masset, P., Ott, T. & Kepecs, A. Frontal cortex neuron types categorically encode single decision variables. *Nature* **576**, 446-451, doi:10.1038/s41586-019-1816-9 (2019).

- 8 Shenhav, A., Botvinick, M. M. & Cohen, J. D. The expected value of control: an integrative theory of anterior cingulate cortex function. *Neuron* **79**, 217-240, doi:10.1016/j.neuron.2013.07.007 (2013).
- 9 Jo, S. & Jung, M. W. Differential coding of uncertain reward in rat insular and orbitofrontal cortex. *Sci Rep* **6**, 24085, doi:10.1038/srep24085 (2016).
- 10 Noonan, M. P., Mars, R. B. & Rushworth, M. F. Distinct roles of three frontal cortical areas in reward-guided behavior. *J Neurosci* **31**, 14399-14412, doi:10.1523/JNEUROSCI.6456-10.2011 (2011).
- 11 Kennerley, S. W., Behrens, T. E. & Wallis, J. D. Double dissociation of value computations in orbitofrontal and anterior cingulate neurons. *Nat Neurosci* **14**, 1581-1589, doi:10.1038/nn.2961 (2011).
- 12 Wilson, R. C., Takahashi, Y. K., Schoenbaum, G. & Niv, Y. Orbitofrontal cortex as a cognitive map of task space. *Neuron* **81**, 267-279, doi:10.1016/j.neuron.2013.11.005 (2014).
- 13 Akam, T. *et al.* The Anterior Cingulate Cortex Predicts Future States to Mediate Model-Based Action Selection. *Neuron*, doi:10.1016/j.neuron.2020.10.013 (2020).
- 14 Mukherjee, A. & Caroni, P. Infralimbic cortex is required for learning alternatives to prelimbic promoted associations through reciprocal connectivity. *Nat Commun* **9**, 2727, doi:10.1038/s41467-018-05318-x (2018).
- 15 Pfarr, S. *et al.* Losing Control: Excessive Alcohol Seeking after Selective Inactivation of Cue-Responsive Neurons in the Infralimbic Cortex. *J Neurosci* **35**, 10750-10761, doi:10.1523/JNEUROSCI.0684-15.2015 (2015).
- 16 Peters, J., LaLumiere, R. T. & Kalivas, P. W. Infralimbic prefrontal cortex is responsible for inhibiting cocaine seeking in extinguished rats. *J Neurosci* **28**, 6046-6053, doi:10.1523/JNEUROSCI.1045-08.2008 (2008).
- 17 Xie, Y., Nie, C. & Yang, T. Covert shift of attention modulates the value encoding in the orbitofrontal cortex. *Elife* **7**, doi:10.7554/eLife.31507 (2018).
- 18 Oemisch, M., Westendorff, S., Everling, S. & Womelsdorf, T. Interareal Spike-Train Correlations of Anterior Cingulate and Dorsal Prefrontal Cortex during Attention Shifts. *J Neurosci* **35**, 13076-13089, doi:10.1523/JNEUROSCI.1262-15.2015 (2015).
- 19 Uddin, L. Q. Salience processing and insular cortical function and dysfunction. *Nat Rev Neurosci* **16**, 55-61, doi:10.1038/nrn3857 (2015).
- 20 Gogolla, N., Takesian, A. E., Feng, G., Fagiolini, M. & Hensch, T. K. Sensory integration in mouse insular cortex reflects GABA circuit maturation. *Neuron* **83**, 894-905, doi:10.1016/j.neuron.2014.06.033 (2014).
- 21 Winkowski, D. E., Bandyopadhyay, S., Shamma, S. A. & Kanold, P. O. Frontal cortex activation causes rapid plasticity of auditory cortical processing. *J Neurosci* **33**, 18134-18148, doi:10.1523/JNEUROSCI.0180-13.2013 (2013).
- 22 Zhang, S. *et al.* Selective attention. Long-range and local circuits for top-down modulation of visual cortex processing. *Science* **345**, 660-665, doi:10.1126/science.1254126 (2014).
- 23 Schneider, D. M., Nelson, A. & Mooney, R. A synaptic and circuit basis for corollary discharge in the auditory cortex. *Nature* **513**, 189-194, doi:10.1038/nature13724 (2014).
- 24 Liu, D. *et al.* Medial prefrontal activity during delay period contributes to learning of a working memory task. *Science* **346**, 458-463, doi:10.1126/science.1256573 (2014).

- 25 Inagaki, H. K., Fontolan, L., Romani, S. & Svoboda, K. Discrete attractor dynamics underlies persistent activity in the frontal cortex. *Nature* **566**, 212-217, doi:10.1038/s41586-019-0919-7 (2019).
- 26 Gisquet-Verrier, P. & Delatour, B. The role of the rat prelimbic/infralimbic cortex in working memory: not involved in the short-term maintenance but in monitoring and processing functions. *Neuroscience* **141**, 585-596, doi:10.1016/j.neuroscience.2006.04.009 (2006).
- 27 Giustino, T. F. & Maren, S. The Role of the Medial Prefrontal Cortex in the Conditioning and Extinction of Fear. *Front Behav Neurosci* **9**, 298, doi:10.3389/fnbeh.2015.00298 (2015).
- 28 Izquierdo, A., Wellman, C. L. & Holmes, A. Brief uncontrollable stress causes dendritic retraction in infralimbic cortex and resistance to fear extinction in mice. *J Neurosci* **26**, 5733-5738, doi:10.1523/JNEUROSCI.0474-06.2006 (2006).
- 29 Jinks, A. L. & McGregor, I. S. Modulation of anxiety-related behaviours following lesions of the prelimbic or infralimbic cortex in the rat. *Brain Res* **772**, 181-190, doi:10.1016/s0006-8993(97)00810-x (1997).
- 30 Chen, T. W., Li, N., Daie, K. & Svoboda, K. A Map of Anticipatory Activity in Mouse Motor Cortex. *Neuron* **94**, 866-879 e864, doi:10.1016/j.neuron.2017.05.005 (2017).
- 31 Cao, V. Y. *et al.* Motor Learning Consolidates Arc-Expressing Neuronal Ensembles in Secondary Motor Cortex. *Neuron* **86**, 1385-1392, doi:10.1016/j.neuron.2015.05.022 (2015).