

Supplementary Online Content

Kühn S, Gallinat J. Brain structure and functional connectivity associated with pornography consumption. *JAMA Psychol*. Published online May 28, 2014. doi:10.1001/jamapsychiatry.2014.93.

eAppendix. Computation of literature-based probabilistic region of interests.

eReferences.

This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix. Computation of literature based probabilistic region of interests

A Region of Interest (ROI) for the ventral striatum was created combining anatomical hypotheses with functional findings as reported in literature for comparable experimental designs. To this end, firstly we created an anatomical ROI for the basal ganglia (as provided by the Automated Anatomical Labeling (AAL) brain atlas, Tzourio-Mazoyer et al., 2002). Secondly, spatial coordinates for this ROI were taken from fMRI publications from reward anticipation contrast of healthy volunteers (Abler et al., 2007, 2006; Bjork and Hommer, 2007; Bjork et al., 2010, 2004; Cooper and Knutson, 2008; Dichter et al., 2012; Dillon et al., 2008; Dreher et al., 2008; Elliott et al., 2000; Ernst et al., 2004; Figeo et al., 2011; Galvan et al., 2007, 2005; Hoogman et al., 2011; Jones et al., 2011; Juckel et al., 2006; Kappel et al., 2013; Kirsch et al., 2003; Knutson and Greer, 2008; Knutson and Wimmer, 2007; Knutson et al., 2008, 2005, 2004, 2001a, 2001b; Kuhnen and Knutson, 2005; Martino et al., 2009; Ossewaarde et al., 2011; Samanez-Larkin et al., 2007; Schlagenhaut et al., 2008; Schmack et al., 2008; Spicer et al., 2007; Stoy et al., 2012; Ströhle et al., 2008; Wrase et al., 2007a, 2007b; Xue et al., 2010; Yau et al., 2012; Yu et al., 2010). Based on this data set, we created the ROI in a three-step process (Schubert et al., 2008):

(1) The probability that a voxel at a given position within an anatomical ROI showed neural activity regarding the corresponding literature was estimated by calculating a 3D normal (Gaussian) distribution $G(x, y, z)$ as follows (Turkeltaub et al., 2002):

$$G(x, y, z) = \frac{1}{2\pi\sqrt{|Det(C)|}} \exp\left(-\frac{1}{2}\begin{bmatrix} x - \bar{x} & y - \bar{y} & z - \bar{z} \end{bmatrix} C^{-1} \begin{bmatrix} x - \bar{x} \\ y - \bar{y} \\ z - \bar{z} \end{bmatrix}\right)$$

where C is the covariance matrix for all coordinate triples x, y, z from the underlying literature and $\bar{x}, \bar{y}, \bar{z}$ are the mean values of the $x, y,$ and z coordinates, respectively (Nielsen and Hansen, 2002).

(2) The outer limits of the finally used ROI were defined by the outer limits of the anatomical ROI and a threshold of three standard deviations of the resulting 3D distribution.

(3) Finally, a binary mask including all voxels within these boundaries was formed.

Note: The script for generating the probabilistic ROIs (written in Matlab by author TW and compatible with SPM8) and the full lists of coordinates used for ROI generation can be obtained from the authors upon request.

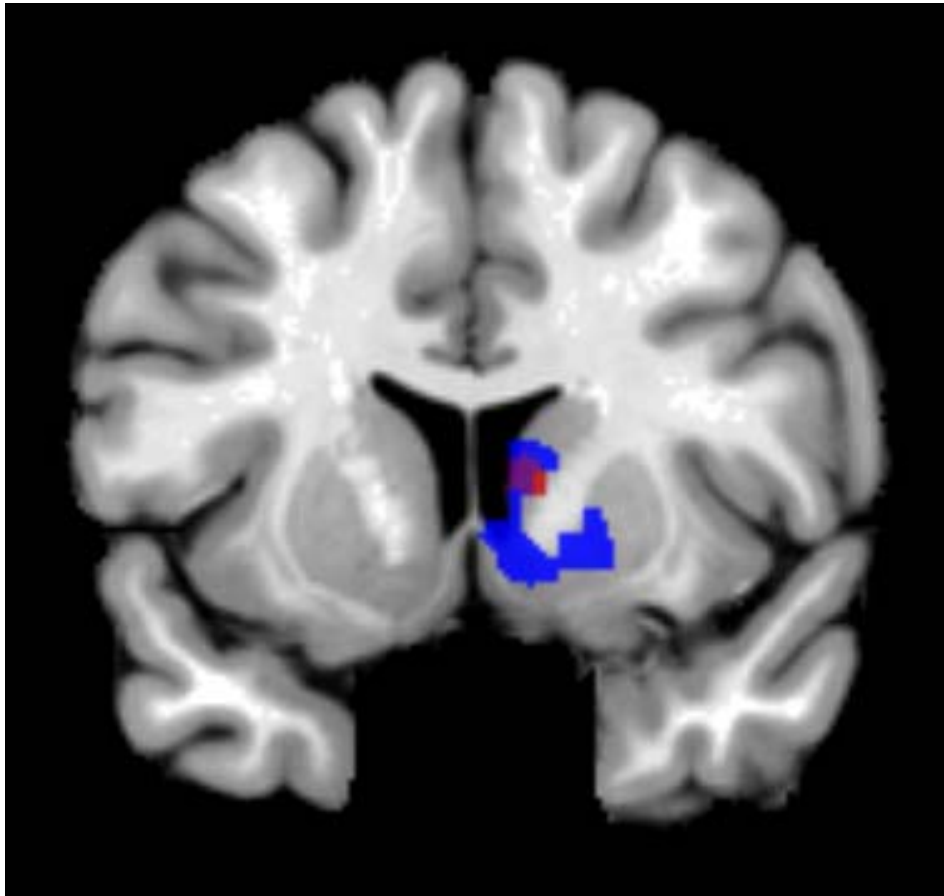


Figure S1: Literature based ROI is depicted in blue and the grey matter region in right caudate identified in the voxel-based morphometry analysis is depicted in red.

eReferences

1. Tzourio-Mazoyer, N., Landeau, B., Papathanassiou, D., Crivello, F., Etard, O., Delcroix, N., Mazoyer, B., Joliot, M., 2002. Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *Neuroimage* 15, 273–289.

2. Abler, B., Erk, S., Walter, H., 2007. Human reward system activation is modulated by a single dose of olanzapine in healthy subjects in an event-related, double-blind, placebo-controlled fMRI study. *Psychopharmacology (Berl.)* 191, 823–833.
3. Abler, B., Walter, H., Erk, S., Kammerer, H., Spitzer, M., 2006. Prediction error as a linear function of reward probability is coded in human nucleus accumbens. *NeuroImage* 31, 790–795.
4. Bjork, J.M., Hommer, D.W., 2007. Anticipating instrumentally obtained and passively-received rewards: A factorial fMRI investigation. *Behav. Brain Res.* 177, 165–170.
5. Bjork, J.M., Knutson, B., Fong, G.W., Caggiano, D.M., Bennett, S.M., Hommer, D.W., 2004. Incentive-Elicited Brain Activation in Adolescents: Similarities and Differences from Young Adults. *J. Neurosci.* 24, 1793–1802.
6. Bjork, J.M., Smith, A.R., Chen, G., Hommer, D.W., 2010. Adolescents, Adults and Rewards: Comparing Motivational Neurocircuitry Recruitment Using fMRI. *PLoS ONE* 5, e11440.
7. Cooper, J.C., Knutson, B., 2008. Valence and salience contribute to nucleus accumbens activation. *NeuroImage* 39, 538–547.
8. Dichter, G.S., Felder, J.N., Green, S.R., Rittenberg, A.M., Sasson, N.J., Bodfish, J.W., 2012. Reward circuitry function in autism spectrum disorders. *Soc. Cogn. Affect. Neurosci.* 7, 160–172.
9. Dillon, D.G., Holmes, A.J., Jahn, A.L., Bogdan, R., Wald, L.L., Pizzagalli, D.A., 2008. Dissociation of neural regions associated with anticipatory versus consummatory phases of incentive processing. *Psychophysiology* 45, 36–49.
10. Dreher, J.-C., Meyer-Lindenberg, A., Kohn, P., Berman, K.F., 2008. Age-related changes in midbrain dopaminergic regulation of the human reward system. *Proc. Natl. Acad. Sci.* 105, 15106–15111.
11. Elliott, R., Friston, K.J., Dolan, R.J., 2000. Dissociable Neural Responses in Human Reward Systems. *J. Neurosci.* 20, 6159–6165.
12. Ernst, M., Nelson, E.E., McClure, E.B., Monk, C.S., Munson, S., Eshel, N., Zarah, E., Leibenluft, E., Zametkin, A., Towbin, K., Blair, J., Charney, D., Pine, D.S., 2004. Choice selection and reward anticipation: an fMRI study. *Neuropsychologia* 42, 1585–1597.
13. Figeet, M., Vink, M., de Geus, F., Vulink, N., Veltman, D.J., Westenberg, H., Denys, D., 2011. Dysfunctional Reward Circuitry in Obsessive-Compulsive Disorder. *Biol. Psychiatry* 69, 867–874.
14. Galvan, A., Hare, T., Voss, H., Glover, G., Casey, B. j., 2007. Risk-taking and the adolescent brain: who is at risk? *Dev. Sci.* 10, F8–F14.
15. Galvan, A., Hare, T.A., Davidson, M., Spicer, J., Glover, G., Casey, B.J., 2005. The Role of Ventral Frontostriatal Circuitry in Reward-Based Learning in Humans. *J. Neurosci.* 25, 8650–8656.
16. Hoogman, M., Aarts, E., Zwiers, M., Slaats-Willems, D., Naber, M., Onnink, M., Cools, R., Kan, C., Buitelaar, J., Franke, B., 2011. Nitric Oxide Synthase Genotype Modulation of Impulsivity and Ventral Striatal Activity in Adult ADHD Patients and Healthy Comparison Subjects. *Am. J. Psychiatry* 168, 1099–1106.

17. Jones, C.L., Minati, L., Harrison, N.A., Ward, J., Critchley, H.D., 2011. Under Pressure: Response Urgency Modulates Striatal and Insula Activity during Decision-Making under Risk. *PLoS ONE* 6, e20942.
18. Juckel, G., Schlagenhauf, F., Koslowski, M., Wüstenberg, T., Villringer, A., Knutson, B., Wrase, J., Heinz, A., 2006. Dysfunction of ventral striatal reward prediction in schizophrenia. *NeuroImage* 29, 409–416.
19. Kappel, V., Koch, A., Lorenz, R.C., Brühl, R., Renneberg, B., Lehmkuhl, U., Salbach-Andrae, H., Beck, A., 2013. CID: a valid incentive delay paradigm for children. *J. Neural Transm.* 120, 1259–1270.
20. Kirsch, P., Schienle, A., Stark, R., Sammer, G., Blecker, C., Walter, B., Ott, U., Burkart, J., Vaitl, D., 2003. Anticipation of reward in a nonaversive differential conditioning paradigm and the brain reward system:: an event-related fMRI study. *NeuroImage* 20, 1086–1095.
21. Knutson, B., Adams, C.M., Fong, G.W., Hommer, D., 2001a. Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *J. Neurosci. Off. J. Soc. Neurosci.* 21, RC159.
22. Knutson, B., Bhanji, J.P., Cooney, R.E., Atlas, L.Y., Gotlib, I.H., 2008. Neural Responses to Monetary Incentives in Major Depression. *Biol. Psychiatry* 63, 686–692.
23. Knutson, B., Bjork, J.M., Fong, G.W., Hommer, D., Mattay, V.S., Weinberger, D.R., 2004. Amphetamine Modulates Human Incentive Processing. *Neuron* 43, 261–269.
24. Knutson, B., Fong, G.W., Adams, C.M., Varner, J.L., Hommer, D., 2001b. Dissociation of reward anticipation and outcome with event-related fMRI. *Neuroreport* 12, 3683–3687.
25. Knutson, B., Greer, S.M., 2008. Anticipatory affect: neural correlates and consequences for choice. *Philos. Trans. R. Soc. B Biol. Sci.* 363, 3771–3786.
26. Knutson, B., Taylor, J., Kaufman, M., Peterson, R., Glover, G., 2005. Distributed Neural Representation of Expected Value. *J. Neurosci.* 25, 4806–4812.
27. Knutson, B., Wimmer, G.E., 2007. Splitting the Difference. *Ann. N. Y. Acad. Sci.* 1104, 54–69.
28. Kuhnen, C.M., Knutson, B., 2005. The Neural Basis of Financial Risk Taking. *Neuron* 47, 763–770.
29. Martino, B.D., Kumaran, D., Holt, B., Dolan, R.J., 2009. The Neurobiology of Reference-Dependent Value Computation. *J. Neurosci.* 29, 3833–3842.
30. Nielsen, F.A., Hansen, L.A., 2002. Automatic anatomical labeling of Talairach coordinates and generation of volumes of interest via the BrainMap database. *Neuroimage* 16.
31. Ossewaarde, L., Verkes, R.J., Hermans, E.J., Kooijman, S.C., Uner, M., Tendolkar, I., van Wingen, G.A., Fernández, G., 2011. Two-Week Administration of the Combined Serotonin-Noradrenaline Reuptake Inhibitor Duloxetine Augments Functioning of Mesolimbic Incentive Processing Circuits. *Biol. Psychiatry* 70, 568–574.
32. Samanez-Larkin, G.R., Gibbs, S.E.B., Khanna, K., Nielsen, L., Carstensen, L.L., Knutson, B., 2007. Anticipation of monetary gain but not loss in healthy older adults. *Nat. Neurosci.* 10, 787–791.

33. Schlagenhauf, F., Juckel, G., Koslowski, M., Kahnt, T., Knutson, B., Dembler, T., Kienast, T., Gallinat, J., Wrase, J., Heinz, A., 2008. Reward system activation in schizophrenic patients switched from typical neuroleptics to olanzapine. *Psychopharmacology (Berl.)* 196, 673–684.
34. Schmack, K., Schlagenhauf, F., Sterzer, P., Wrase, J., Beck, A., Dembler, T., Kalus, P., Puls, I., Sander, T., Heinz, A., Gallinat, J., 2008. Catechol-O-methyltransferase val158met genotype influences neural processing of reward anticipation. *NeuroImage* 42, 1631–1638.
35. Spicer, J., Galvan, A., Hare, T.A., Voss, H., Glover, G., Casey, B., 2007. Sensitivity of the Nucleus Accumbens to Violations in Expectation of Reward. *Neuroimage* 34, 455–461.
36. Stoy, M., Schlagenhauf, F., Sterzer, P., Bermpohl, F., Hägele, C., Suchotzki, K., Schmack, K., Wrase, J., Ricken, R., Knutson, B., Adli, M., Bauer, M., Heinz, A., Ströhle, A., 2012. Hyporeactivity of ventral striatum towards incentive stimuli in unmedicated depressed patients normalizes after treatment with escitalopram. *J. Psychopharmacol. (Oxf.)* 26, 677–688.
37. Ströhle, A., Stoy, M., Wrase, J., Schwarzer, S., Schlagenhauf, F., Huss, M., Hein, J., Nedderhut, A., Neumann, B., Gregor, A., Juckel, G., Knutson, B., Lehmkuhl, U., Bauer, M., Heinz, A., 2008. Reward anticipation and outcomes in adult males with attention-deficit/hyperactivity disorder. *Neuroimage* 39, 966–972.
38. Wrase, J., Kahnt, T., Schlagenhauf, F., Beck, A., Cohen, M.X., Knutson, B., Heinz, A., 2007a. Different neural systems adjust motor behavior in response to reward and punishment. *Neuroimage* 36, 1253–1262.
39. Wrase, J., Schlagenhauf, F., Kienast, T., Wüstenberg, T., Bermpohl, F., Kahnt, T., Beck, A., Ströhle, A., Juckel, G., Knutson, B., Heinz, A., 2007b. Dysfunction of reward processing correlates with alcohol craving in detoxified alcoholics. *Neuroimage* 35, 787–794.
40. Xue, G., Lu, Z., Levin, I.P., Bechara, A., 2010. The Impact of Prior Risk Experiences on Subsequent Risky Decision-Making: The Role of the Insula. *Neuroimage* 50, 709–716.
41. Yau, W.-Y.W., Zubieta, J.-K., Weiland, B.J., Samudra, P.G., Zucker, R.A., Heitzeg, M.M., 2012. Nucleus Accumbens Response to Incentive Stimuli Anticipation in Children of Alcoholics: Relationships with Precursive Behavioral Risk and Lifetime Alcohol Use. *J. Neurosci.* 32, 2544–2551.
42. Yu, R., Mobbs, D., Seymour, B., Calder, A.J., 2010. Insula and Striatum Mediate the Default Bias. *J. Neurosci.* 30, 14702–14707.
43. Schubert, R., Ritter, P., Wüstenberg, T., Preuschhof, C., Curio, G., Sommer, W., Villringer, A., 2008. Spatial Attention Related SEP Amplitude Modulations Covary with BOLD Signal in S1-A Simultaneous EEG-fMRI Study. *Cereb. Cortex* 18, 2686–2700.
44. Turkeltaub, P.E., Eden, G.F., Jones, K.M., Zeffiro, T.A., 2002. Meta-analysis of the functional neuroanatomy of single-word reading: Method and validation. *Neuroimage* 16, 765–780.