Structure of orbitofrontal cortex predicts social influence

Article (Accepted Version)

Campbell-Meiklejohn, Daniel K, Kanai, Ryota, Bahrami, Bahador, Bach, Dominik R, Dolan, Raymond J, Roepstorff, Andreas and Frith, Chris D (2012) Structure of orbitofrontal cortex predicts social influence. Current Biology, 22 (4). R123-R124. ISSN 0960-9822

This version is available from Sussex Research Online: http://sro.sussex.ac.uk/43907/

This document is made available in accordance with publisher policies and may differ from the published version or from the version of record. If you wish to cite this item you are advised to consult the publisher's version. Please see the URL above for details on accessing the published version.

Copyright and reuse:
Sussex Research Online is a digital repository of the research output of the University.

Copyright and all moral rights to the version of the paper presented here belong to the individual author(s) and/or other copyright owners. To the extent reasonable and practicable, the material made available in SRO has been checked for eligibility before being made available.

Copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

http://sro.sussex.ac.uk
Correspondence

Structure of orbitofrontal cortex predicts social influence

Daniel K Campbell-Meiklejohn\textsuperscript{1,2}, Ryota Kanai\textsuperscript{3}, Bahador Bahrami\textsuperscript{3}, Dominik R Bach\textsuperscript{4}, Raymond J Dolan\textsuperscript{4}, Andreas Roepstorff\textsuperscript{2} and Chris D. Frith\textsuperscript{4}

Some people conform more than others. Across different contexts, this tendency is a fairly stable trait [1]. This stability suggests that the tendency to conform might have an anatomical correlate [2]. Values that one associates with available options, from foods to political candidates, help to guide choices and behaviour. These values can often be updated by the expressed preferences of other people as much as by independent experience. In this correspondence, we report a linear relationship between grey matter volume (GM) in a region of lateral orbitofrontal cortex (\textit{IOFC}_{GM}) and the tendency to shift reported desire for objects toward values expressed by other people. This effect was found in precisely the same region in each brain hemisphere. \textit{IOFC}_{GM} also predicted the functional hemodynamic response in the middle frontal gyrus to discovering that someone else’s values contrast with one’s own. These findings indicate that the tendency to conform one’s values to those expressed by other people has an anatomical correlate in the human brain.

In an earlier study [3], we found that the brain’s functional hemodynamic response to another person’s preference for an object, and the impact of that preference on the brain’s reward response to receiving that object, correlated with the subject’s tendency to conform self-reported desire for objects to preferences expressed by others. This highlighted some physiological
dynamics of social influence on value in the brain, but did not address the structural foundations that would link social influence to developmental and evolutionary theory. Moreover, we could not reliably investigate the blood oxygenation level dependent (BOLD) signal from orbitofrontal cortex (OFC) because of signal dropout and distortion in the region. Lesion studies suggest that OFC is causally involved in central components of social influence on value. Damage to this region impairs one’s ability to correctly assign value to stimuli, respond appropriately to social cues, and act appropriately during social interaction [4–7]. To investigate the relationship of OFC structure to social influence in healthy individuals, we can use volumetric based morphometry (VBM) methods, which are unaffected by signal dropout and distortion. That is, we can test for a correlation between GM of the OFC and the tendency to conform value to the preferences of others in the same 28 adult subjects (15 male) of our previous study [3] (see Supplemental Experimental Procedures in the Supplemental Information available on-line).

A week prior to testing, subjects provided the names of twenty pieces of music that they would like to own, but did not own yet. On the test day, subjects rated each submitted song for desirability, from 1 (low) to 10 (high). Next, subjects were told that two music ‘reviewers’, of whom subjects had read descriptions and rated as capable of choosing enjoyable music, had listened to each song; the subjects then performed the task illustrated in Supplemental Figure S1. During a trial, subjects indicated their preference, given a choice of a song they had submitted and an alternative song, which they had never heard. Subjects were then told which song the reviewers preferred. Each submitted song was evaluated relative to six alternatives. After the task, subjects rerated their desire for each submitted song. Change in desire was tested for a linear relationship with net reviewer preference for the song (times preferred – times not
preferred). The resulting coefficient, $B_{\text{inf}}$ (M 0.091, SD 0.17), provided a measure of tendency to conform values to values expressed by the reviewers for each subject [3].

Using VBM, we tested the relationship between $B_{\text{inf}}$ and OFC GM. Age, gender, total brain GM and $B_{\text{inf}}$ were entered into a multiple regression to OFC GM using T1-weighted MRI images. $B_{\text{inf}}$ was linearly related to GM in a specific lateral OFC region ($\text{IOFC}_{\text{GM}}$) in both hemispheres (Figure 1A,B). No other regions correlated with $B_{\text{inf}}$ in a separate whole-brain search, even at a reduced statistical threshold. A functional analysis (see Supplemental Experimental Procedures and Data) found that like $B_{\text{inf}}$ [3], $\text{IOFC}_{\text{GM}}$ predicted the functional hemodynamic response to disagreement with the reviewers about song value, in the middle frontal gyrus (Figure 1C).

This is new evidence of an anatomical correlate of social influence on value. Surprisingly, the correlate was found in lateral rather than medial OFC regions that are typically associated with monitoring option value [6]. This likely relates to the precise conformity-related mechanism mediated by $\text{IOFC}_{\text{GM}}$. Such a mechanism may well affect non-social learning too. IOFC is particularly tuned to punishment, when option values need updating [6, 7]. $\text{IOFC}_{\text{GM}}$ predicts frontal responses to social disagreement about value. Therefore, $\text{IOFC}_{\text{GM}}$ could index the salience of social disagreement or interpretation of that disagreement as a punishing event that requires an update of values. It could also index the ability to credit detected changes of value to the correct song option [7].

$\text{IOFC}_{\text{GM}}$ could reflect a single psychological trait that directly corresponds to behavior ranging from conformity to anticonformity (for example, affinity for group membership). On the other hand, it is possible that conformity and anticonformity are mediated by two separate mechanisms. For example, $\text{IOFC}_{\text{GM}}$ could mediate only
conformity-related cognition that, when reduced, allows anticonformity-related cognition to have a greater impact on behavior (negative $B_{inf}$ coefficients). It seems unlikely that conformity and anti-conformity are completely independent given that functional and anatomical correlates span the whole range of positive and negative $B_{inf}$ values [3] in a single brain region. However, this possibility is consistent with results obtained in a subsample of 23 subjects with $B_{inf}$ scores near zero or above, and in all 28 subjects when anticonforming changes of value are coded as independence (no change) (see Supplemental Information). The precise conformity-related cognition associated with lOFC$_{GM}$ is now an enticing question for future research.

These new findings carry implications for many fields. Clinically, changes in social conduct that result from atrophy or damage to prefrontal cortex [4,6] might result from a reduced tendency to adopt values expressed by others. In addition, expansion of prefrontal cortical grey matter may play a role in the tandem changes of social learning during primate evolution and development [8–10].

Supplemental Information

Supplemental Information includes experimental procedures, two figures, and supplemental data and can be found with this article online at *bxs.

Acknowledgements

This research was funded by the Danish Research Foundation Neils Bohr Visiting Professorship to CDF, A Danish Council for Independent Research Sapere Aude Fellowship to DCM and a
Wellcome Trust Programme Grant to RJD. DRB was supported by a Max Planck Award to RJD.

We would like to thank Dr. Mark Walton and Dr. Steve Fleming for helpful comments.

References

1. McGuire, M. (1967). Personality and Susceptability to Social Influence. In Handbook of Personality Theory and Research, E.F. Borgatta and W.W. Lambert, eds. (Chicago: Rand McNally).

2. Kanai, R., and Rees, G. (2011). The structural basis of inter-individual differences in human behaviour and cognition. Nat. Rev. Neurosci. 12, 231-242.

3. Campbell-Meiklejohn, D.K., Bach, D.R., Roepstorff, A., Dolan, R.J., and Frith, C.D. (2010). How the opinion of others affects our valuation of objects. Curr. Biol. 20, 1165-1170.

4. Hornak, J., Bramham, J., Rolls, E.T., Morris, R.G., O'Doherty, J., Bullock, P.R., and Polkey, C.E. (2003). Changes in emotion after circumscribed surgical lesions of the orbitofrontal and cingulate cortices. Brain 126, 1691-1712.

5. Machado, C., and Bachevalier, J. (2006). The Impact of Selective Amygdala, Orbital Frontal Cortex, or Hippocampal Formation Lesions on Established Social Relationships in Rhesus Monkeys (Macaca mulatta). Behav. Neurosci. 120, 761-786.

6. Kringelbach, M., and Rolls, E. (2004). The functional neuroanatomy of the human orbitofrontal cortex: evidence from neuroimaging and neuropsychology. Prog. Neurobiol. 72, 341-372.
7. Rushworth, M.F.S., Noonan, M.P., Boorman, E.D., Walton, M.E., and Behrens, T.E. (2011). Frontal cortex and reward-guided learning and decision-making. Neuron 70, 1054-1069.

8. Reader, S.M., and Laland, K.N. (2002). Social intelligence, innovation, and enhanced brain size in primates. Proc. Natl. Acad. Sci. USA. 99, 4436-4441.

9. Giedd, J.N., Blumenthal, J., and Jeffries, N.O. (1999). Brain development during childhood and adolescence: a longitudinal MRI study. Nat. Neurosci. 10, 861-863.

10. Costanzo, P.R. (1966). Conformity as a function of age level. Child Dev. 30, 967-975.

1Center for Neural Science, New York University, 4 Washington Place, NY 10003, USA.

2Danish Neuroscience Centre, Aarhus University, Nørrebrogade 44, 10G, Århus Universitetshospital, Århus Sygehus, Aarhus, Denmark. 3UCL Institute of Cognitive Neuroscience, University College London, 17 Queen Square, London WC1N 3AR, UK.

4Wellcome Trust Centre for Neuroimaging, University College London, 12 Queen Square, London WC1N 3BG, UK. E-mail: dan.cfin@gmail.com

Figure 1. Structural and overlapping functional correlates of social influence.

Statistical maps are overlaid onto a standard MNI brain at coordinates: –40mm, 33 mm, –14mm. (A) OFC regions in which GM correlated with social influence on value (Binf) (threshold p < 0.001, FWE corrected at p < 0.05; right peak 36mm 33mm -10mm, P_{FWE} = 0.023, T = 5.56, 73 voxels; left peak –33mm 28mm –16mm, P_{FWE} =0.029, T=5.43, 183 voxels. (B) Mean GM value (a.u.) within the entire right cluster (red triangles) and entire left cluster (blue circles) plotted against social influence on value (Binf). GM values were mean corrected within each cluster. (C)
Overlap (green) in middle frontal gyrus functional activity predicted by conjunction of $\text{IOFC}_{\text{GM}}$ and $B_{\text{inf}}$ during disagreement with experts (vs. agreement) about object value (peak: $–40\text{mm}$ $46\text{mm}$ $4\text{mm}$, $Z = 3.72$, 768 voxels).

Supplemental Information

Document S1. Experimental Procedures, Two Figures and Supplemental Data.

Figure 1