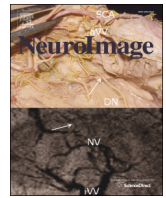




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Q2 Brain networks underlying bistable perception

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A B S T R A C T

Bistable stimuli, such as the Necker Cube, demonstrate that experience can change in the absence of changes in the environment. Such phenomena can be used to assess stimulus-independent aspects of conscious experience. The current study used resting state functional magnetic resonance imaging (rs-fMRI) to index stimulus-independent changes in neural activity to understand the neural architecture that determines dominance durations during bistable perception (using binocular rivalry and Necker cube stimuli). Anterior regions of the Superior Parietal Lobule (SPL) exhibited robust connectivity with regions of primary sensorimotor cortex. The strength of this region's connectivity with the striatum predicted shorter dominance durations during binocular rivalry, whereas its connectivity to pre-motor cortex predicted longer dominance durations for the Necker Cube. Posterior regions of the SPL, on the other hand, were coupled to associative cortex in the temporal and frontal lobes. The posterior SPL's connectivity to the temporal lobe predicted longer dominance during binocular rivalry. In conjunction with prior work, these data suggest that the anterior SPL contributes to perceptual rivalry through the inhibition of incongruent bottom up information, whereas the posterior SPL influences rivalry by supporting the current interpretation of a bistable stimulus. Our data suggests that the functional connectivity of the SPL with regions of sensory, motor, and associative cortex allows it to regulate the interpretation of the environment that forms the focus of conscious attention at a specific moment in time.

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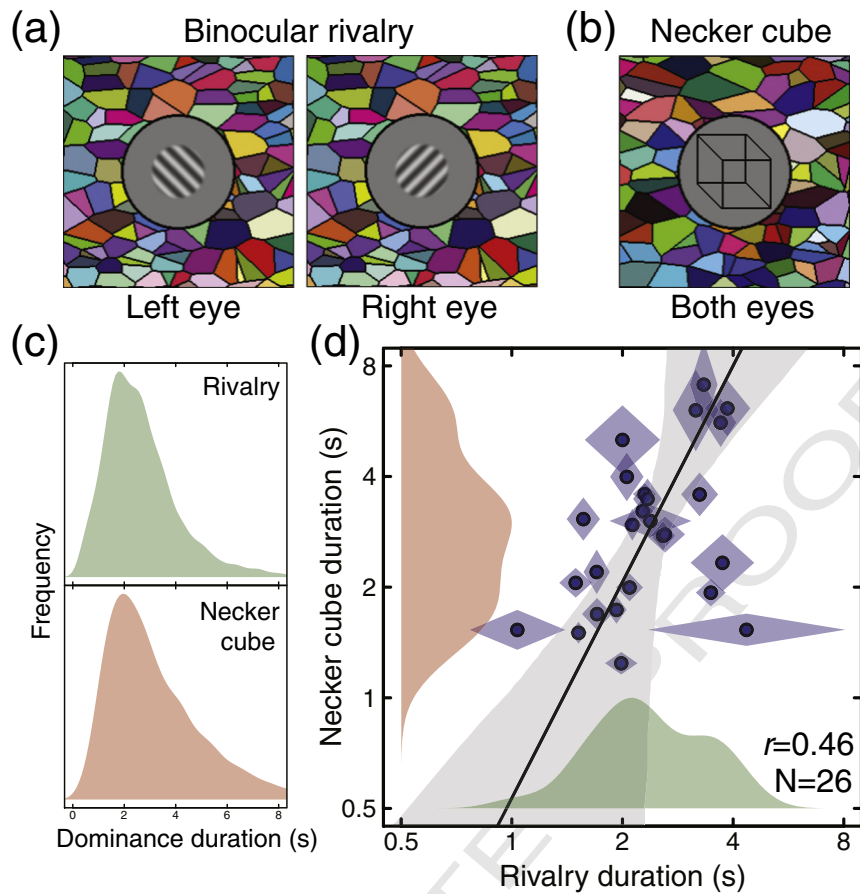
34 Introduction

35 A remarkable feature of the human mind is its capacity to process
36 information that is independent of environmental input. We often lose
37 ourselves in our thoughts, decoupling experience from the here and
38 now (Baird et al., 2014). At other times we suddenly realize that we
39 have been looking at the world from the wrong perspective: many
40 famous visual illusions depend upon the resolution of uncertain percep-
41 tual input (Sterzer et al., 2009). These examples demonstrate that our
42 conscious experience of our surroundings does not depend solely on
43 the sensory information we receive at any moment in time, an observa-
44 tion that allows insight into the stimulus-independent basis of con-
45 scious perception. A popular way to study this dissociation between
46 sensory inputs and conscious experience is to use stimuli that are
47 ambiguous in their interpretation, and for which perception alternates
48 over time. Classic examples include binocular rivalry (Fig. 1a), in
49 which incompatible images shown to the two eyes compete for aware-
50 ness, and the Necker cube (see Fig. 1b), in which a wire-frame cube can
51 be perceived from multiple perspectives. Understanding the neural
52 architecture that mediates these alternations is considered a critical
53 step in uncovering neural correlates of consciousness (Crick and Koch,
54 1998).

Identifying the neural correlates of bistable perception by recording
online activity, however, may confound activity that is causally linked to
bistable alternations with activity that is merely correlated with it.
The finding that activity in a given brain region (e.g. frontoparietal cor-
tex Kleinschmidt et al., 1998; Lumer and Rees, 1999; Sterzer and
Kleinschmidt, 2007; Weilhhammer et al., 2013) correlates with percep-
tion does not reveal whether that region drives the alternations, or
reflects a consequence of processes occurring elsewhere. Carefully con-
trolling for the character of perceptual transitions has been shown to
dramatically reduce the number of brain regions that are viable candi-
dates for determining alternations (Knapen et al., 2011). Consequently,
it is still a matter of debate whether different forms of bistable stimuli
depend on bottom-up or top down influences, and which specific neural
systems support these aspects of conscious experience.

The current work capitalizes on the fact that stimulus-independent
changes in neural processing occur naturally during wakeful rest.
Neuroimaging has revealed that almost all functional networks that
support aspects of task related processing have a comparable resting
state network (Smith et al., 2009), and the integrity of these networks
varies across individuals in a manner that is predictive of complex
forms of cognition such as meta-cognitive accuracy (Baird et al., 2013),
spontaneous thought (Gorgolewski et al., 2014), reading comprehension
(Smallwood et al., 2013), and executive control (Reineberg et al., 2015).
As the neural activity at rest is uncontaminated by external input, it pro-
vides a relatively pure method to explore stimulus-independent neural

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Q1 **Fig. 1.** Example stimuli and summary of psychophysical results. (a) Binocular rivalry stimuli shown to the left and right eyes. The central gratings conflict and cause rivalry alternations, the surrounding Voronoi texture was used to encourage good binocular fusion. (b) Necker cube stimulus, shown binocularly. The wireframe cube can be interpreted from two different perspectives, which alternate over time. (c) Histograms of dominance durations for rivalry (green) and the Necker cube (red) across 26 participants. The individual epoch durations were normalized to the geometric (log) mean for their respective participant, then pooled across participants, and rescaled by the group mean. Both distributions show the positive skew typically observed for such stimuli. (d) Scatterplot showing the correlation ($r = 0.46$) between rivalry and Necker cube dominance durations for 26 participants. The blue diamonds indicate $\pm 1SD$ of each mean, and the red and green density plots show the distributions for each measure. The black line is the best fitting Deming regression line that minimised the absolute (geometric) distance between each point and the line, and the grey shaded region indicates bootstrapped 95% confidence limits of the regression.

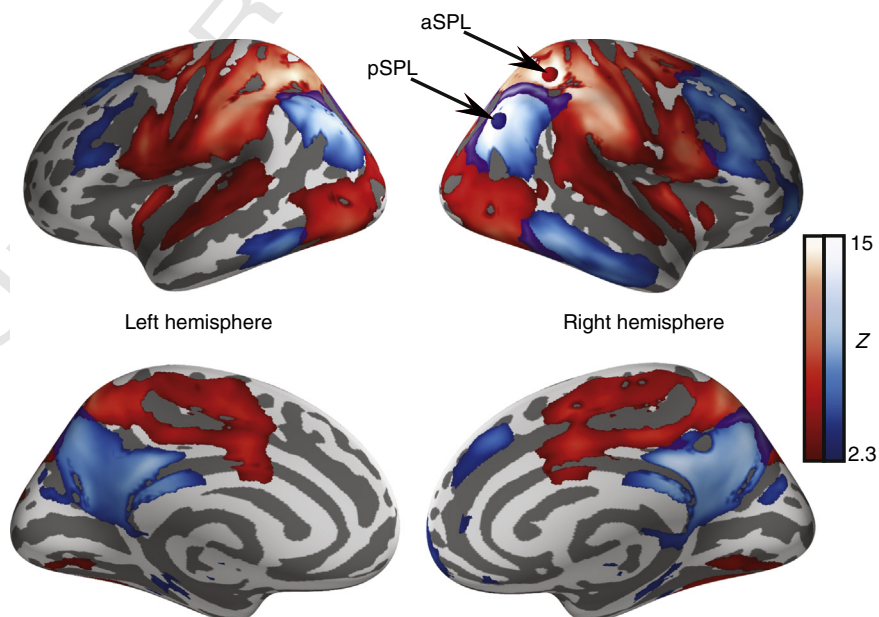


Fig. 2. Resting state networks derived from 141 participants. Seed regions were in the anterior superior parietal lobule (aSPL, red button, MNI coordinates: $x = 36, y = -45, z = 51$) and in the posterior superior parietal lobule (pSPL, blue button, MNI coordinates: $x = 38, y = -64, z = 32$) of the right hemisphere.

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