

**Background:** Humans engage in spontaneous Self-Generated Thought (SGT) up to 50% of the time, particularly when external task demands are low [1, 2]. Also referred to as mind wandering or day dreaming, SGT is characterized by an internal focusing of attention towards personally relevant thoughts, such as when reflecting on the past or planning for the future [1, 2]. In the brain, SGT has been most strongly associated with the Default Network (DN) [2, 3], though recent work has also implicated the Frontoparietal Network (FPN) [3, 4], particularly during periods of overtly goal-directed SGT [4].

**Preliminary Work:** Anecdotal reports of the phenomenology of SGT often describe periods of free-flowing thought (e.g. mind wandering) intermingled with periods of more overtly goal-directed cognition (e.g. future planning, self reflection, etc.). The existence of these two broad categories of thought during spontaneous SGT is corroborated by the results of a recent study in which we investigated individual differences in the content and quality of SGT [5]. Presented with a retrospective questionnaire after a 5 minute resting fMRI scan, some subjects reported their thoughts as being purposeful and directed, while others described their thoughts as free-flowing and undirected. Given evidence that spontaneous SGT may be experienced as more or less intentionally directed, a question arises as to the neural mechanisms responsible for directing SGT. Exploratory whole-brain analysis identified two regions whose activity was associated with these ratings, medial occipital cortex and right angular gyrus, the latter of which is often characterized as being part of the DN.

**Research Question:** Coordination between DN and FPC in support of goal-directed SGT has been observed in settings where subjects were asked to intentionally engage in a particular type of SGT (e.g. future planning) [4], but it is unclear whether these networks are similarly engaged during periods of spontaneous SGT, as it is possible that previously observed FPN activity may be due to the presence of explicit experimental instructions to engage in a particular kind of SGT. The proposed study will use thought sampling [3] and fMRI to investigate associations between the subjectively reported directedness of spontaneous SGT and activity in DN and FPN, and test the hypothesis that higher ratings of directedness will correlate with stronger connectivity between these networks.

**Experimental Paradigm:** To avoid potential confounds due to imposition of external task goals, the proposed study will utilize a resting-state paradigm. Once situated in the scanner, subjects will be presented with a screen instructing them to relax, keep their eyes open, and think about whatever comes to mind. Subjects will complete 16 resting scans of 3 minutes each. To ensure subjects do not fall asleep, an eye-tracker will be used to monitor compliance with these instructions, and blocks during which subjects close their eyes for an extended period will be discarded. At the end of each scan, subjects will immediately be asked to indicate on a 10 point non-numeric Likert scale the extent to which their thoughts were intentionally directed (Purposeful and directed / Free-flowing and undirected). The position (left/right) of the scale labels will be counterbalanced between subjects.

**MRI Protocol:** Imaging will take place at the University of Texas at Austin Imaging Resource Center using a 3T Siemens Skyra MRI. Functional images will be acquired using a multi-band EPI sequence with TR=1400ms and 2mm isometric voxels.

Anatomical images will be acquired at 1mm using a standard MPRAGE sequence.

**Data Analysis:** Standard preprocessing of functional and anatomical images will be carried out using CPAC [6]. For each scan session, we will extract the time series for DN and FPN using previously defined network maps [7]. We will then calculate the Pearson correlation between these time series to quantify inter-network connectivity. Correlation values and subjective ratings of directedness will then be entered into a GLM with age, sex, and head motion (Mean FD) as nuisance covariates. Contrasts will test for both positive and negative relationships between network connectivity and subjective ratings.

**Summary of Intellectual Merit:** Where thoughts come from and how they are directed is a fundamental question about the human mind. However, despite a rich literature on individual differences and dysfunction in regulatory control during task execution, relatively little work has been done to characterize these differences during spontaneous cognition, a ubiquitous type of thinking that occupies our mind up to 50% of the time. In an effort to better understand these issues, the proposed study will build on preliminary work to directly test an *a priori* hypothesis about the neural mechanisms responsible for the regulation of spontaneous self-generated thought.

**Summary of Broader Impacts:** Many debilitating psychiatric disorders involve an inability to regulate the occurrence and content of SGT. Previous work has associated the inability to suppress SGT during task execution with reduced anti-correlation between DN and executive networks. However, to our knowledge, no study has directly investigated the mechanisms involved in regulating the type of thought experienced during SGT. In many disorders (e.g. depression, anxiety, PTSD, schizophrenia), it is the content of SGT rather than its occurrence that people find most distressing [1]. Expanding our understanding of the factors responsible for regulating the content of thoughts during SGT will allow researchers and clinicians to better develop interventions and therapies that directly target distressing thought content while preserving other types of SGT that may play an adaptive role in daily life [1,2].

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