**Supplementary Video S1, Sample illustrations of simultaneously recorded phase field, vorticity (curl) field and phase vector field.** Left, sample single-trial instantaneous phase field. The colour map denotes phase values (in radians). Right, simultaneously recorded sample vorticity (curl) field overlaid with phase vector field of the same time. The colour map denotes vorticity (curl) values between -2 and 2. The grey vectors denote phase vector field.

**Supplementary Video S2, Rotational dynamics in task-evoked unfiltered fMRI signals of both hemispheres following math task onset.** Left, Zoomed-in view of the rotational dynamics in task-evoked unfiltered fMRI signals covering the posterior cingulate cortex (PCC), dorsal stream (DS) and superior parietal cortex (SPC) of the flattened left cortex, 0.72-14.4s after the math task onset. Right, same as left, but over the flattened right cortex. The colourmap denotes the min-max normalized unfiltered task-evoked fMRI signals averaged across trials. The white solid lines mark the boundaries separating twenty-two functional regions51.

**Supplementary Video S3, Side-by-side comparisons of task-evoked fMRI signals across different stages of filtering and flattening procedures following the math task onset.** Top row, Task-evoked unfiltered original fMRI signals over the flattened left cortex (left) and the inflated left cortex (middle and right). Middle row, Same as top row but in fMRI slow fluctuations (0.01-0.1Hz) after temporal bandpass filtering. Bottom row, Same as top row, but in spatially filtered fMRI slow fluctuations. The colourmap denotes the min-max normalized task-evoked fMRI signals averaged across trials.

**Supplementary Video S4, Side-by-side comparisons of task-evoked fMRI signals across different stages of filtering and flattening procedures following the story task onset.** Top row, Task-evoked unfiltered original fMRI signals over the flattened left cortex (left) and the inflated left cortex (middle and right). Middle row, Same as top row but in fMRI slow fluctuations (0.01-0.1Hz) after temporal bandpass filtering. Bottom row, Same as top row, but in spatially filtered fMRI slow fluctuations. The colourmap denotes the min-max normalized task-evoked fMRI signals averaged across trials.

**Supplementary Video S5, Correlated activations and deactivations of default mode network collectively coordinated by multiple brain spirals during math tasks.** Top row, Task-evoked fMRI slow fluctuations (0.01-0.1Hz) over the flattened left cortex (left), as well as zoomed-in views of rotational dynamics covering PCC/DS/PC (mid-left), IPC (mid-right) and LTC/MTC (right). The colour map denotes min-max normalized task-evoked fMRI slow fluctuations. The black and white circles approximate the centres of anticlockwise and clockwise rotational dynamics, respectively. The grey solid lines mark the boundaries separating seven functional networks59. Middle and bottom row, same as top row, but over the inflated left cortex.

**Supplementary Video S6, Correlated activations and deactivations of default mode network collectively coordinated by multiple brain spirals during story tasks.** Top row, Task-evoked fMRI slow fluctuations (0.01-0.1Hz) over the flattened left cortex (left), as well as zoomed-in views of rotational dynamics covering PCC/DS/PC (mid-left), IPC (mid-right) and LTC/MTC (right). The colour map denotes min-max normalized task-evoked fMRI slow fluctuations. The black and white circles approximate the centres of anticlockwise and clockwise rotational dynamics, respectively. The grey solid lines mark the boundaries separating seven functional networks59. Middle and bottom row, same as top row, but over the inflated left cortex.