Supplemental Information

Supplemental Figures

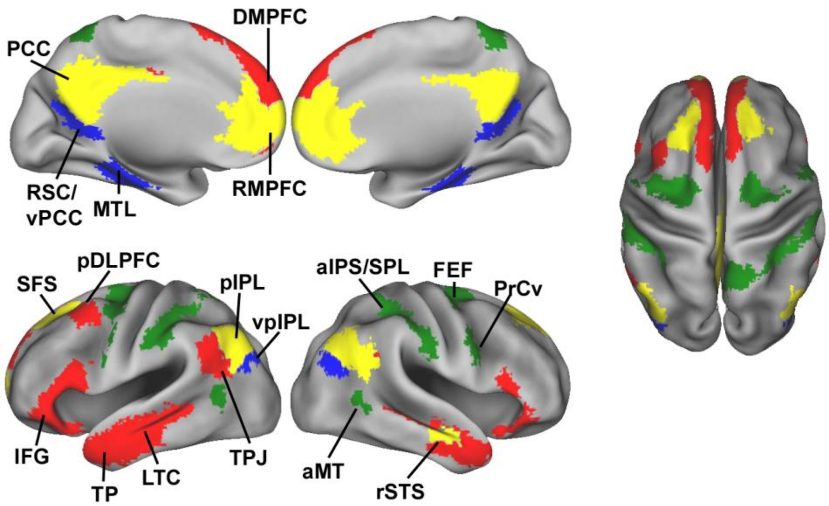

Figure S1. (Related to Figure 1) ROIs for the DAN and three DN subsystems. The ROIs were created by Yeo and colleagues (Krienen, Yeo, & Buckner, 2014; Yeo, Tandi, & Chee, 2015) based on their 17-network parcellation (Yeo et al., 2011). The DAN (green) included the frontal eye fields (FEFs), anterior intraparietal sulcus/superior parietal lobule (aIPS/SPL), ventral precentral cortex (PrCv), and anterior middle temporal region (aMT). The DN core subsystem (yellow) included the rostromedial prefrontal cortex (RMPFC), posterior cingulate cortex (PCC), posterior inferior parietal lobule (pIPL), superior frontal sulcus (SFS), and right rostral superior temporal sulcus (rSTS). The DN dorsomedial subsystem (red) included the dorsomedial prefrontal cortex (DMPFC), left temporoparietal junction (TPJ), temporopolar cortex (TP), lateral temporal cortex (LTC), inferior frontal gyrus (IFG), and left posterior dorsolateral prefrontal cortex (pDLPFC). The DN medial temporal subsystem (blue) included the medial temporal lobe (MTL; specifically the parahippocampal gyrus), retrosplenial cortex/ventral posterior cingulate cortex (RSC/vPCC), and ventral posterior inferior parietal lobule (vpIPL).

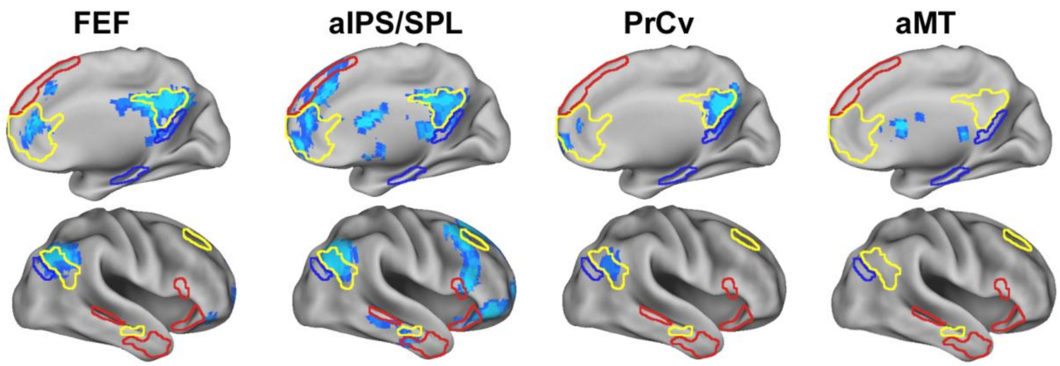

Figure S2. (Related to Figure 1). Seed-based connectivity analyses showing negative connectivity with DAN regions ($Z > 2.57$, $p < .05$ FDR corrected for cluster extent), with the borders of each DN subsystem highlighted. Data for right hemisphere. FEF, Frontal eye fields; aIPS/SPL, anterior intraparietal sulcus/superior parietal lobule; PrCv, ventral precentral cortex; aMT, anterior middle temporal region.

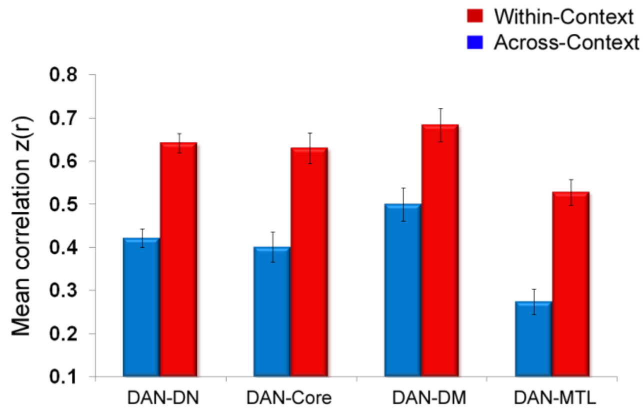

Figure S3. (Related to Figure 2). Mean within- and across-context similarity of anticorrelations. In this case, across-context similarity was based on comparing connectivity in adjacent conditions, thus ensuring that separation in time was not driving the lower across-context similarity. Across-context similarity was again low in this case indicating that the results reflect a true reconfiguration of DN-DAN interactions across contexts. DN, entire default network, DM, dorsomedial subsystem; MT, medial temporal subsystem. Error bars reflect within-subject SEM (Loftus & Masson, 1994).

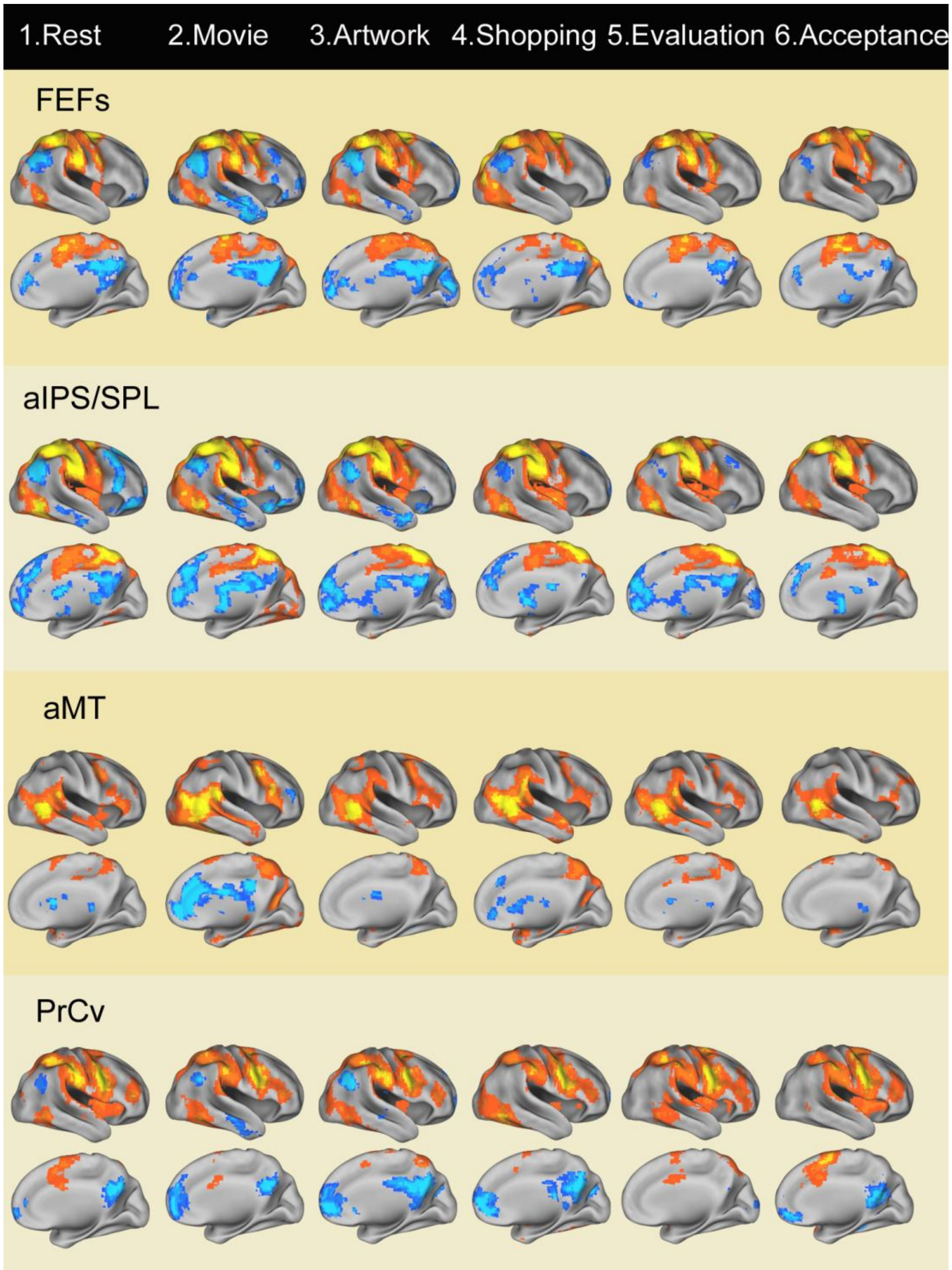

Figure S4. (Related to Figure 4). Positive and negative connectivity for each DAN seed region, for each context. Anticorrelations flexibly increased and decreased in different cognitive contexts relative to rest ($Z > 2.57$, $p < .05$ FDR cluster corrected). Data for right hemisphere. FEF, Frontal eye fields; aIPS/SPL, anterior intraparietal sulcus/superior parietal lobule; PrCv, ventral precentral cortex; aMT, anterior middle temporal region.

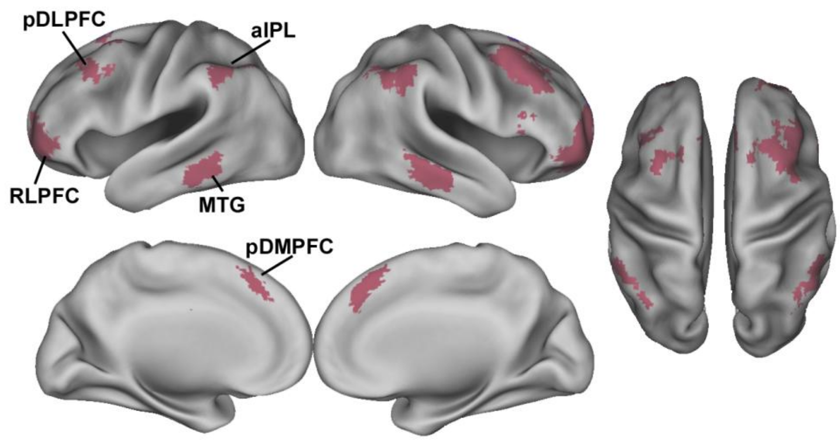

Figure S5. (Related to Figure 6) ROIs for the frontoparietal control network. The ROIs were created by Yeo and colleagues (Krienen, et al., 2014; Yeo, et al., 2015) based on their 17-network parcellation (Yeo, et al., 2011) and included the rostrolateral prefrontal cortex (RLPFC), posterior dorsolateral prefrontal cortex (pDLPFC), anterior inferior parietal lobule (aIPL), posterior dorsomedial prefrontal cortex (pDMPFC), and middle temporal gyrus (MTG).

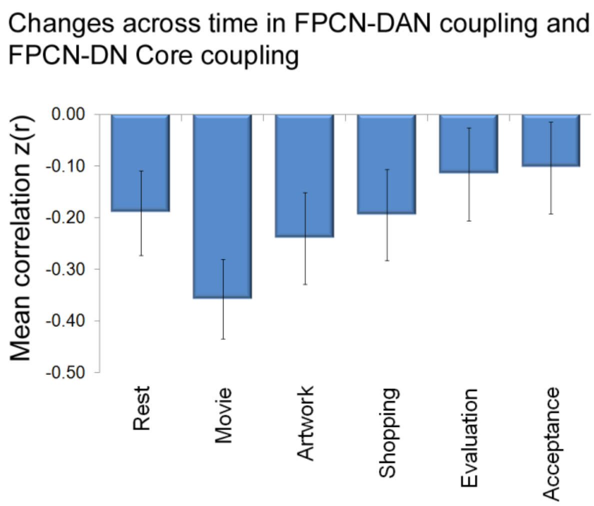

Figure S6. (related to figure 6). Temporal fluctuations in FPCN-DAN coupling were negatively correlated with FPCN-Core coupling in four of six contexts (rest: $p = .029$; movie: $p < .001$; artwork: $p = .012$; shopping: $p = .038$; evaluation-based introspection: $p = .21$; acceptance-based introspection: $p = .26$). When the FPCN is more coupled with the DN Core it becomes more anticorrelated with the DAN. Error bars reflect between-subject SEM.

Supplemental Experimental Procedures

Participants. Participants were 24 healthy adults (Mean age = 30.33, SD = 4.80; 10 female; 22 right handed), with no history of head trauma or psychological conditions. This study was approved by the UBC clinical research ethics board, and all participants provided written informed consent, and received payment ($20/hour) for their participation. Due to a technical error, data for the movie and acceptance-based introspection conditions were not collected for one participant (S04). At the end of scanning, one participant (S01) reported experiencing physical discomfort throughout the scan. Similar results were obtained with our without inclusion of this participant's data.

Experimental Task Conditions. Each participant performed six task conditions in separate six-minute fMRI runs:

(1) *Resting state.* Participants lay in the scanner with their eyes closed and were instructed to relax and stay awake, and to allow their thoughts to flow naturally.

(2) *Movie watching*. Participants watched a clip from the movie *Star Wars: Return of the Jedi*. The clip is the climactic scene in which Luke Skywalker engages in a light-saber duel with Darth Vader, and tries to convince him to return to the light side. This clip involves dynamic whole-body goal-directed actions and is emotionally evocative. We instructed participants to pay attention to the actions of the characters, and also to what they may be thinking and feeling. We presented the clip without sound inside the scanner so that participants would not have to effortfully attend to the clip while ignoring the scanner noise. One week prior to scanning, we asked all participants to watch the film clip to ensure that they were equally familiar with the clip, including the conversation between the characters.

(3) *Artwork analysis*. Participants viewed four pieces of artwork in the scanner, each for 90 seconds. These pieces were selected by participants from a large collection prior to scanning. They were instructed to select pieces that they found personally meaningful and would enjoy looking at in the scanner. During scanning, participants received the following instructions: “as you view each picture, please try to pay attention to two things: (i) the perceptual details of the art; and (ii) your inner experience (i.e., thoughts and feelings). In particular, think about what the image means to you personally; for example, think about whether it symbolizes or reminds you of a time in your life, or an experience you may have had, or something about yourself. Just allow yourself to continuously analyze what the image means to you, and notice the feelings that arise as you look at the pictures.”

(4) *Shopping task*. While in the scanner, participants viewed a pre-recorded video shot from a first-person perspective of items within several stores in a shopping mall. They received the following instructions: “you are going to view a video of items from several stores in a mall. Try to imagine that it is you going through the mall in order to find a birthday gift for a friend. Think of a specific male friend that you will pick out a present for. As you look at each item, think about whether it would be a suitable birthday gift based on the preferences of your friend. If you find a good gift before the video is over, keep paying attention to each item and think about whether your friend would or would not like that item. Imagine that you and several friends and pooling your money together and getting one single gift, so you have a fair amount of money to spend. The important point is that for every item you look at, you think about whether it would make a good gift based on your friend's preferences. ”

(5) Evaluation-based introspection. We asked participants to engage in a type of introspection characterized by evaluative/narrative processing. Participants were asked to think about a mildly upsetting issue involving a specific person in their life (e.g., a friend, roommate, sibling, or partner). We asked participants to engage in an evaluative mode of introspection for the duration of the 6-minute run with the following instructions: “ I would like you to reflect on an aspect of this person's personality or an interaction with them that was mildly upsetting; something that you find difficult to accept and wish were different. As you think about this person and situation, reflect on why this situation is upsetting to you, why the person is the way they are, who caused the situation and why, what has happened in the past to lead up to this point in your relationship, and what might happen going forwards into the

future—how things might get worse or better. Think about how you would feel if things with this person were different. As you think about this topic, allow yourself to become fully caught up in your thoughts and emotions. Try to think about what the person and situation means to you, and what aspects are good or bad. Analyze whether you like or dislike the feelings associated with this situation. Analyze why you think the person is the way they are." Thus, this type of introspection involves reflection on life events within a narrative that links past, present, and future, and the cognitive elaboration and evaluation of those events based on personal preferences. Participants were instructed to keep their eyes closed, but were told that they could open their eyes if they needed a reminder of the instructions (short sentences capturing the essence of the instructions were presented on the screen). Prior to scanning, participants were asked to select the person/situation that they would think about, and were given an overview of the instructions, and asked if they understood how to adopt this mode of introspection. Then just prior to this scanning run, detailed instructions were provided, and participants were asked to engage in this specific type of introspection for the entire duration of the scan.

*(6) Acceptance-based introspection***.** We asked participants to engage in a type of introspection inspired by contemporary mindfulness/acceptance-based treatment techniques. This type of introspection focuses on cultivating a present-centered awareness, grounded in the acceptance of moment-to-moment viscero-somatic sensations. In other words, the goal is to fully notice and experience arising thoughts and emotions with acceptance, and without any elaborative mental analysis or judgment. In this condition, participants were asked to reflect on the same upsetting issue as in the case of the evaluation-based introspection condition, but this time, received the following instructions: "In this condition, please think about the same upsetting issue (same person and situation), but this time, do your best to avoid any type of mental analysis of the situation. Instead, as you hold this person in your mind, try to pay attention to the feelings of your body in the present moment. For example, as you think of this person, notice whether your heart starts to beat faster, or whether your body becomes tense or relaxed, and notice how you are breathing. Try your best to stay with the feelings of your body as they come and go. When thoughts or feelings arise, try to observe them and then let them go. Think of your thoughts and feelings as waves that emerge and then disappear back into the ocean. Try not to analyze your thoughts and feelings as good or bad and try not to think about the cause of the situation or what might happen in the future. Just keep returning to the sensations of your body in the present moment, and allow yourself to experience them fully, whatever they are. Whenever you notice that you have become caught up in a train of thought or you start to analyze your experience, that is totally okay; just calmly re-focus on how your body is feeling in the present moment. There is no specific goal or purpose other than noticing what you are thinking and feeling from one moment to the next." Participants were instructed to keep their eyes closed, but were told that they could open their eyes if they needed a reminder of the instructions (short sentences capturing the essence of the instructions were presented on the screen). Prior to scanning, participants were given an overview of the instructions, and asked if they understood how to adopt this mode of introspection. Then just prior to this scanning run, detailed instructions were provided.

*Task Order***.** Task order was held constant to optimize psychological state. The introspection conditions were placed at the end so that participants would not continue thinking about the upsetting issue and engaging in mind wandering during the other tasks. Furthermore, because acceptance-based evaluation requires an inhibition of the default tendency to engage in evaluative/narrative processes (Farb et al., 2007), we placed this condition after evaluation-based introspection. Given that the task conditions were completely different and did not require responses, there was no concern about practice effects. The transition from waking to sleep is associated with attenuated DN-DAN anticorrelations (Larson-Prior et al., 2011), however, critically, before each of the six conditions we stressed to participants that they should remain as alert as possible, and they reported that they did so (this was confirmed through post-scanning questions regarding attention and the content of each condition). Furthermore, we designed our conditions to be engaging, and importantly, not a single participant exhibited a linear change in DN-DAN connectivity across the six contexts. In fact, Figure 4 reveals that changes in connectivity across context are region specific, and vary in direction (anticorrelations may increase or decrease); no global patterns emerged, suggesting that a general factor such as fatigue cannot account for our findings. Thus, we suggest that our results reflect a true difference in connectivity specifically driven by each context.

Preprocessing. Image preprocessing and analysis were conducted with Statistical Parametric Mapping (SPM8, University College London, London, UK; http://www.fil.ion.ucl.ac.uk/spm/software/spm8). The time-series data were slice-time corrected (to the middle slice), realigned to the first volume to correct for between-scan motion (using a 6 parameter rigid body transformation), and coregistered with the T1-weighted structural image. The T1 image was bias-corrected and segmented using template (ICBM) tissue probability maps for gray/white matter and CSF. Parameters obtained from this step were subsequently applied to the functional (re-sampled to 3 mm^3 voxels) and structural (re-sampled to 1 mm^3 voxels) data during normalization to MNI space. The data were spatially-smoothed using an 8-mm^3 full-width at half-maximum Gaussian kernel to reduce the impact of inter-subject variability in brain anatomy.

To address the spurious correlations in resting-state networks caused by head motion, we identified problematic time points during the scan using Artifact Detection Tools (ART, www.nitrc.org/projects/artifact_detect/). Images were specified as outliers according to the following criteria: translational head displacement greater than .5 mm from the previous frame, or rotational displacement greater than .02 radians from the previous frame, or global signal intensity > 4 standard deviations above the mean signal for that session. The mean number of identified outliers was 4.93 (range: 0 - 15) and did not differ across conditions ($p > .4$). Each participant had at least 5.3 minutes of non-outlier time points. Outlier images were not deleted from the time series, but rather, modeled in the first level general linear model (GLM) in order to keep intact the temporal structure of the data. Each outlier was represented by a single regressor in the GLM, with a 1 for the outlier time point and 0 elsewhere.

Using the 'CONN' software (Whitfield-Gabrieli & Nieto-Castanon, 2012), physiological and other spurious sources of noise were estimated and regressed out using the anatomical CompCor method (Behzadi, Restom, Liau, & Liu, 2007). Global signal regression was not used due to fact that it mathematically introduces negative correlations, and renders the results difficult to interpret (Murphy et al., 2009). The normalized anatomical image for each participant was segmented into white matter (WM), gray matter, and CSF masks using SPM8. To minimize partial voluming with gray matter, the WM and CSF masks were eroded by one voxel. The eroded WM and CSF masks were then used as noise ROIs. Signals from the WM and CSF noise ROIs were extracted from the unsmoothed functional volumes to avoid additional risk of contaminating WM and CSF signals with gray matter signals. The following nuisance variables were regressed out: three principal components of the signals from the WM and CSF noise ROIs; head motion parameters (three rotation and three translation parameters) along with their first-order temporal derivatives; each artifact outlier image; linear trends. A band-pass filter (0.009 Hz $< f <$ 0.10 Hz) was simultaneously applied to the BOLD time series during this step.

Subsystem analysis. To examine interactions between the DAN and each DN subsystem, we first extracted the mean timeseries from each of 32 ROIs spanning the DAN and three DN subsystems. The residual timeseries (following nuisance regression) for each ROI was used to compute condition-specific correlation matrices consisting of all node-to-node connections. After Fisher r-to-z transforming the correlation values, we averaged the z(r) values reflecting pairwise connections between the DAN and each subsystem. This yielded a single value reflecting the relationship between the DAN and each DN subsystem for each participant. This approach was advantageous over correlating signal from entire network/subsystem ROIs because it ensured that larger regions were not disproportionately driving the results. Average connectivity was computed separately for the left and right hemispheres and then averaged, given the similar results. The resulting values were submitted to a one-way repeated measures analysis of variance (ANOVA), with subsystem as the factor.

Similarity Analysis. For each participant, we extracted and vectorized all between-network correlations (i.e., all pairwise correlations between each DAN region and each DN region). After applying a Fisher's r-to-z-transform, we used the Pearson correlation as a measure of the similarity of the connectivity vectors for each pair of contexts.

These correlation values were Fisher transformed and averaged, to arrive at a single value reflecting the similarity of connectivity across contexts. To examine the similarity of within-context connectivity, we first computed correlation matrices for the early period (first three minutes) and late period (last three minutes) of each condition, and then extracted and vectorized the relevant between-network correlations, applied a Fisher's r-to-z-transform, and computed the Pearson's correlation on the resulting early and late vectors of FC values. This was done for each context separately, and then we fisher r-to-z transformed the correlation values, and averaged across contexts to arrive at a single value reflecting the similarity of connectivity within each context. We performed these analysis steps separately for the left and right hemispheres, and then averaged across them, given the nearly identical results.

Ruling out motion as a confound.

We attempted to limit the possibility that motion may influence functional connectivity values through several preprocessing steps noted above (i.e., regressing out outlier time-points, as well as timeseries signals from the white matter and ventricles). Nevertheless, motion may still have an impact, and we thus conducted control analyses to ensure that motion could not explain our results. We examined total motion (TM) and framewise displacement (FD). Both TM and FD were very similar across contexts. On average, participants exhibited less than 1 mm in TM within each context (rest: 0.88 mm; movie viewing: 0.88 mm; artwork analysis: 0.68 mm; shopping task: 0.75 mm; evaluation-based introspection: 0.99 mm; acceptance-based introspection: 1.04 mm). TM did not differ across contexts [$F(5, 110) = 1.82$, $p = .12$]. Average FD was also very small within each context (rest: 0.17 mm; movie viewing: 0.14 mm; artwork analysis: 0.14 mm; shopping task: 0.15 mm; evaluation-based introspection: 0.16 mm; acceptance-based introspection: 0.19 mm). FD did show a difference across contexts [$F(5, 110) = 4.64$, $p = .001$] due to less displacement during movie viewing and artwork analysis relative to rest (*p*s < .05). However, the actual differences in movement between conditions were extremely small. Next, we examined whether the amount of variation in movement across contexts was correlated with the amount of variation in DAN-DN connectivity strength. Notably, in all cases there was no relationship or a negative relationship, indicating that those participants that showed the greatest change in DN-DAN connectivity across contexts were the ones that exhibited the *least* amount of movement across contexts. After removing one outlier (> 2 SD from mean), we found no relationship or a negative relationship between connectivity variability and TM variability (DAN-Core left: $r = -.36$, $p = .09$; DAN-Core right: $r = -.39$, $p = .059$; DAN-dorsomedial subsystem left: $r = -.52$, $p = .01$; DAN-dorsomedial subsystem right: $r = -.12$, $p = .58$; DAN-medial temporal subsystem left: $r = -.03$, $p = .89$; DAN-medial temporal subsystem right: $r = -.23$, $p = .28$), and no relationship or a negative relationship between connectivity variability and FD variability (DAN-Core left: $r = -.49$, $p = .02$; DAN-Core right: $r = -.06$, $p = .78$; DAN-dorsomedial subsystem left: $r = .04$, $p = .85$; DAN-dorsomedial subsystem right: $r = .01$, $p = .96$; DAN-medial temporal subsystem left: $r = -.15$, $p = .48$; DAN-medial temporal subsystem right: $r = -.18$, $p = .40$). Thus, motion was generally associated with less influence of context on connectivity strength. To probe deeper, we looked more specifically at whether the change (Δ) in motion from one context to the next was correlated with change (Δ) in functional connectivity strength from one context to the next. Of 36 correlation analyses performed (3 subsystems x 2 hemispheres x 5 context changes), there was no significant associations between ΔTM and Δfunctional connectivity at a liberal $p < .05$ uncorrected threshold. Furthermore, of 36 correlation analyses performed, there was only one significant associations between ΔFD and Δfunctional connectivity at a liberal $p < .05$ uncorrected threshold (DAN-medial temporal subsystem right: $r = .52$, $p = .01$). These analyses provide robust evidence that the effect of context on functional connectivity was not driven by motion.

Supplemental References

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