WITHIN-TASK CODING OF HEADING AND LOCATION.

In the main text, we report that it was possible to cross-decode location and heading between the picture and verbal versions of the JRD task. Because the stimuli in the two versions of the task are very different, these cross-decoding results strongly suggest that the brain regions thus identified support abstract spatial codes. Here we examine spatial coding *within* each task. This analysis allows us to test for spatial codes that are specific to each task but do not generalize across tasks, and it also allows us to compare the strength of the effects across task.

Before describing these results, it is important to consider three caveats that restrict our interpretations. First, the activity patterns used for these analyses are necessarily noisier than those in the previous analyses because the patterns must be estimated from individual scan runs rather than from all three scan runs used for each version of the JRD task. This reduces the number of trials used to estimate each activity pattern by two-thirds. Second, because our stimulus sequences were only balanced for carryover effects over the length of an entire task version rather than within each scan run, these activity patterns are not wholly independent of the carryover effect of the previous trial (see (Aguirre 2007)), adding more noise to the pattern estimate. (Note that this does not introduce bias to the pattern estimates because we used a unique stimulus sequence for each task version for each participant.) Finally, trials from runs of the same task version were not controlled for low-level visual similarity. Photographs facing the same view, even if not exactly the same, are by necessity very visually similar, and photographs from the same location or facing the same heading may have visual regularities, as we have previously noted (Vass and Epstein 2013). Verbal stimuli for trials for the same view necessarily shared two words (indicating the location and the heading), while trials from the same location necessarily shared one word (indicating that location). As a consequence, positive effects could potentially be explained by visual similarity rather than spatial coding.

Indeed, examination of the results indicated that the strongest effects, as expected, were similarities across trials corresponding to the same view (Figure S2). Specifically, the pattern similarities were greater for the SL-SH-SR and SL-SH-DR conditions than for the other conditions, which were the two conditions in which view (i.e. both location *and* heading) was the same. To confirm this view effect, we ran Location x Heading x Response ANOVAs (2x2x2) within each task. RSC exhibited a significant interaction between Location and Heading in the verbal task (F(1,15)=6.4, P=0.02) and the picture task (F(1,15)=6.5, P=0.02), whereas PPA exhibited a significant interaction in the picture version of the task (F(1,15)=32.8, P=0.00004), but not the verbal version (F(1,15)=1.8, P=0.20). Thus, our results indicate that PPA and RSC coded specific viewpoints within the picture task, consistent with our previous findings (Vass & Epstein, 2013). Moreover, RSC coded viewpoint in the verbal task, but the view effect during this task in PPA was not reliable. Notably, these view representations did not appear to generalize across the two versions of the task, as this effect was not observed in the cross-tasks analyses (compare Figure S2 to Figure 3). This lack of generalization may reflect the fact that there was no exact correspondence of views across tasks, because the landmarks used to define heading in the verbal task were not always visible in the photographs used in the picture task.

We next moved on to examine effects of location and heading in the PPA and RSC. We restricted all analyses of location coding to trials facing different headings and all analyses of heading coding to trials from different locations. This ensured that location and heading effects could not be attributed to the highly significant effect of view. For each region, we performed two sets of analyses. First, we performed Location x Response and Heading x Response ANOVAs, constrained as described above, to test for spatial coding within each task. Second, we tested whether the strength of spatial coding differed between tasks by performing Task x Location x Response and Task x Heading x Response ANOVAs.

When we tested for spatial coding in RSC within each task, we found that the effects were consistent with those observed in the cross-task analyses. In the Heading x Response ANOVAs, RSC showed a main effect of heading in the Picture task (F(1,15) = 19.7, P=0.0005) and a marginal effect in the Verbal task (F(1,15) = 3.2, P=0.09); there were no effects of response. Although the heading effect in RSC was numerically stronger in the picture task than in the verbal task, this difference was not significant (Task x Heading interaction effect: F(1,15)=1.9, P=0.19). In the Location x Response ANOVAs, we observed a marginal effect of location in the Verbal task (F(1,15) = 4.4, P=0.054), but no effect in the Picture task (F(1,15) = 1.4, P=0.26). The difference in the strength of the location effect between tasks was not significant (Task x Location interaction effect: F(1,15)=0.04, P=0.84).

When we broke the heading coding in RSC down by direction, we found evidence for preferential coding of North, as we did in the cross-task analysis. Direction indices (see main text) were significant for North (Picture: t(15) = 3.4, P < 0.001; Verbal: t(15) = 1.3, P = 0.046), but other headings were marginal (East Picture: t(15) = 1.0, P = 0.07; Verbal West: t(15) = 0.8, P = 0.08) or not significant (all other Ps > 0.11).

When we tested for spatial coding in PPA within each task, we found that the effects were again consistent with those observed in the cross-task analyses (Figure S2). In the Location x Response ANOVAs, we observed a significant main effect of Location in the Picture task (F(1,15) = 9.0, P=0.009) and a marginal effect in the Verbal task (F(1,15) = 3.1, P=0.098). Again, despite the numerically stronger effect in the location task, the difference between tasks was not significant (Task x Location interaction effect: F(1,15)=1.1, P=0.31). We did not observe coding of Heading in the PPA in either task (Picture: F(1,15) = 0.7, P=0.41; Verbal: F(1,15) = 0.3, P=0.59).

When we broke the location coding in the PPA down by location, we observed significant location indices in the Picture task for locations 1, 2, and 4 (ts > 1.5, Ps < 0.02), and significant coding of location 4 in the Verbal task (t(15) = 2.1, P = 0.02; all other Ps > 0.28). Although it is unclear why patterns that were not distinguishable within-task should be consistent with location-specific patterns in a different task, the noisiness of the patterns in these analyses makes it difficult to determine whether any potential differences are meaningful.

In summary, when we separately interrogated spatial coding within each version of the task, we found results that were somewhat noisier, as expected, but generally consistent with those observed in the cross-task analyses. RSC coded for the heading instantiated during the JRD, and PPA coded for the starting location of the JRD. Although there was some indication that effects were numerically stronger in the picture version of the task, these differences were not significant. Moreover, as expected, we observed a significant effect of view.

References

Aguirre GK. 2007. Continuous carry-over designs for fMRI. Neuroimage 35:1480-1494.

Vass LK, Epstein RA. 2013. Abstract representations of location and facing direction in the human brain. J Neurosci 33:6133-6142.

Captions to Supplemental Figures

**Figure S1.** Within-task multivoxel pattern correlations in PPA and RSC. Within-task pattern similarities in PPA and RSC were generally consistent with effects observed in the cross-task analyses (see Figure 3), with RSC exhibiting higher pattern similarity for JRDs sharing the same heading and PPA exhibiting higher pattern similarity for JRDs sharing the same starting location. Beyond this, JRDs corresponding to the same view (i.e. the same combination of starting location and heading) had an additional degree of similarity in both regions, an effect that was not observed in the cross-task analyses.

**Figure S2.** Multivoxel pattern correlations in medial temporal lobe regions of interest. Pattern similarity in the displayed medial temporal regions (anterior and posterior hippocampus, presubiculum, PRC) did not significantly vary as a function of shared location or heading across JRDs.