Supplementary Materials

The integration of information from two landmarks on the Reversal test

Results. The distribution of signed deviation on the Reversal test for each group were shown in Figure S1. The responses spread in a wide range into three sections. Based on the locations of two landmarks, we divided the possible responding region (from -240 to 360 px, where the original goal location was at 40 px) into three sections: 1) from -240 px to the reliable cue (-80 px), which includes g_R, 2) from the reliable cue to the unreliable cue (120 px), which includes g_I and g_L, and 3) from the unreliable cue to 360 px, which includes g_U. Most extreme responses outside this region [-240, 360] were excluded. The proportions are 0.14% of all responses in Group T-H, 0.15% in Group T-V, 0% for Group T-many, 0.17% for Group S-few, and 0.32% for Group S-many. The responses around g_R and g_U suggest the independent use of each landmark while the responses around g_I and g_L suggest the integrative use of two landmarks. Accordingly, we classified people's responses into three strategies--*Independent Reliable* (IR), *Integrated in the Middle* (IM) and *Independent Unreliable* (IU)—and counted the responding frequency by each strategy. Both IR and IU were seen as independent strategies, therefore the frequencies of IR and IU were combined in analyses.

[Figure S1]

Figure S2 shows the percentages of responses by each strategy for each group. To compare the use of integrative strategy (IM) and independent strategies (IR and IU), we conducted a Chi-square test for each group separately.

[Figure S2]

For Experiment 1, the responses by IM were more than those by IR and IU both for Group T-H [$\chi^2(1, n = 701) = 62.31, p < .001$] and for Group T-V [$\chi^2(1, n = 656) = 96.81, p$

< .001]. Furthermore, the frequencies of using strategies was not related to groups [$\chi^2(1, n = 1357) = 2.83, p = .092$].

For Experiment 2, a Chi-square test was conducted and showed that the three groups were significantly different in searching patterns [$\chi^2(2, n = 1840) = 119.67, p < .001$]. Group T-many showed more responses by IM than by IR and IU [$\chi^2(1, n = 585) = 26.71, p < .001$]. However, the other two groups without Both-cue condition in training did not show this pattern; both Group S-few [$\chi^2(1, n = 627) = 44.48, p < .001$] and Group S-many [$\chi^2(1, n = 628) = 87.19, p < .001$] more often used independent strategies than integration strategy, although a difference was found between these two groups [$\chi^2(1, n = 1255) = 3.95, p = .047$].

We also conducted a Chi-square test to compare Group T-many with Group T-H in Experiment 1. As predicted, the response patterns on the Reversal test in Group T-many was identical to that in Group T-H in Experiment 1 [$\chi^2(1, n = 1286) = 2.44, p = .118$].

Discussion. In Experiment 1, the similar results in both groups suggest that the integrative strategy (IM) appears to be generally preferred regardless of screen orientation. When the directional information was distorted but the distance information remained the same, participants frequently compromised and responded between the landmarks rather than outside the array. The results suggest that the information from two landmarks was more often integrated than used independently. In Experiment 2, Group T-many responded most between the two landmarks, which is similar to Experiment 1, but the other two groups without Both-cue condition in training more often used independent strategies and searched almost equally often to left of, to the right of, or within the landmark array. The different response patterns in Experiment 2 suggest that the integration of information was unlikely to occur if the information was encoded separately in learning. Furthermore, extra training with single landmarks (Group S-

many) did not increase responses in the middle section by IM. For participants trained only with single landmarks, the integrative strategy was not preferred when landmarks provided conflicting directional information. Consistent with the findings on shift trials, the co-occurrence of two cues in encoding phase is essential for the integration of both distance and directional information for the goal location. This extends the existing findings about cue integration of distance information to directional information in at least one dimension.

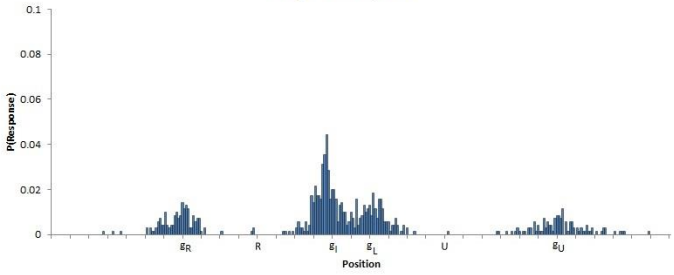
Individual participant's search response on the shift tests

The search response of individual participants (mean SD and mean rp_R) on the shift tests are shown in Figure S3. Since each test type only contained five trials, we did not compare the SD on the single tests with the SD on the shift tests individually.

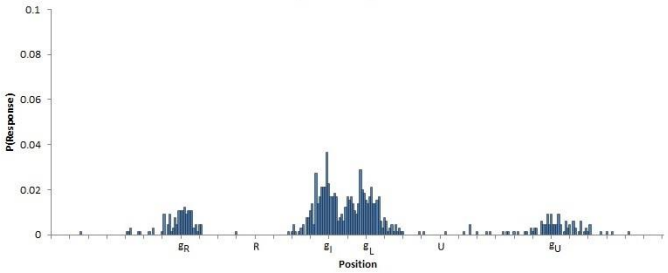
For Groups T-H, T-V and T-many, most of the responses showed smaller SD than that on the single cue tests, which suggests variance reduction in most participants. Most of the responses also showed a relative proximity to the reliable landmark greater than 0.5, which suggests a heavier weighting on the reliable landmark.

In contrast, for Groups S-few and S-many, most of the responses showed larger SD than that on the single cue tests, which suggests that there was no variance reduction in most participants. There was no clear central tendency for the relative proximity to the reliable landmark, which suggests a searching mode with random noise in the group.

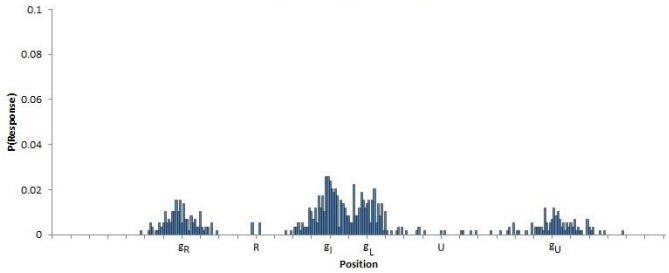
Exp 1 Group T-H



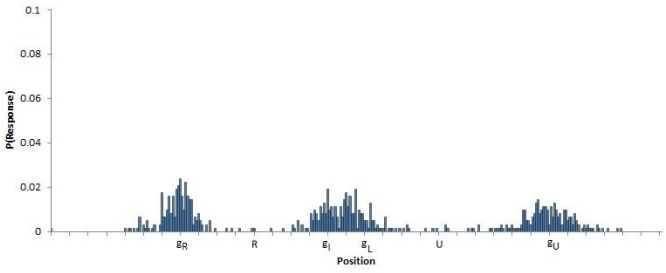
Exp 1 Group T-V



Exp 2 Group T-many



Exp 2 Group S-few



Exp 2 Group S-many

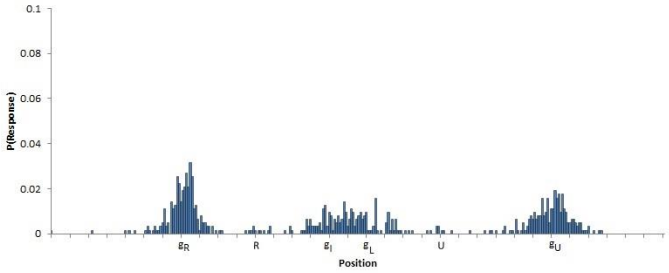


Figure S1. Distributions of response locations on the Reversal test for each group. The x axes correspond to the line shown in experiments. *G* indicates the original goal location. *R* and *U* indicate the locations of reliable landmark and unreliable landmark after switching respectively. g_R indicates the goal location predicted by the reliable landmark alone. g_U indicates the goal location predicted by the unreliable landmark alone. g_L indicates the goal location predicted by two landmarks but ignored their identity. g_I indicates the goal location predicted by two landmarks but ignored their switched directions.

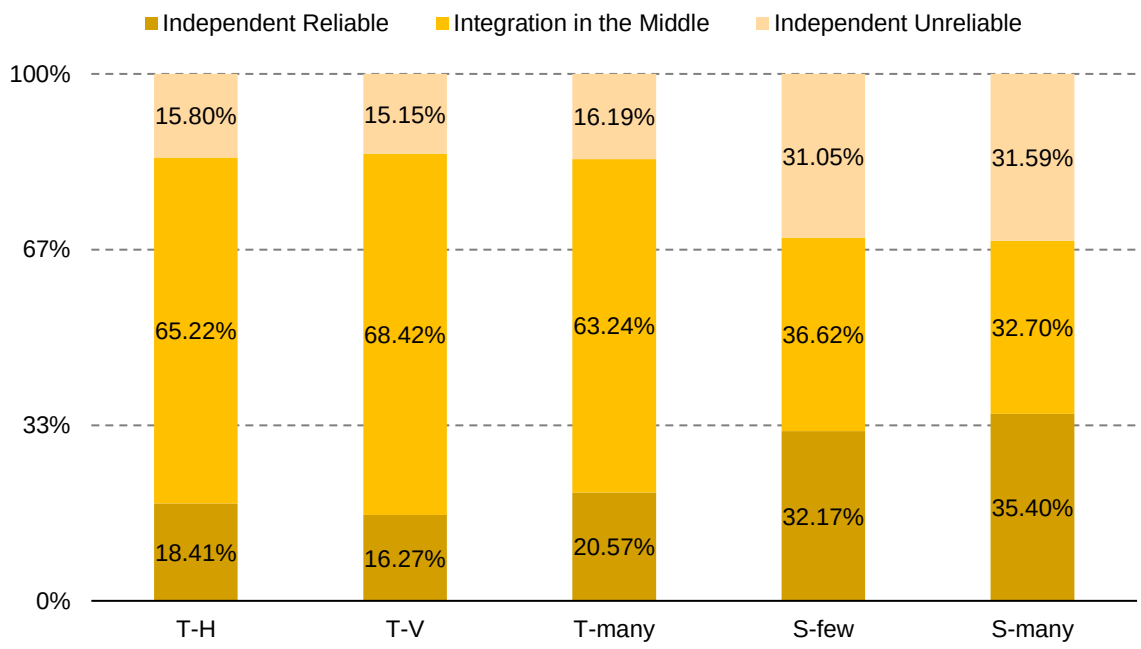


Figure S2. Percentages of responses by different strategies on the Reversal test for each group.

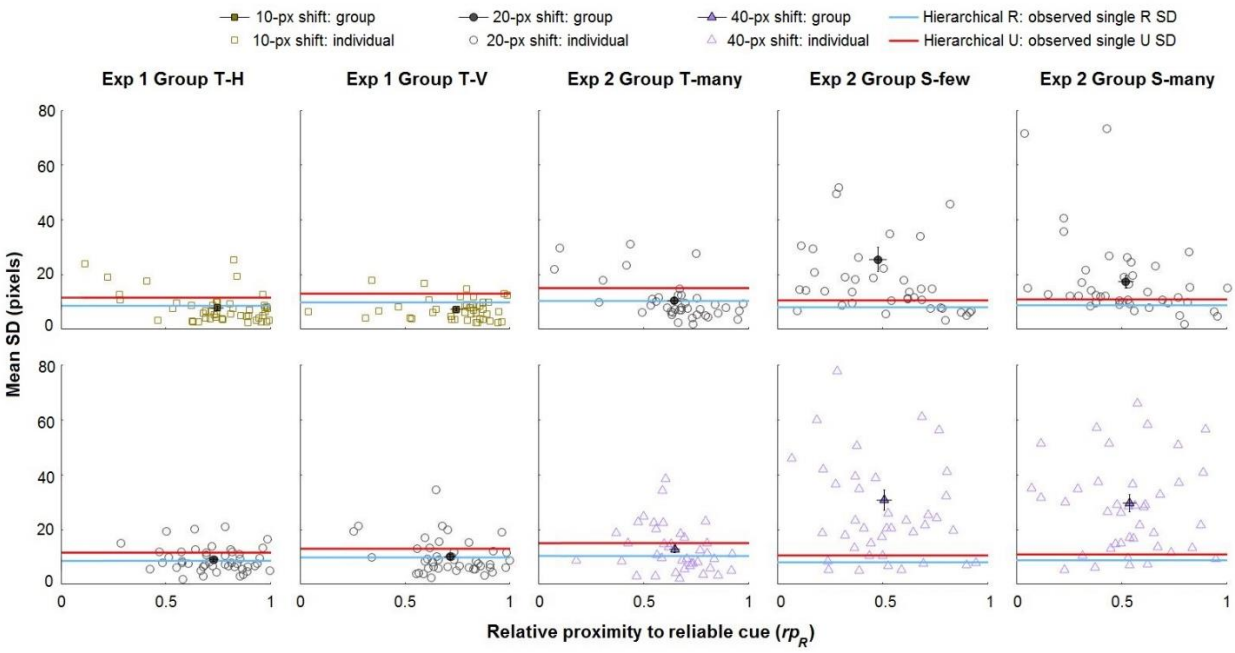


Figure S3. Observed mean SD of signed deviation for individual participants and for the whole group on the shift tests. The *x* axes correspond to greater reliance on the reliable landmark, from left to right. The empty points represent observed mean SDs and mean rp_R for individual participants (brown square: 10-px shift; black circle: 20-px shift; purple triangle: 40-px shift). The filled points represent observed mean SDs and mean rp_R of the group on shift tests. Error bars represent standard errors of the mean.