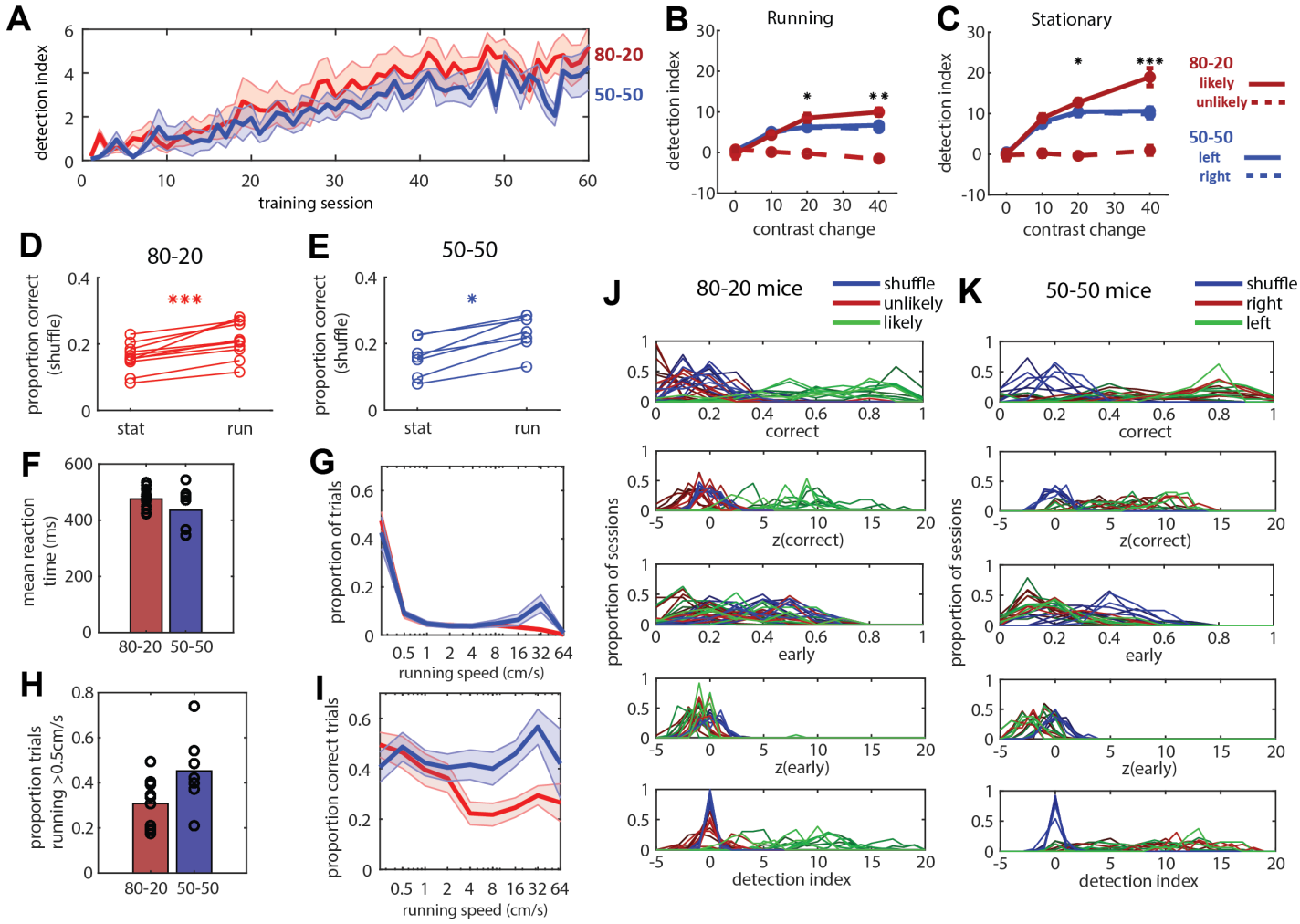
A
detection index
training session
80-20
50-50
B
Running
detection index
contrast change
C
Stationary
detection index
contrast change
80-20
likely
unlikely
50-50
left
right
D
80-20
proportion correct (shuffle)
stat
run
E
50-50
proportion correct (shuffle)
stat
run
F
mean reaction time (ms)
80-20 50-50
G
proportion of trials
running speed (cm/s)
H
proportion trials running >0.5cm/s
80-20 50-50
I
proportion correct trials
running speed (cm/s)
J
80-20 mice
shuffle
unlikely
likely
correct
z(correct)
early
z(early)
detection index
proportion of sessions
K
50-50 mice
shuffle
right
left
correct
z(correct)
early
z(early)
detection index
proportion of sessions

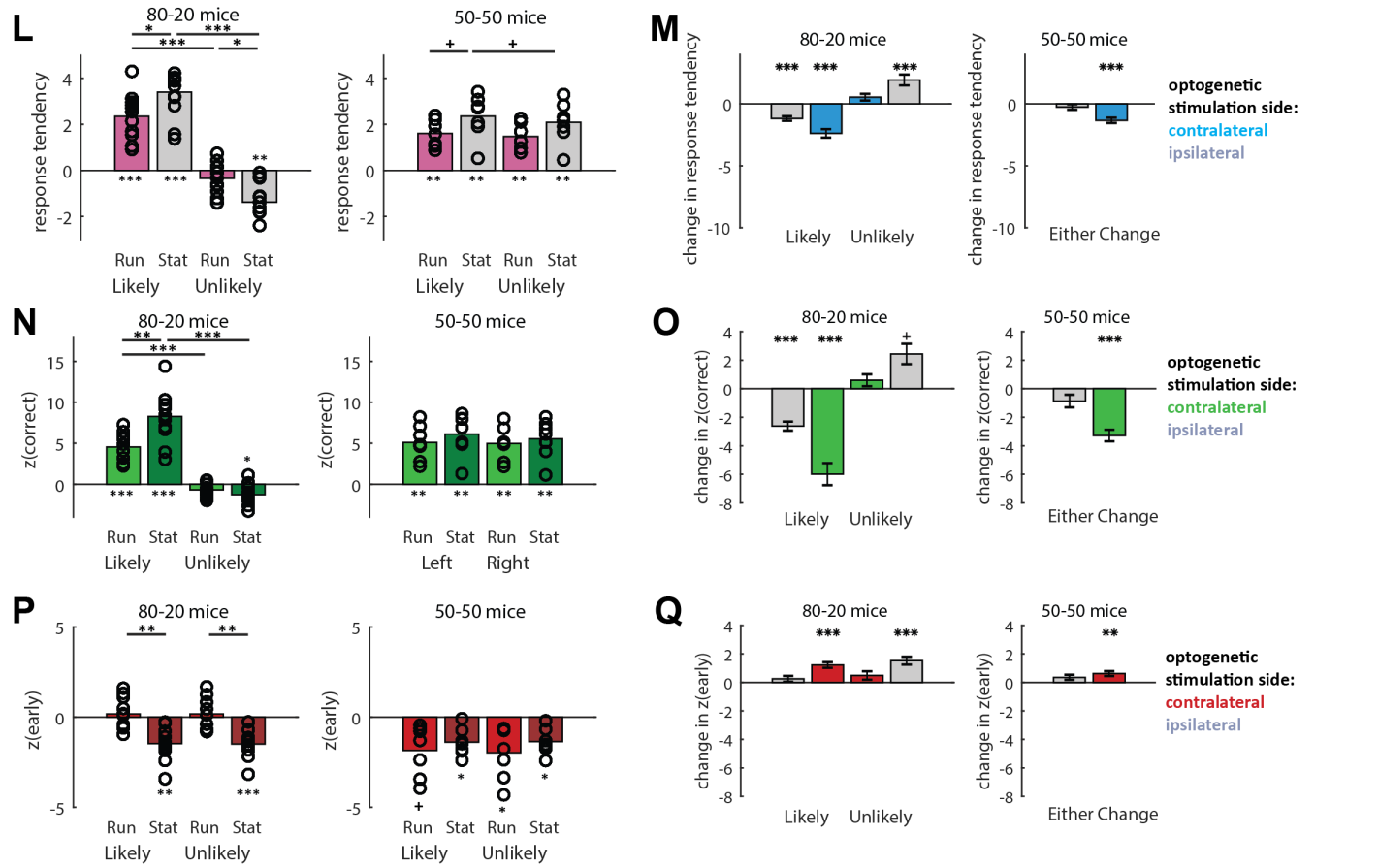
L
80-20 mice
50-50 mice
response tendency
Run Stat Run Stat
Likely Unlikely
M
80-20 mice
50-50 mice
change in response tendency
Likely Unlikely
Either Change
optogenetic stimulation side:
contralateral
ipsilateral
N
80-20 mice
50-50 mice
z(correct)
Run Stat Run Stat
Likely Unlikely
Left Right
O
80-20 mice
50-50 mice
change in z(correct)
Likely Unlikely
Either Change
optogenetic stimulation side:
contralateral
ipsilateral
P
80-20 mice
50-50 mice
z(early)
Run Stat Run Stat
Likely Unlikely
Q
80-20 mice
50-50 mice
change in z(early)
Likely Unlikely
Either Change
optogenetic stimulation side:
contralateral
ipsilateral

Figure S1. Supplemental behavioral data, Related to Figure 1

(A) Learning curves. Red line shows 80-20 learning curve (n=11 mice), blue line shows 50-50 learning curve (n=7 mice). Learning progress of the different groups was similar. Error bars SEM.

(B, C) Dependence of behavior on magnitude of contrast change under different conditions. Both groups of mice performed better with larger contrast changes, and 80-20 mice outperformed 50-50 mice with 20% or greater contrast changes on the likely side, even when running. 80-20 N=51 sessions, 3 mice; 50-50 N=100 sessions, 5 mice. Error bars SEM. *p<0.05, **p<0.01, ***p<0.001, rank-sum test.

(D, E) Proportion correct by chance in different running conditions. We separately shuffled behavioral performance on running and stationary trials and found that in both groups, mice were more likely to get a trial correct by chance when running, likely due to increased response rate. For further calculation of detection index we separately normalized to running and stationary trial shuffle. Each point represents a single mouse. Comparisons between running and stationary, sign-rank test, *p<0.05 ***p<0.001.

(F) Reaction times of each group were not significantly different. 80-20: 475±39ms; 50-50: 435±81ms; p=0.479, rank-sum test.

(G) Proportion of trials versus running speed. Both groups of mice spent most of their time stationary, but 50-50 mice (blue line) spend more trials running ≥16 cm/sec than 80-20 mice (red line). Error bars SEM.

(H) Proportion of trials spent running >0.5 cm/sec. 80-20 mice ran >0.5 cm/sec on fewer trials than 50-50 mice. 80-20: 30.8% of trials, 50-50: 45.3% of trials; p=0.0346, rank-sum test.

(I) Proportion of correct trials versus running speed. 80-20 mice performed progressively worse with higher running speeds, while 50-50 mice performed as well or better than they did when stationary.

(J,K) Examples showing process of calculating detection index from raw correct trial rate and raw early trial rate for 80-20 mice (J) and 50-50 mice (K). First panel, raw correct trial rate. Green lines show distribution of correct trial rates on likely trials across sessions. Red lines show distribution on unlikely trials, and blue lines show the distribution when lick times were shuffled with respect to stimulus times. Different shades of each color correspond to distributions from different mice. Second panel, correct trial rates were z-scored with respect to the shuffle performance, now showing number of standard deviations from chance performance. Third and fourth panels, same as first and second but for early lick trials. Fifth panel, detection index which was computed by subtracting z(correct) – z(early).

(L) Response tendency of mice. Response tendency was calculated as (z(correct)+z(early))/2. Higher response tendency indicates a higher chance of responding. 80-20 mice (N=11) were more likely to respond to likely versus unlikely changes overall, though less likely to respond on running trials. 50-50 mice (N=7) were equally likely to respond to either change, but also slightly less likely to respond on running trials.

(M) Effect of optogenetic silencing on response tendency. Change in response tendency due to optogenetic silencing is plotted according to which hemisphere was silenced and which change occurred. In 80-20 mice, when the likely hemisphere was silenced, mice responded less on likely change trials and more on unlikely change trials. When the unlikely hemisphere was silenced, mice responded less to on unlikely change trials and the same on likely change trials.

(N) Same as (L) but for z(correct). 80-20 mice respond correctly more often in response to likely changes, and get more likely change trials correct when stationary versus when running. Locomotion and change side do not affect how many trials 50-50 mice correctly respond to.

(O) Same as (M) but for z(correct). For 80-20 mice, silencing the likely or unlikely hemisphere on likely change trials decreases the number of correct trials, while silencing the likely hemisphere on unlikely change trials increases the relative number of correct trials.

(P) Same as (L) but for z(early). 80-20 mice lick early more often running versus when stationary, regardless of which side changes. Locomotion and change side do not affect how many trials 50-50 mice correctly respond to.

(Q) Same as (M) but for z(early). For 80-20 mice, silencing the likely hemisphere increases early licks. For 50-50 mice, silencing the hemisphere contralateral to the change increases early licks.

(Statistical comparisons between different conditions indicated with horizontal line. Comparisons to chance shown directly above each bar. *p<0.05, **p<0.01, ***p<0.001; +p<0.05 before Bonferroni adjustment. Unless otherwise noted, we performed a Shapiro-Wilk test for a normal distribution. If the null hypothesis of a normal distribution held, we used a one-sample or paired t-test. Otherwise, if the sample was not normal, we used a non-parametric Wilcoxon sign-rank or rank-sum test. We then performed a Bonferroni adjustment for multiple comparisons. All adjustments in this plot used n=4.)

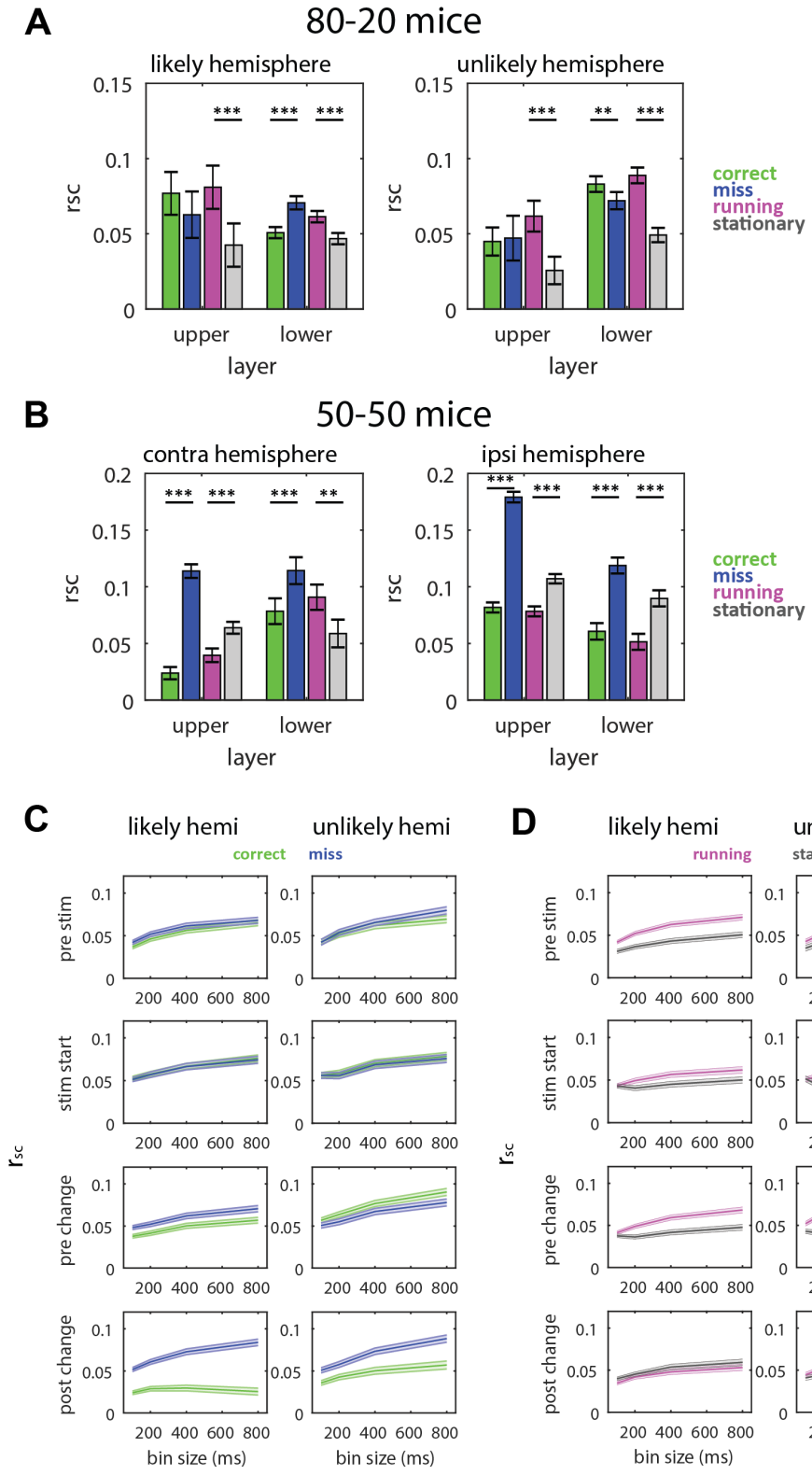

Figure S2. Differences in r_{sc} across layers and dependence of r_{sc} on time window, Related to Figure 2
(A) Differences in r_{sc} across layers at the prechange timepoint. In 80-20 mice, correct r_{sc} is significantly lower than miss r_{sc} only in the likely hemisphere in lower layers ($p<1e-8$, sign rank test with Bonferroni adjustment). In contrast, running r_{sc} is higher than stationary r_{sc} in both hemispheres across layers.
(B) In 50-50 mice, correct r_{sc} is lower than miss r_{sc} across both hemispheres and layers. Running r_{sc} is lower than stationary r_{sc} except for in the hemisphere contralateral to the slight behavioral bias.
(C) Example comparison of r_{sc} on correct (green) and miss (blue) trials using different spike count time bins, and across different trial time points. Example data from 80-20 mice. In general, r_{sc} increased with larger time bins, but our observed decreases on correct trials were present in time windows as small as 100-200ms.

(D) same as (C) but comparing running (magenta) versus stationary (black) trials, observed increases of r_{sc} on running trials was present down to 200 ms. Error bars SEM.
(*p<0.05, **p<0.01, **p<0.001, sign-rank test; +p<0.05 before Bonferroni adjustment of N=2. Comparisons between correct and miss (green) or running and stationary (magenta) trials, averaged across time windows indicated with colored horizontal bars)

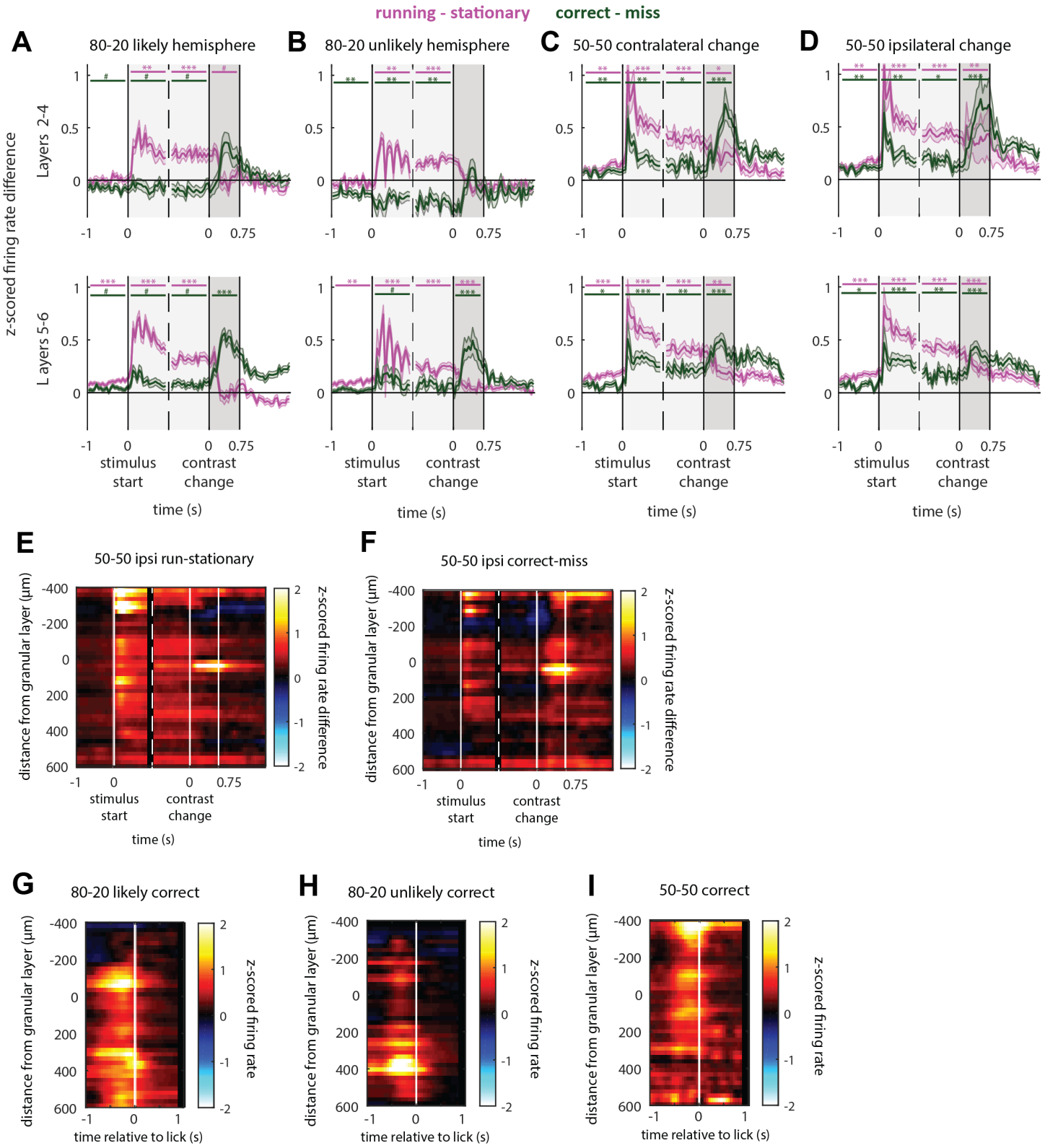

Figure S3. Task- versus locomotion-related effects on spike rates, Related to Figure 3
Z-scored firing rate differences between conditions averaged across superficial (2-4) or deep layers (5-6).
(A) Differences in 80-20 likely hemisphere. Running enhances stimulus onset response (magenta line) in all layers, selection (green line) enhances contrast change response in all layers, and stimulus onset response slightly in deep layers. Upper layer N=139 neurons; lower layer N=504.
(B) 80-20 unlikely hemisphere. Running has similar effects as in likely hemisphere (magenta), but selection suppresses firing rates in upper layers (green). Upper layer N=107 neurons; lower layer N=296.

(C) 50-50 mice, contralateral change. Running and selection have similar effects on stimulus onset, while selection enhances contrast change response more. Upper layer N=299; lower layer N=359.
(D) 50-50 mice, ipsilateral change. Similar effects as in C. Increased firing on correct versus miss trials in response to change, even though these neurons do not directly represent that location in space. Upper layer N=299; lower layer N=359.
(E-F) Heatmap plot of data in D, plotted according to depth as in Figure 3.
(G-I) Z-scored firing rates across layers aligned to lick onset on correct trials. Peak of activity precedes lick in all mice and hemispheres.
(Statistical comparisons relative to zero; #p<0.05 *p<1e-2, **p<1e-4, ***p<1e-8, sign-rank test. Bonferroni correction performed with N=4.)

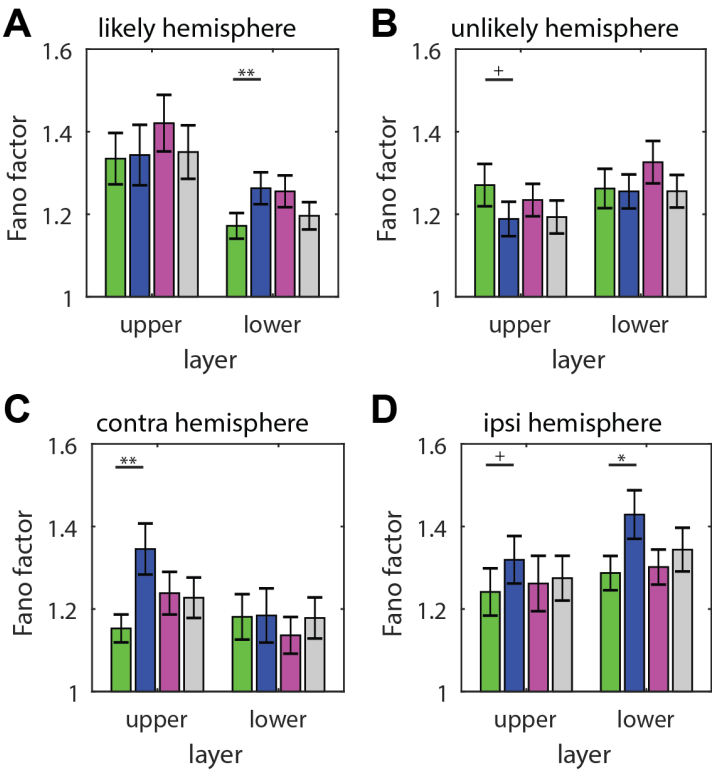

Figure S4. Layer dependence of changes in Fano factor, Related to Figure 5
(A) Layer dependence of Fano factor changes at the prechange timepoint. In 80-20 mice, correct Fano factor is lower than miss in the likely hemisphere in deep layers. Running does not significantly affect Fano factor.
(B) In the unlikely hemisphere and in upper layers, Fano factor is higher on correct versus miss trials.
(C,D) In 50-50 mice, Fano factor is lower on correct versus miss trials except for the lower layer in the hemisphere contralateral to the slight behavioral bias.
(*p<0.05, **p<0.01, **p<0.001, sign-rank test; +p<0.05 before Bonferroni adjustment of N=2. Comparisons between correct and miss or running and stationary trials indicated with horizontal line)

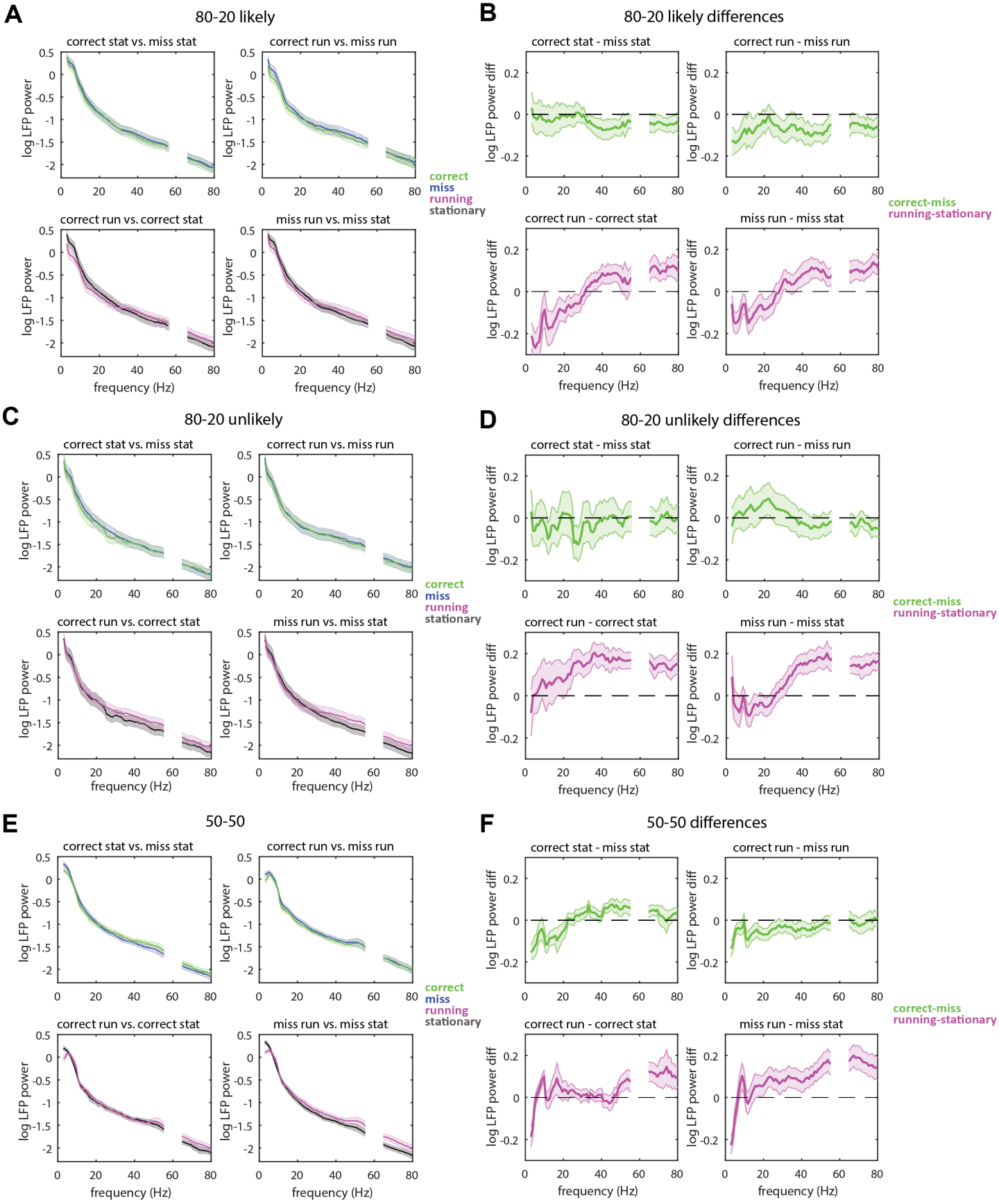
A
80-20 likely
correct stat vs. miss stat
correct run vs. miss run
correct run vs. correct stat
miss run vs. miss stat
log LFP power
frequency (Hz)
correct
miss
running
stationary
B
80-20 likely differences
correct stat - miss stat
correct run - miss run
correct run - correct stat
miss run - miss stat
log LFP power diff
correct-miss
running-stationary
C
80-20 unlikely
D
80-20 unlikely differences
E
50-50
F
50-50 differences

Figure S5. Local field potential spectra, Related to Figure 6

(A) Comparison of local field potential (LFP) spectra across conditions in 80-20 likely hemisphere recordings. Pre-change time point is shown in all figures. Correct versus miss LFPs were plotted separately for running and stationary trials and running versus stationary LFPs were plotted separately for correct and miss trials. N=15 included recordings. Error bars SEM.

(B) Same as (A) but with spectra subtracted across conditions, correct-miss (green) and running-stationary (magenta). Dotted black line indicates a difference of 0.

(C-D) Same as (A-B) but for 80-20 unlikely hemisphere, N=14 recordings.

(E-F) Same as (A-B) but for 50-50 mice, N=19 recordings.

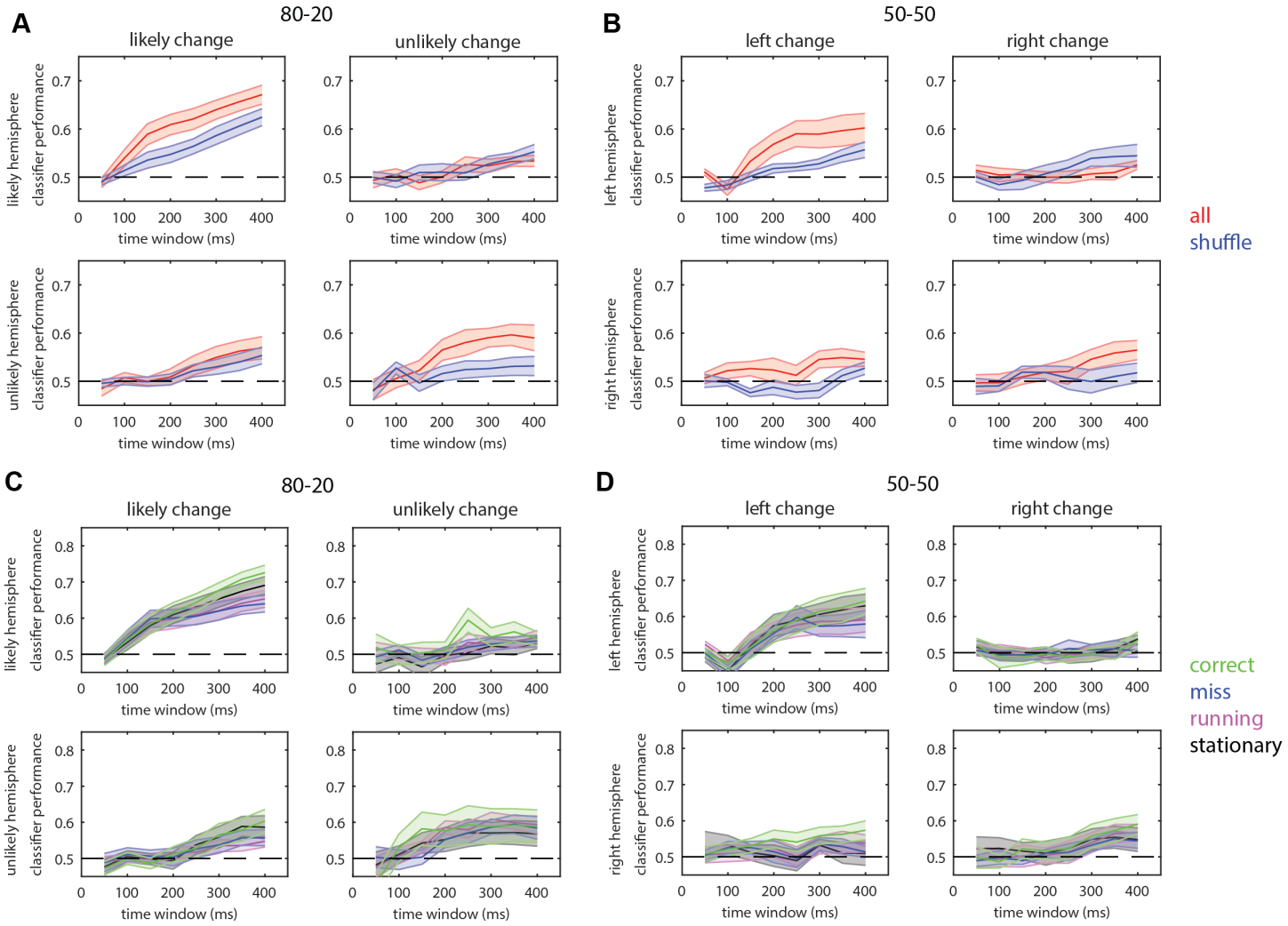

Figure S6. Linear classifier performance at different time windows, Related to Figure 7
Performance of linear classifier trained with spike counts from different sized time windows prior to and following the contrast change.
(A) Performance of linear classifier trained on either the raw spike counts from all neurons (counts, red), or trial-shuffled spike counts to remove correlated variability (shuffle, blue), using data from 80-20 mice. Error bars SEM.
(B) Same as (A) but for 50-50 mice.
(C) Performance of linear classifier trained on raw spike counts on subsets of trials: correct (green), miss (blue), running (magenta), and stationary (black), using data from 80-20 mice. Error bars SEM.
(D) Same as (C) but for 50-50 mice.

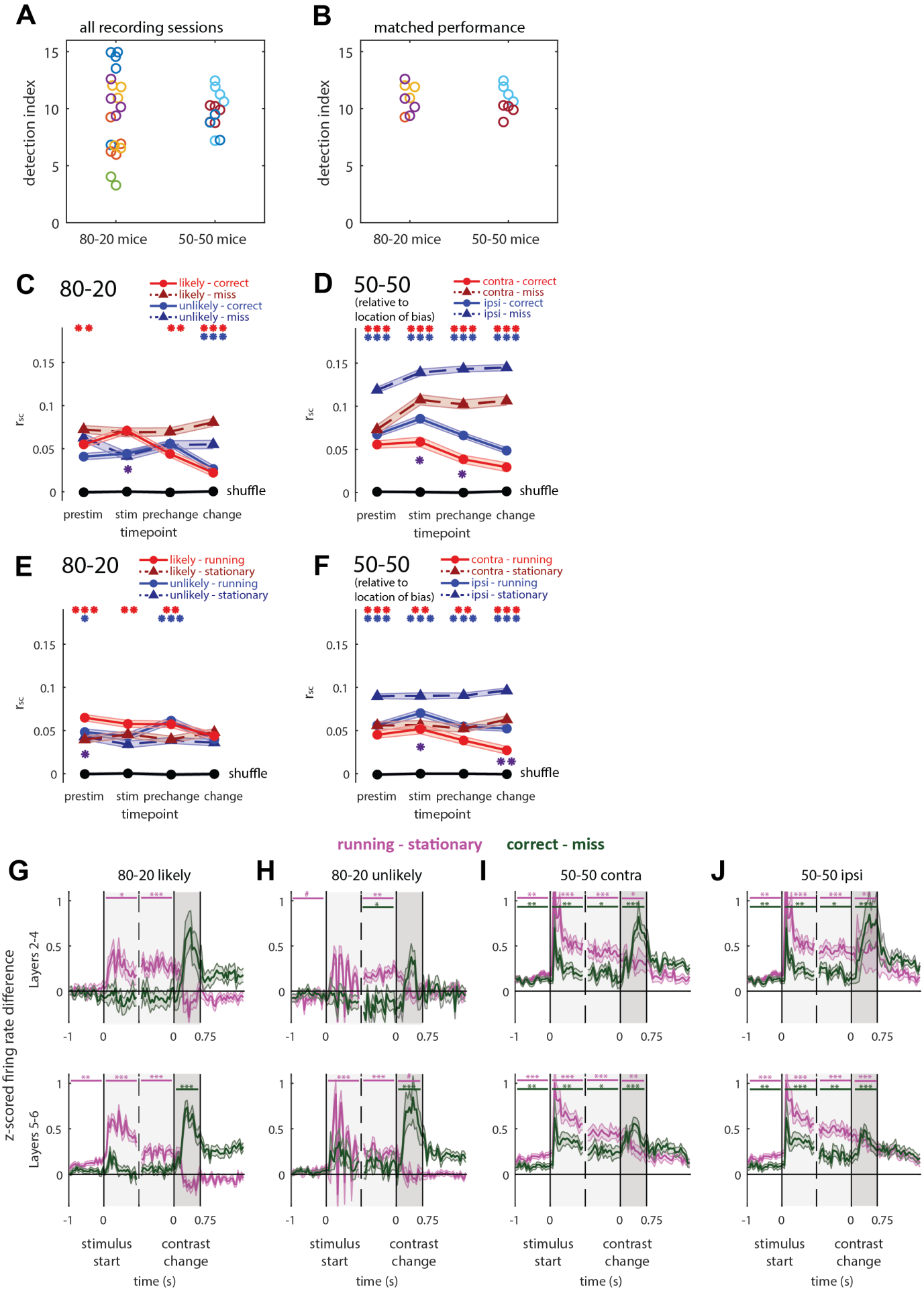
A
all recording sessions
detection index
80-20 mice
50-50 mice
B
matched performance
C
80-20
likely - correct
likely - miss
unlikely - correct
unlikely - miss
shuffle
prestim
stim
prechange
change
timepoint
D
50-50
(relative to location of bias)
contra - correct
contra - miss
ipsi - correct
ipsi - miss
E
likely - running
likely - stationary
unlikely - running
unlikely - stationary
F
contra - running
contra - stationary
ipsi - running
ipsi - stationary
running - stationary
correct - miss
G
80-20 likely
H
80-20 unlikely
I
50-50 contra
J
50-50 ipsi
Layers 2-4
Layers 5-6
z-scored firing rate difference
stimulus start
contrast change
time (s)

Figure S7. Analysis of a subset of recording sessions with matched behavioral performance recapitulates results, Related to Figures 1, 2, and 3

(A) Performance of mice across all recording sessions. Different colors indicate different mice. 80-20 mice are shown on the left, 50-50 on the right. Performance varied across sessions and across mice.

(B) Matched performance across groups. We selected recording sessions where detection index was between 8 and 13 (50-50 mice had to perform at this level for both left and right changes). 8 sessions each for 80-20 and 50-50 mice fell within these criteria. Sessions were included from 3/5 80-20 mice and 2/3 50-50 mice. These sessions were re-analyzed and compared to results from including all recordings.

(C) Local reduction in spike count correlations in 80-20 mice on correct versus miss trials, replicating main results. Decreases in r_{sc} prior to the contrast change only occurred in the likely hemisphere on correct trials (red, solid lines) relative to miss trials (red, dotted lines), while r_{sc} in the unlikely hemisphere did not change until after the contrast change (blue lines). Likely hemisphere, N=3376 pairs; unlikely, N=2586 pairs.

(D) Global reduction in spike count correlations in 50-50 mice on correct versus miss trials, also replicating main results. Decreases in r_{sc} are present at every time point in both hemispheres on correct (solid lines) versus miss trials (dotted lines). Contralateral hemisphere, N=2678; ipsilateral, N=6893 pairs.

(E) Locomotion globally increases r_{sc} in 80-20 mice, replicating main results. In both the likely and unlikely hemispheres, r_{sc} is increased on running (solid lines) versus stationary trials (dotted lines) in both hemispheres prior to the contrast change.

(F) Locomotion globally decreases r_{sc} in 50-50 mice, replicating main results. In both hemispheres of 50-50 mice, r_{sc} is decreased on running (solid lines) versus stationary (dotted lines) trials.

(G) Z-scored firing rate differences in 80-20 likely hemisphere. Running enhances stimulus onset response (magenta line) in all layers, selection (green line) enhances contrast change response in deep layers. Upper layer N=67; lower layer N=228 neurons.

(H) Differences in 80-20 unlikely hemisphere. Running has similar effects as in likely hemisphere (magenta), but selection suppresses firing rates in upper layers prior to the change (green), while no significant difference was observed in the likely hemisphere at this time point. Upper layer N=63; lower layer N=164 neurons.

(I) Differences in 50-50 mice, contralateral change. Running and selection both enhance the stimulus onset response, while selection enhances contrast change response more. Upper layer N=248; lower layer N=266 neurons.

(J) Differences in 50-50 mice, ipsilateral change. Similar effects as in C. Increased firing on correct versus miss trials in response to change, even though these neurons do not directly represent that location in space. Upper layer N=248; lower layer N=266 neurons.

(plots C-F: *p<1e-2, **p<1e-4, ***p<1e-8, sign-rank test. Error bars SEM. Red * reflect comparisons in the likely hemisphere in 80-20 mice, and in the contra hemisphere of 50-50 mice. Blue * reflect comparisons in the unlikely hemisphere of 80-20 mice, and in the ipsi hemisphere of 50-50 mice. Cross-hemisphere comparisons on correct or running trials denoted with purple * below plots, computed with rank-sum test. Bonferroni adjustment performed with N=4. +p<0.05, ++p<0.01 before Bonferroni adjustment)

(plots G-J: Statistical comparisons relative to zero; #p<0.05 *p<1e-2, **p<1e-4, ***p<1e-8, sign-rank test. Bonferroni correction performed with N=4.)