

Supplementary Materials For:  
Double Responding: A New Constraint for Models of Speeded  
Decision Making

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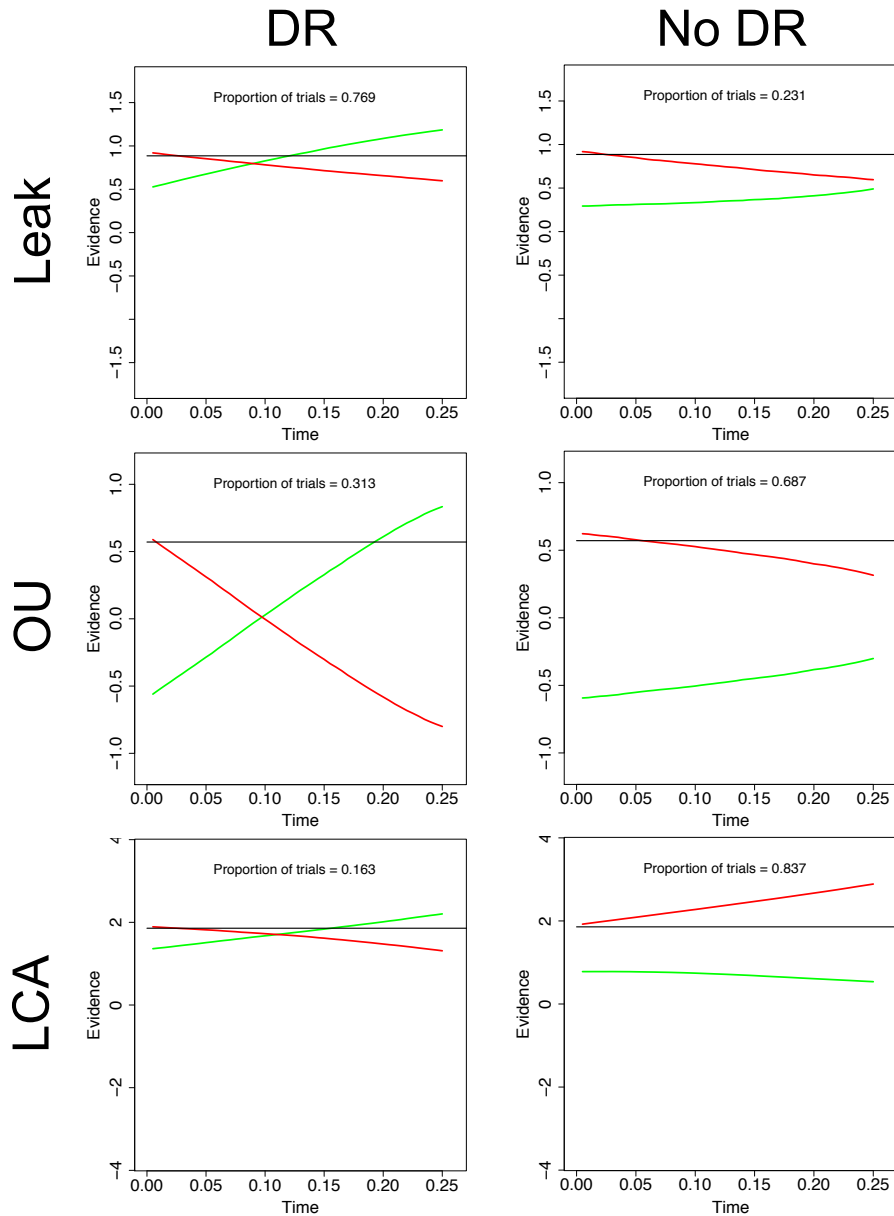
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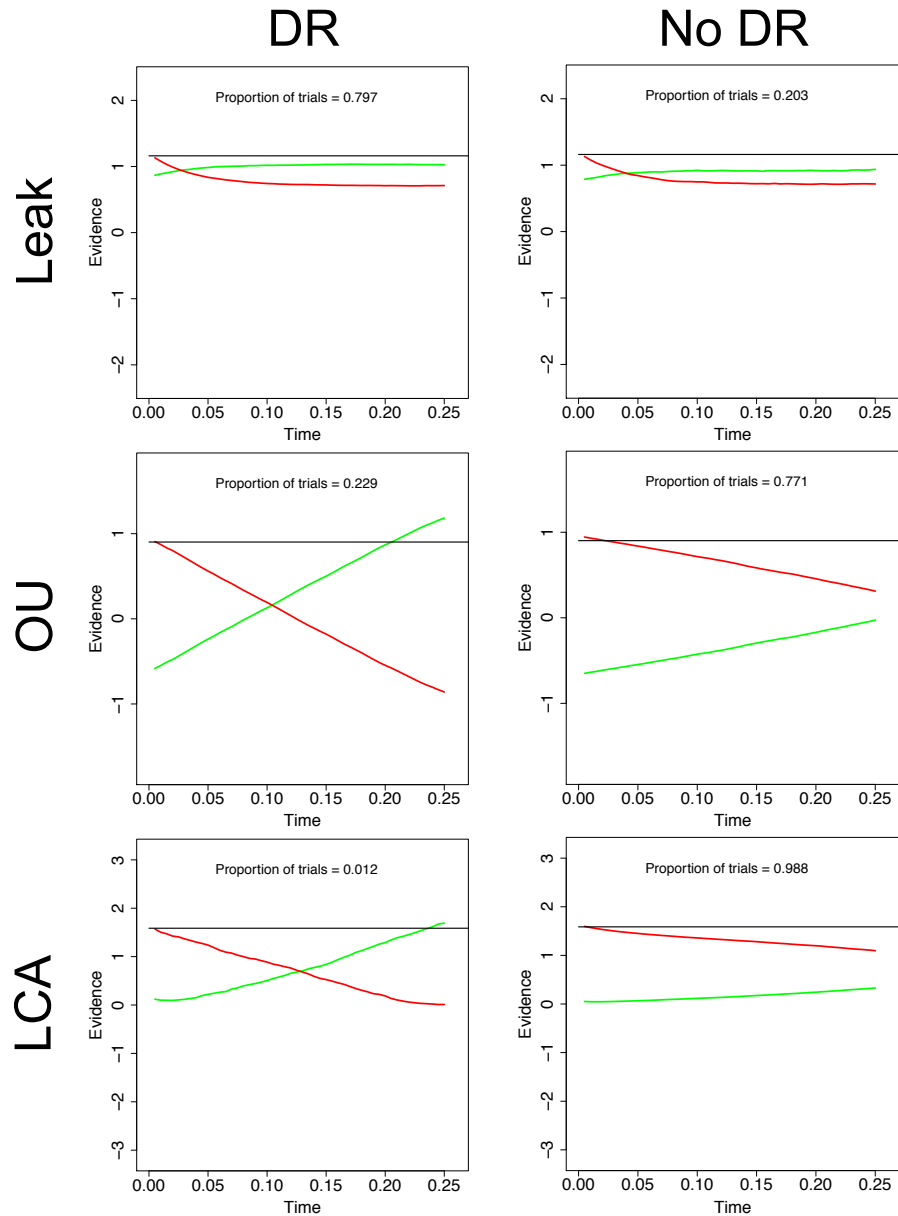
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## Post-error evidence accumulation process in Experiment 1

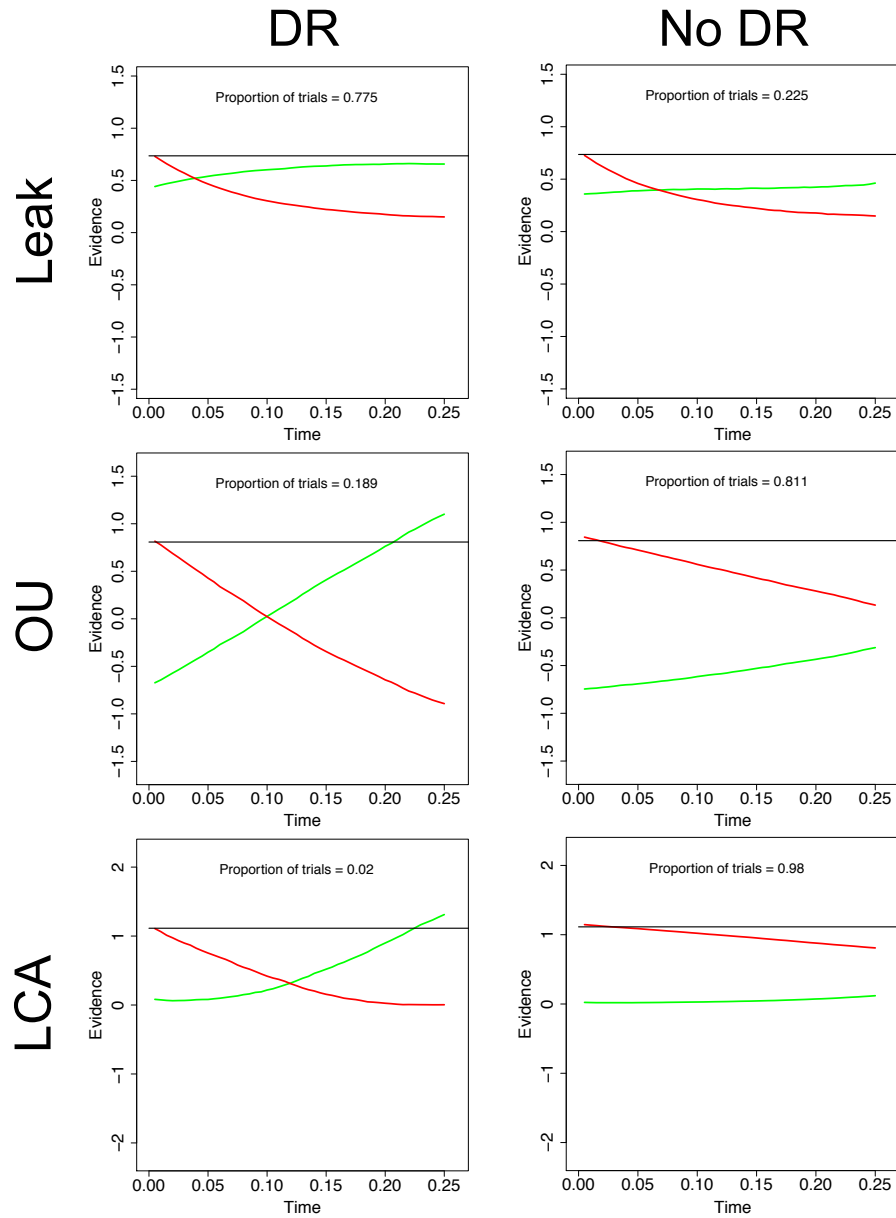
In the results for Experiment 1, we attempt to provide some insight into *why* lateral inhibition is able to help in accounting for double responding behaviour by plotting the predicted evidence accumulation process for three models (Leak, OU, and LCA). To avoid redundancy, we only plotted these trajectories for participant S1, as all participants provide the same overall conclusion on *why* lateral inhibition is helpful in capturing double responses. For completeness, Figures SM1, SM2, and SM3 display the trajectories for participants S2, A1, and A2, respectively.



*Figure SM1.* Predicted evidence accumulation processes following errors for the Leak (top), OU (middle), and LCA (bottom) models based on the best fitting parameters for participant S2. The x-axis displays the time from the initial response, up until the double response time limit of 0.25 seconds, and the y-axis displays the accumulated evidence, starting at the finishing evidence at the initial response. The green line displays the evidence for the correct response alternative, and the red line displays the evidence for the error response alternative, with the latter being the initial response. The left panel displays accumulation processes that result in double responses (though the accumulation continues beyond the threshold for this plot), and the right panel displays accumulation processes that do not result in double responses.



*Figure SM2.* Predicted evidence accumulation processes following errors for the Leak (top), OU (middle), and LCA (bottom) models based on the best fitting parameters for participant A1. The x-axis displays the time from the initial response, up until the double response time limit of 0.25 seconds, and the y-axis displays the accumulated evidence, starting at the finishing evidence at the initial response. The green line displays the evidence for the correct response alternative, and the red line displays the evidence for the error response alternative, with the latter being the initial response. The left panel displays accumulation processes that result in double responses (though the accumulation continues beyond the threshold for this plot), and the right panel displays accumulation processes that do not result in double responses.



*Figure SM3.* Predicted evidence accumulation processes following errors for the Leak (top), OU (middle), and LCA (bottom) models based on the best fitting parameters for participant A2. The x-axis displays the time from the initial response, up until the double response time limit of 0.25 seconds, and the y-axis displays the accumulated evidence, starting at the finishing evidence at the initial response. The green line displays the evidence for the correct response alternative, and the red line displays the evidence for the error response alternative, with the latter being the initial response. The left panel displays accumulation processes that result in double responses (though the accumulation continues beyond the threshold for this plot), and the right panel displays accumulation processes that do not result in double responses.

Results when only considering the alternative definition for how  
double responses are triggered

Here, we provide the results for Experiment 1 when only considering the alternative definition for how double responses are triggered, without the inclusion of between-trial variability in drift rate and non-decision time. Figures SM4 and SM5 provide the same comparisons as the main text Figures 7 and 8. For the models with lateral and feed-forward inhibition, the results are near-identical to those in the main text. This probably not surprising given the evidence accumulation processes shown in main text Figure 11 and supplementary Figures SM1, SM2, and SM3, as the evidence for the initial response alternative generally dropped below the threshold in these models even under the primary definition<sup>1</sup>. However, the models without inhibition (RDM and Leak) show a large improvement, providing much less of an over-prediction of the double response proportions. It should also be noted that for S2, the predictions of the models without inhibition become about as good as those with lateral inhibition (which are both superior to those with feed-forward inhibition), as reflected in the RDM outperforming the lateral inhibition models for S2 in BIC (Table SM1), suggesting that the lateral inhibition models are no longer superior for this subject. However, the lateral inhibition models remain qualitatively (Figures SM4 and SM5) and quantitatively (Table SM1) superior to all other models for participants S1, A1, and A2, meaning that our general pattern of results appears to hold even under the alternative definition. This is further supported by the results for Experiment 2 based on the alternative definition – which can be seen in Figure SM6 and provides the same comparisons as the main text Figure 12 – where the models with lateral inhibition clearly qualitatively outperform all other models, and are favoured by 12/15 participants on BIC (Table SM2). However, it should be noted that the RDM now outperforms the

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<sup>1</sup>For the DM and OU, where feed-forward inhibition is fixed to 1, and therefore, evidence for one alternative is evidence against the other alternative, it is a necessity.

lateral inhibition models in 3/15 participants on BIC, which is better than the 0/15 in the primary definition in the main text.

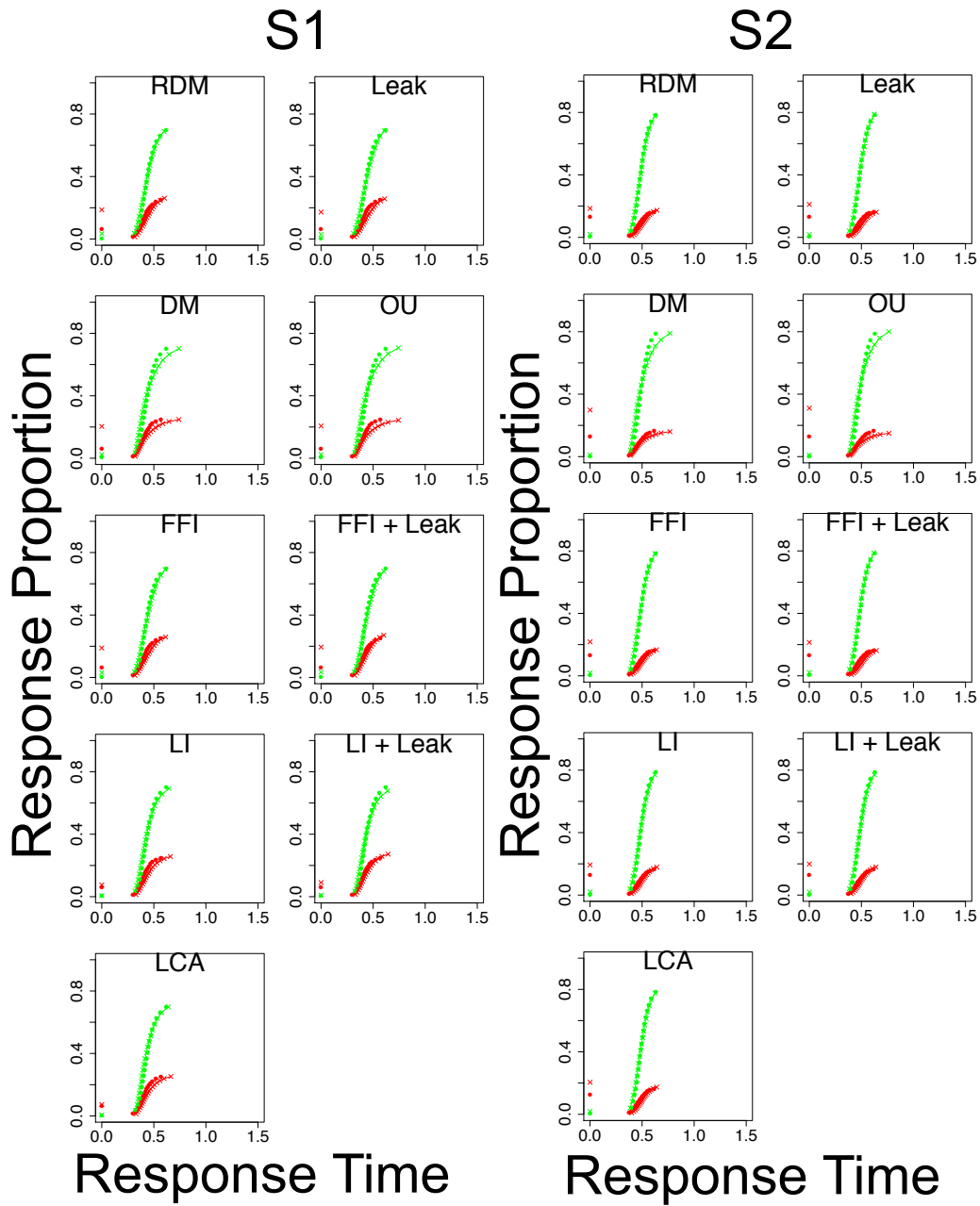


Figure SM4. CDF plots performed jointly for the response time distributions and the double response proportions (i.e., the same parameter values for each type of data) – for the two participants in the speed emphasis condition in Experiment 1, with the left half of the figure being one participant (S1), and the right half being the other (S2).



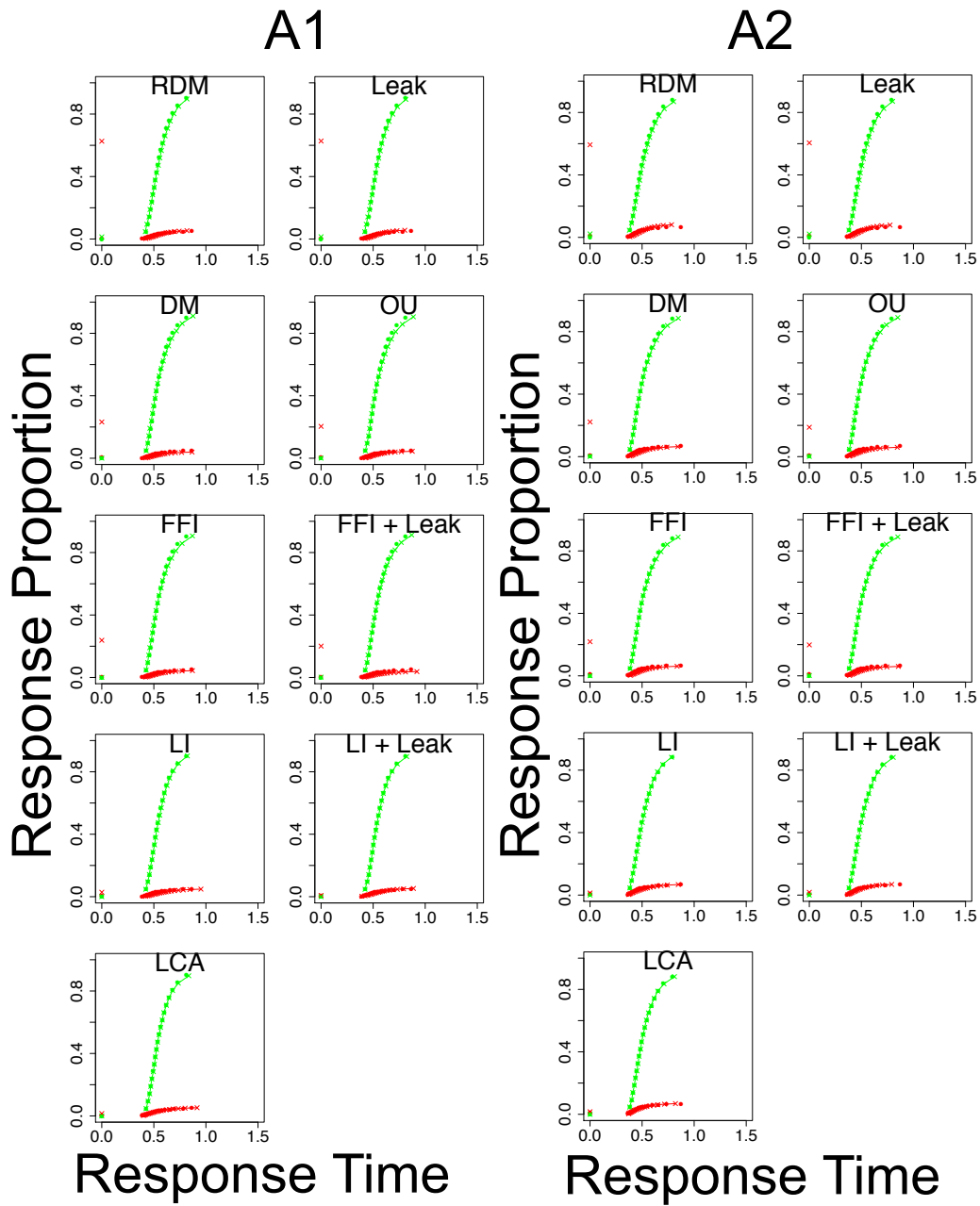


Figure SM5. CDF plots performed jointly for the response time distributions and the double response proportions (i.e., the same parameter values for each type of data) – for the two participants in the accuracy emphasis condition in Experiment 1, with the left half of the figure being one participant (A1), and the right half being the other (A2).

	1	2	3	4
RDM	-6617.23	<b>-12791.76</b>	-10335.74	-8550.50
Leak	-6596.14	-12766.23	-10331.13	-8493.99
DM	-5215.10	-9525.93	-11282.94	-10011.11
OU	-5198.60	-9501.49	-11280.70	-10031.68
FFI	-6574.05	-12765.25	-11280.41	-10000.86
FFI + Leak	-6571.81	-12711.14	-11340.24	-10024.63
LI	-7458.85	-12761.48	-11821.32	-10339.82
LI + Leak	-7409.61	-12730.39	-11941.81	-10397.83
LCA	<b>-7465.82</b>	-12728.62	<b>-11948.76</b>	<b>-10453.86</b>

Table SM1: BIC values for all 9 models (columns) for each of the 4 participants (rows) in Experiment 1. The best model for each participant is in **bold** within the table. Note that BIC is on the deviance scale, and therefore, smaller values indicate better performance.

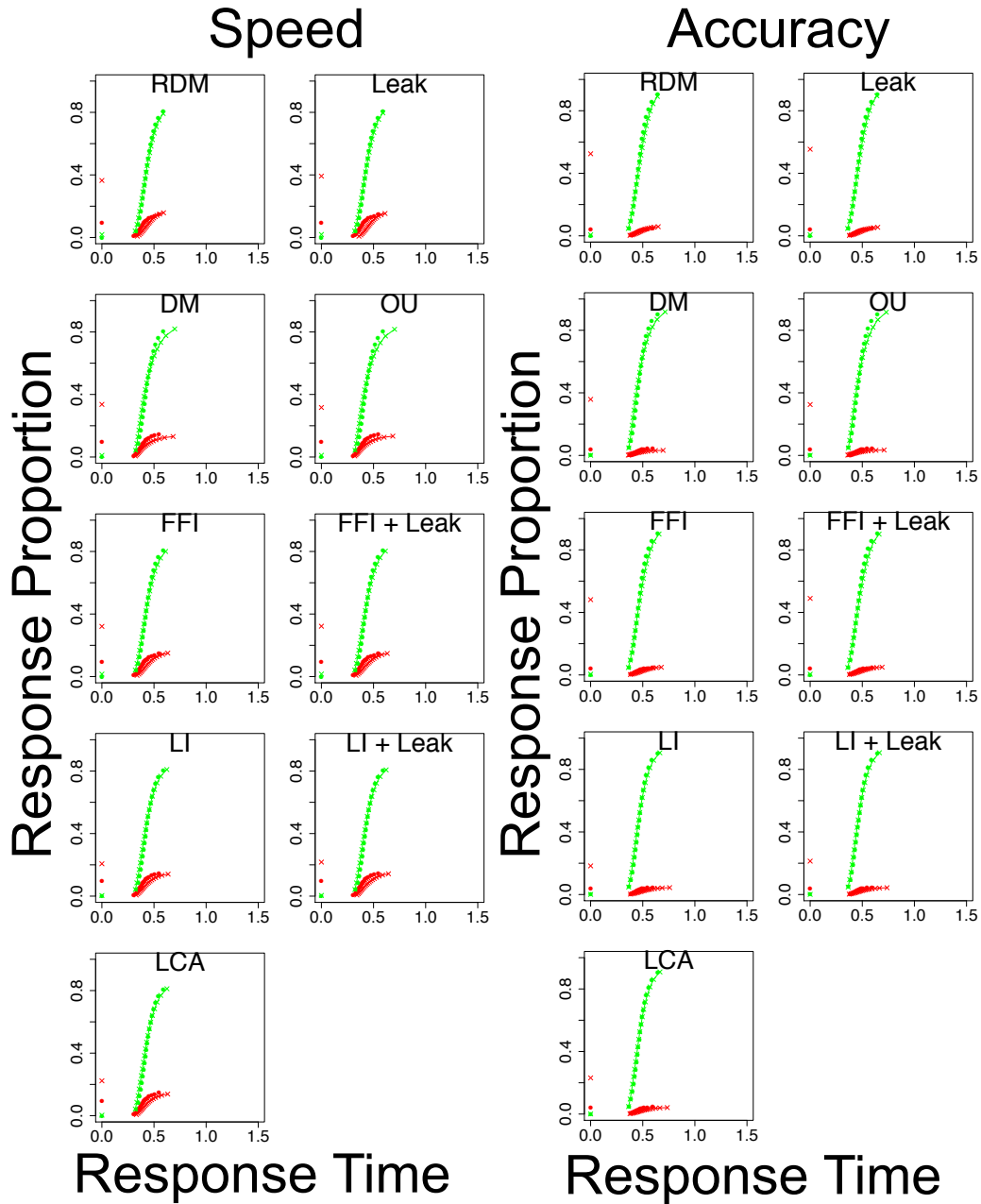


Figure SM6. CDF plots performed jointly for the response time distributions and the double response proportions (i.e., the same parameter values for each type of data), for the speed (left) and accuracy (right) conditions of Experiment 2. The data of each participant was fit separately to obtain the observed and predicted response time quantiles and response proportions, with these quantiles and proportions then then averaged over participants to create these group-averaged CDF plots.

Sub	RDM	Leak	DM	OU	FFI	FFI + Leak	LI	LI + Leak	LCA
1	-1011	-1003	-954	-949	-1000	-995	<b>-1030</b>	-1022	-1026
2	-299	-303	-296	-291	-292	-291	<b>-348</b>	-342	-343
3	-1025	-1011	-910	-902	-1010	-1001	<b>-1066</b>	-1054	-1055
4	-369	-357	-292	-283	-363	-348	<b>-433</b>	-426	-432
5	23	31	216	224	44	85	<b>-77</b>	-68	-73
6	<b>-259</b>	-254	-222	-217	-255	-249	-253	-249	-250
7	-1255	-1248	-1121	-1114	-1247	-1237	<b>-1276</b>	-1265	-1270
8	-905	-899	-788	-782	-897	-887	<b>-906</b>	-897	-904
9	-751	-749	-653	-643	-731	-686	<b>-856</b>	-851	-854
10	<b>-244</b>	-239	-230	-225	-238	-233	-238	-232	-233
11	-871	-862	-887	-883	-877	-879	<b>-960</b>	-953	-947
12	-967	-961	-981	-979	-973	-973	<b>-1048</b>	-1043	-1039
13	-750	-744	-763	-756	-758	-757	<b>-789</b>	-786	-782
14	-288	-273	-314	-312	-315	-308	<b>-344</b>	-340	-333
15	<b>-1369</b>	-1361	-1206	-1201	-1362	-1353	-1362	-1354	-1344

Table SM2: BIC values for all 9 models (rows) for each of the 15 participants (columns) in Experiment 2. The best model for each participant is in **bold** within the table. Note that BIC is on the deviance scale, and therefore, smaller values indicate better performance.

### Results when only considering all between-trial variability parameters

Here, we provide the results for Experiment 1 when only considering all three between-trial variability parameters, without the alternative definition for how double responses are triggered. Figures SM7 and SM8 provide the same comparisons as the main text Figures 7 and 8. As can be seen, the inclusion of these additional between-trial variability parameters does not change the overall inferences from Experiment 1, as the qualitative pattern of results remains the same (see also Table SM3 for BIC).

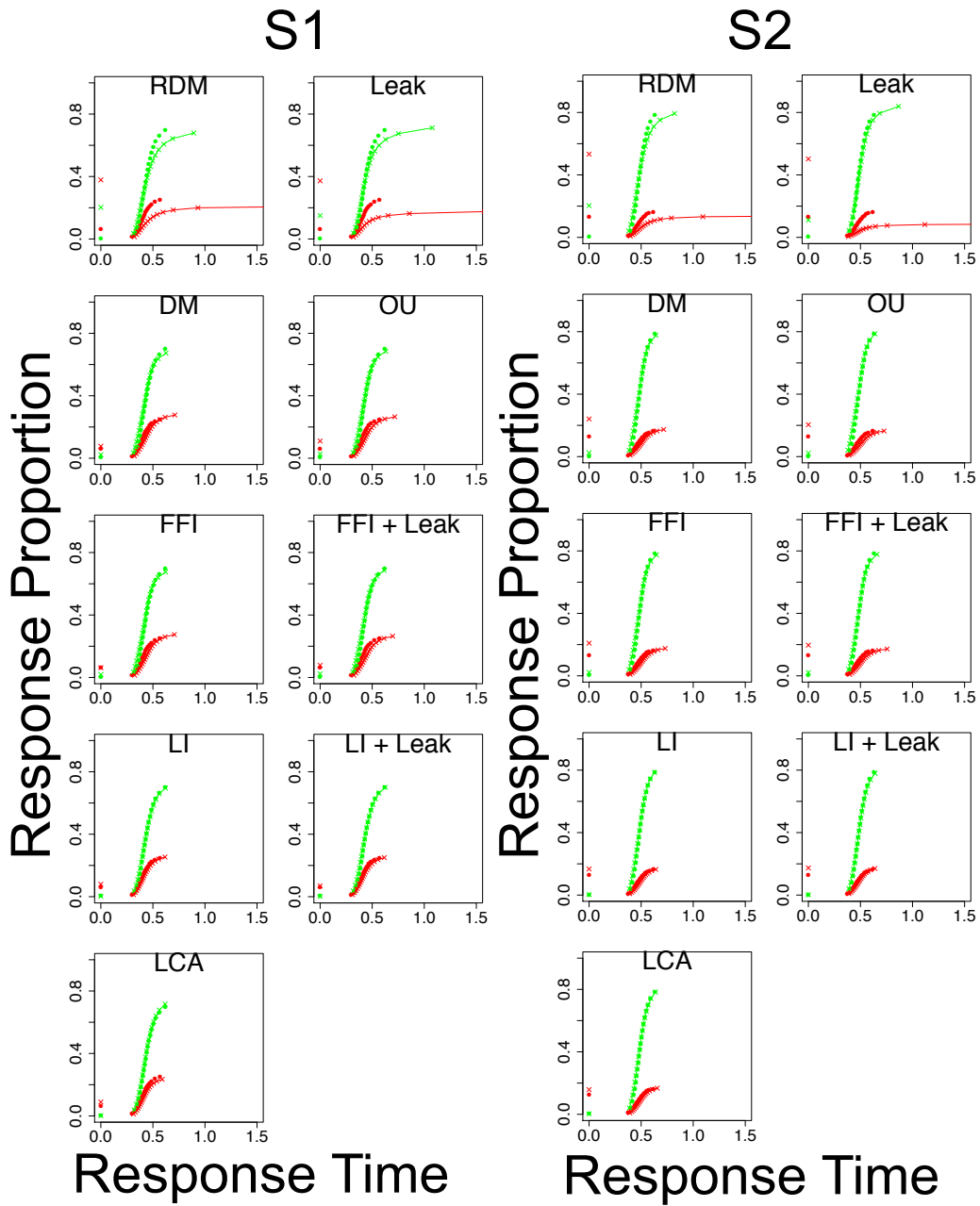


Figure SM7. CDF plots for the two participants in the speed emphasis condition in Experiment 1, with the left half of the figure being one participant (S1), and the right half being the other (S2).

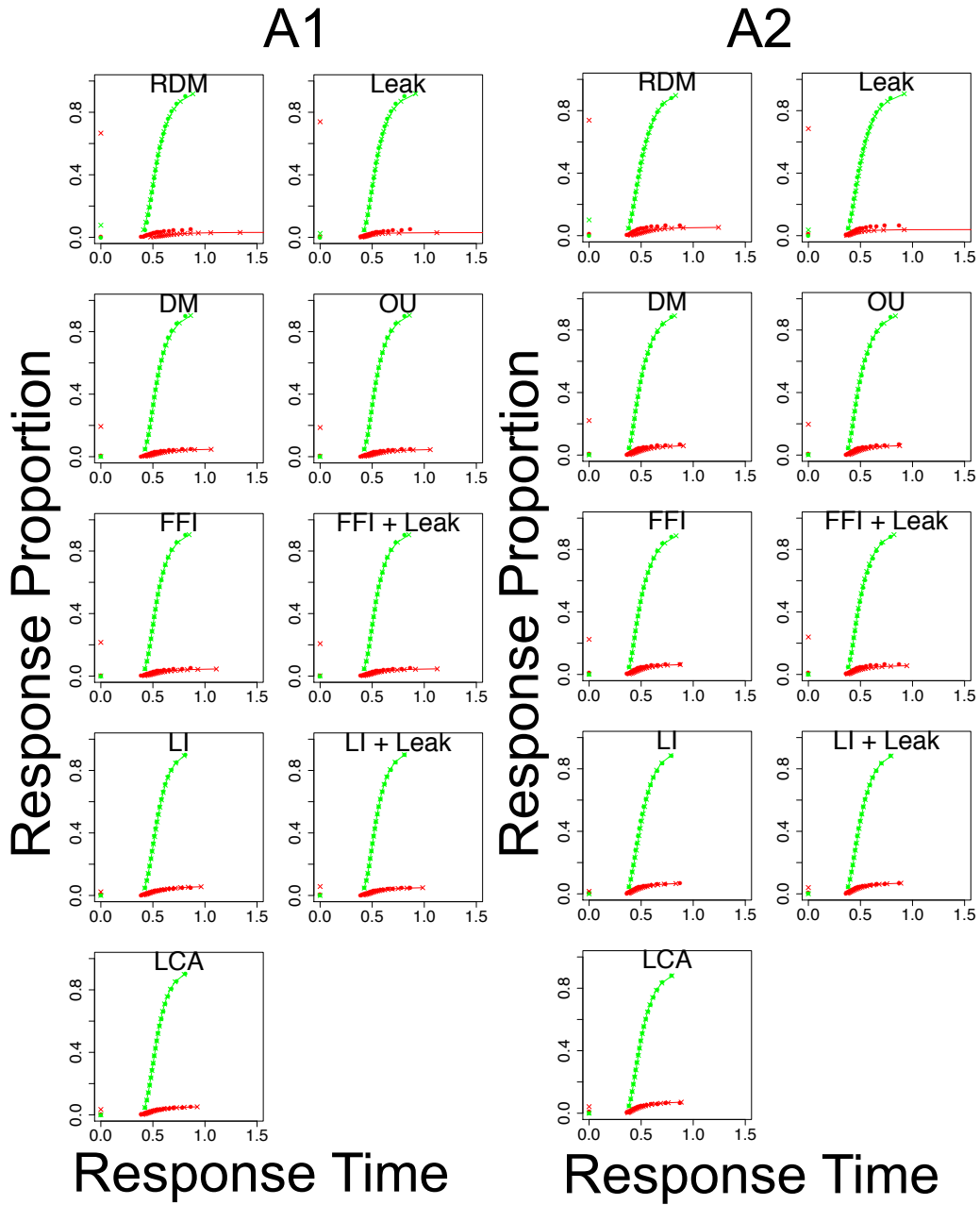


Figure SM8. CDF plots for the two participants in the accuracy emphasis condition in Experiment 1, with the left half of the figure being one participant (A1), and the right half being the other (A2).

Model	1	2	3	4
RDM	362.16	-5435.95	-8122.10	-5904.06
Leak	-240.68	-6642.45	-9518.78	-7305.84
DM	-7325.97	-12150.16	-11683.61	-10051.82
OU	-7296.13	-12133.66	-11691.23	-10081.41
FFI	-7309.38	-12156.97	-11682.66	-10062.24
FFI + Leak	-7273.57	-12108.93	-11711.15	-10081.02
LI	<b>-8384.81</b>	<b>-13201.70</b>	-11895.42	-10371.34
LI + Leak	-8369.69	-13195.48	<b>-11983.36</b>	<b>-10448.94</b>
LCA	-8356.63	-13185.05	-11982.40	-10442.25

Table SM3: BIC values for all 9 models (columns) for each of the 4 participants (rows) in Experiment 1. The best model for each participant is in **bold** within the table. Note that BIC is on the deviance scale, and therefore, smaller values indicate better performance.