EXTENDED RESULTS

A Robust Decision-Making Framework Based on Collaborative Agents

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This document contains a full gallery of extended results not included in the main publication.

Table 1 indicates the abbreviations used to refer to the employed decision making methods in both tables and graphical results. A detailed explanation on how to interpret the displayed graphs can be found in the main article.

Method	N_{LDM}	N_{CDM}	FDSS	P	D	M	V
Abbreviation	L	N	F	Ω_P	Ω_D	Ω_M	Ω_V

TABLE 1. Abbreviations list for the decision-making methods.

Numerical results are grouped as follows:

- Table 2 shows complete numerical results (for both training and validation) obtained over the DB0 [2] dataset;
- Table 3 shows complete numerical results (fro both training and validation) obtained over the DB1 [3] dataset;
- Table 4 shows complete numerical results (for both training and validation) obtained over the DB2 [4] dataset;
- Table 5 shows complete numerical results (for both training and validation) obtained over the DB2 [5] dataset;

Each table has a column for results relative to the training phase and a column for those relative to the validation phase. Theese numerical values represents the evaluation metrics "accuracy" (ACC), "Root Mean Square Error" (RMSE) and "Area Under the ROC Curve" (AUC), as defined in the main article. Best results are displayed in boldface while second best values in blue.

Extended graphical results are grouped as follows:

- Figure 1 and 2 depict the ROC curves, for the training and validation processes respectively, obtained over the DB0 [2] dataset;
- Figure 3 and 4 depict the ROC curves, for the training and validation processes respectively, obtained over the DB1 [3] dataset;
- Figure 5 and 6 depict the ROC curves, for the training and validation processes respectively, obtained over the DB2 [4] dataset;
- Figure 7 and 8 depict the ROC curves, for the training and validation processes respectively, obtained over the DB3 [5] dataset;

Each figure contains 15 sugbfigures arranged in 3 rows and 5 columns. The top row depict the graphical results of local decision-making processes (L), which are implemented with the neuroevolution approach, while the middle and bottom rows depict the graphical results of collaborative decision-making processes (N), which are implemented with the neuroevolution approach (mid row), FDSS, statistical operators, i.e. mean, median and maximum value, and the voting method (bottom row). On each column, the number of agents used can range from from 2 to 6.

For the sake of reproducibility, the source code implementing our "RDM_{CA}" framework and leading to the presented results is made available in [6].

	Training					Validation				
n	DM	ID	ACC	RMSE	AUC	DM	ID	ACC	RMSE	AUC
1	L	-	0.8582	0.3766	0.8582	L	-	**0.7162**	0.5327	0.7189
2	N	1	**0.8881**	0.3024	0.9358	N	2	**0.7568**	0.4932	**0.7371**
2	N	2	0.8657	0.3665	0.8646	N	1	0.6892	**0.4660**	0.6894
3	N	1	0.8284	0.3740	0.8672	Ω_M	A	0.6892	0.4752	0.6500
3	N	2	0.8209	0.3730	0.8797	F	A	0.6892	0.4893	0.7258
4	N	2	**0.8881**	**0.2984**	**0.9550**	N	3	0.6757	0.5695	0.6902
4	N	4	**0.8881**	**0.2987**	**0.9552**	Ω_D	A	0.6622	0.4795	0.6652
5	N	2	**0.8731**	0.3063	0.9345	Ω_D	A	0.7027	**0.4686**	0.7318
5	N	3	**0.8731**	0.3181	0.9240	Ω_P	A	0.7027	0.4751	0.7318
6	N	4	0.8433	0.3314	0.9263	N	1	0.7027	0.4769	**0.7424**
6	N	5	0.8433	0.3447	0.9138	F	A	0.7027	0.4987	0.7144

TABLE 2. Numerical results of the training and validation process for the DB0 data set. This table contents the best two cooperative decision-making methods accuracy performance per number of agents (n) vs. the performance of the single agent case. A indicates that all the agents in the RDM_{CA} system have the same collaborative decision-making method.

	Training					Validation				
n	DM	ID	ACC	RMSE	AUC	DM	ID	ACC	RMSE	AUC
1	L	-	0.8421	0.3974	0.8452	L	-	0.5550	0.6671	0.7082
2	N	1	**0.9079**	0.2925	0.9138	N	1	0.6545	0.5076	0.6858
2	N	2	0.8684	0.3352	0.8805	Ω_D	A	0.6126	0.4147	0.6739
3	N	2	**0.8947**	**0.2901**	0.9186	Ω_D	A	0.7225	0.3722	0.7050
3	N	1	0.8684	**0.2900**	0.9127	N	1	0.7068	0.5566	0.7537
4	N	4	0.8816	0.3236	**0.9474**	F	A	**0.9110**	0.4575	0.7684
4	N	1	0.8684	0.3076	**0.9443**	Ω_D	A	**0.8482**	**0.3131**	0.7441
5	N	5	**0.9079**	0.2989	0.9307	Ω_D	A	0.7435	0.3210	**0.7880**
5	N	1	0.8553	0.3381	0.9193	F	A	0.7382	0.4972	0.7693
6	N	4	**0.8947**	0.3195	0.9086	Ω_D	A	0.8220	**0.3107**	0.7333
6	N	3	**0.8947**	0.3199	0.9100	F	A	0.7225	0.4988	**0.7831**

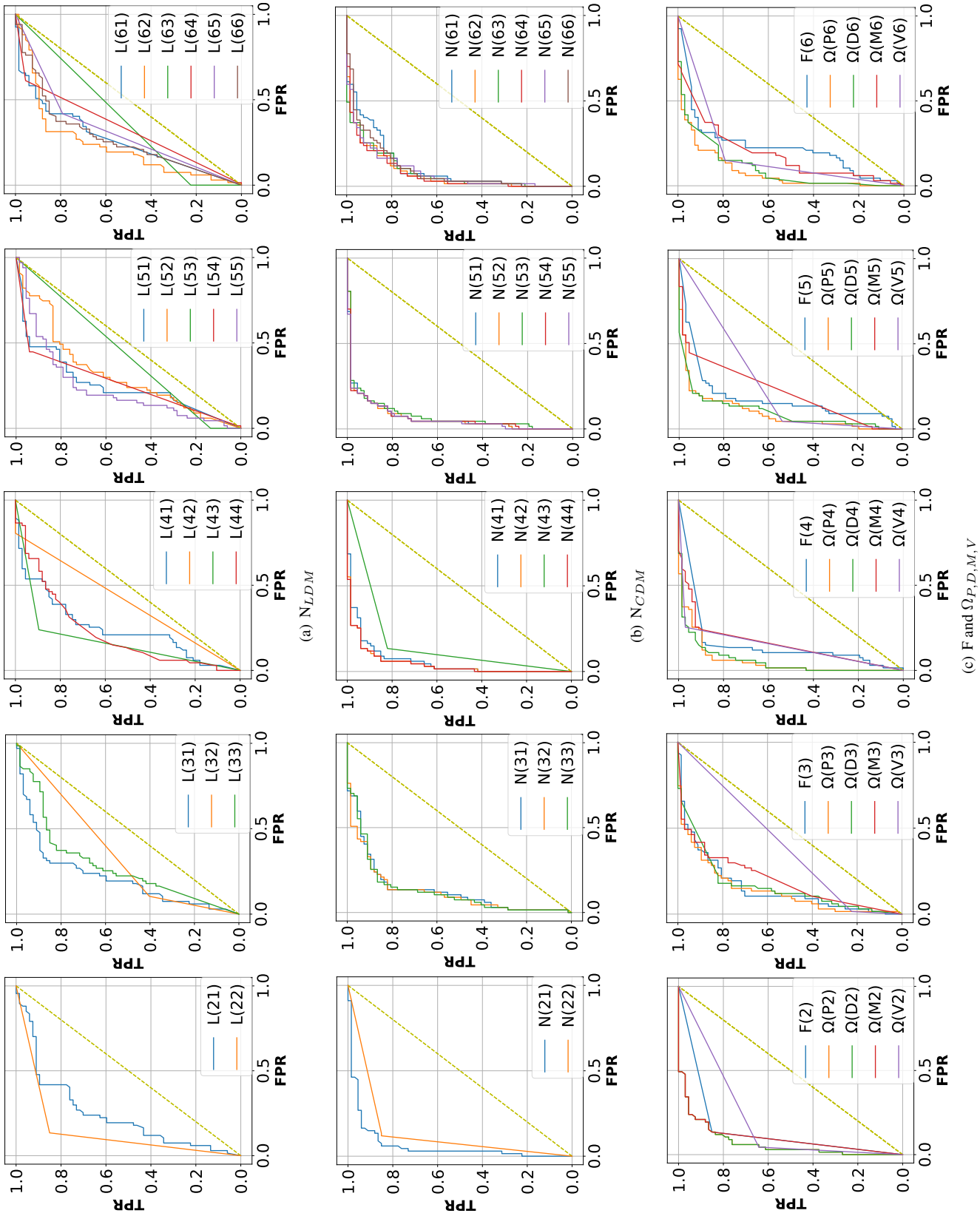
TABLE 3. Numerical results of the training and validation process for the DB1 data set. This table contents the best two cooperative decision-making methods accuracy performance per number of agents (n) vs. the performance of the single agent case. A indicates that all the agents in the RDM_{CA} system have the same collaborative decision-making method.

	Training					Validation				
n	DM	ID	ACC	RMSE	AUC	DM	ID	ACC	RMSE	AUC
1	L	-	0.9426	0.2396	0.9550	L	-	0.9414	0.2442	0.9699
2	N	2	0.9628	0.1928	0.9624	Ω_V	A	0.9377	0.2495	0.9268
2	N	1	0.9561	0.2096	0.9555	F	A	0.9377	0.2630	0.9447
3	N	3	0.9696	0.1772	0.9886	N	2	0.9414	0.2421	0.9449
3	N	1	0.9527	0.1948	0.9839	N	3	0.9451	0.2240	0.9806
4	N	3	**0.9797**	**0.1298**	**0.9974**	Ω_D	A	0.9414	0.2152	0.9802
4	N	2	0.9662	0.1699	0.9924	Ω_P	A	0.9414	0.2273	0.9768
5	N	4	0.9730	0.1552	0.9938	N	1	**0.9560**	0.1988	**0.9841**
5	N	5	0.9730	0.1719	0.9933	N	4	0.9451	0.2007	0.9807
6	N	6	**0.9764**	0.1571	0.9922	N	5	**0.9670**	**0.1816**	0.9474
6	N	1	0.9730	**0.1438**	**0.9954**	N	1	**0.9560**	**0.1977**	**0.9862**

TABLE 4. Numerical results of the training and validation process for the DB2 data set. This table contents the best two cooperative decision-making methods accuracy performance per number of agents (n) vs. the performance of the single agent case. A indicates that all the agents in the RDM_{CA} system have the same collaborative decision-making system.

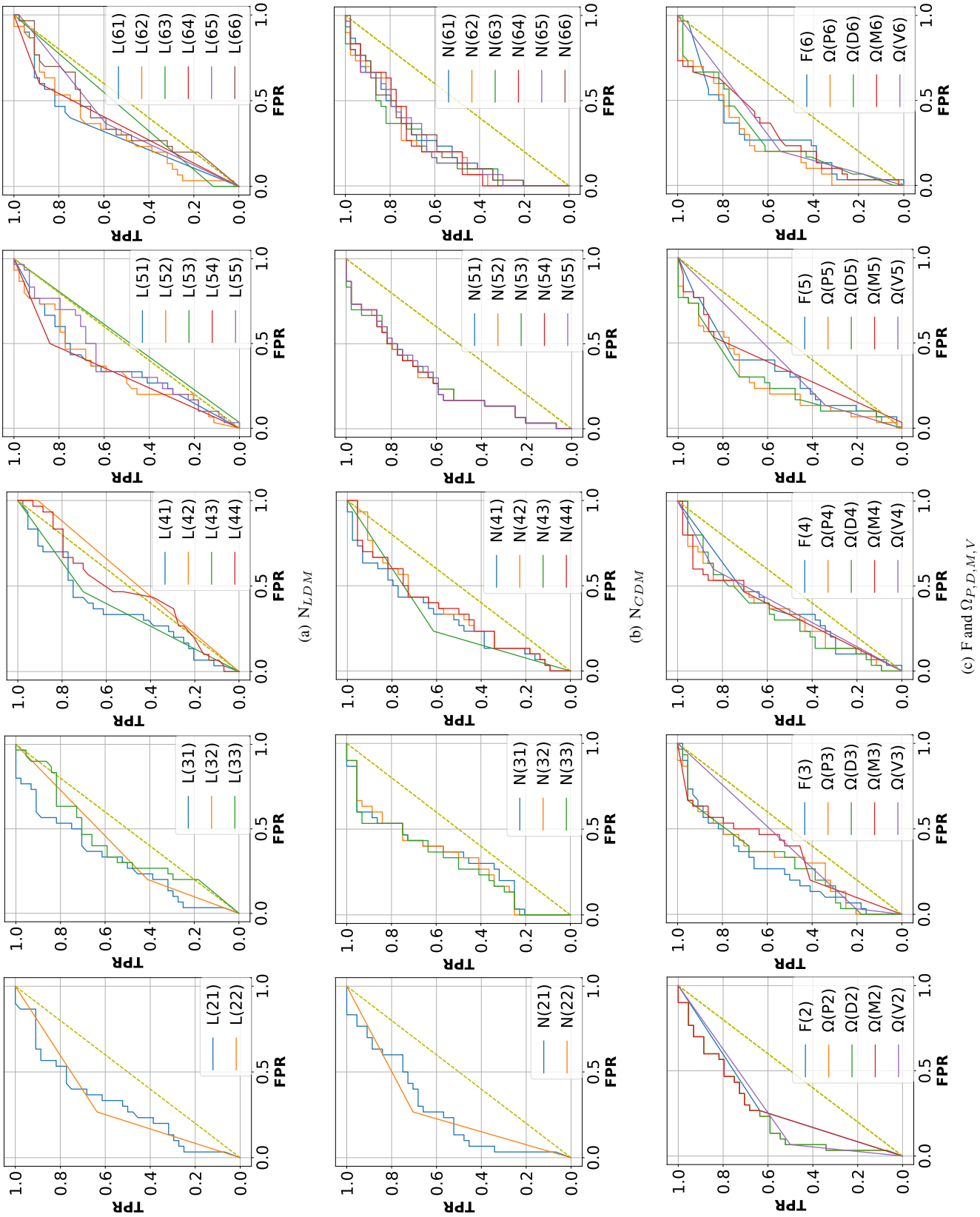
	Training					Validation				
n	DM	ID	ACC	RMSE	AUC	DM	ID	ACC	RMSE	AUC
1	L	-	**0.8186**	0.4259	0.8186	L	-	0.7467	0.5033	0.7467
2	N	1	0.7971	0.3887	0.8390	N	2	0.7300	0.4380	0.7706
2	N	2	0.7971	0.3887	0.8390	N	1	0.7300	0.4391	0.7706
3	N	3	0.7829	0.3820	0.8593	N	3	**0.7700**	**0.3927**	**0.8431**
3	N	2	0.7829	0.3822	0.8576	N	2	**0.7700**	**0.3930**	**0.8398**
4	N	4	0.7757	0.3910	0.8559	N	4	0.7400	0.4144	0.8245
4	Ω_P	A	0.7757	0.4455	0.8559	N	2	0.7400	0.4204	0.8071
5	N	4	**0.8271**	**0.3580**	**0.8992**	N	5	0.7600	0.4147	0.8323
5	N	3	**0.8271**	**0.3584**	**0.9007**	N	4	0.7567	0.4150	0.8306
6	N	6	0.8029	0.3794	0.8792	Ω_P	A	**0.7633**	0.4617	0.8260
6	N	2	0.8014	0.3794	0.8824	N	6	0.7533	0.4323	0.8162

TABLE 5. Numerical results of the training and validation process for the DB3 data set. This table contents the best two cooperative decision-making methods accuracy performance per number of agents (n) vs. the performance of the single agent case. A indicates that all the agents in the RDM_{CA} system have the same collaborative decision-making system.



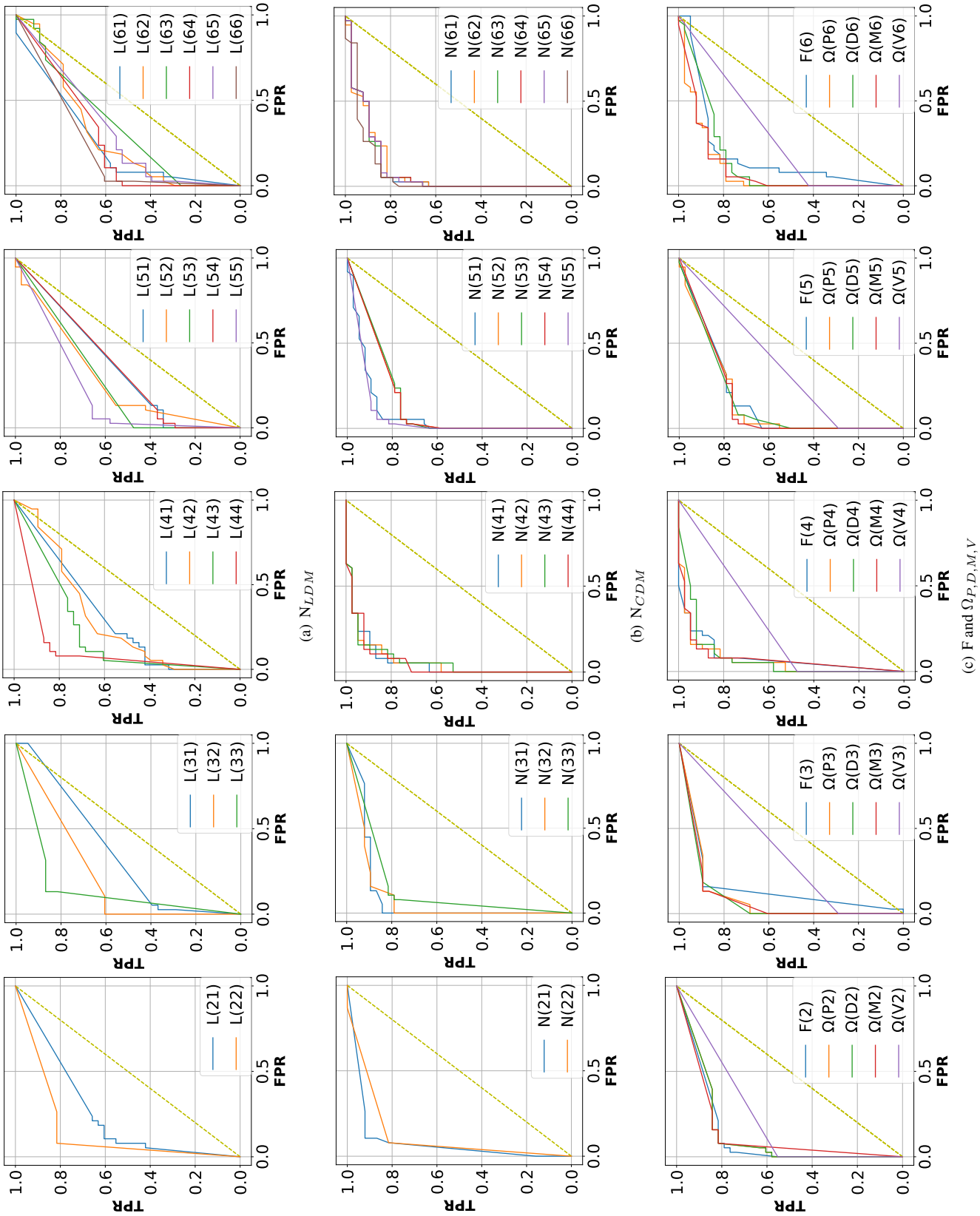
(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 1. ROC graphs of DB0 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the training process.



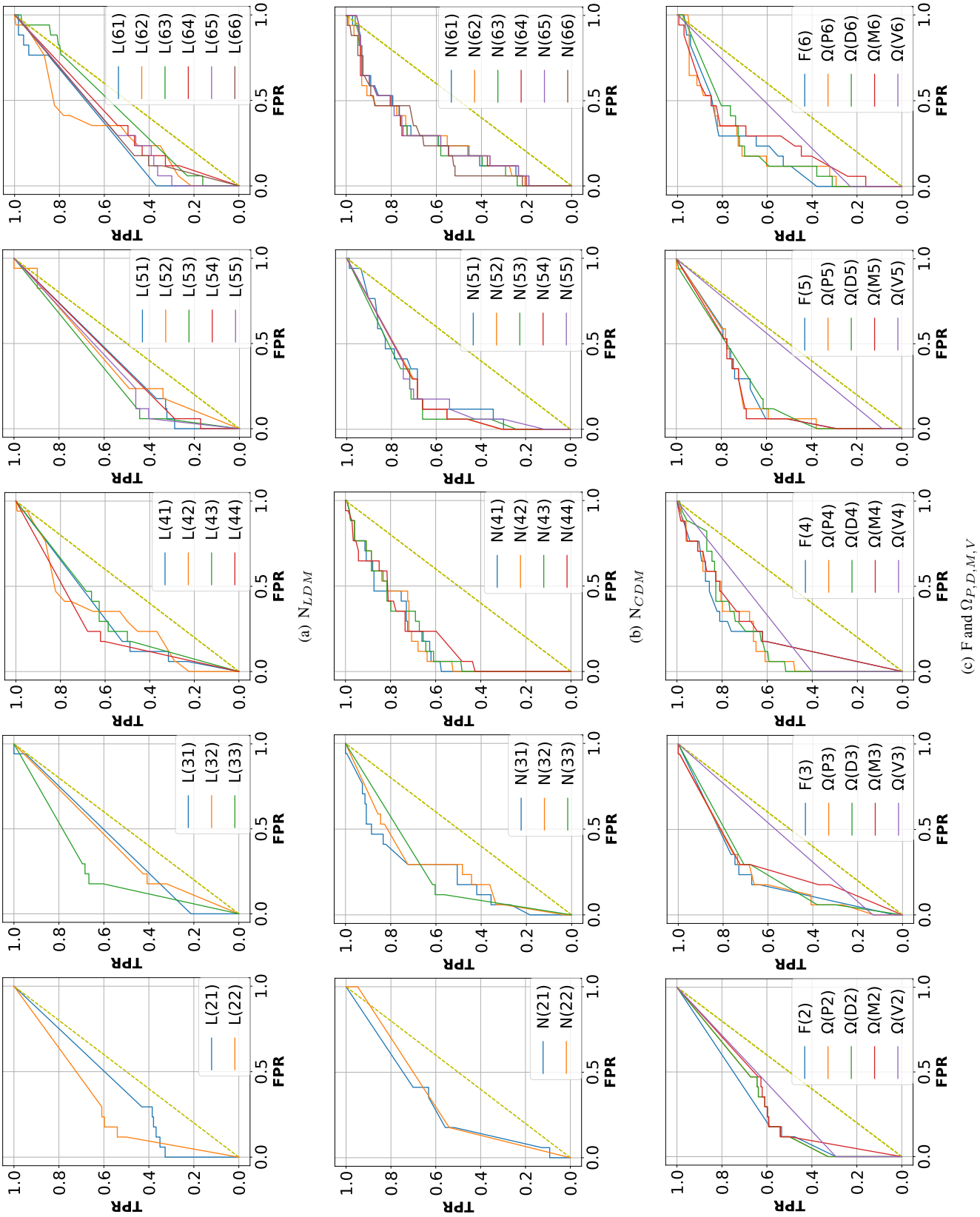
(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 2. ROC graphs of DB0 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the validation process.



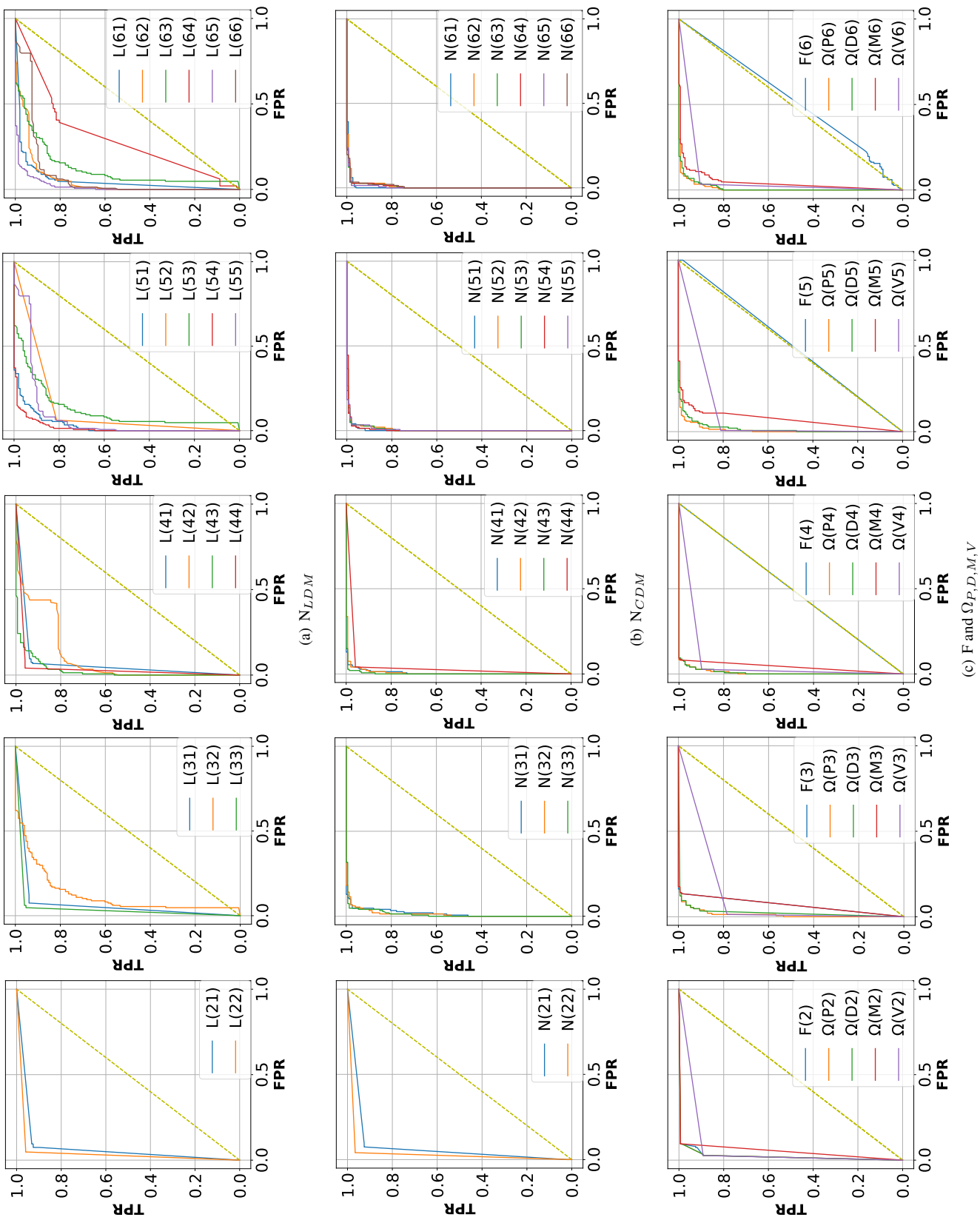
(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 3. ROC graphs of DB1 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the training process.



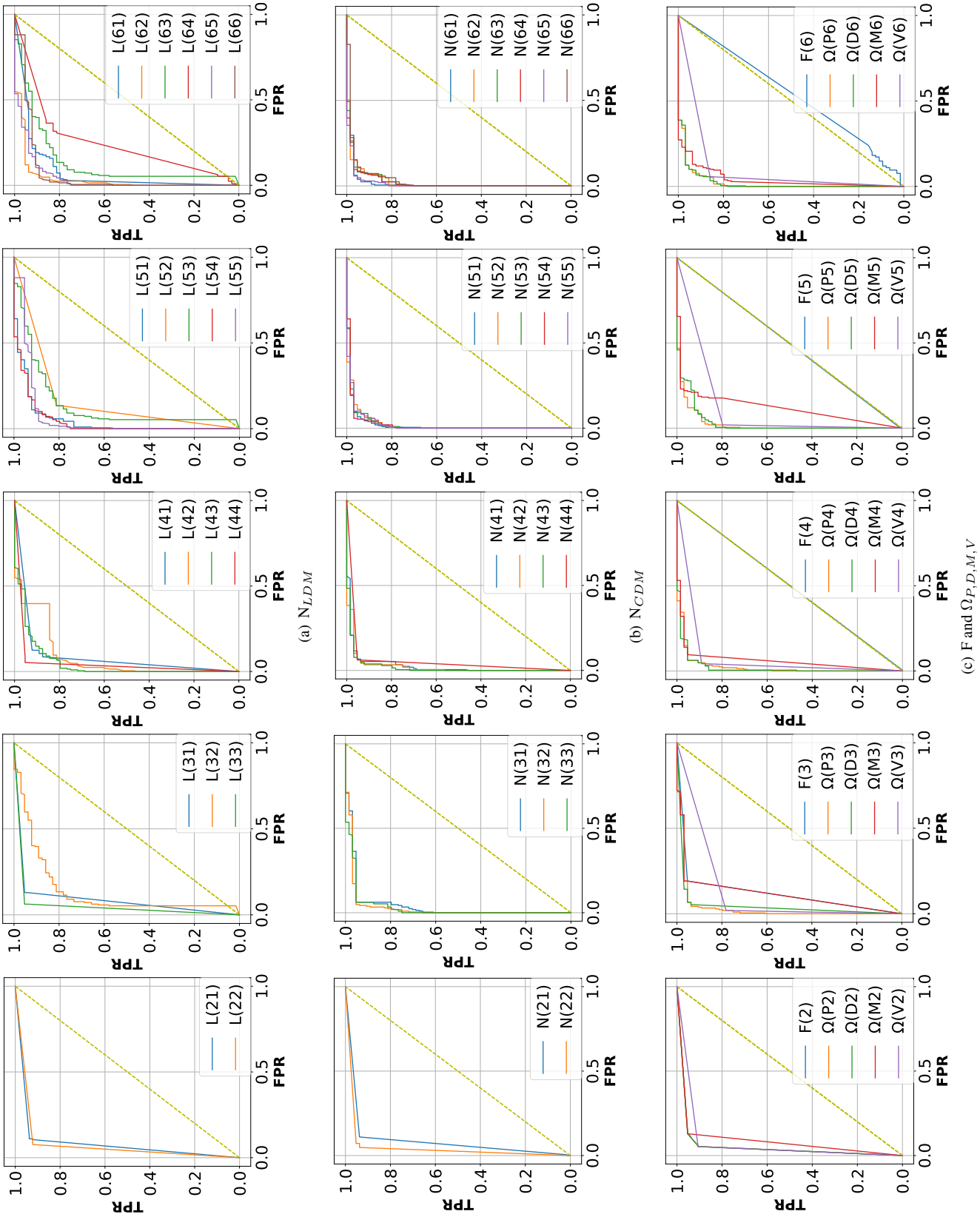
(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 4. ROC graphs of DB1 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the validation process.



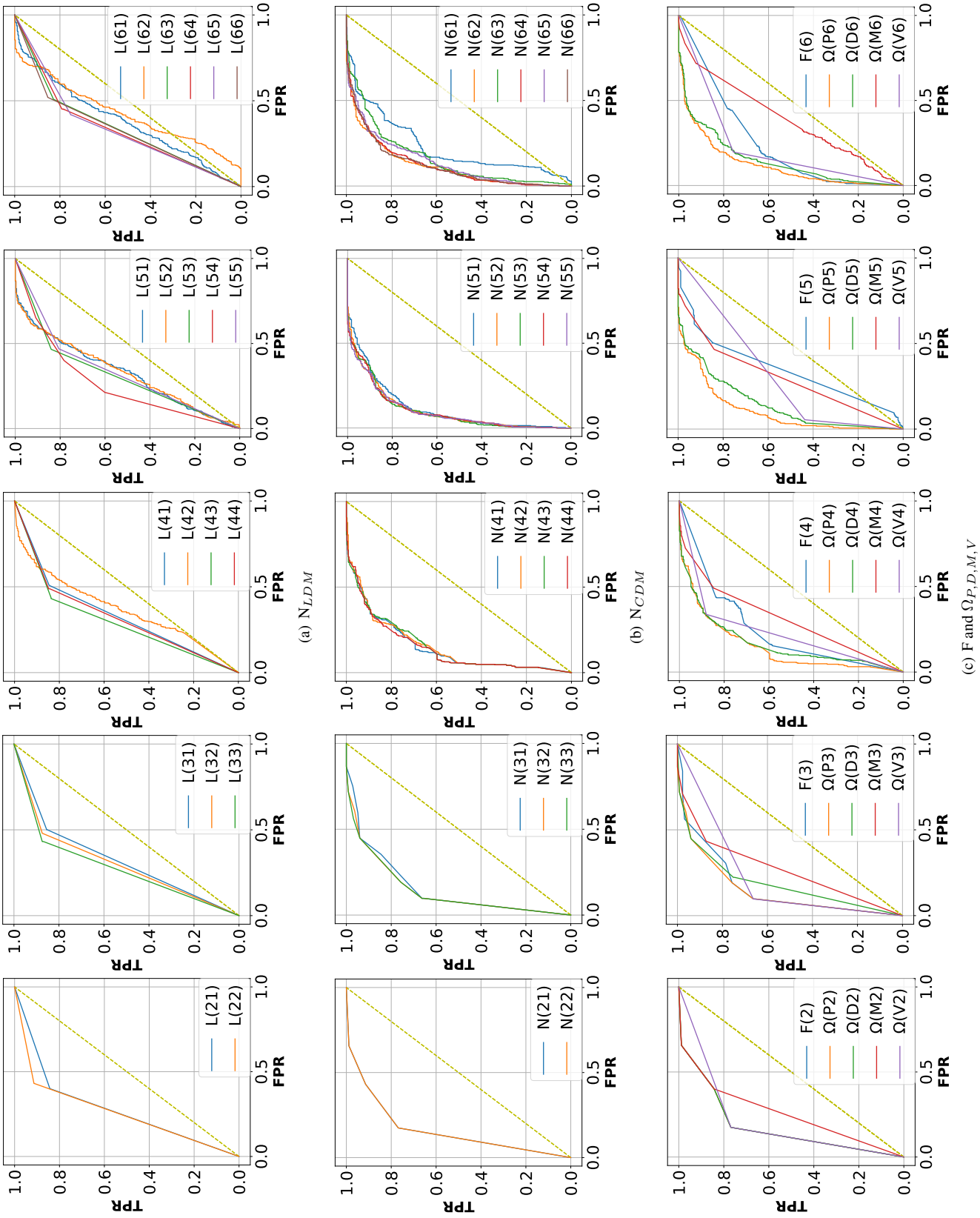
(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 5. ROC graphs of DB2 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the training process.



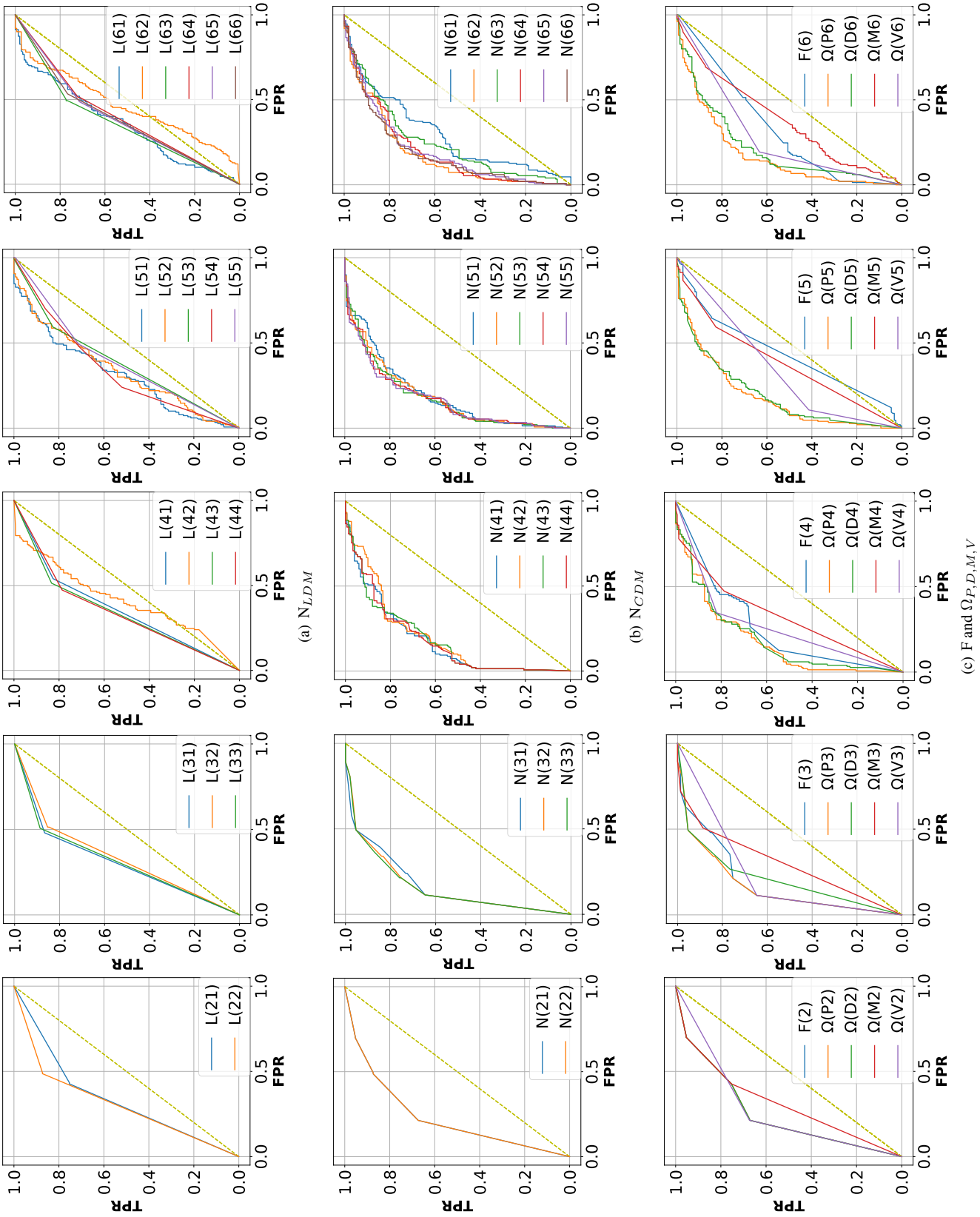
(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 6. ROC graphs of DB2 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the validation process.



(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 7. ROC graphs of DB3 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the training process.



(a) N_{LDM} (b) N_{CDM} (c) F and $\Omega_{P,D,M,V}$

FIGURE 8. ROC graphs of DB3 data set from systems with multiple agents (2, 3, 4, 5, and 6) on the validation process.

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