Coordination in Organizations with Heterogeneous Minimal Intelligence Agents

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1. Research Agenda
2. Outline of the Model
3. Results
4. Conclusions

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Research agenda (1) - Motivation

- Inconsistent empirical evidence on effects of workforce diversity in organizations
  (e.g., with further references Guillaume et al 2017; van Knippenberg et al. 2004)
- Methodological problems of unobserved / unobservable diversity
  (e.g., Carroll and Harrison 1998; Milliken and Martins 1996; van Knippenberg and Schippers 2007)
- Shift from "effect studies" to studies on moderators of effects of diversity
  (e.g., van Knippenberg and Schippers 2007; Guillaume et al 2017)
- Coordination as a reasonable candidate for shaping effects of diversity
  (e.g., Auh and Menguc 2005; Zoogah 2011)

Research questions:

- Are coordination mechanisms sensitive to the heterogeneity of decision-makers?
- Does coordination attenuate or even amplify the effects of heterogeneity of decision-makers?

Research agenda (1) - Method

Research questions:

- Are coordination mechanisms sensitive to the heterogeneity of decision-makers?
- Does coordination attenuate or even amplify the effects of heterogeneity of decision-makers?

- Agent-based approach - rationale
  - heterogeneity of agents as “built-in” feature
    (e.g., Kirman 1992; Hommes 2006; Tesfatsion 2006; Axtell 2007)
  - simulation at the technical core:
    → full control of (unobservable) diversity
    → analysis of interactions among different attributes of diversity
- Model
  - based on (noisy) NK fitness landscapes:
    (Kauffman/Levin 1987; Kauffman 1995; Levitan/Kauffman 1995; Wall 2016)
  - controls for
    - complexity of task environment,
    - coordination modes employed in the organization and
    - decision-making styles of managers, i.e., a hard to observe dimension of diversity

Model overview (1) – Decision problem of the organizations

- NK-fitness landscapes as basis (Kauffman/Levin 1987; Kauffman 1995)

- *N*-dimensional binary decision problem:

$$\mathbf{d} = (d_1, \ldots, d_N) \text{ with } d_1 \in \{0;1\}$$

- every single choice d_i contributes to overall performance by

$$C_i = f_i(d_i; d_{i_1}, \ldots, d_{i_K})$$

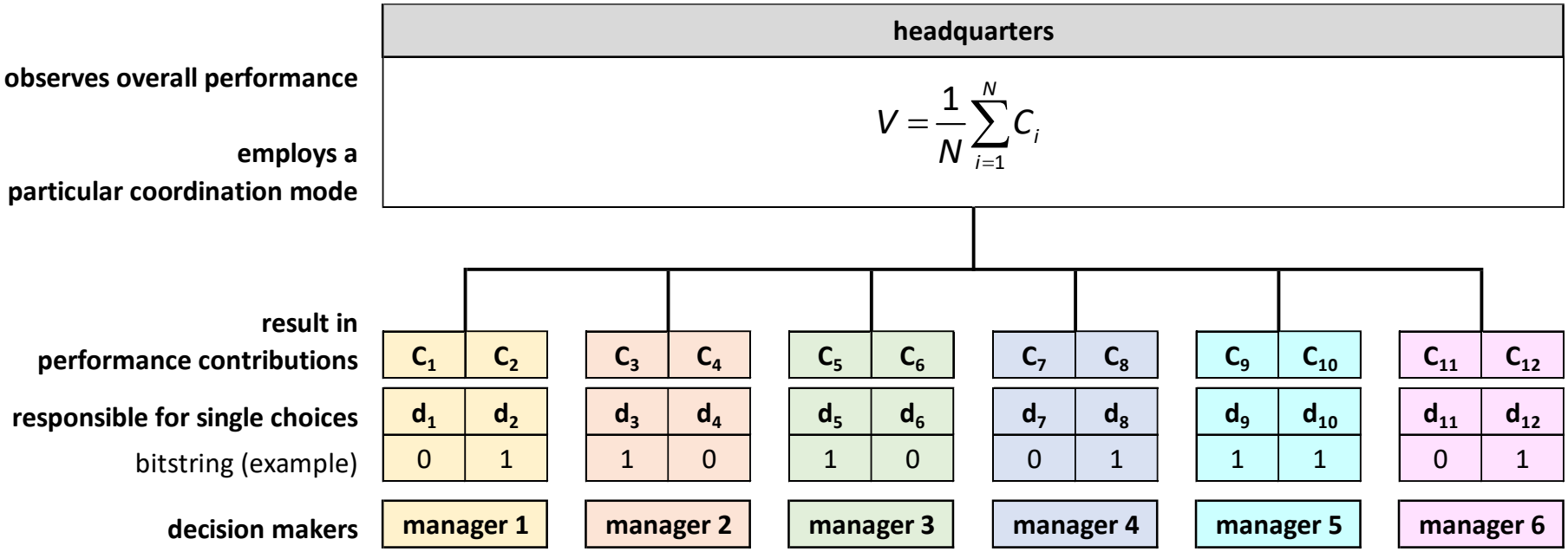
$$\text{where } \{i_1, \ldots, i_K\} \subset \{1, \ldots, i-1, i+1, \ldots, N\} \text{ and } 0 \le C_i \le 1$$

- with level *K* of complexity

- overall performance is given by

$$V = \frac{1}{N} \sum_{i=1}^{N} C_i$$

Model Overview (2) – Agents in the organizations



Each manager

- decides on “own” partition of the overall *N*-dimensional decision problem
- seeks to maximize the individual objective
- has time-delayed knowledge of fellow managers’ choices

Model overview (3) – Managers' steps in decision-making

In every time step t, each manager

- performs a neighbourhood search,
- based on search could keep the status quo or opt for one of the newly found options
- (imperfectly) evaluates new options subject to a relative error (with N(0;σ^{ϵ}))
- considering that changing the status quo induces effort / personal cost
- chooses that option which promises highest performance with respect to the own objective

Model overview (4) – Managers' steps in decision-making

… and diversity thereof

In every time step t, each manager

- performs a neighbourhood search,
- based on search could keep the status quo or opt for one of the newly found options
- (imperfectly) evaluates new options subject to a relative error (with $N(0;\sigma^r)$)
- considering that changing the status quo induces effort / personal cost
- chooses that option which promises highest performance with respect to the own objective

equally or diversely innovative and exhaustive in search

equal or different precision in evaluating new options

equally or diversely cost efficient when implementing new options

equal or diverse identification with organizational goals

Model overview (5) – Coordination modes

- **“decentralized”**
  - headquarter does not intervene in decision-making
  - each manager's first preference is implemented
- **"sequential planning"**
  - headquarter does not intervene in decision-making
  - managers make their choices sequentially: e.g., manager *r* takes choices of manager *r*-1 into account and eventually adjusts preferences
- **“hierarchy”**
  - managers form preferences and communicate these to headquarter
  - headquarter "composes" managers' preferences to overall candidate solutions
  - based on imprecise evaluations, headquarter chooses that candidate solution which promises highest overall performance

Model overview (6) – Interactions structures (examples)

N=12-dimensional decision-problem, partitioned into 6 equal-sized subproblems and each exclusively assigned to one out of 6 departments/managers

Decomposable with *N*=12, K^{ex}=0

Performance Contribution C_j

Choice d_i	1	2	3	4	5	6	7	8	9	10	11	12
1 DecM	X	X	-	-	-	-	-	-	-	-	-	-
2 DecM	X	X	-	-	-	-	-	-	-	-	-	-
3 DecM	-	-	X	X	-	-	-	-	-	-	-	-
4 DecM	-	-	X	X	-	-	-	-	-	-	-	-
5 DecM	-	-	-	-	X	X	-	-	-	-	-	-
6 DecM	-	-	-	-	X	X	-	-	-	-	-	-
7 DecM	-	-	-	-	-	-	X	X	-	-	-	-
8 DecM	-	-	-	-	-	-	X	X	-	-	-	-
9 DecM	-	-	-	-	-	-	-	-	X	X	-	-
10 DecM	-	-	-	-	-	-	-	-	X	X	-	-
11 DecM	-	-	-	-	-	-	-	-	-	-	X	X
12 DecM	-	-	-	-	-	-	-	-	-	-	X	X

Non-decomposable with *N*=12, K^{ex}=7

Performance Contribution C_j

Choice d_i	1	2	3	4	5	6	7	8	9	10	11	12
1 DecM	X	X	X	X	-	X	-	X	-	X	-	X
2 DecM	X	X	-	X	X	X	X	-	X	X	X	X
3 DecM	-	X	X	X	X	-	X	X	X	-	X	-
4 DecM	X	-	X	X	X	X	-	X	X	X	-	X
5 DecM	-	X	X	-	X	X	X	-	X	X	X	X
6 DecM	X	X	-	X	X	X	-	X	-	X	X	-
7 DecM	X	-	X	X	-	X	X	X	X	X	-	X
8 DecM	-	X	X	X	X	-	X	X	X	-	X	X
9 DecM	X	X	-	X	X	X	-	X	X	X	X	X
10 DecM	X	-	X	X	X	X	X	-	X	X	X	-
11 DecM	X	X	X	-	-	X	X	X	X	-	X	X
12 DecM	X	X	X	-	X	-	X	X	-	X	X	X

Notes:

	Scope of primary control of decision maker *r*
X	Choice *i* affects performance contribution *j*
-	Choice *i* does not affect performance contribution *j*
DecM	Decision maker

Simulation Experiments (1)

Set-up of experiments:

- organizations are observed for 250 periods in searching for superior performance
- homogeneity: 6 managers at medium level of the respective attribute
- heterogeneity:
  - "symmetric" diversity of managers, i.e., 2 low / 2 medium / 2 high level for each attribute
    - behavior in search for new options
    - precision of evaluation of new options
    - cost efficiency
    - identification with organizational objective
  - for multi-attributive diversity: polarising / accumulating of low / medium / high levels across attributes of workforce (not compensating)

Simulation Experiments (2)

Two types of experiments:

Comparison of organizations with heterogeneous decision-making styles against organizations with homogeneous decision-making across various levels of intra-organizational complexity K^{ex} for

- type 1: "decentralized" coordination
- type 2: different coordination modes

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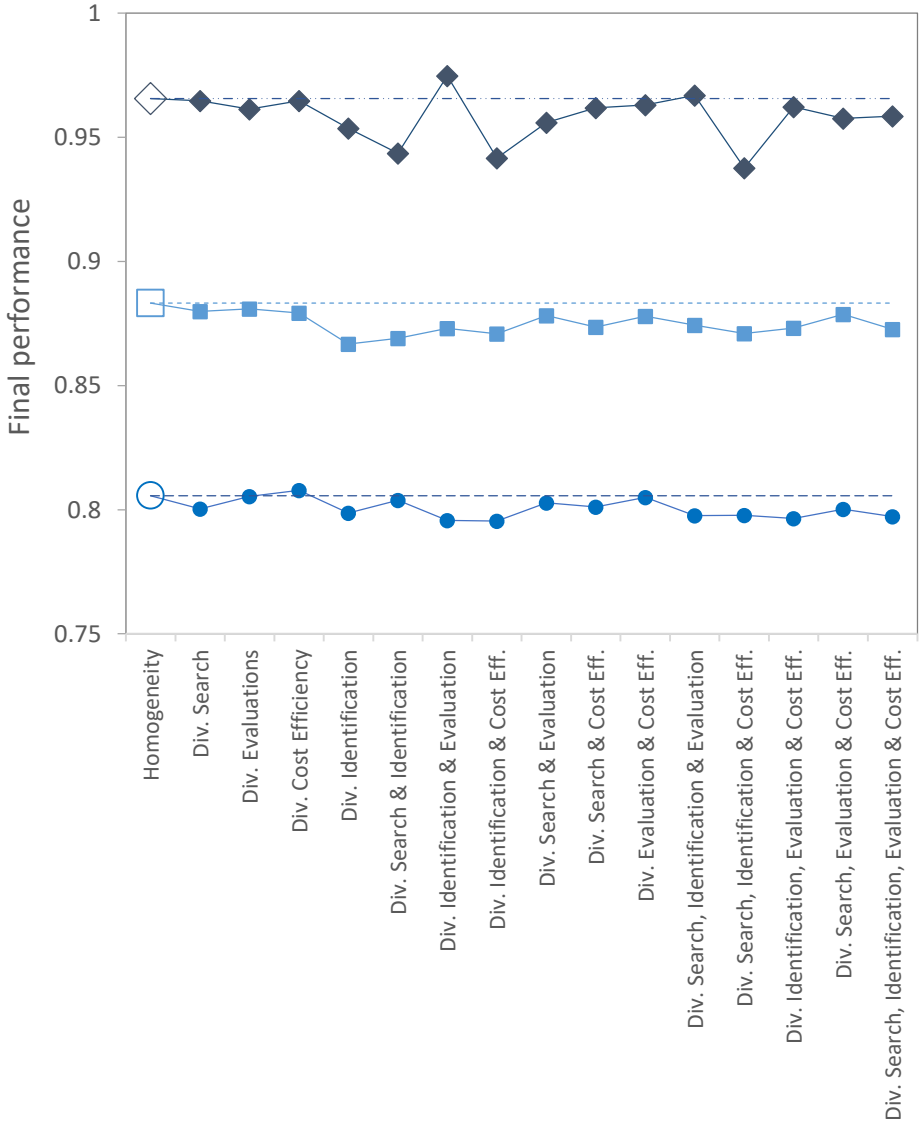
Results (1) – Homogeneous vs. heterogenous decision-making styles with "decentralized" coordination mode



Decomposable structure
(N = 12, K^{ex} = 0)

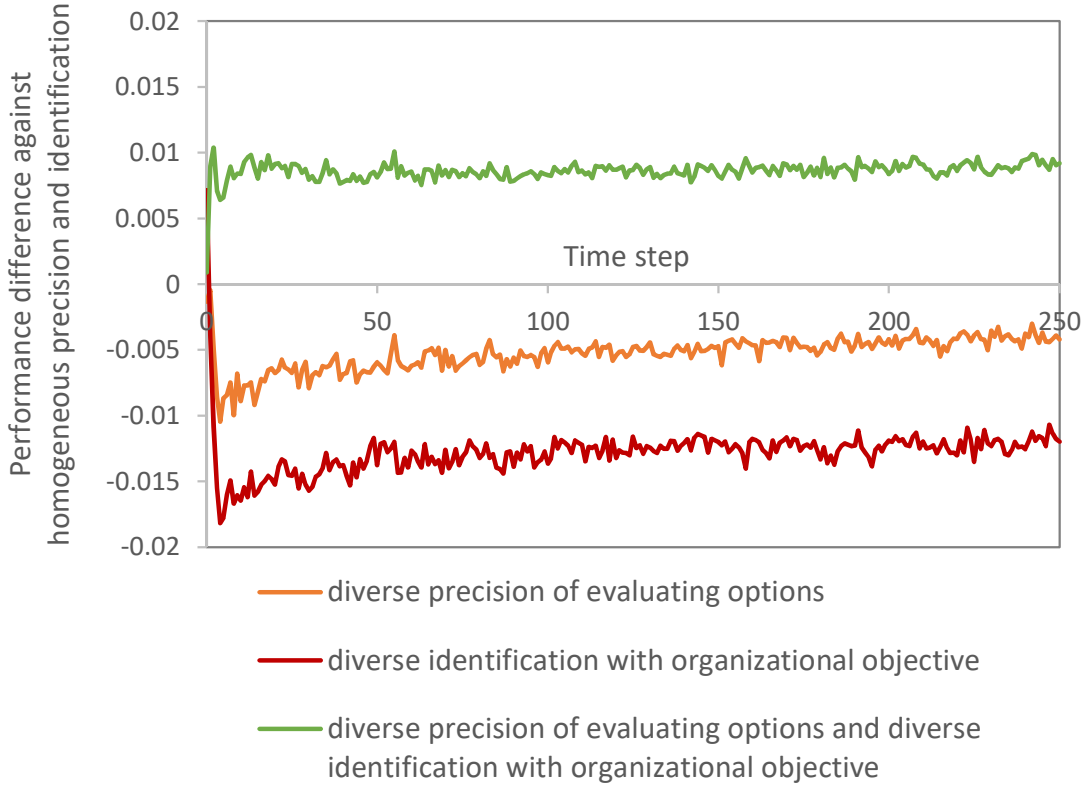
Non-decomposable structure
(N = 12, K^{ex} = 5)

Non-decomposable structure
(N = 12, K^{ex} = 9)

Each mark in the plot indicates the averaged results of 2500 simulation runs.

Results (2) – Non-trivial interactions among attributes of decision-making

Example: decomposable structure (N = 12, K^{ex} = 0)



Mean differences of final performance $V_{t=250}$ and half-lengths of confidence intervals at a confidence level of 0.99 percent according to Welch's test (1936)

	Homogenous precision and identification	Diverse precision	Diverse identification
Diverse precision	-0.0042 ±0.0024*		
Diverse identification	-0.012 ±0.0026*	-0.0078 ±0.0027*	
Homogenous precision and identification	**0.0092 ±0.0021***	**0.0134 ±0.0022***	**0.0212 ±0.0025***

Each line in the plot indicates the averaged results of 2500 simulation runs.

Simulation Experiments (2)

Two types of experiments:

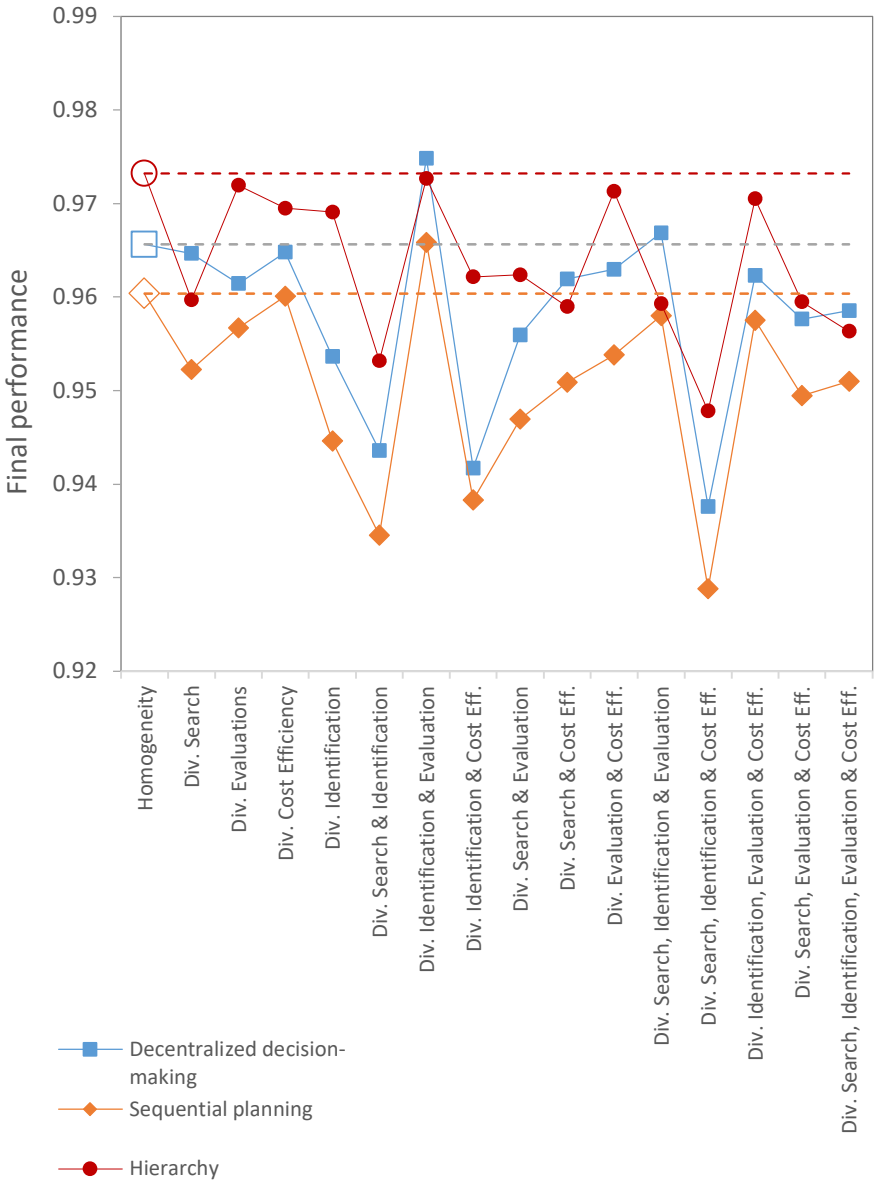
Comparison of organizations with heterogeneous decision-making styles against organizations with homogeneous decision-making across various levels of intra-organizational complexity K^{ex} for

- type 1: "decentralized" coordination
- **type 2: different coordination modes**

Results (3) – Heterogeneous decision-making styles under the regime of different coordination modes

decomposable structure
(N = 12, K^{ex} = 0)

	Decen-tralized	Sequential Planning	Hierarchy
(1) Final performance for homogen. decision-making	0.96562	0.96038	0.97322
(2) Mean of final perf. of scenarios with heterogeneous decision-making styles	0.95790	0.94991	0.96296
(3) Difference (2) - (1)	-7.72E-03	-1.05E-02	-1.03E-02
(4) StDev of final perf. of scenarios with heterogeneous decision-making styles	1.01E-02	1.00E-02	7.57E-03

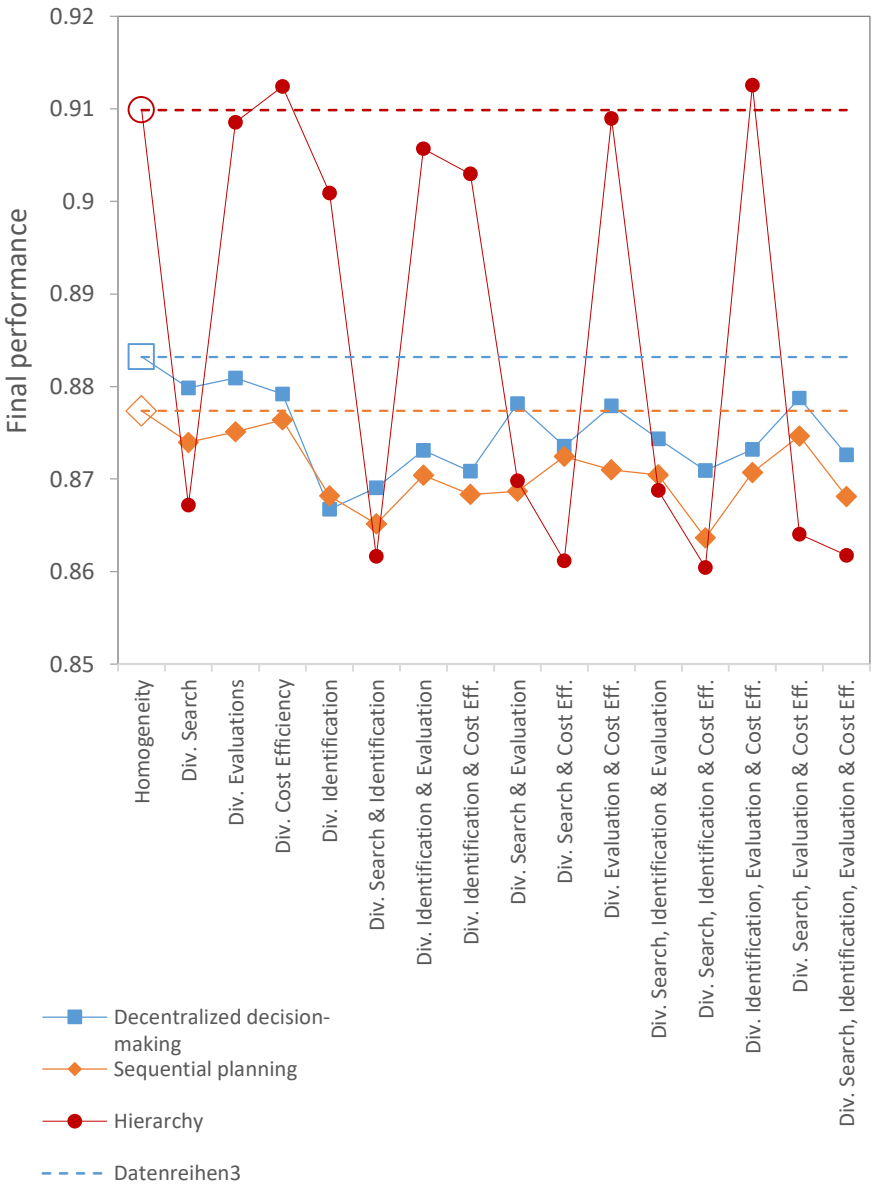


Each mark in the plot indicates the averaged results of 2500 simulation runs.

Results (4) – Heterogeneous decision-making styles under the regime of different coordination modes

non-decomposable structure
(N = 12, K^{ex} = 5)

	Decen-tralized	Sequential Planning	Hierarchy
(1) Final performance for homogen. decision-making	0.88319	0.87737	0.90986
(2) Mean of final perf. of scenarios with heterogeneous decision-making styles	0.87461	0.87048	0.88446
(3) Difference (2) - (1)	-8.58E-03	-6.89E-03	-2.54E-02
(4) StDev of final perf. of scenarios with heterogeneous decision-making styles	4.30E-03	3.63E-03	2.26E-02

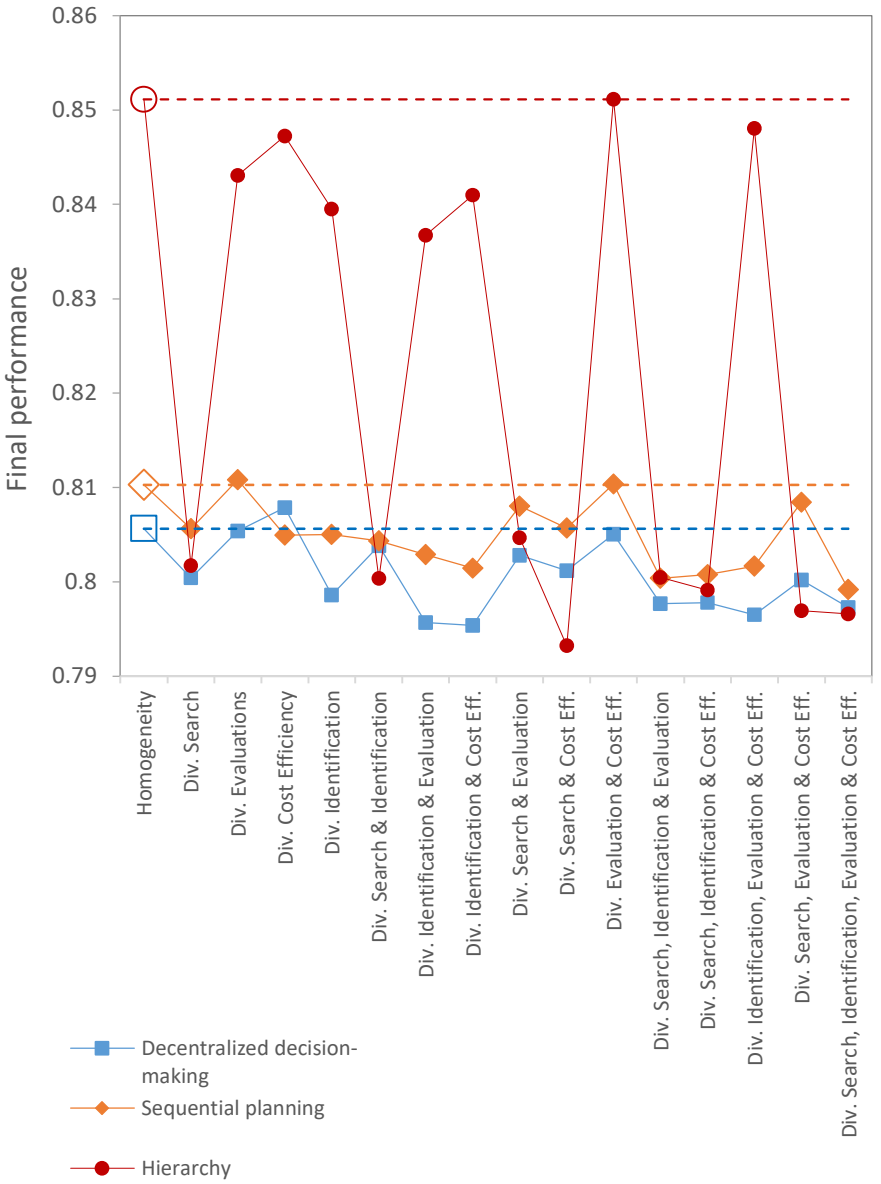


Each mark in the plot indicates the averaged results of 2500 simulation runs.

Results (5) – Heterogeneous decision-making styles under the regime of different coordination modes

non-decomposable structure
(N = 12, K^{ex} = 9)

	Decen-tralized	Sequential Planning	Hierarchy
(1) Final performance for homogen. decision-making	0.80563	0.81027	0.85112
(2) Mean of final perf. of scenarios with heterogeneous decision-making styles	0.80037	0.80464	0.81998
(3) Difference (2) - (1)	-5.26E-03	-5.64E-03	-3.11E-02
(4) StDev of final perf. of scenarios with heterogeneous decision-making styles	3.87E-03	3.63E-03	2.34E-02



Each mark in the plot indicates the averaged results of 2500 simulation runs.

Conclusion

Research questions:

- Are coordination mechanisms sensitive to the heterogeneity of decision-makers?
- Does coordination attenuate or even amplify the effects of heterogeneity of decision-makers?

- **Results suggest the following hypotheses:**
  - Tight coordination via hierarchy may not attenuate, but even amplify effects of heterogeneity in decision-making styles – shaped by the attributes of heterogeneity and the complexity of the task environment.
  - The sensitivity of coordination modes to heterogeneous decision-making styles is affected by the complexity of the task environment.

- **Further research opportunities:**
  - Examination of further coordination modes (e.g., lateral veto mode)
  - …and of robustness of further organizational arrangements (e.g., incentive schemes, task allocation)
  - …

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Parameter Settings (1)

Parameter	Settings in the experiments
Fixed for all experiments	
Number of decisions	$N = 12$
Number of departments	$M = 6$ with each department responsible for two decisions
Intra-organizational complexity	decomposable $K^{ex} = 0$ non-decomposable $K^{ex} \in \{5, 9\}$
Observation period	$T = 250$
Runs per scenario	2500 runs where each scenario is given by - interaction structure - combination of attributes that define heterogeneity/ homogeneity of decision-making style - coordination mode employed
Subject to variation in the experiments	
Coordination mode	type 1 experiments: decentralized type 2 experiments: decentralized, sequential planning, hierarchy

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Parameter Settings (2)

Parameter	Settings in the experiments
Subject to variation in the experiments	
Search behaviour	homogen.: each agents finds 2 alternatives with Hamming distances $H_1(\mathbf{d}^r) = 1$ and $H_2(\mathbf{d}^r) = 2$ to status quo heterogen.: 2 agents with $H_1(\mathbf{d}^r) = 1$ 2 agents with $H_1(\mathbf{d}^r) = 1$ and $H_2(\mathbf{d}^r) = 2$ 2 agents with $H_1(\mathbf{d}^r) = 1$, $H_2(\mathbf{d}^r) = 1$ and $H_3(\mathbf{d}^r) = 2$
Precision of evaluation	homogen.: each agent has medium precision: $\sigma^{r,own} = 0.06$; $\sigma^{r,rest} = 0.12$ heterogen.: 2 agents have low precision: $\sigma^{r,own} = 0.09$; $\sigma^{r,rest} = 0.2$ 2 agents have medium precision: $\sigma^{r,own} = 0.06$; $\sigma^{r,rest} = 0.12$ 2 agents have high precision: $\sigma^{r,own} = 0.03$; $\sigma^{r,rest} = 0.06$
Cost efficiency	homogen.: each agent has medium costs: $c^r = 0.01$ heterogen.: 2 agents have high costs: $c^r = 0.02$ 2 agents have medium costs: $c^r = 0.01$ 2 agents have low costs: $c^r = 0.005$
Identification with organizational objective	homogen.: each agent pursues departmental performance and gives medium weight $\alpha^r = 0.5$ to organizational performance heterogen.: 2 agents show no identification with organizational performance: $\alpha^r = 0$ (i.e., only parochial performance pursued) 2 agents give medium weight $\alpha^r = 0.5$ to organizational performance 2 agents fully identify with organizational performance, $\alpha^r = 1$