

Developing an empirically based agent-based model to support local transitions

Symposium: Human-centred energy modelling
Novel methodological pathways for environmental psychology

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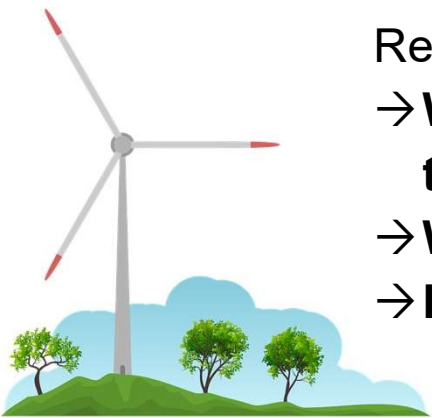
Background and Research Questions

Background:

- Importance of sustainable technologies (e.g., hydrogen)
- Limited adoption of sustainable technologies

Research questions:

- **What are the most important factors for the adoption of sustainable technologies?**
- **What is the joined impact of these factors?**
- **How to accelerate the adoption of sustainable technologies?**



Can be Approached From Different Disciplines

	Environmental Psychology	Transition Studies
Insights:	Factors influencing individual sustainable technology adoption behaviour of e.g., electric vehicles or PV (micro level)	Diffusion of innovations on the system level (macro level)
Methods:	<ul style="list-style-type: none"> • Self-reports • Experiments • Field studies • Etc. 	<ul style="list-style-type: none"> • System analysis • Simulations (Agent-based modelling) • Exploration of scenarios
Limitations:	<ul style="list-style-type: none"> • Low external validity • Limited insights on what happens after the adoption behaviour 	<ul style="list-style-type: none"> • Assumption of the rational actor in simulations (homo economicus) • Low psychological (or social) reliability

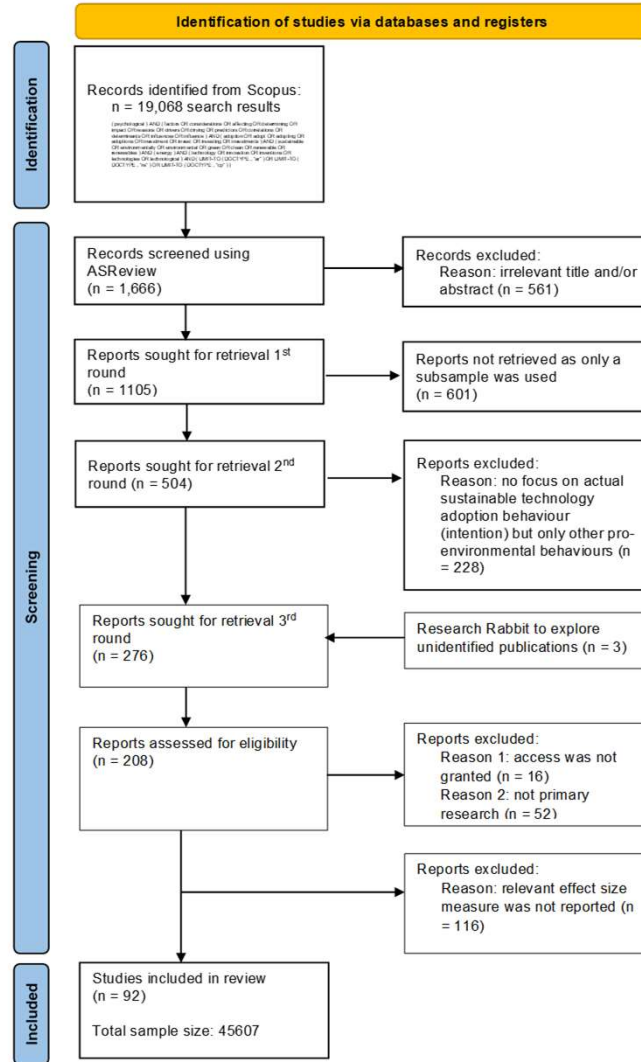
Interdisciplinary Approach

→ Integrating findings from the literature on sustainable technology adoption into an agent-based model

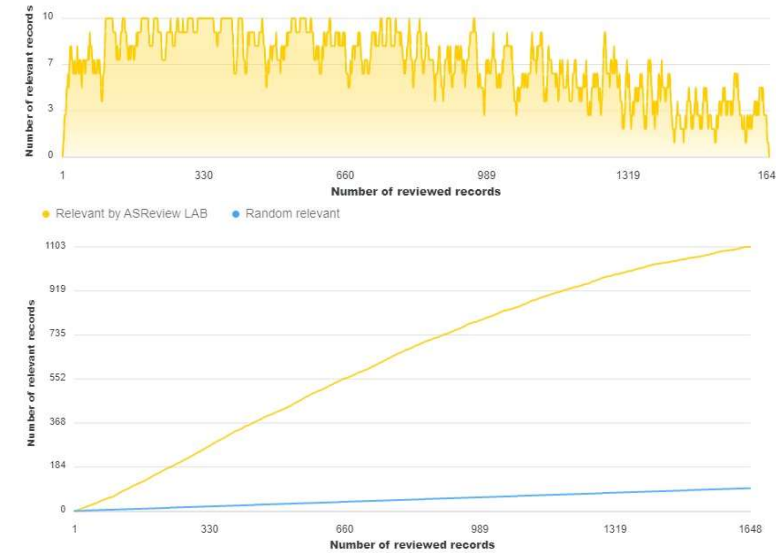
Aim:

- Addressing the complexity of interrelated social and technical phenomena and heterogeneous social actors
- Understanding sustainable technology adoption at the micro and macro level (emergent behaviour)

Methodology: Systematic Literature Review PRISMA Flow Diagram

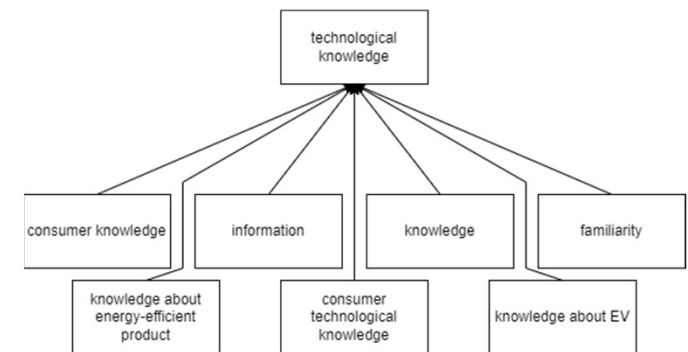
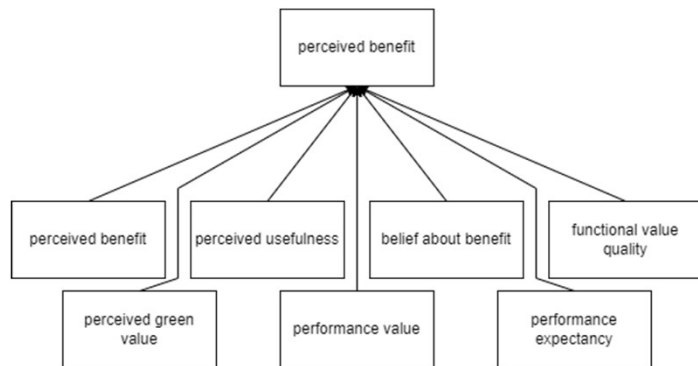
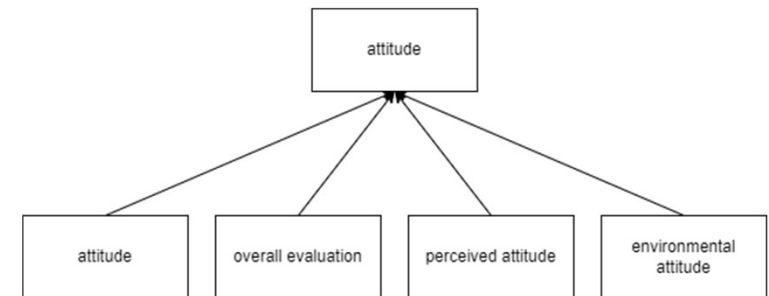
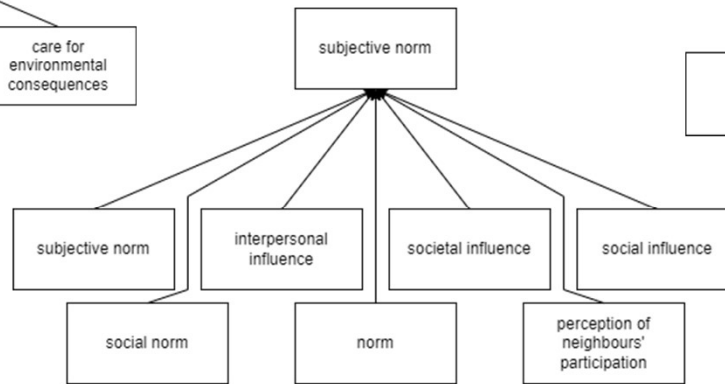
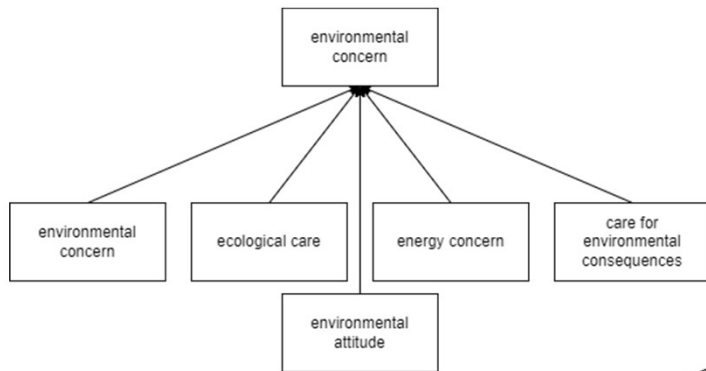


ASReview:



Merging Variables for Better Comparability

- A few Examples



Key Findings

Psychological Factors

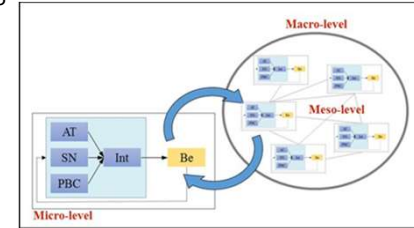
Factor	No. of Studies	No. of Part.	Mean r *	Std. Deviation
Attitude	58	30 436	0.532	0.140
Subjective Norm	60	26 916	0.497	0.151
Environ. Concern	35	15 585	0.426	0.136
Perceived Behavioural Control	35	14 768	0.525	0.152
Perceived Benefit	29	14 620	0.426	0.177
Tech. Knowledge	21	14 188	0.393	0.139
Perceived Cost	26	13 700	<u>-0.292</u>	0.190
Personal Norm	26	13 030	0.508	0.149
Perceived Ease of Use	23	10 946	0.355	0.140

* Mean of the Pearson Correlation Coefficient;

Key Findings

Differences Between Regions and Technologies

Factor	Regions								Technologies					
	Africa (n = 7)		Asia (n = 65)		Europe (n = 15)		North America (n = 5)		Alternative-Fuel Vehicles (n = 48)		Energy-Efficient Appliances (n = 23)		Renewable Energy Technologies (n = 21)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Attitude	0.557	0.166	0.522	0,134	0.543	0.143	0.510	0.00	0.579	0.160	0.494	0.100	0.527	0.150
Subjective Norm	0.542	0.147	0.509	0,146	0.464	0.142	0.430	0.173	0.552	0.157	0.467	0.141	0.480	0.141
Environ. Concern	0.444	0.115	0.401	0,142	0.518	0.048	/	/	0.432	0.147	0.378	0.057	0.454	0.150
Perceived Behavioural Control	0.524	0.149	0.536	0,156	0.282	0.00	0.470	0.00	0.437	0.121	0.561	0.132	0.567	0.176
Perceived Benefit	0.640	0.048	0.440	0,200	0.363	0.068	0.379	0.173	0.583	0.184	0.358	0.112	0.339	0.107
Tech. Knowledge	0.395	0.118	0.418	0,058	0.373	0.179	/	/	0.323	0.174	0.463	0.052	0.404	0.094
Perceived Cost	-0.351	0.025	-0.301	0,219	-0.272	0.163	/	/	-0.286	0.151	-0.120	0.121	-0.341	0.219
Personal Norm	0.510	0.065	0.525	0,174	0.473	0.083	/	/	0.486	0.169	0.536	0.111	0.582	0.045
Perceived Ease of Use	0.272	0.080	0.367	0,179	0.387	0.056	/	/	0.436	0.173	0.353	0.107	0.261	0.075



From: Scalco et al. (2018)

Integration Into Agent-Based Models

Understanding emergent behaviour (from micro to macro)

→ Interrelatedness between factors:

- Positive attitudes might influence PBC
- Strong personal norms might influence attitudes
- Strong personal norms might influence PBC

→ Formalisation:

- Define attributes to each agent (empirically): Attitudes, PBC and personal norms (e.g., -1 to 1)
- Define within-agents behaviours:
 - Attitude updates: Exposure to information or social interactions
 - PBC updates: Resource availability or supporting infrastructure
 - Personal Norm updates: Exposure to environmental degradation

→ Model interactions:

- Attitude diffusion through social networks (convergence or divergence?)
- PBC contagion: Sharing of information or resources and observability of successful adoption
- Normative influence: Agents with strong personal norms exert social pressure

Formalisation Challenges and Solutions

- Hurdles in formalising the theoretical framework:
 - Translating a linear and static psychological theory into a dynamic and time-based simulation
 - Determining the effect of technical, economic, environmental, political changes and interventions on the psychological factors

- Importance of validation and reliability:
 - Sensitivity analysis
 - Expert interviews
 - Checking for face validity and comparing to historical data

Conclusion

- Context-specific differences in psychological factors → need for tailored approaches
- Complex interplay between psychological factors, social dynamics, and technical aspects → need for interdisciplinary collaboration and data-driven approaches
- Bridging psychology and agent-based modeling enables the exploration of more realistic scenarios → exploration of large scale interventions to facilitate sustainable socio-technical transitions
- Formalisation of psychological theories forces us to really think about commonly used theories and their underlying assumptions

Thank you!

Feedback is more than welcome

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