universität freiburg

Advancement of Cognitive-Affective Map

CAM tools list

- Data collection tool Cognitive-Affective Map Extended Logic (C.A.M.E.L.) 🐫: https://camgalaxy.github.io/
- Data Analysis CAM-App programmed in Shiny (R), links to
  - version 1.X: not updated anymore
  - version 2.X: https://fennapps.shinyapps.io/CAMtools_CAMapp/
- in the future an administrative webpage, current developer version: https://dashboard-vercel-8aen53m4y-fennstatistics.vercel.app/
- Slack support channel: https://join.slack.com/t/cognitiveaffe-um96332/shared_invite/zt-1cybwr0tf-u2PWQh4L3BP3tuxLuH4c5w
- **Online documentation**: https://camtools-documentation.readthedocs.io/en/master/
  - Manuscript
- all collected CAM data sets with analysis files / explanations can be found here [future meta-analysis]: https://github.com/FennStatistics/CAMdatasets

Advancement of the methodology of Cognitive-Affective Mapping

Developed tools, a bird's-eye view

Main article:
Fenn, J., Gouret, F., Gorki, M., Reuter, L., Gros, W., Hüttner, P., & Kiesel, A. (under review). *Cognitive Affective Maps Tools: Proposing Multiple Software Solutions to Collect and Analyze Belief Systems*.

Cognitive-Affective Mapping

a quantitative and qualitative research method

motivated by previous dissertation (Reuter, 2022)

Florian Gouret (data engineer and software developer)

Example: Motivation to use the own car vs. public transport (Sendtner, 2021)

Overview: CAMs - Theory

What are CAMs?

- CAMs are „conceptual structures that people use to represent important aspects of the world“
- „cognitive-affective map is a visual representation of the emotion values of a group of interconnected concepts“
  - this is how CAMs differ from semantic networks, because CAMs additionally contain emotions (valence)
  - hot cognition: emotions cannot be separated from cognitions

How are CAMs constructed?

- the stepwise construction process of CAMs can be understood as a **multiple constraint satisfaction process**, where concepts, conditions, goals, etc. are mentally represented with the involvement of emotions
  - Concepts in the CAM are only changed or added if they correspond to the „most coherent account of what we want to understand“

Thagard (2000); Thagard (2006); Thagard (2021)

Overview: CAMs - Theory

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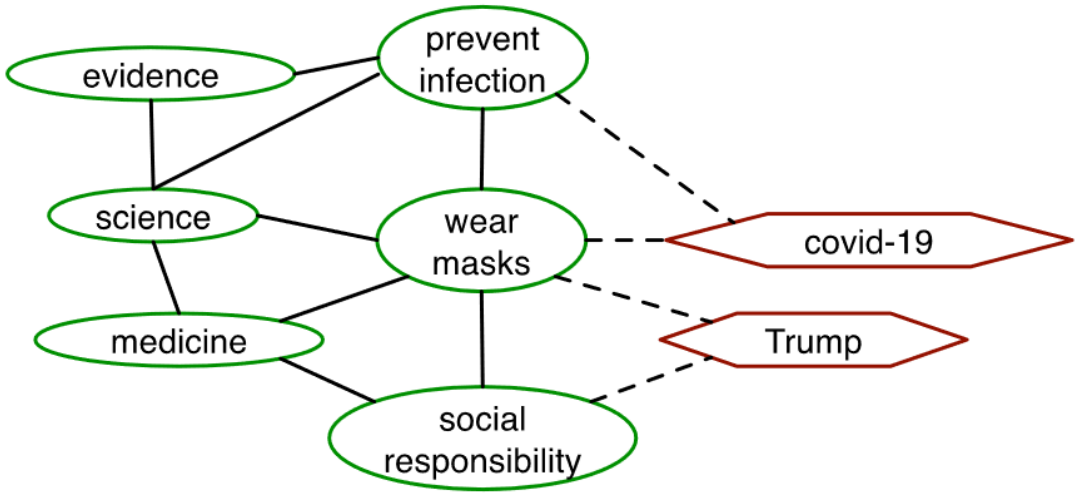
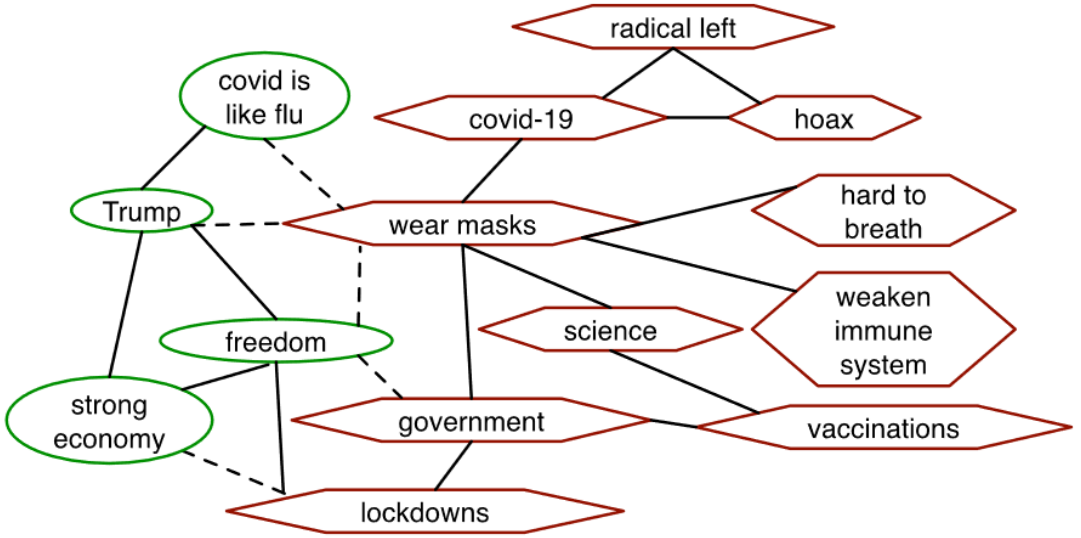


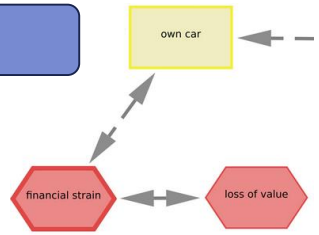


Thagard (2021)

Advancement of Cognitive-Affective Mapping

a quantitative and qualitative research method

Semantic content



Network parameters

μ_{CAM} = -1.33

Qualitative

- Expression of individual / group perspectives
- Little suggestive influence by researchers' presuppositions
- Contextualization

Quantitative

- Quantification of semantic content, of valence ratings and of network parameters
  - Network topology
- Enables statistical analyses / significance tests

Mixed Methods

(Estadieu* et al., in prep.; **Fenn** et al., under review; **Fenn**, Gorki, et al., in prep.; **Fenn**, Sölder, et al., in prep.; **Fenn** et al., 2023; Gros et al., submitted manuscript; Höfele et al., 2022; Livanec et al., 2022; Luthardt et al., 2020, 2022; Mansell, Mock, et al., 2021; Mansell, Reuter, et al., 2021; Reuter et al., 2021, 2022)

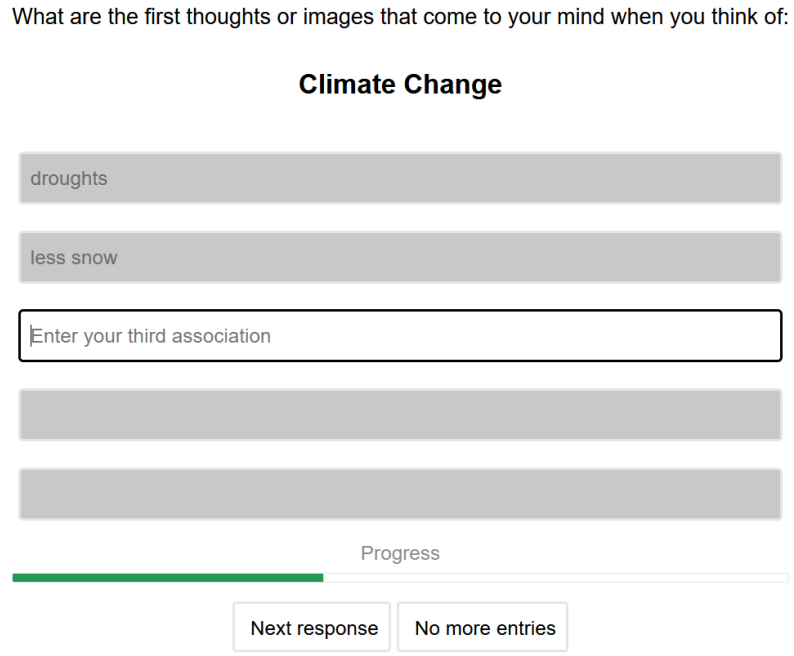
Cognitive-Affective Maps
Dimensionality of Data?

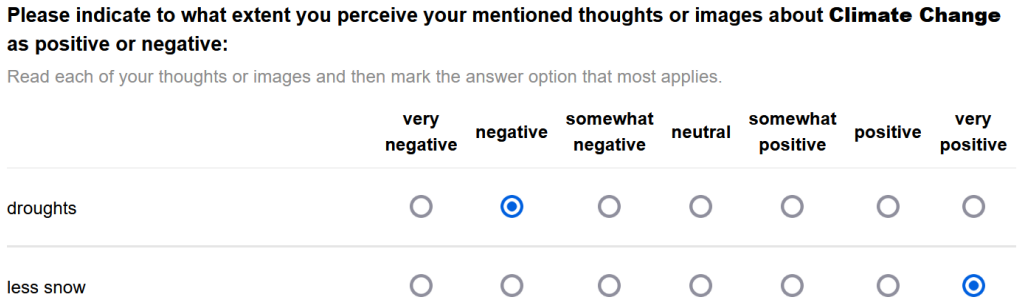
Affective Imagery Technique, Word Association Game

measures free associations (perceptual representations such as images, sounds, words) of people to a specific object

Affective images contain two elements:

- cognitive component (the triggered image or thought)
- affective component (positive or negative evaluation)



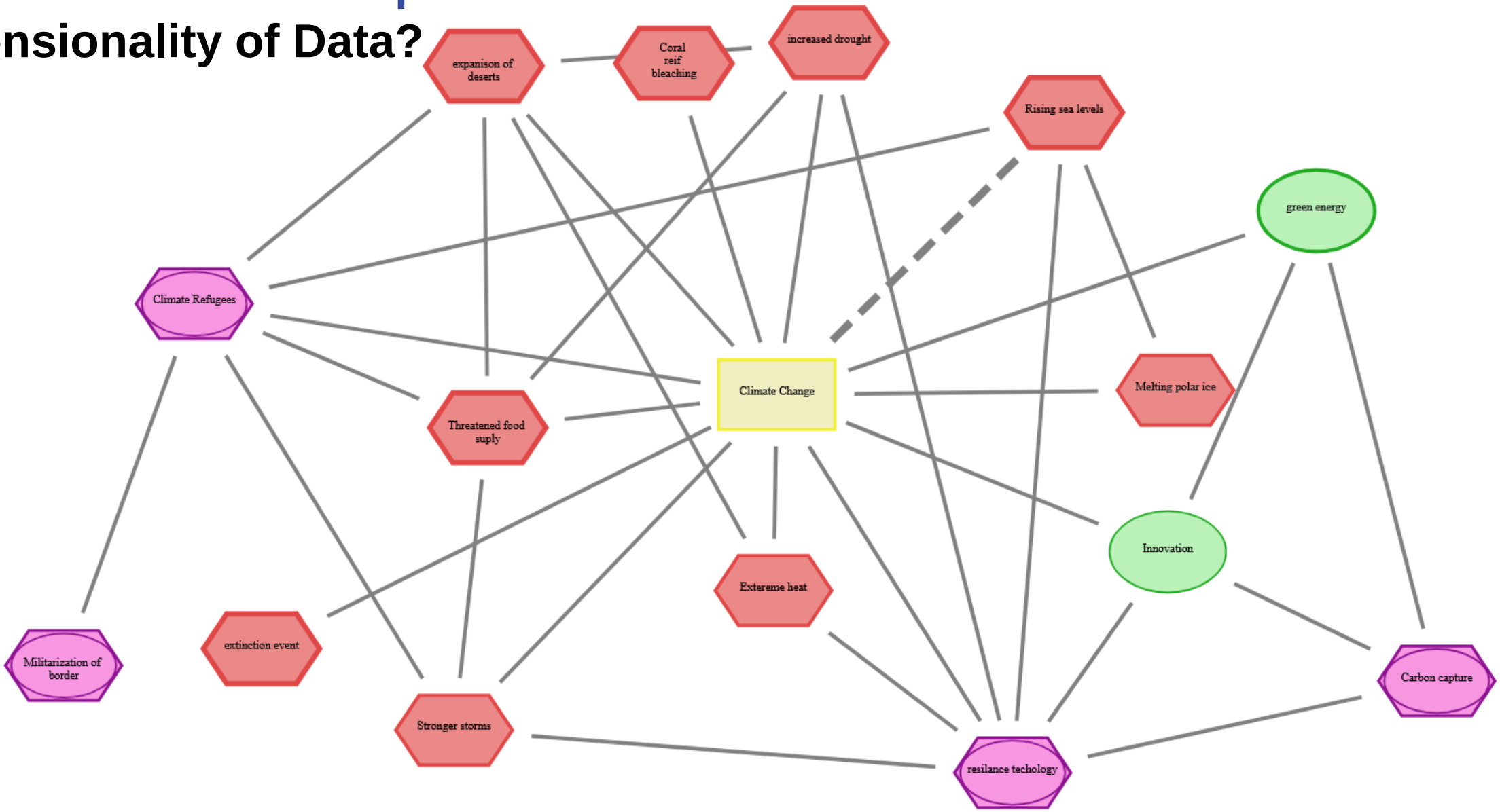


Supervising Bachelor thesis: “Comparative analysis of Cognitive Affective Mapping and the Affective Imagery Technique for the assessment of belief systems: An empirical investigation”

(e.g., Leiserowitz, 2006)

Cognitive-Affective Maps

Dimensionality of Data?



Overview: CAMs - Fields of Application

- to study if CAMs are supplementary to questionnaires - Mansell et al. (2021); Mansell et al. (2021)
- agent-based modelling - e.g. Wolf et al. (2015); Schröder et al. (2017)
- use CAMs for conflict mediation - e.g. Gros et al. (2021)
- evaluate via CAMs the success of an intervention - e.g. Reuter et al. (2021); Luthardt et al. (2020)
- use CAMs as a pre-study to entrich subsequent survey studies - e.g. Fenn et al. (2023)
- …

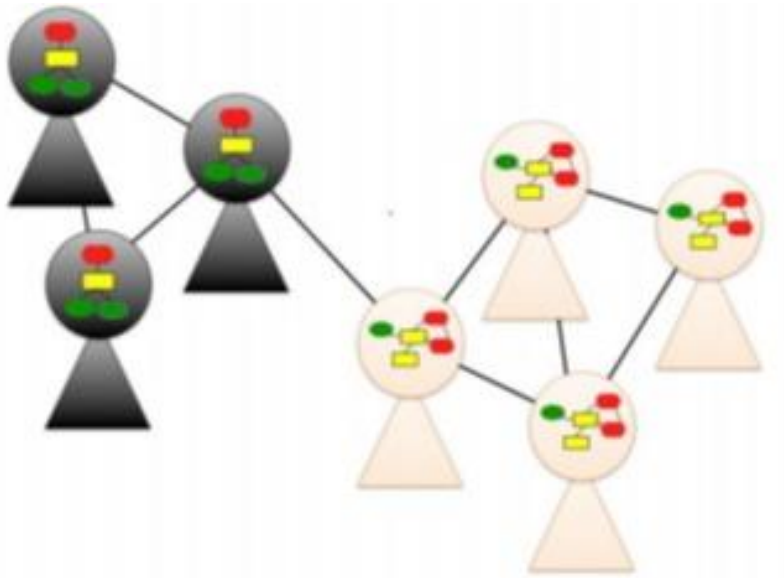
- see two sections of CAM tools online documentation: “Additional Resources”; “What are the advantages of using Cognitive-Affective Maps?” in https://osf.io/q5hj4/

Thagard (2000); Thagard (2006); Thagard (2021)

Cognitive-Affective Mapping
Fundamental Hypothesis

Hypothesis: The generation process of CAMs is not arbitrary, but is determined by multiple processes at multiple levels, and thus CAMs from similar individuals on an identical topic exhibit systematic correlations (similar data generating process)

- can be presented by a „emergent product of interaction between networks of mental representations at the individual level and networks of social communication at the group level“



Homer-Dixon, T., Maynard, J. L., Mildenberger, M., Milkoreit, M., Mock, S. J., Quilley, S., Schröder, T., & Thagard, P. (2013). A Complex Systems Approach to the Study of Ideology: Cognitive-Affective Structures and the Dynamics of Belief Systems. *Journal of Social and Political Psychology*, *1*(1), Article 1. https://doi.org/10.5964/jspp.v1i1.36; Figure 1

if stochasticity is ubiquitous in complex networks, these networks are not maximally random either; rather, they obey organization principles that make them functional

(Bianconi, 2018)

DGP: Stochastic Process > see “CAMtools Workshop 20231128”

Bianconi (2018); Homer-Dixon et al. (2013)

Literature related to CAMs

- **Mental models** are internal representations of the world that individuals create to interpret, understand, and interact with their environment. These models are shaped by personal experiences, knowledge, and beliefs, and they guide how people perceive situations, make decisions, and solve problems. Mental models are dynamic and can evolve with new information and experiences.
- **Semantic networks** are a type of knowledge representation in cognitive science, artificial intelligence, and computer science. These networks are used to model the relational structure of knowledge, showing how different concepts are interconnected. Semantic networks can be used for information retrieval, understanding language, and in artificial intelligence for tasks like reasoning and decision-making.
- **Fuzzy Cognitive Map** is a cognitive model that represents the causal reasoning and decision-making processes of individuals or systems. Causal relationships between concepts are depicted as weighted, directed edges. The weights (degrees of influence) can have positive or negative values, indicating the type and strength of the influence one concept has on another.

Thagard (2000); Thagard (2006); Thagard (2021)

Current Work Publication List I - Empirical Articles

- Höfele, P., Reuter, L., Estadieu, L., Livanec, S., Stumpf, M., & Kiesel, A. (2022). Connecting the methods of psychology and philosophy: Applying Cognitive-Affective Maps (CAMs) to identify ethical principles underlying the evaluation of bioinspired technologies. Philosophical Psychology, 0(0), 1–24. https://doi.org/10.1080/09515089.2022.2113770
- **Luthardt**, J., Morgan, J. H., Bormann, I., & Schröder, T. (2022). Quantifying emotionally grounded discursive knowledge with cognitive-affective maps. Quality & Quantity, 56(3), 1557–1595. https://doi.org/10.1007/s11135-021-01195-7
- **Luthardt**, J., Schröder, T., Hildebrandt, F., & Bormann, I. (2020). "And Then We'll Just Check If It Suits Us" – Cognitive-Affective Maps of Social Innovation in Early Childhood Education. Frontiers in Education, 5, 1–19. https://doi.org/10.3389/feduc.2020.00033
- **Mansell**, J., Mock, S., Rhea, C., Tecza, A., & Piereder, J. (2021). Measuring attitudes as a complex system: Structured thinking and support for the Canadian carbon tax. Politics and the Life Sciences, 40(2), 179–201. https://doi.org/10.1017/pls.2021.16
- **Mansell**, J., Reuter, L., Rhea, C., & Kiesel, A. (2021). A Novel Network Approach to Capture Cognition and Affect: COVID-19 Experiences in Canada and Germany. Frontiers in Psychology, 12, 1–14. https://doi.org/10.3389/fpsyg.2021.663627
- Reuter, L., Fenn, J., Bilo, T. A., Schulz, M., Weyland, A. L., Kiesel, A., & Thomaschke, R. (2021). Leisure walks modulate the cognitive and affective representation of the corona pandemic: Employing Cognitive-Affective Maps within a randomized experimental design. Applied Psychology: Health and Well-Being, 13(4), 952–967. https://doi.org/10.1111/aphw.12283
- **Fenn**, J., Helm, J., Höfele, P., Kulbe, L., Ernst, A., & Kiesel, A. (2023). Identifying Key-Psychological Factors Influencing the Acceptance of yet Emerging Technologies – A Multi-Method-Approach to Inform Climate Policy.

Thagard (2000); Thagard (2006); Thagard (2021)

Current Work Publication List II - Bachelor, Master Theses I

- Bilo, T., & Helm, J. (2021). A Further Step Towards Sustainable Development – Re-evaluating and Expanding Cognitive-Affective Mapping for Technology Acceptance Prediction. https://www.psychologie.uni-freiburg.de/abteilungen/Allgemeine.Psychologie/research/cam-research/bachelorthesis_bilo-helm_2021_english.pdf
- Dörr, M. (2020). Eine Qualitative Analyse von Kognitiv-Affektiven Karten: Können Daten von Kognitiv-Affektiven Karten im Vergleich zu Fragebögen zusätzliche Informationen geben? https://www.psychologie.uni-freiburg.de/abteilungen/Allgemeine.Psychologie/research/cam-research/masterthesis_doerr_2021_german.pdf
- Gros, W., Reuter, L., Stumpf, M., & Kiesel, A. (2021). CAMediaid: Multimethod approach to assess Cognitive-Affective Maps in mediation - A quantitative validation study. https://doi.org/10.13140/RG.2.2.12436.78726
- Koloczek, N. (2020). Förderung der Benutzerfreundlichkeit für die Methode „Cognitive-Affective-Mapping“. https://www.psychologie.uni-freiburg.de/abteilungen/Allgemeine.Psychologie/research/cam-research/masterthesis_koloczek_2020_german.pdf
- Kreil, A. (2018). Cognitive-Affective Mapping within the context of staircase and elevator use. Evaluating a new method in empirical psychological research [Master’s Thesis]. Albert-Ludwigs-Universität Freiburg i. Br. Lewis, A. J. (2020). The Public Acceptability of Perovskite Solar Photovoltaics in the Context of the German Energy Transition.
- Reuter, L. (2019). Collection and evaluation of basal attributes of living materials systems [University of Freiburg]. https://doi.org/10.13140/RG.2.2.27832.90889

Thagard (2000); Thagard (2006); Thagard (2021)

Current Work Publication List II - Bachelor, Master Theses II

- Ricken, D. (2020). A Step towards Sustainable Development: Predicting the Acceptance of life-like Materials Systems with Cognitive-Affective Mapping. https://www.psychologie.uni-freiburg.de/abteilungen/Allgemeine.Psychologie/research/cam-research/masterthesis_ricken_2020_english.pdf
- Rothmann, W. (2022). Cognitive-Affective Maps—Verständnis für Konzeptzusammenhänge in Abhängigkeit der Valenzen. https://www.psychologie.uni-freiburg.de/abteilungen/Allgemeine.Psychologie/research/cam-research/rothmann2022.pdf
- Sendtner, C. (2021). Kostbare Kisten: Gründe für Fehleinschätzungen der Kosten des eigenen Autos und deren Auswirkungen auf die Bewertung des ÖPNV -Masterarbeit [University of Freiburg]. https://doi.org/10.13140/RG.2.2.32640.56325

Thagard (2000); Thagard (2006); Thagard (2021)

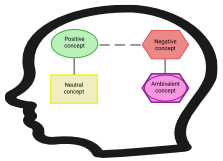
Current Work Publication List III - Conceptual Articles

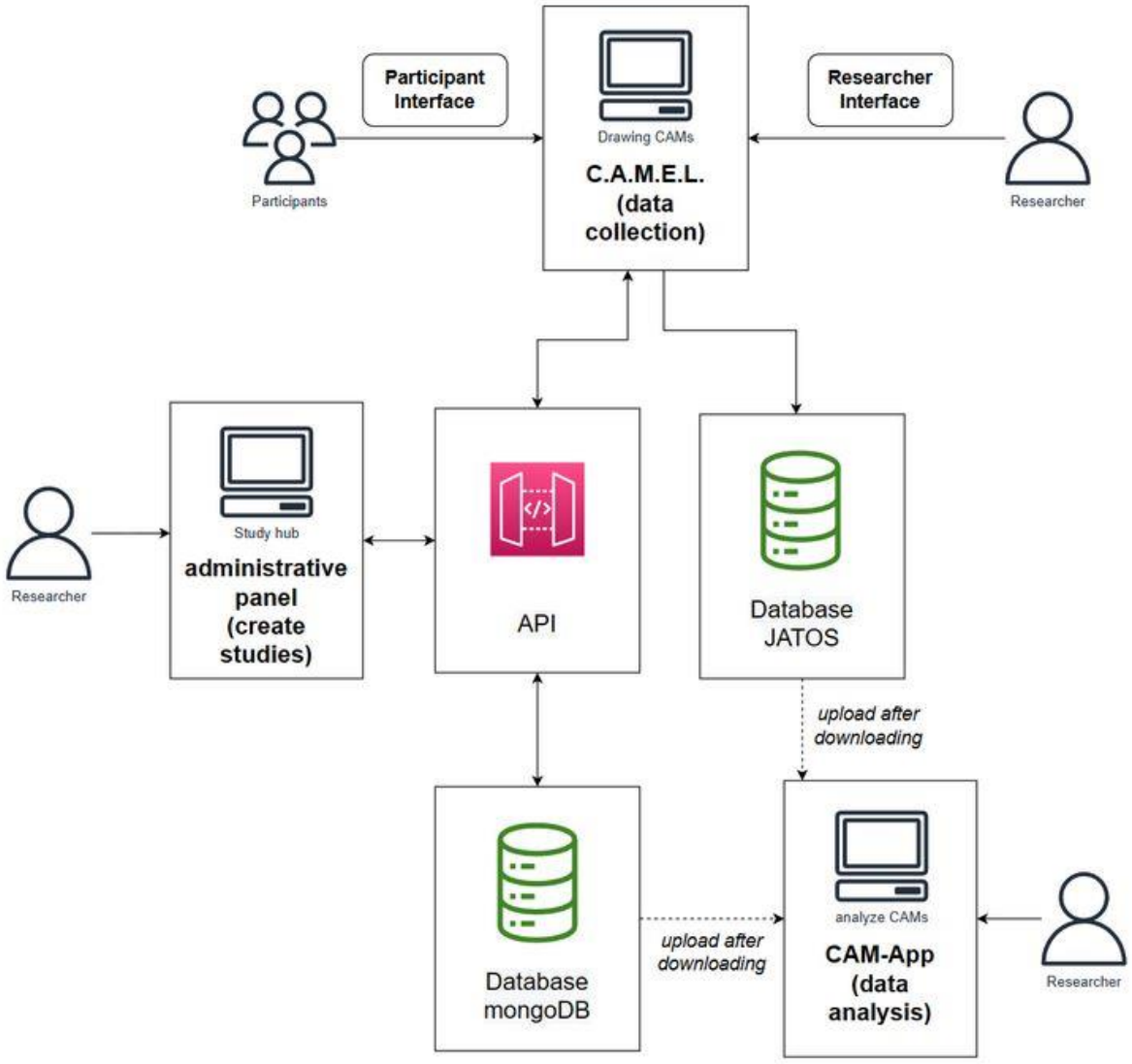
- Homer-Dixon, T., Maynard, J. L., Mildenberger, M., Milkoreit, M., Mock, S. J., Quilley, S., Schröder, T., & Thagard, P. (2013). A Complex Systems Approach to the Study of Ideology: Cognitive-Affective Structures and the Dynamics of Belief Systems. Journal of Social and Political Psychology, 1(1), Article 1. https://doi.org/10.5964/jspp.v1i1.36
- Homer-Dixon, T., Milkoreit, M., Mock, S. J., Schröder, T., & Thagard, P. (2014). The Conceptual Structure of Social Disputes: Cognitive-Affective Maps as a Tool for Conflict Analysis and Resolution. SAGE Open, 4(1), 1–20. https://doi.org/10.1177/2158244014526210
- Livanec, S., Stumpf, M., Reuter, L., Fenn, J., & Kiesel, A. (2022). Who's gonna use this? Acceptance prediction of emerging technologies with Cognitive-Affective Mapping and transdisciplinary considerations in the Anthropocene. The Anthropocene Review, 1–20. https://doi.org/10.1177/20530196221078924
- **Reuter**, L., Mansell, J., Rhea, C., & Kiesel, A. (2022). Direct assessment of individual connotation and experience: An introduction to cognitive-affective mapping. Politics and the Life Sciences, 41(1), 131–139. https://doi.org/10.1017/pls.2021.31

- Thagard, P. (2000). Coherence in Thought and Action. MIT Press.
- Thagard, P. (2006). Hot Thought: Mechanisms and Applications of Emotional Cognition. MIT Press.
- **Thagard**, P. (2021). The cognitive science of COVID-19: Acceptance, denial, and belief change. Methods, 195, 92–102. https://doi.org/10.1016/j.ymeth.2021.03.009

Thagard (2000); Thagard (2006); Thagard (2021)

Developed Tools





Central web page: https://drawyourminds.de

General information on the developed tools; possible to set-up CAM studies without the need for programming

Central web page: https://osf.io/q5hj4/

Detailed documentation of developed CAM tools and explanations for how to set up studies with multiple examples; thematically sorted CAM literature

Slack Channel: http://tinyurl.com/bdeka4kx

Support channel for setting up CAM studies and most recent updates; invitation

CAM-App: https://fennapps.shinyapps.io/CAMtools_CAMapp/

CAM-App deployed on Shiny server to analyze resulting CAM data

GitHub: https://github.com/Camel-app

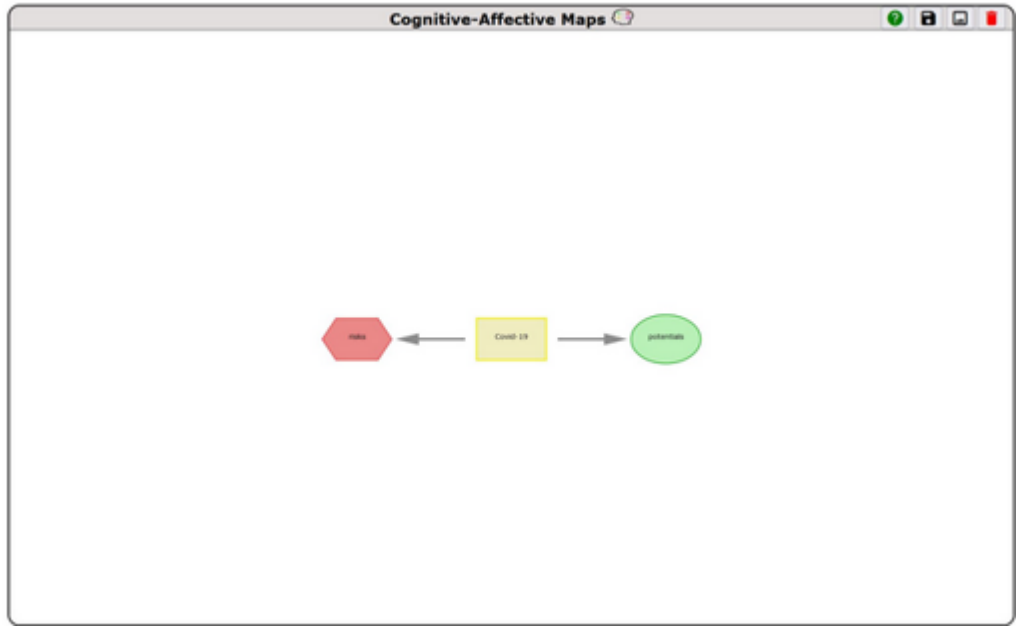
All the code of the programmed CAM tools

Data Collection

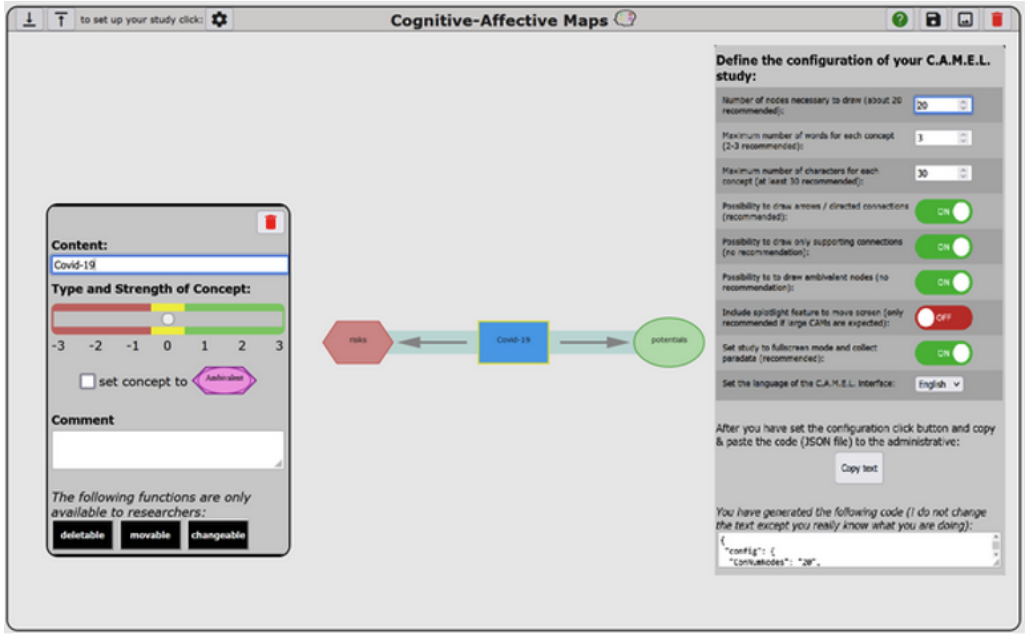
Cognitive-Affective Map Extended Logic (C.A.M.E.L.)

- an easy and intuitive interface to draw Cognitive-Affective Maps (CAMs) for participants and researchers
- drawn CAMs are saved on the client-side as Java Script classes, which respects the classical data model of networks

Participant view:



Researcher view:



Data Collection - highly adaptable

Cognitive-Affective Map Extended Logic (C.A.M.E.L.)

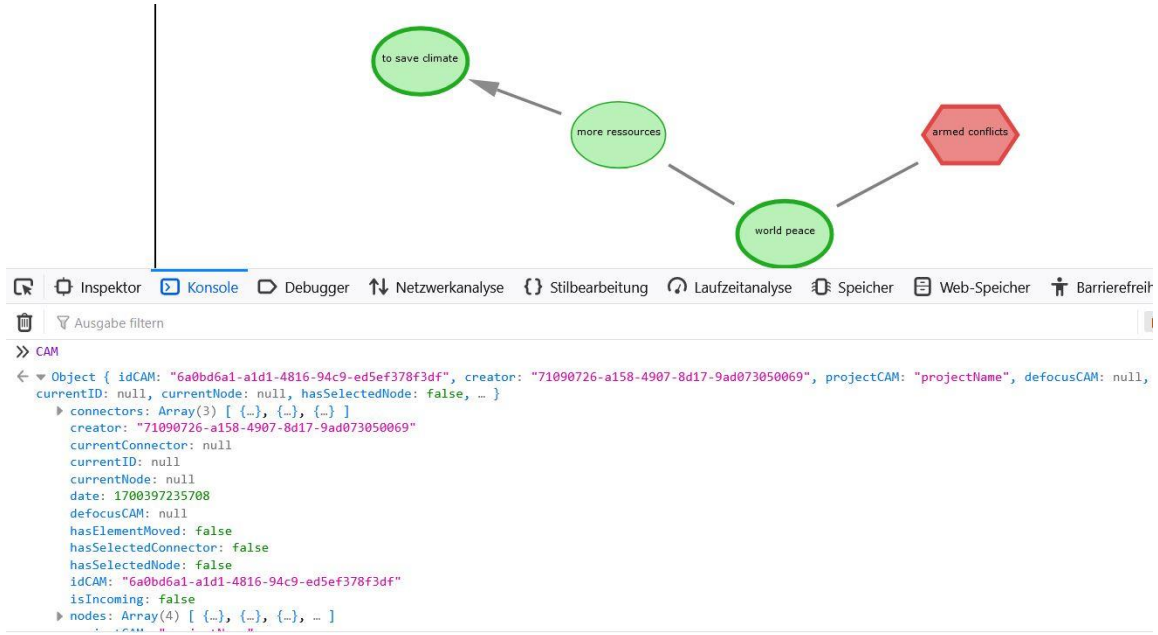
Possible **configurations** of C.A.M.E.L.:

Parameter	Meaning	Possible values
#ConNumNodes	Number of nodes a participant needs to draw before she / he is can save the CAM.	1-50[1]
#MaxLengthWords	Maximum number of words allowed for each concept.	1-5[2]
#MaxLengthChars	Maximum number of characters for each concept allowed.	30-300
#hideArrows	If ON possible to draw draw arrows / directed connections.	ON / OFF
#showOnlyPosSlid	If ON possible to draw supporting connections.	ON / OFF
#hideAmbivalent	If ON possible to draw ambivalent concepts.	ON / OFF
#cameraFeature	If ON an splotlight feature is included to move the drawing screen. If participants move their mouse to the edges the drawing screen is moved to the respective side.	ON / OFF
#fullScreen	If ON study is set to fullscreen mode and paradata is collected (defocus, focus events).	ON / OFF
#setLanguage	Set the language of the C.A.M.E.L. interface:	English, German, Spanish

[1]Maxmimum number is restricted, because the drawing space is limited. In the future 3D environments will be implemented.

[2]It is **highly recommened to set this value to 1-3** if you are aiming to summarize / aggregate the CAM data. Instruct participants to avoid writing sentences and to draw instead multiple concepts.

Data model of CAMs allows to run **adaptive study designs**, e.g., using Java Script library Cytoscape



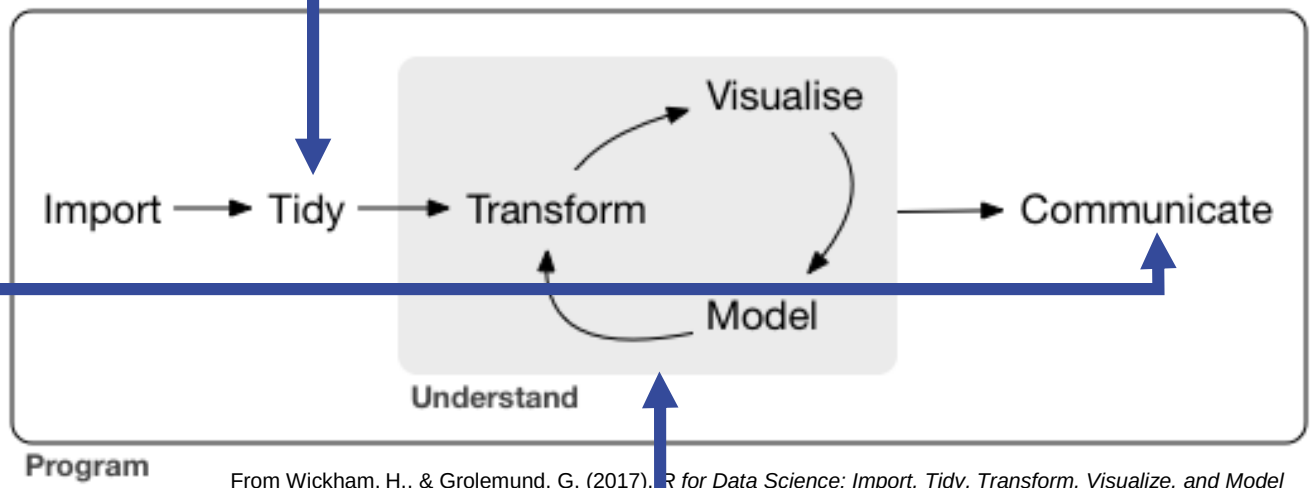
Fenn, J., Sölder, P., Königs, L., Reuter, L., Conrad, S., Estadieu, L., Höfele, P., & Kiesel, A. (in prep.). *Using Basal Attributes to Identify Key Properties of New Material Systems to Increase the Acceptance*.

Estadieu*, L., **Fenn***, J., Gorki, M., Monno, I., Tauber, F., Teichmann, J., Levy-Tzedek, S., Müller, O., & Kiesel, A. (in prep.). *Societal Assessment of Soft Robots: Identifying Key Risks and Benefits of Soft Robots Compared to Conventional Robots.*
Kulbe, L., **Fenn**, J., Sendtner, C., Reuter, L., Stumpf, M., & Kiesel, A. (in prep.). *Connecting Instrumental and Affective Motives of Transportation Modality Choice—Realistic Cost Assessment Influences Affective Evaluation of Private Car*.

Data Analysis
CAM-App

- Pre-processing:
  - summarizing concepts under superordinate categories; modules for training raters and computing inter-rater reliability coefficients

protocol is automatically generated in the background capturing each data pre-processing and analysis step



From Wickham, H., & Grolemund, G. (2017). *R for Data Science: Import, Tidy, Transform, Visualize, and Model Data*. O'Reilly Media, Inc. https://r4ds.had.co.nz/; Chapter 1 Introduction

- Analysis step:
  - analyze CAM data; multiple modules for semantic content (e.g., aggregate CAMs) and network parameters (e.g., slice CAMs)

Data Analysis - Modules

CAM-App

functionalities are based on over 31 R functions, Python code divided in 28 modules (modularly programmed)

Preprocessing Part

1. Import/Upload data
2. Draw CAMs
3. Approximate matching
4. Searching terms
5. Search for synonyms
6. Apply word2vec model
7. Overview of non-summarized concepts
8. Compute inter-rater reliability
9. Train raters for summarizing of concepts

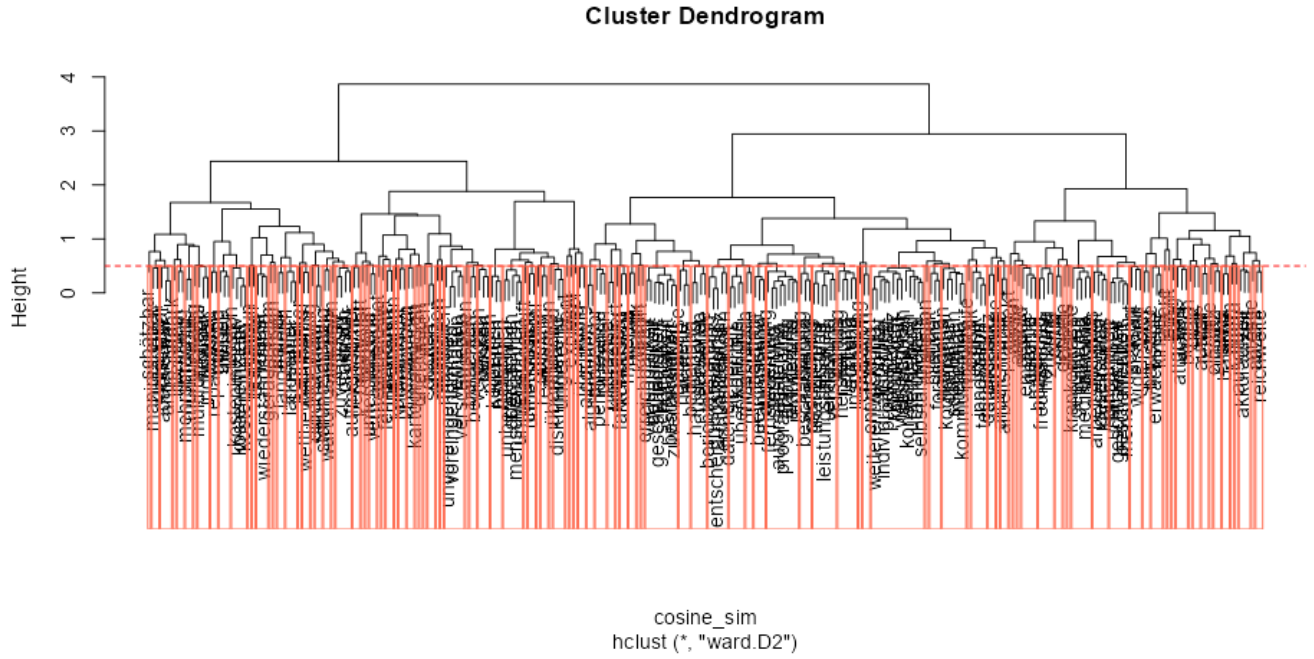
Analysis Part

1. Import/Upload data
2. Draw CAMs
3. Compute network indicators
4. Compute neighborhood indicators
5. Compute descriptive statistics on network indicators
6. Create wordlist
7. Create word cloud
8. Get table, pie chart
9. Get summary statistics
10. Aggregate CAMs
11. Concept co-occurrences
12. Valence co-occurrences
13. Similarity Algorithms
14. Slice CAMs
15. Get summary statistics
16. Get Report

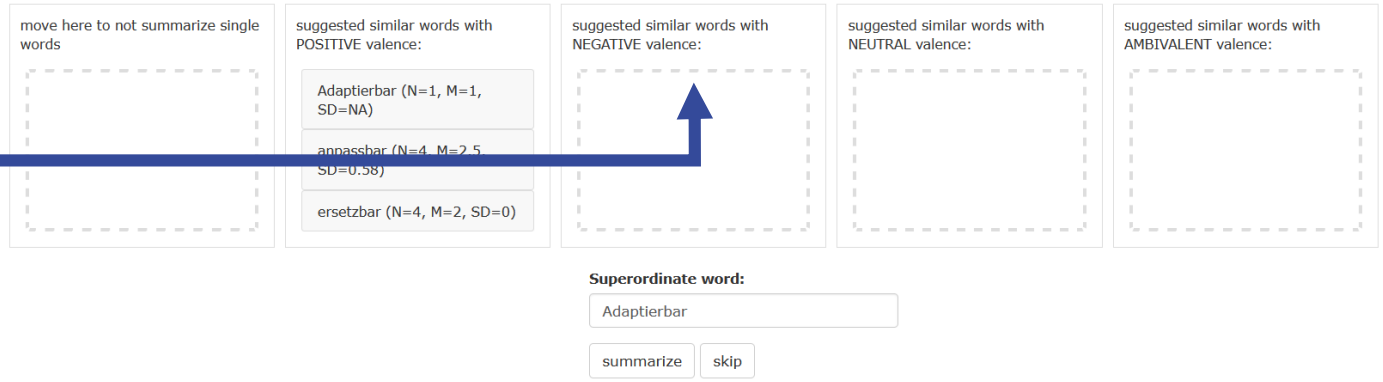
Data Analysis - pre-processing

Apply Large Language Model

- applying a word2vec Model it is possible to compute the cosine similarity between drawn concepts pairwise to identify groups of drawn concepts with similar meaning
  - cosine similarity between the words “responsibility” and “accountability” would be .70



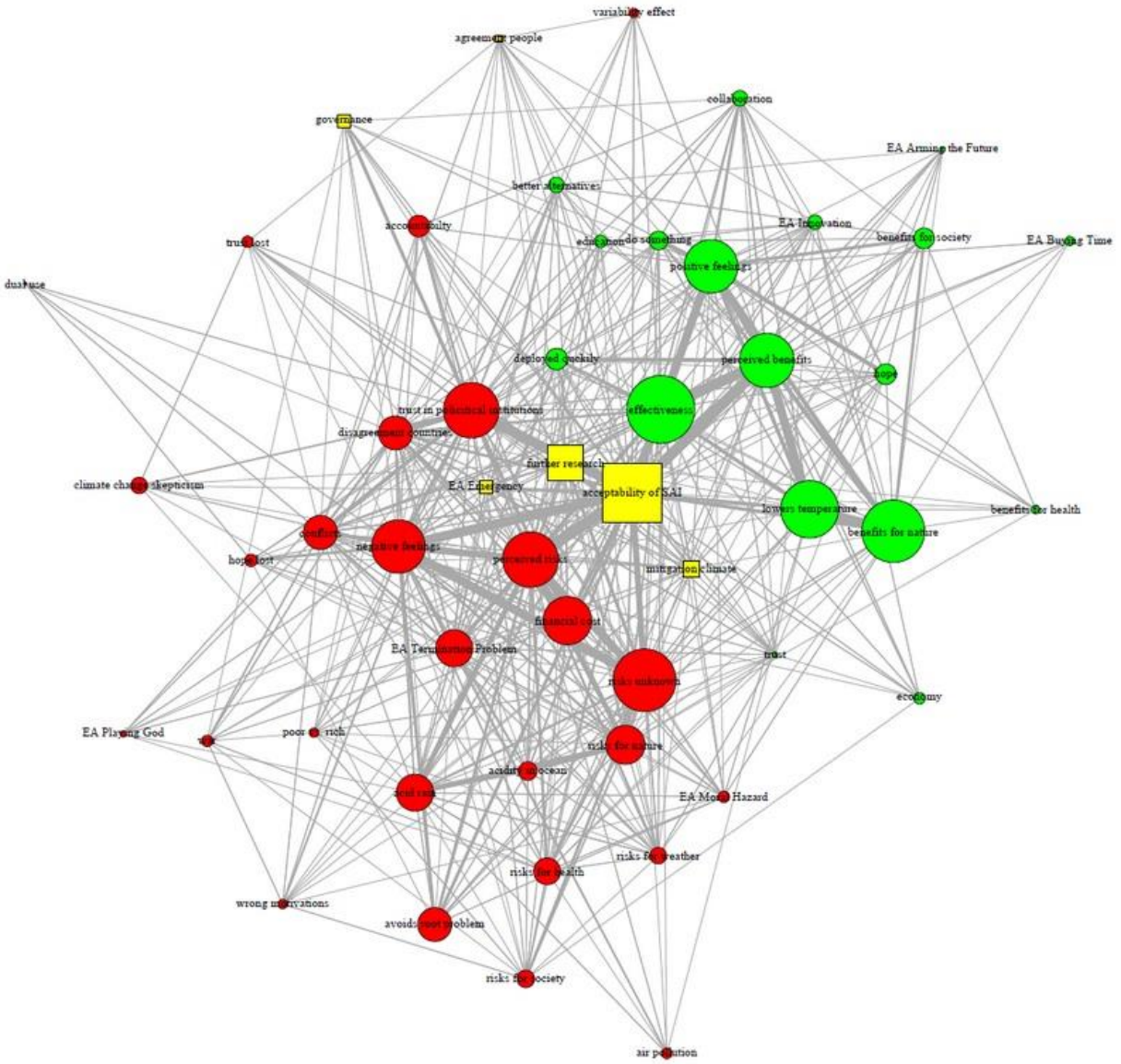
valence-sensitive summary process



Data Analysis - analysis step

Aggregate CAMs

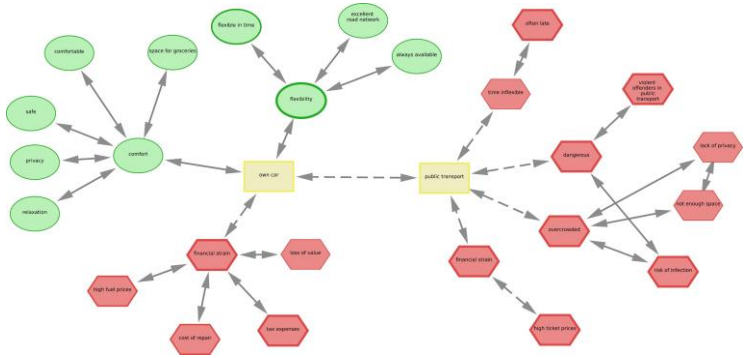
- to highlight the inter-relatedness of all summarized terms, the CAMs can be aggregated by creating a so-called *“canonical adjacency matrix”*
  - example of 58 summarized CAMs:

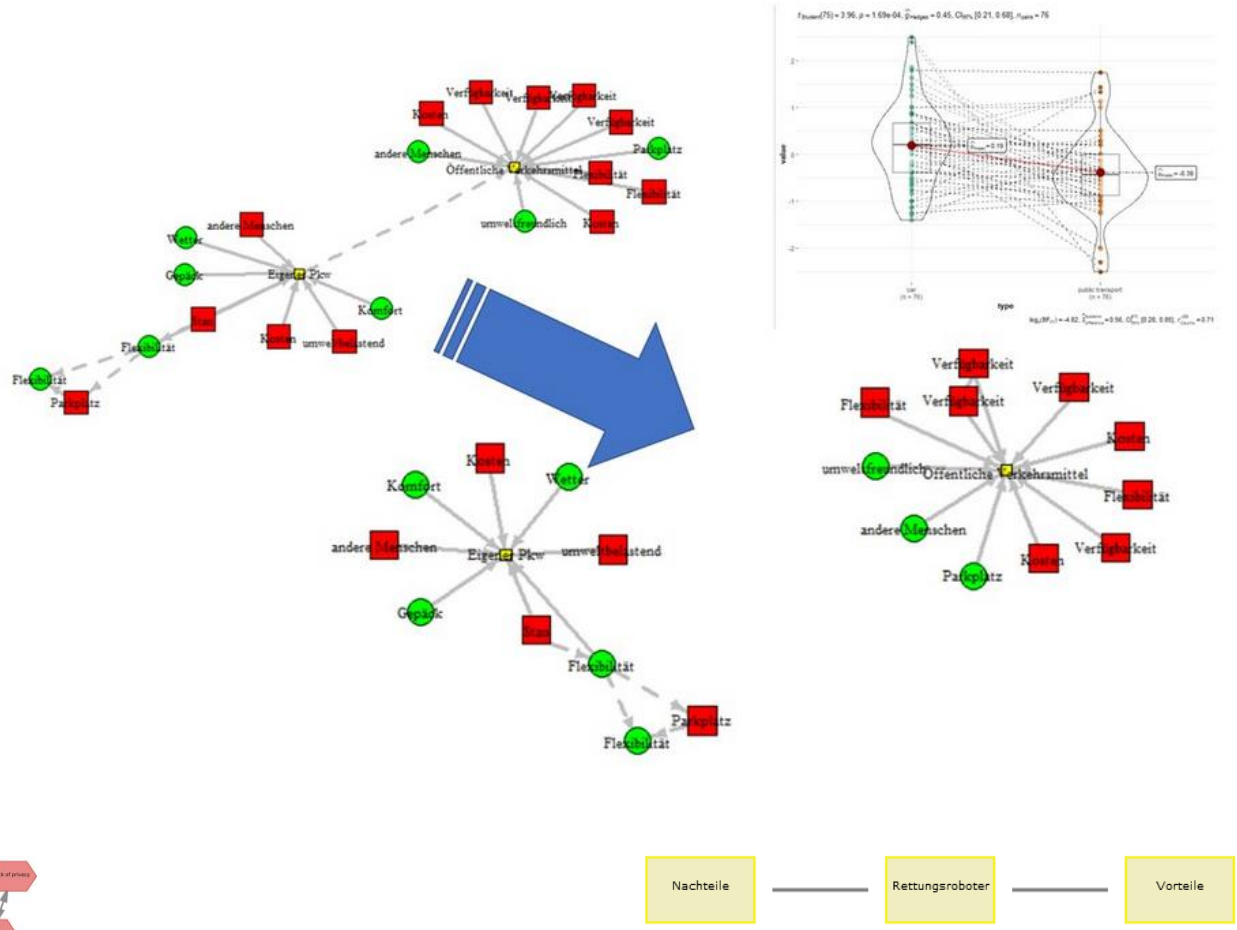


concept is drawn as neutral if the average valence of the respective concept is within [-.5, .5]

Data Analysis - analysis step
Slice CAMs

- CAMs can be automatically sliced according to two possible criteria: (a) delete a connection between two concepts, (b) delete a concept
  - example previously shown CAM:

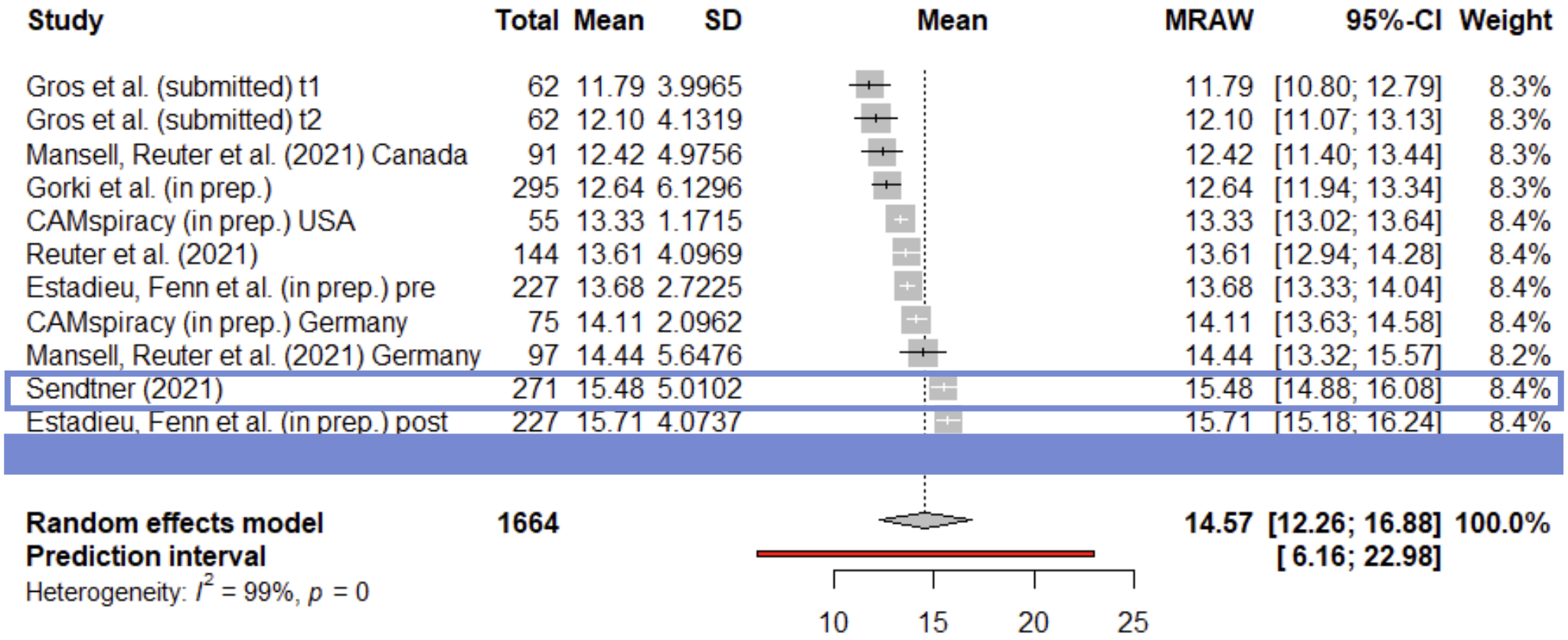




Estadieu*, L., **Fenn***, J., Gorki , M., Monno, I., Tauber, F., Teichmann, J., Levy-Tzedek, S., Müller, O., & Kiesel, A. (in prep.). *Societal Assessment of Soft Robots: Identifying Key Risks and Benefits of Soft Robots Compared to Conventional Robots.*

Meta-Analytical Perspective

Number of drawn concepts



estimated average mean based on the random-effects model was μ = 14.57 (95% CI: 12.51 to 16.63)

without Fenn et al. (2023) μ = 13.61 (95% CI: 12.74 to 14.48)

Who is currently using the developed CAM tools?

Prof. Dr. Andrea Kiesel

Dr. Lisa Reuter (Psychology)

Michael Gorki (PhD, Psychology)

Wilhelm Gros (PhD, Psychology)

Sabrina Livanec (PhD, Psychology)

Dr. Louisa Estadieu (Postdoc, Philosophy)

Dr. Philipp Höfele (Philosophy)

Paul Sölder (Student, Psychology)

Christophe Becht (Student, Psychology)

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Dr. Estefania Gazzo (Psychology)

More to come:

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Appendix

CAM-App - protocol

Please provide the number of predefined concepts in your study (=starting concepts):

3

Select the concepts for which you want to receive additional statistics (alphabetically sorted):

Rettungsroboter Soziale Assistenzroboter

Get Report:

get report

*To download the report download all your files globally using the button top right. Please **adjust the report** according to your specific needs!*

Description of dataset

In total we collected 454 CAMs, of which 0 (0%) CAMs were excluded from further analysis. Participants drew on average 14.7 (*SD* =3.61)concepts (whereby 42% were positive, 35% negative, 18% neutral and 6% ambivalent). Please note that the technical settings required participants to draw at least XXX concepts. On average 16.24 (*SD* =5.67) connectors were drawn. 91% of the connectors were agreeing and 9% disagreeing. Furthermore 0% of the connectors were bidirectional and 100% unidirectional. The valence for the concepts range from [-3,-1] for negative and [1,3] for positive concepts, with ambivalent and neutral concepts being assigned a value of 0. The mean average valence over all the CAMs was 0.19 (*SD* =0.45). In 3% of the non-deleted CAMs one or more of the predefined concepts were removed by the participants.

Summarizing concepts

We summarized the CAMs using the dedicated CAM-App. The CAM-App generates a protocol, which tracks every summarizing step, so that the summarizing process is completely transparent. The 2471 raw unique concepts (6684 in total) were summarized to 2302 concepts using 213 times the "approximate matching", 0 times the "searching terms", 0 times the "search for synonyms" and 35 times the "apply word2vec model" functionalities.

Statistics of individual concepts

- The concept "Rettungsroboter" has an average valence of 0.43 (*SD* =0.96) and was drawn in 242 (53%) of the CAMs.The average degree is 2.63 (*SD* =1.27). In total the (summarized) concept was drawn 244 times.
- The concept "Soziale Assistenzroboter" has an average valence of 0.37 (*SD* =0.93) and was drawn in 203 (45%) of the CAMs.The average degree is 2.66 (*SD* =1.56). In total the (summarized) concept was drawn 203 times.

Estadieu*, L., **Fenn***, J., Gorki, M., Monno, I., Tauber, F., Teichmann, J., Levy-Tzedek, S., Müller, O., & Kiesel, A. (in prep.). *Societal Assessment of Soft Robots: Identifying Key Risks and Benefits of Soft Robots Compared to Conventional Robots.*

Different (experimental) designs

Design CAM study

CAM as graphical representation:

- CAMs as a **one time elicitation** of the cognitive-affective representation a person/a group has about a certain concept / topic

quantitative/network parameters and qualitative analyses of CAMs as measurements ("dependent variables") in empirical/experimental studies:

- CAMs as a **dependent variable in a pre-post intervention design**, where participants either draw two separate CAMs before and after an intervention or have the chance to adjust the first CAM at a later point in time
- CAMs in a **mixed method design** to augment questionnaire data with rich information about cognitive-affective representations and the possibility of freely associating, away from prespecified answer options

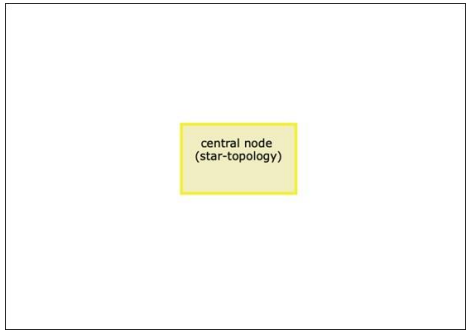
CAM as independent variable to influence/inform participants:

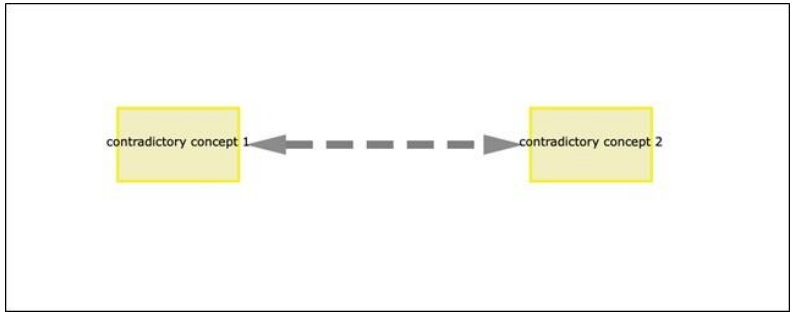
- Using **CAMs themselves as an intervention**, where participants are shown a CAM that is not their own and the influence of this exposure to somebody else's representation is assessed
- CAMs in an **adaptive design**, where participants receive an adaptive intervention based on an automated real time analysis of the CAM they have just drawn (e.g. specific intervention depending on mean valence of the CAM)

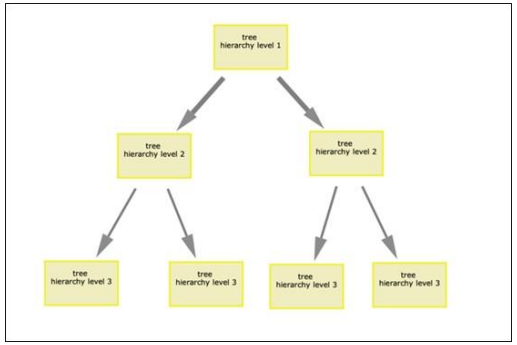
Network topologies
Design CAM study

different sets of predefined concepts and connections are possible (network topologies):

- Single concept in the middle: design likely evokes a network which is equivalent to a physical star topology, where all concepts are connected to a central concept; high local and global density
- Two contradictory concepts: interesting way of analyzing the perception of opposite poles or concepts; sub-networks of the resulting CAMs can be analyzed and compared separately; high local densities and medium global density
- Tree Topology: nudges participants towards “adding leaves to a predefined tree”: typically have low overall and local density
- No predefined concepts: typically results in a partially connected mesh topologies



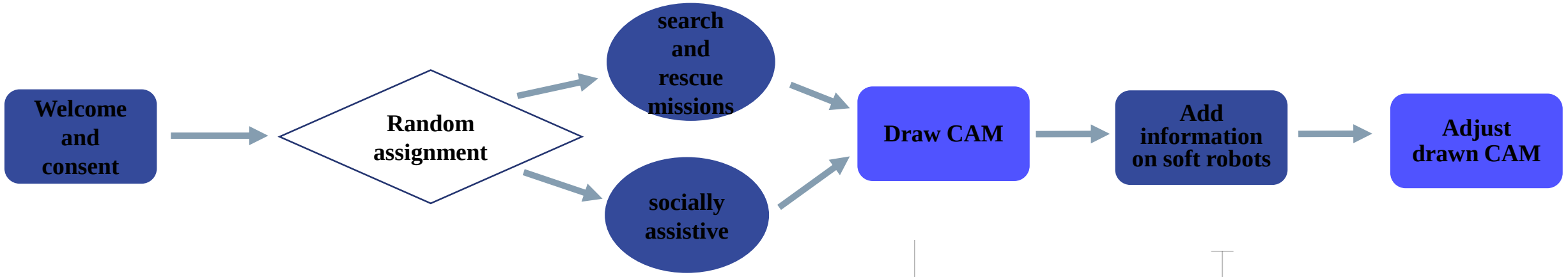




Intervention Design

Example soft robot intervention

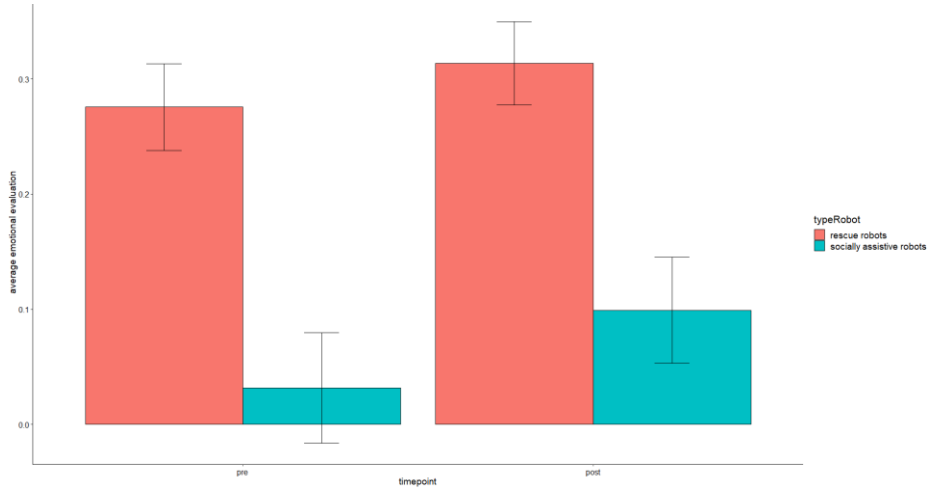
Study Design



Results

(1) Within: More positive assessment of soft robots compared to
rigid robots in both case studies

(2) Between: More positive assessment of *search and rescue soft robots*
compared to *socially assistive soft robots*



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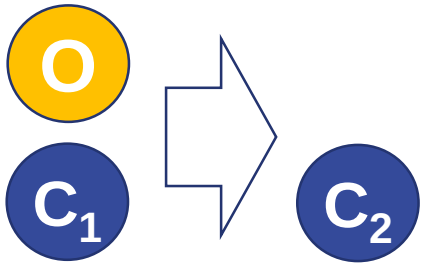
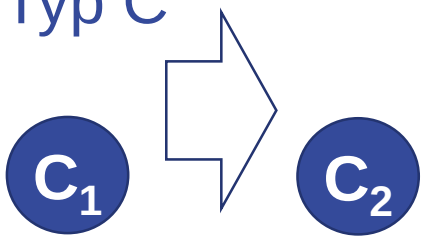
Intervention Design

Delta CAMs – conceptual perspective

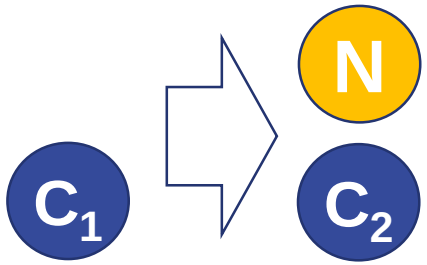
Typ A



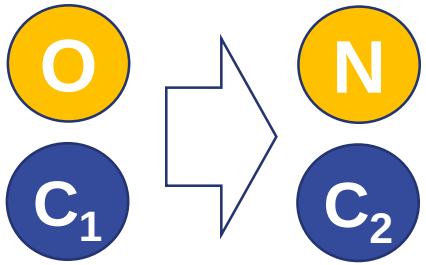
Typ C



Typ B



Typ D

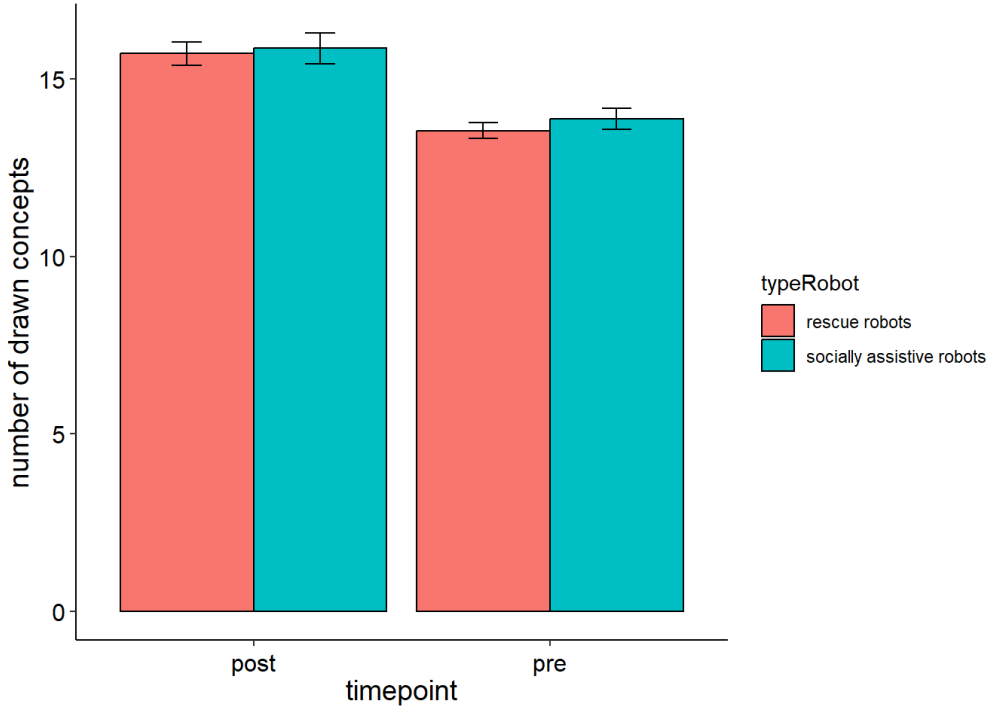


O = old, N = new, C = constant

(Reuter et al., 2021)

Results (N=224 CAMs)

A	B	C	D
1	145	39	39



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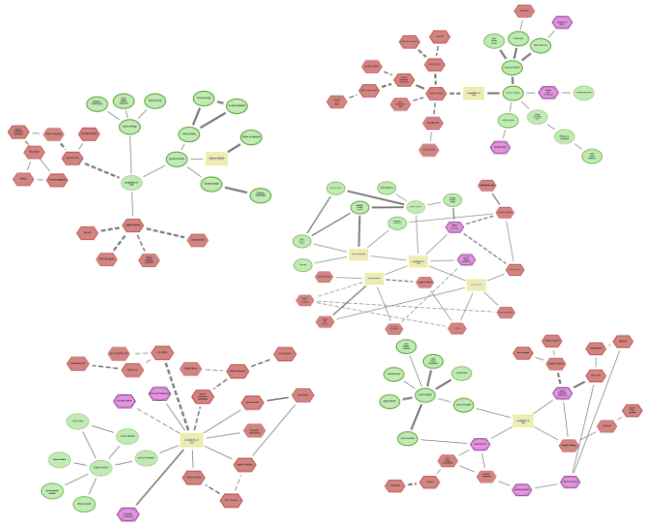
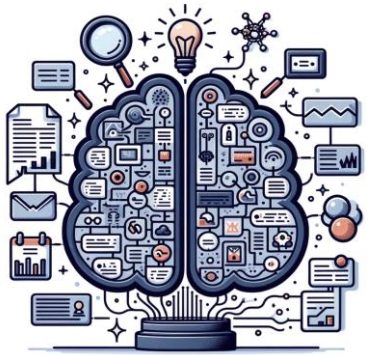
Boost analysis of CAMs

Conceptual perspective

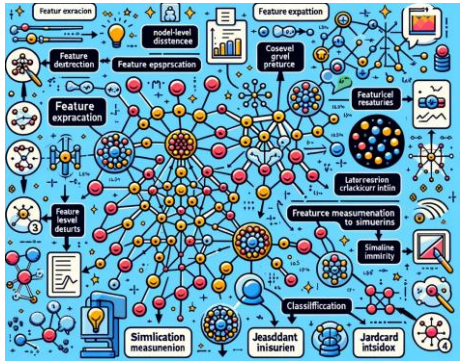


large-scale CAM study



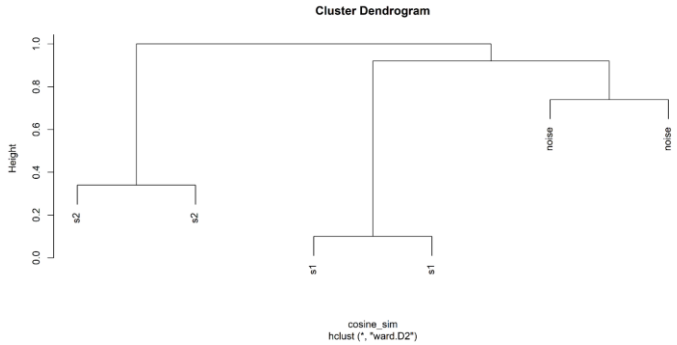
(a) applying large language models

to automatically summarize data



(b) applying network similarity algorithms

to automatically identify structures within CAM data



followed by cluster analysis

to identify important sub-groups

enables the identification of (a) central **arguments / narratives** and (b) latent **network topologies** regarding emerging technologies between groups of people

Boost analysis of CAMs

Conceptual perspective on complexity

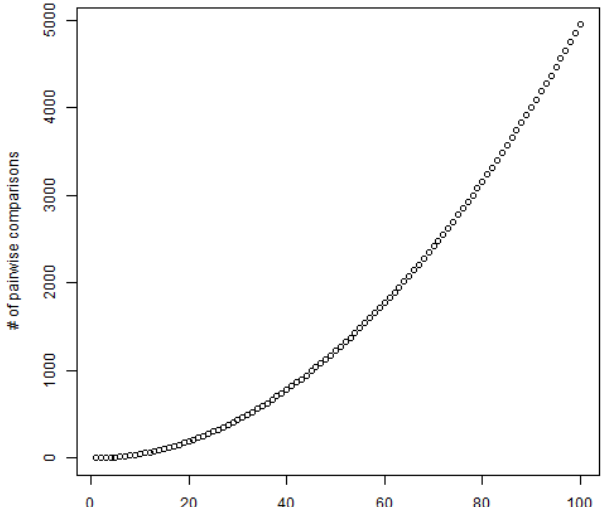
time complexity (TO) is the computational complexity that describes the amount of computer time it takes to run an algorithm

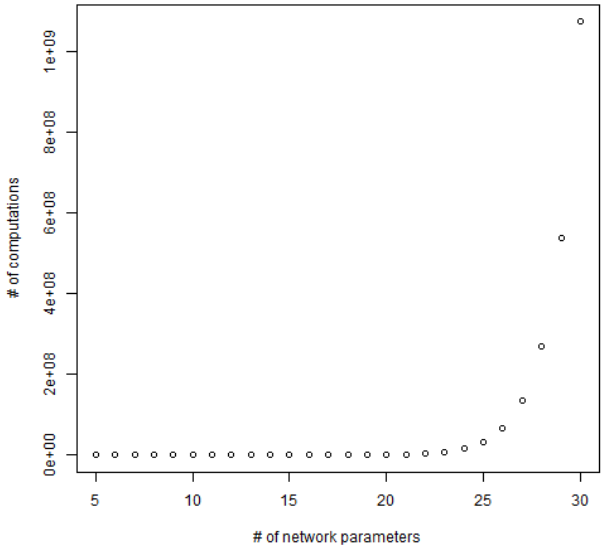
TO1: number of possible pairwise CAM comparisons determined by the binomial coefficient, whereby c is the number of CAMs to compare

$$\binom{n}{2}; \frac{c * (c-1)}{2}$$

TO2: number of network parameters determined by the sum over different binomial coefficients, whereby k is the number of parameters

$$\sum_{k=5}^{n} \binom{n}{k}$$



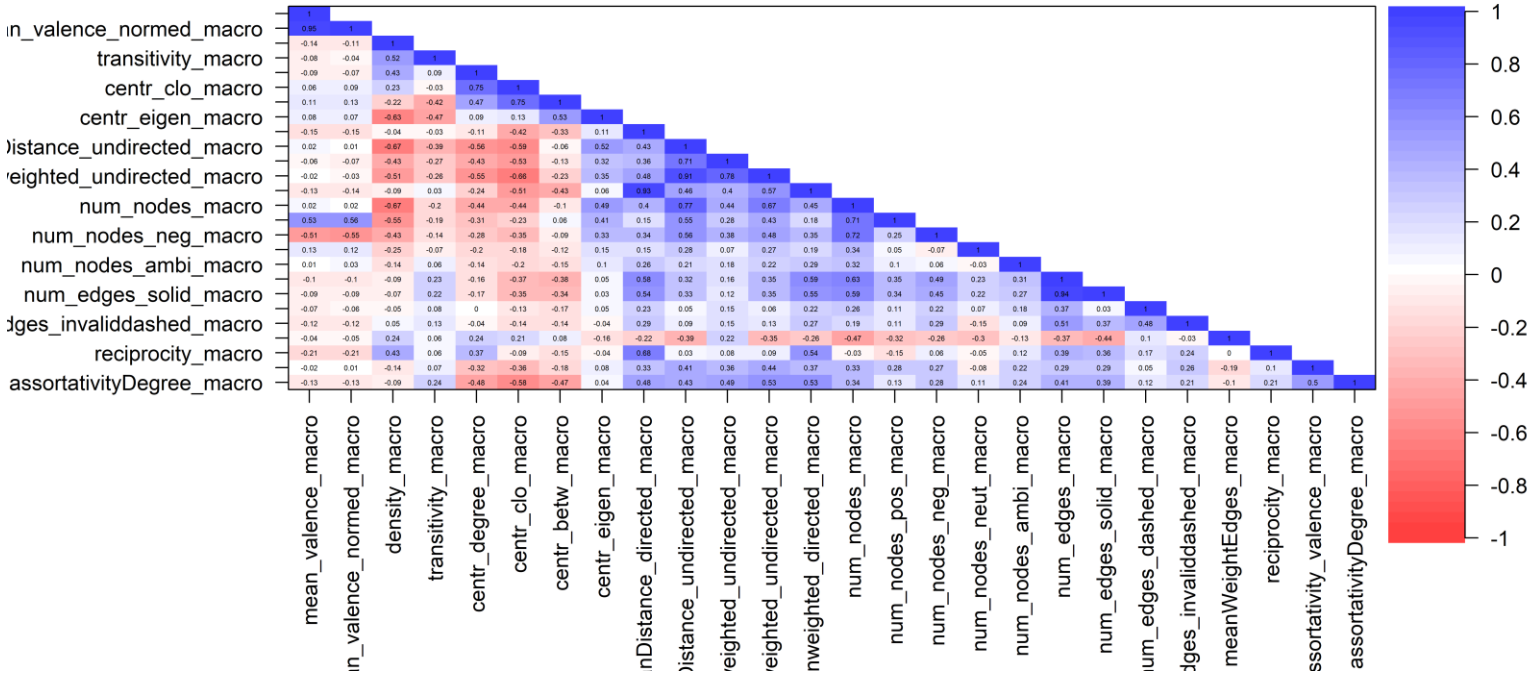


Boost analysis of CAMs
reduce TO2

$$\sum_{k=5}^{n} \binom{n}{k}$$

TO2: number of network parameters determined by the sum over different binomial coefficients, whereby k is the number of parameters

- Network indicators are highly correlated, statistical artifacts



Boost analysis of CAMs

Outcome – multilayer perspective

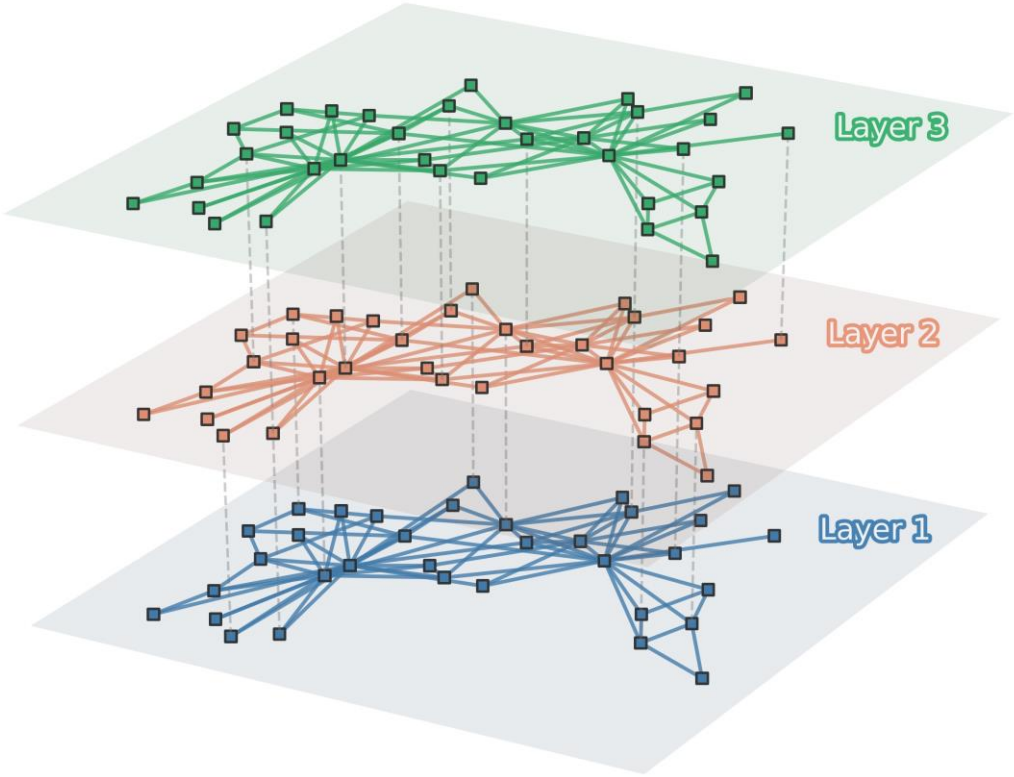
After (a) applying large language models or (b) applying network similarity algorithms

A CAM (graph) is in general defined by $G = (V, E)$

Multilayer networks are defined by $G = (V, E, D)$

, whereby D is a set of dimensions (or layers = CAMs)

Community Extraction in Multilayer Networks with Heterogeneous Community Structure (2017);
https://jmlr.csail.mit.edu/papers/volume18/16-645/16-645.pdf



enables the identification of (a) central **arguments / narratives**