Bridging Over the Troubled Waters of Quantitative and Qualitative Methods: Exploring Cognitive-Affective Maps in Empirical Research

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☼

Abstract

Cognitive-Affective Maps (CAMs) visualize perspectives and beliefs in the form of networks, in which the concepts can be affectively evaluated as positive, negative, neutral, or ambivalent. To date, CAMs have been primarily drawn by researchers in order to visualize conflicting perspectives. In this dissertation, I explore the role *Cognitive-Affective Mapping* might be able to play in empirical and mixed methods research. The thesis comprises four article contributions (chapters 5-8) framed by a comprehensive synopsis (chapters 1-4).

In the first contribution, we investigated whether participants' (N=66) cognitive-affective representations of the corona pandemic depicted in CAMs changed due to *leisure walking*. To this end, we applied an experimental pre/post design with a control group and tested our hypotheses statistically. Additionally, we examined the CAMs exploratively using qualitative and quantitative analysis approaches. The second contribution presents a cross-sectional study. We used General Linear Models to test whether network parameters of CAMs on the corona pandemic are suitable to predict the external questionnaire variable *perceived coronavirus threat*. We collected CAMs from participants in Germany (N=100) and Canada (N=93) to further identify differences and similarities between the samples. In the third contribution, we examined CAMs on *nature imitation in technology development,* drawn by 18 students of an ethics seminar at the beginning and the end of the semester. Using coding and rating procedures, we analyzed pre/post differences of CAMs concerning ethical principles and the overall appearance of the CAMs. The fourth contribution provides an overview of several ways of applying and assessing CAMs, addressing various aspects of the empirical studies.

We could show that study participants without previous related methodological experience can be instructed to create CAMs online and that the method opens up diverse ways for quantitative and qualitative analyses. We argue that Cognitive-Affective Mapping combines

advantages of quantitative and qualitative approaches since it allows for the collection of large data sets while also offering the participants considerable freedom to depict their subjective perspectives.

Exploring new methodological applications for CAMs has left some questions unanswered concerning the balance between empirical practicality and theoretical grounding of the method in general. In particular, I discuss some uncertainties regarding connection options between concepts, firstly with respect to the concept of *emotional coherence* as the theoretical root of the CAMs, and secondly in terms of instructional difficulties. In addition, I take a first step to apply quantitative and qualitative research quality criteria to CAMs. I reflect that the methodological approaches of the present empirical studies were primarily quantitative, although qualitative approaches could reveal more profound levels of meaning of CAMs' subjective content. I do not consider the aspects above merely as methodological limitations but also believe that they provide fresh impetus for future research projects. In sum, the thesis contributes to the development of empirical applications for Cognitive-Affective Mapping. The potential to combine quantitative and qualitative elements with CAMs represents a promising approach for mixed methods research.

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1. Introduction

Psychological research aims to describe and explain the human mind and behavior (American Psychological Association, n.d.-b). Located at the border between natural sciences, humanities, and social sciences, psychology combines various thematic and methodological directions (Döring & Bortz, 2016a). The latter are traditionally divided into quantitative and qualitative methods. Recently, it has been gaining ground to regard quantitative and qualitative approaches as complementary rather than competitive, which is reflected in the popularity of *mixed methods* designs (Dawadi et al., 2021; Döring & Bortz, 2016a; Kuckartz, 2014). In this thesis, I present *Cognitive-Affective Mapping* as a valuable tool that combines advantages from different methodological approaches. Since Cognitive-Affective Maps (CAMs) have been applied sparingly for empirical data collection, I aim to broaden the method's scope.

I will first elaborate on the distinction between quantitative, qualitative, and mixed methods research, followed by an introduction to Cognitive-Affective Mapping. Based on that, I will propose CAMs as a bridge between quantitative and qualitative research approaches. I will then give an overview of the four articles (Contributions 1–4) that are part of my cumulative dissertation. The discussion includes experiences from our empirical investigations (Contributions 1–3[1]) with data collection, different study designs, and data analysis approaches. I will elaborate on quality criteria of quantitative and qualitative research and apply them to Cognitive-Affective Mapping and specifically to our approaches. Further, I will address difficulties between empirical practice and theoretical foundations of Cognitive-Affective Mapping, focusing on ambiguities with connections in CAMs. After reflecting on my role as a researcher, I will end with a summarizing conclusion.

[1] Since Contribution 4 is a research note intended to serve researchers as a review article for Cognitive-Affective Mapping, it is less relevant to this discussion.

1.1 Quantitative and Qualitative Research

Quantitative research approaches are often attributed to natural sciences and qualitative ones to humanities (Döring & Bortz, 2016a), whereby quantitative-statistical methods dominate the research landscape in academic psychology (Schreier & Odağ, 2020). In quantitative research, it is common to test theoretically derived hypotheses in order to explore cause-effect relations (Döring & Bortz, 2016a; Schumann, 2018). For this purpose, specific characteristics, called variables, are measured either with standardized questionnaires or under controlled conditions in the laboratory using preferably large samples (Döring & Bortz, 2016e). Critical rationalism is the main reference point of quantitative empirical research, stating that a theory can never be definitively verified but only falsified. In this way, truth is approached by eliminating false hypotheses (Döring & Bortz, 2016a).

It is difficult to pinpoint such an explicit reference in the heterogeneous qualitative research field (Rahman, 2017). Depending on the method, references are made to constructivism, idealism, relativism, humanism, postmodernism, or hermeneutics (Johnson & Onwuegbuzie, 2004). Common to these approaches is an interpretative, understanding reconstruction of social relations, aiming to take a holistic view of individuals' experiences and dynamic life contexts. The reflection of the researcher's role concerning the conducted research and the participants is crucial.

While qualitative researchers focus more on theory building and interpretation of linguistically coded data, quantitative researchers concentrate on theory testing and statistical analysis of numerical measures. In terms of philosophy of science, the two approaches are based on different paradigms that differ in their epistemological, ontological, and axiological basic assumptions (Döring & Bortz, 2016b; Landrum & Garza, 2015). Thus, the difference between quantitative and qualitative research is not limited to the level of data but concerns the entire research logic, from researchers' self-conception to the research procedure, including determining research questions, data collection, analysis, and interpretation. To emphasize the polarity of quantitative and qualitative paradigms, researchers use contrasting terms like materialism-determinism versus humanism-constructivism (Schumann, 2018), positivism versus interpretivism (Johnson & Onwuegbuzie, 2004; Dawadi et al., 2021), or critical rationalism versus social constructivism (Döring & Bortz, 2016b). Similar dichotomizations of terminologies can be found in methodological disputes in the 20th century, such as objectifying versus subjectifying, nomothetic versus idiographic, or explanatory versus understanding (Billmann-Mahecha, 2001). Some researchers criticize such binary distinctions between quantitative and qualitative research for being too general and unclear and instead suggest discussing the advantages and disadvantages of particular research methods in the context of specific research questions (Allwood, 2012). However, I will refer to these categories in my thesis since they are widespread in the psychological research landscape.

1.2 Mixed Methods Research

In order to combine and integrate qualitative and quantitative elements within a study, mixed methods research goes beyond a mere juxtaposition of different methods and data (Schreier & Odağ, 2020). Mixed methods have only recently become popular (Billmann-Mahecha, 2001), though the integration of different research traditions has been proposed for quite some time (e.g., Denzin, 2017; Hunter & Brewer, 1989). It is argued that both quantitative and qualitative approaches have specific advantages that provide a more comprehensive understanding of human experience and behavior when combined (Dawadi et al., 2021; Johnson & Onwuegbuzie, 2004). Qualitative data and analyses are further said to be better suited for capturing human experience in the context of individual and social environments (Döring & Bortz, 2016b). In contrast, the advantage of quantitative data and analyses is seen especially in exploring causal relationships and representative findings.

Thus, open-ended qualitative methods can provide a deeper understanding of individuals' experiences, while close-ended quantitative methods allow the generalization to larger populations (Dawadi et al., 2021).

Different views exist on what such integration of approaches should look like (Schreier & Odağ, 2020). There is also controversy about whether findings from methods with conflicting epistemological premises can be combined (Döring & Bortz, 2016b). From a pragmatistic perspective, methods can be combined if this serves the purpose of addressing the research question (Johnson & Onwuegbuzie, 2004). Data and findings in mixed methods research can converge, diverge, or complement each other (Schreier & Odağ, 2020). There are other terms for integrative approaches besides mixed methods, which are sometimes difficult to distinguish, such as multitrait-multimethod, integrative research, and mixed research (Schreier & Odağ, 2020). The concepts of mixed methods and triangulation dominate the research literature. Triangulation refers to the inclusion of different research perspectives, although this does not necessarily mean a combination of quantitative and qualitative approaches (Flick, 2020). Thus, triangulation can also denote the combination of several qualitative approaches or the collaboration of researchers with different backgrounds and theories. Since I focus on combining qualitative and quantitative research, I refer to mixed methods in my thesis. I argue that Cognitive-Affective Mapping is particularly suitable for mixed methods research as CAMs combine qualitative and quantitative aspects.

1.3 Cognitive-Affective Mapping

CAMs were introduced by philosopher and cognitive scientist Paul Thagard (2010a) as an extension of his theory of *emotional coherence*. I will first outline how CAMs are constructed, then discuss the theory of emotional coherence, followed by references to cognitive maps. Finally, I will point to software tools for creating CAMs.

1.3.1 Basic Principles for Drawing Cognitive-Affective Maps

CAMs resemble *mind maps* in their representation as they consist of concepts (*nodes*[2] or *vertices* in graph theory; Kolaczyk, 2009; Newman, 2018) that are interconnected by links[3] (*edges*). Unlike other versions of *cognitive mapping*, Cognitive-Affective Mapping allows us to evaluate the concepts affectively[4]. The initially presented rating categories were *positive*, *negative*, and *neutral* (Thagard, 2010a); later on, *ambivalent* was added for concepts that have both positive and negative affects at the same time (Homer-Dixon et al., 2013). Affective ratings of concepts are represented by color and shape. The thickness of the concept border represents the intensity of ratings: green ovals (positive), red hexagons (negative), yellow rectangles (neutral), superimposed ovals, and hexagons (ambivalent). There are three intensity levels for positive and negative ratings and one for neutral and ambivalent. According to Thagard (2010a), concepts can be connected in two ways: When concepts are mutually supportive, they are connected with solid links, and in case they are in conflict, they are connected with dashed ones. For both types of connections, there are three different intensity levels; the thicker the line, the more intense the connection. Figure 1 shows an exemplary CAM.

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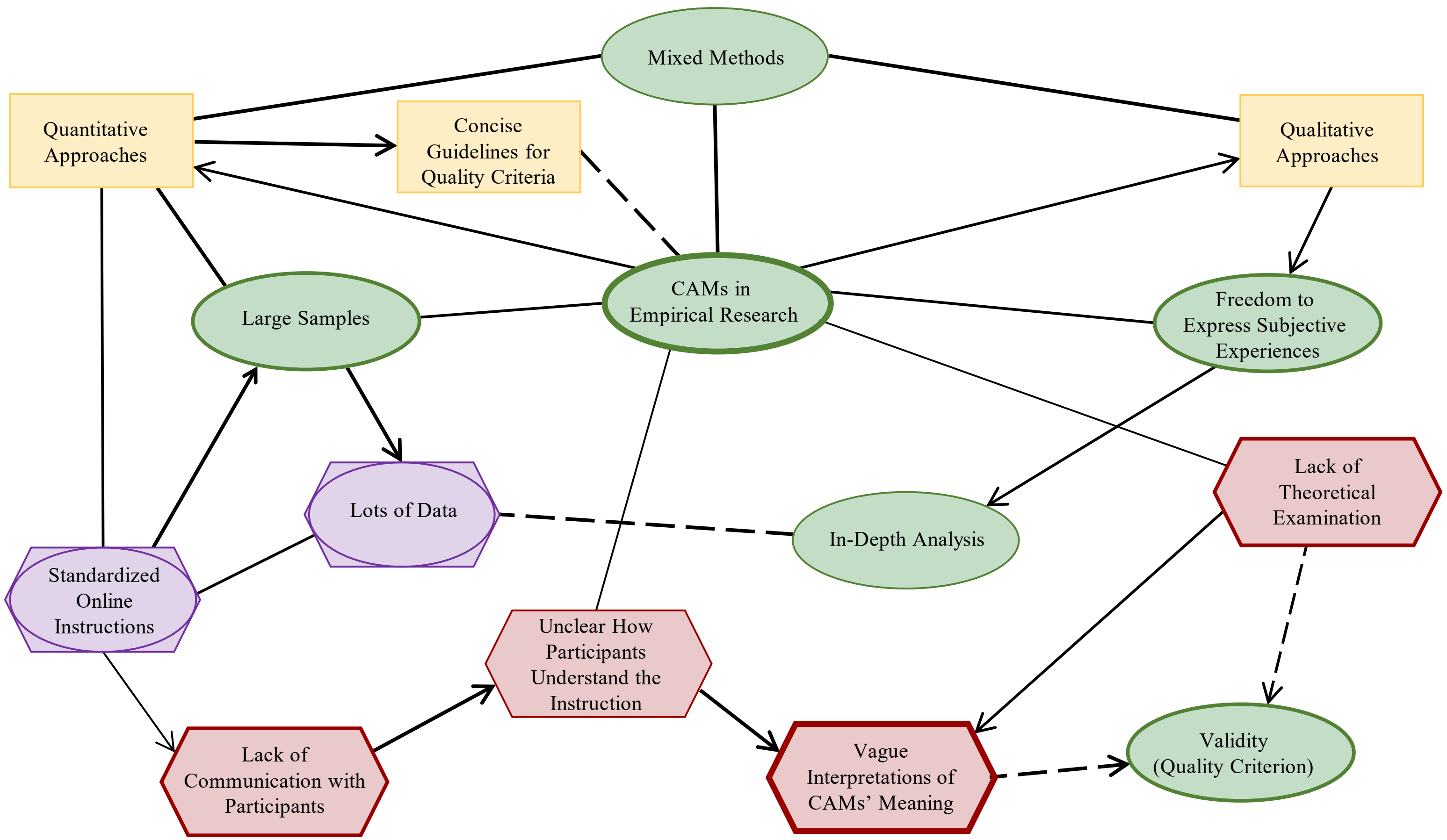
[2] In chapters 1-3, I use mainly the term *concept*, whereas, in the individual contributions (chapters 5-8), the term *node* occurs more frequently - both terms refer to the same elements of the CAMs.

[3] In this thesis, *links* and *connections* are used synonymously.

[4] *Affects* include a wide range of feelings, emotions, and states, and are often described as positive or negative affects (American Psychological Association, n.d.-a).

Figure 1

Exemplary CAM on the Topic of CAMs in Empirical Research



Note. The figure serves as an illustration of what a CAM may look like. Although its content relates to remarks in this thesis, the CAM does not comprehensively and accurately reflect the reasoning in this paper or my perspectives. According to Thagard's original CAM rules, arrows, as well as dashed links between concepts of equal valence, are not intended; however, we have allowed these options for our studies with CAMs.

1.3.2 Thagard's Theory of Emotional Coherence

The roots of Cognitive-Affective Mapping lay in Thagard's theory of *coherence*, with which he describes and explains human thinking and reasoning (2000; 2006). His explanations integrate elements from neuroscience, philosophy, and cognitive science. According to his theory, human reasoning is characterized by a process of coherence maximization[5], whereby coherence can be understood as the satisfaction of positive and negative constraints (Thagard, 1989; Thagard, 2000). Thagard (2006; 2010b) conceptualizes the human mental model as a pattern of neural activations. Accordingly, if elements cohere and fit together, there is a positive constraint between them that can be satisfied when both elements are accepted or rejected. If elements are incoherent and do not fit together, the resulting negative constraint can only be satisfied when one element is accepted and the other is rejected. Examples of coherence relations are explanation, deduction, facilitation, and association, whereas examples of incoherence relations are inconsistency, incompatibility, and negative association.

In his theory of emotional coherence, an extension of the coherence theory, Thagard (2006) states that human reasoning is emotionally shaped. In his HOTCO (for *Hot Coherence*) model, Thagard presents an approach to computing emotional coherence in which network elements carry valences and activations. The network is adjusted until a stable, coherent state is reached. This process is repeated whenever new information and valuations change the network. Some elements have intrinsic values, i.e., are valued per se good (e.g., pleasure) or bad (e.g., pain), others receive their value from constraining elements. Coherent elements influence each other toward having the same valence, while incoherent

[5] Some researchers argue that coherence rules cannot generally be adopted as a priori norms for behavior and cognition. For example, Arkes et al. (2016) argue that there is little evidence of incoherence costs, that adaptive behavior can imply incoherence, and conflicting goals can prevent coherence.

elements influence each other toward having opposite valence (Homer-Dixon et al., 2014). What CAMs visualize in this context is the static end product of the dynamic HOTCO simulations used to compute emotional coherence (Homer-Dixon et al., 2014; Mansell et al., 2021). Similarly, other concepts of cognitive mapping are also thought to have a dynamic nature of underlying mental processes (Jones et al., 2011). CAMs cannot provide an accurate representation of the functioning of human neural networks. Moreover, reducing valence ratings to four categories neglects more nuanced emotional feelings (Mock & Homer-Dixon, 2015). However, at a practical level, Cognitive-Affective Mapping enables the representation of belief systems in vivid networks.

1.3.3 Research on Cognitive Maps. Graphical networks and computations in social sciences often concern social networks, in which nodes represent individuals and vertices represent their interpersonal communicative relationships (Borgatti et al., 2009). CAMs, instead, follow the tradition of models, theories, and methods related to cognitive mapping and mental models (other related terms include mental representations, conceptual graphs, and concept maps). Common to these concepts is the internal representation of individuals' perceived reality (Gottschling, 2009). Prominent elaborations on this have been presented by Craik (1943), Tolman (1948), Axelrod (1976), Gentner & Stevens (1983), Kosko (1986), and Johnson-Laird (1983; 2010)[6]. The roots of such approaches can further be traced back to earlier philosophical thoughts, e.g., Kant's conception of the world (Holmén, 2020; Kubie & Fenton, 2009) or Wittgenstein's picture theory of language (Al-Diban, 2012). References are also drawn to constructivism and the processes of accommodation and assimilation described by Piaget (Gray et al., 2014; Kapuza, 2020). Generally, mental models are thought to play a role in the processes of perception and reasoning (Gottschling, 2009). References to different

[6] In behavioral geography, *mental maps* conceptualize mental representations of spatial knowledge (Götz & Holmén, 2018; Gould & White, 1974).

concepts of cognitive maps and mental models can be found in Al-Diban (2012), Gottschling (2009), and Jones et al. (2011). Gray et al. (2014) provide a review of *fuzzy cognitive maps* (FCMs), which are gaining popularity in various application domains (Felix et al., 2019). FCMs are an extension of Axelrod's cognitive maps (1976), which were initially used to study politicians' decision-making. These cognitive maps consist of asserted beliefs, policy options, or goals that are causally (positively or negatively) connected (Axelrod, 1976; Hermann, 1978). While there are only two possibilities for causal relationships in Axelrod's maps, namely positive or negative causality, Kosko (1986) introduces FCMs with connection values ranging between −1 and 1, where −1 implies wholly negative causality, +1 implies wholly positive causality, and 0 implies no causality at all. Thus, Kosko combines cognitive maps with fuzzy logic. Multiple FCMs can be translated into adjacency matrices and can be used for computations and simulations. Similar network analytic approaches will be elaborated in this paper for CAMs. While cognitive maps and FCMs focus on causal relationships between concepts, CAMs emphasize the importance of the emotional value of concepts.

1.3.4 Software Applications for Drawing Cognitive-Affective Maps

Currently, there are three freely available software applications developed specifically for the creation of CAMs: *EMPATHICA*[7] (Thagard, 2010a), *Valence*[8], (Rhea et al., 2020), and *C.A.M.E.L.*[9] (Gouret et al., 2022). The programs provide functions beyond drawing, saving, and exporting a CAM. With *EMPATHICA*, the concepts of conflicting CAMs can be automatically compared to highlight differences. With *C.A.M.E.L.,* CAMs can be aggregated,

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[7] Available online at http://cogsci.uwaterloo.ca/empathica.html
[8] Available online at http://cogsci.uwaterloo.ca/empathica.html and https://cam1.psychologie.uni-freiburg.de
[9] Available online at https://fennapps.shinyapps.io/shinyCAMELv01/ and https://camgalaxy.github.io/

and network parameters and concept lists can be generated.

The CAMs in this thesis were collected using *Valence*, running on a website hosted by the University of Freiburg. It allows researchers to create projects and lets other participants access them anonymously. Simple network information (e.g., node values, edge values) of the CAMs can be exported as tabular files, which allows for the calculation of various network parameters[10], such as the *mean valence* or *density* of a CAM (Contributions 1, 2 & 4). Our calculations were carried out by using the publicly available code of Rhea et al. (2021). Deviating from the original CAM conventions, the Freiburg version of *Valence* allows to connect concepts with arrows in addition to using bidirectional connections. The software development of *Valence* continued in parallel with our data collections. One goal of our studies was to test to which extent participants can be instructed to draw CAMs online with the software without being in direct contact with the researchers.

1.4 Bridging Quantitative and Qualitative Research with Cognitive-Affective Mapping

Cognitive-Affective Mapping is a versatile method by which perspectives of individuals or groups can be graphically represented and used for data collection and communication. CAMs have been presented as a method for conflict resolution (Findlay & Thagard, 2014; Homer-Dixon et al., 2014; Thagard, 2010a), for promoting cross-cultural understanding (Thagard, 2012b), for representing allegories (Thagard, 2011), values (Thagard, 2012a), the structure of political ideologies (Clapp, M., 2021; Homer-Dixon et al., 2013; Mock & Homer-Dixon, 2015; Thagard, 2015a), for psycholinguistic investigations of the concept of leisure (Nothdurft et al., 2021), for personal psychotherapeutic change processes (Thagard & Larocque, 2020), and as a participatory and transdisciplinary method in

[10]An overview with short definitions of several network parameters that can be calculated with the CAMs can be found in Table 6 in the Supplementary Material of Contribution 2, following this link: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.663627/full#supplementary-material

technology research (Dörr, 2021; Gros, 2021; Livanec et al., 2022). Further, CAMs were combined with other empirical methods, e.g., to visualize data from interviews (Milkoreit, 2017; Wolfe, 2012) and discourse analysis (Luthardt et al., 2020).

In most of the studies, CAMs were drawn by researchers themselves. However, instructing others to draw CAMs is also possible, as demonstrated by Thagard (2015b) in the context of an ethics seminar and Kreil (2018) in an environmental psychology study. Researchers have mainly used CAMs to model the beliefs and perspectives of individuals from small samples or a specific population. More recently, CAMs have been used to collect larger amounts of data through standardized instructions and quantify CAM measures. Mansell et al. (2021) used 111 CAMs on carbon taxation to examine whether CAM network measures can predict study participants' support of the tax. The collection of larger CAM data sets is facilitated using the previously described software.

2. Research Questions and Summary of Contributions

I argue that Cognitive-Affective Mapping enables bridging between qualitative and quantitative approaches. They can provide insights into participants' patterns of interpretation and representation without heavily influencing them through preconceived questions and response categories. In this respect, they are similar to qualitative interviews. However, since conducting and analyzing rich interviews is costly, researchers usually only study a few interviews in greater depth. CAMs, by contrast, offer the advantage of standardized instructions and more extensive data collection, which opens up various opportunities for quantitative and qualitative analyses. In the following, I will give an overview of the articles part of this dissertation in which CAMs were tested in different designs.

2.1 Contribution 1: Employing CAMs within a Randomized Experimental Design

In the first contribution, we used CAMs to investigate whether and how leisure walking affects cognitive-affective attitudes toward the corona pandemic compared to the daily home routine. It is the first study in which CAMs were used for an experimental design. Testing causal relationships through a randomized-controlled experiment is well suited for quantitative research and grants high internal validity (Döring & Bortz, 2016a; 2016c).

Sixty-six study participants were recruited via the participant pool of *Prolific*[11] and randomly assigned to either the experimental or the control group. All participants drew a CAM about their experiences with the corona pandemic. They were instructed to use *Valence* to create their CAMs, starting with ten predefined concepts presented unconnected and rated as neutral (*cohesion*, *stress*, *fear*, *mood*, *social isolation*, *mental stress*, *loneliness*, *economic consequences*, *physical isolation*, and *depressiveness*). All participants were asked to connect

[11] https://www.prolific.co

and rate the concepts. While not explicitly requested to do so, they were also able to add new concepts. Next, participants in the experimental group were instructed to take a 1-hour walk, while participants in the control group were instructed to follow their everyday routines at home. Finally, all participants drew a second CAM about their experiences with the corona pandemic. Analyses of the CAMs included exploratory approaches as well as testing the two following hypotheses: (1) The affective change of the central concept (*corona pandemic*) and (2) the total CAM will be more pronounced in the experimental group than in the control group. For variance-analytical hypothesis testing, the affective ratings of the concepts were transformed into numerical values ranging from −3 to +3.

The analyses revealed that regardless of group assignment, only participants from the experimental group rated the central CAM concept significantly worse in the second CAM and that the overall affectivity of the first CAM was more negative than of the second CAM. On descriptive and exploratory levels, we found that although the majority of concepts comprised the predefined ones, most participants also added new ones, such as *time* or *difficult job search*. Further qualitative examinations of the CAM pairs showed a tendency of participants in the experimental group to drop negative concepts in the second CAM. Furthermore, participants from the control group added more new positive and negative concepts in the second CAM compared to the first CAM. Limitations are detailed in the article; for example, we could not verify whether participants were indeed walking. The study showed that CAMs could be applied in an experimental design and analyzed qualitatively and quantitatively.

2.2 Contribution 2: A Novel Network Approach to Capture Cognition and Affect

In the second contribution, we applied CAMs in a correlational study in a cross-sectional design. With a German and Canadian sample, we tested whether network parameters of CAMs can predict the questionnaire measure *perceived coronavirus threat*

(PCT), measured by three questionnaire items, and whether there are differences between the samples. We recruited 93 Canadian and 100 German participants via the participant pool of *Prolific*. They drew a CAM about their experience of the corona pandemic and then completed a questionnaire about the pandemic. We used General Linear Statistical models to examine associations between PCT and 14 (emotional and latent) network parameters of the CAMs. While we found significant correlations between latent network parameters and PCT in both samples, only the Canadian sample's emotional network parameters significantly predicted PCT. To us, some results appeared conclusive immediately, such as the negative correlation between the CAMs' mean affectivity and PCT in the Canadian sample. Others, however, we found more challenging to interpret, such as the significant negative correlation between the network parameter *density* and PCT in the combined sample with a concurrent significant positive correlation in the German sample. We could not derive specific conclusions or recommendations from the study. For this, further research is needed on the significance and interpretation of CAMs' network parameters. However, we showed that quantitative network analyses can be applied to CAMs and may contribute to a broader understanding of human thinking and associated affective connotations.

2.3 Contribution 3: Applying CAMs to Identify Ethical Principles

In the third contribution, we applied CAMs in a pre-post design without a control group. Eighteen participants from an ethics seminar at the University of Freiburg drew CAMs on the topic of *nature imitation in technology development*, the first at the beginning of the semester (pre-CAM) and the second at the end (post-CAM). The topics covered in the seminar included natural and environmental philosophy, ethics of responsibility, and approaches to biocentrism and deep ecology.

The CAMs were analyzed to see if they contained ethical principles and to what extent pre- and post-CAMs differed. We identified various ethical principles in most CAMs, whereby participants expressed principles more explicitly in the post-CAMs than in the pre-CAMs. Moreover, the post-CAMs were more neutral and ambivalent than the pre-CAMs. These changes could be related to students' engagement with the seminar content. However, we could not draw such a conclusion due to the design missing a control group. In this contribution, we combined psychological and philosophical approaches and proposed Cognitive-Affective Mapping as a method for interdisciplinary research.

2.4 Contribution 4: An Introduction to Cognitive-Affective Mapping

In the fourth contribution, a research note, we elaborated on the background, design, and analysis opportunities of CAMs. We combined theoretical explanations and practical empirical data to give researchers an overview of the possible applications and challenges when using Cognitive-Affective Mapping. We referred to studies in which researchers have used CAMs as a visualization tool for previously collected data, use cases in which CAMs have been applied for experimental and correlational studies, and outlined how the semantic content of CAMs can be analyzed. In this contribution, we explicitly propose Cognitive-Affective Mapping as a tool for mixed methods designs.

3. Discussion

We investigated the applicability of Cognitive-Affective Mapping for empirical psychological research. To this end, we applied CAMs in three studies (Contributions 1–3), dealing with different designs, topics, and research questions. The studies broaden the thematic field of research on Cognitive-Affective Mapping by adding CAMs on the corona pandemic and on ethical considerations of nature imitation in technology development. Notable aspects of our work, which differs from previous research with CAMs, are that we instructed participants to draw CAMs in a standardized way and that we combined various quantitative and qualitative analyses of CAMs. On the one hand, the aim was to answer thematic research questions with CAMs and to investigate the method itself on the other.

In a pre/post experimental design including a control group, we investigated whether walking changed participants' cognitive-affective representations of the corona pandemic depicted in the CAMs (Contribution 1). In a correlation study, we examined whether network parameters of participants' CAMs on the topic of the corona pandemic can predict the questionnaire measure *perceived coronavirus threat* (Contribution 2). In a pre/post design without a control group, we investigated to which extent CAMs are suitable for representing ethically influenced attitudes (change) towards *nature imitation in technology development* (Contribution 3). Furthermore, we presented CAMs as an innovative research method in a review article (Contribution 4). Our studies also contributed to the testing and further development of the *Valence* software for creating CAMs.

Below, I will summarize the findings from our investigations with CAMs. First, I will discuss how we instructed study participants to draw CAMs online and how the data collections were embedded in various designs. I will then outline the different analysis approaches we employed, mainly quantitative network analyses, combined with more qualitative approaches of semantic categorization and rating methods. I will also mention the importance of predefined concepts for data analyses of CAMs. I will critically examine the ambiguities between our empirical approach and theoretical foundations. In this regard, I will address quality criteria and then outline difficulties regarding a theoretical consensus on conventions, rules, and interpretations of CAMs and how to convey them to participants. These remarks mainly concern the connections between CAM concepts. Finally, I will reflect on my role as a researcher concerning my research and end with a summarizing conclusion.

3.1 Standardized Online Instruction and Data Collection

In most studies, researchers and experts created CAMs themselves based on data such as interview material, text analyses, or prior knowledge. They were drawn to capture the perspectives of either single individuals or a specific population. Contributions 1–3 demonstrate that also laypersons can be instructed in a standardized way to depict their perspectives with a CAM. After receiving instruction, most participants did not have problems when drawing CAMs with the *Valence* software according to the respective rules. The resulting CAMs were generally rich in concepts and connections, and participants used the available features like creating and connecting concepts, changing valences, and connection types. In rare cases, participants reported technical problems; consequently, we excluded their CAMs from the analysis. Some participants reported difficulties creating concepts or drawing connections, and others had isolated problems with functions that could be fixed by trying several times. Problems with the software may have arisen from a faulty understanding of the instruction or technical flaws in the software. The software has been improved continuously, but due to participants' different technical environments, occasional difficulties could still occur. Some participants felt the method was complicated, while others found it interesting and helpful for their reflection. The majority of study participants reported no problems. As a result of the collected empirical data, we improved the software's user-friendliness. For instance, it has now become possible to register participants directly via an individual URL link in a previously created project without instructing participants to register themselves. We adapted the instructions for drawing the CAMs depending on whether concepts were predefined or not and in which language the data collection was conducted. The starting point in all cases was an instruction created as part of two master's theses on CAMs (Koloczek, 2020; Ricken, 2020). All original data and the applied instructions are available online and can be used by researchers[12].

3.2 Exploring Cognitive-Affective Mapping with Different Study Designs

CAMs have primarily been used in previous work to represent cognitive-affective perspectives as a conceptual network and to show differences between oppositional views. Contribution 1 is one of the first experimental studies in which CAMs were used for hypothesis testing. In Contribution 3, we also examined the change of CAMs in a pre/post design but without a control group, making causal inferences not permissible. However, both studies show that CAMs are suitable not only for cross-sectional studies but also for multiple data collection and for investigating change processes. The stability of individual representation tendencies, such as how densely or extensively individuals draw CAMs, could open up new research perspectives. Contribution 2 is a non-experimental cross-sectional correlational study; thus, causal conclusions are inadmissible in this case either. The added value of the study is the statistical investigation of correlations between network parameters of CAMs and an external questionnaire variable. Furthermore, quantitative and qualitative elements were combined in all studies.

3.3 Quantitative and Qualitative Analyses

The focus of the analyses in Contribution 1 (experimental hypothesis testing by network parameters) and 2 (correlation of CAMs' network parameters with a questionnaire

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[12] How the data and instructions can be accessed is stated in the published articles.

variable) was quantitative, in Contribution 3 (rating of pre/post differences of CAMs and identification of ethical principles in CAMs) it was more qualitative. However, the analyses were still combined with other approaches. I discuss different analysis opportunities below.

3.3.1 Network Analysis

In Contributions 1 and 2, we performed statistical significance tests using the CAMs' network parameters. We chose classical network parameters of graph theory (e.g., Newman, 2018), such as *density* or *centrality*, and affective parameters, such as *average valence*[13]. In Contribution 3, we included quantitative network parameters on a descriptive level without performing statistical significance tests. In Contributions 1 and 2, single parameter tests revealed significance, suggesting that exploring network structures can help to gain and extend insights into the substance captured in CAMs. Further investigations of connections between the network structures of individually drawn CAMs and cognitive and affective mental processes might yield new approaches to cognition and emotion research.

It must be noted, however, that Contribution 2 does not yet provide insight into how to interpret CAMs' network parameters practically. There is hardly any preliminary work on such or similar empirical network analytic approaches in CAM research. A notable exception is Mansell et al. (2021), with a similar approach. However, concerning the network analysis, the CAMs in Contribution 2 were treated as directed graphs, whereas Mansell et al. interpreted CAMs as undirected graphs since they did not use arrows as connecting links. The authors investigated whether network parameters of participants' CAMs on carbon taxation could predict support for such a tax. In their study, network parameters were significantly predictive emotionally but not structurally. Similar to Contribution 2, some of the network analysis results seem apparent, for example, concerning the *mean valence* of CAMs. For the

[13] For an overview of CAMs' network parameters see Table 6 in the Supplementary Material of Contribution 2: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.663627/full#supplementary-material

combined sample in Contribution 2, the *mean valence* of CAMs on the corona pandemic correlated negatively with the questionnaire variable *perceived coronavirus threat*. In Mansell et al. (2021), the *mean valence* of CAMs on carbon taxation correlated positively with the questionnaire variable *agreement with the carbon tax*. However, in both studies, some findings were more challenging to interpret, such as the negative correlation between the percentage of negative nodes in the corona CAMs with *perceived coronavirus threat* (Contribution 2) or in Mansell et al. (2021), the inconsistent results of the interaction effects between the questionnaire variables *issue sophistication* and *issue familiarity* with the network parameters[14] *eigenvector centrality*, *assortativity*, and *triadic closure*.

Likewise, we found inconsistent results between the quantitative and qualitative analysis in Contribution 1. On the one hand, the central concept *corona pandemic* was evaluated significantly more negatively in the second CAM by participants in the walking group than by those in the control group. On the other hand, the qualitative observation showed that participants in the walking group omitted more negative concepts in the second CAM than participants in the control group. It is not uncommon in mixed methods research that quantitative and qualitative results do not immediately provide a coherent overall picture, and disclosing such irritations can provide an impetus for further research (Völcker et al., 2019).

One challenge in computing emotional network measures of CAMs, particularly the *mean valence*, is dealing with ambivalent concepts. In Contributions 1 and 2, ambivalent concepts were mathematically treated as neutral with a value of 0 when calculating the mean valence. However, it is reasonable to assume that neutral and ambivalent evaluations are fundamentally experienced differently. Mansell et al. (2021) additionally included a *mean*

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[14] Definitions of the reported network parameters can be found in Mansell et al. (2021, p. 189).

valence measure by omitting ambivalent nodes. Alternatively, each ambivalent concept could be considered as two concepts, a positive and a negative one, which result in a sum of 0, to reflect that ambivalent concepts have both a positive and negative value. However, none of these solutions seem appropriate to capture the particularities of ambivalent concepts. Thus, I recommend considering ambivalent concepts by including some extra measures, for example, their percentage compared to all other concepts.

More research is also needed to clarify correlations between CAMs' network parameters and external variables. Drawing on experiences from the growing research area of cognitive maps and FCMs may be helpful for this purpose. Gray et al. (2014) review research on FCMs and discuss questions researchers face when using the method, including what structural measures of FCMs may be important. Gray et al. focus on several issues arising in research with CAMs as well: Are FCMs/CAMs drawn by experts or non-experts? How can FCMs/CAMs be aggregated, and what does such a collated form of individual representations mean? What are the advantages and disadvantages of FCMs/CAMs when created collectively by a group or individuals? What are the advantages and disadvantages when concepts are (not) predefined? The last point will be addressed in the following section.

3.3.2 Predefined Concepts

The software *Valence* we used for the studies offers participants the possibility to draw a CAM with or without any predefined concepts. A potential disadvantage of predefined concepts is that they influence participants' CAMs which in turn tend to reflect the researchers' ideas. An advantage is the simplified aggregation and comparability of the semantic content of CAMs. In Contribution 1, we chose ten predefined concepts from literature research on the corona pandemic. In Contributions 2 and 3, we only predefined one concept (*corona pandemic* and *nature imitation in technology development*) respectively. We did not limit the number of concepts participants were allowed to add in any of the studies.

Kapuza (2020) tested whether concept maps of participants differ depending on whether concepts are predefined or not and found not only semantic but also structural differences in the elaborated maps. Thus, the extent to which predefined concepts affect the process of Cognitive-Affective Mapping on semantic, emotional, and structural levels should be investigated in future research. In the following, I will examine how CAMs can be made semantically comparable despite containing different concepts.

3.3.3 Qualitative Analysis Approaches

The present work's primary goal is to combine qualitative and quantitative approaches using CAMs. The method's potential to openly and freely elicit and represent individuals' subjective experiences predestines it for qualitative research. In Contributions 1 and 2, we attempted to quantify data from the CAMs, e.g., by calculating network structures. Analyzing the semantic content of CAMs is more complex, especially with large datasets and concepts that are not predefined. We considered CAMs' semantic content in different ways. In Contribution 1, we automatically and manually summarized all mentioned concepts by creating inductive semantic categories to describe how frequently they were mentioned, e.g., *losing loved ones* and *friends being sick* were merged with other concepts under the category *worry about others*. In addition, we rated differences between two CAMs (pre/post) based on inductively created categories, e.g., whether one CAM was more positive than the other or whether new concepts were added. In Contribution 3, we examined which concepts represent ethical principles. Similar to Contribution 1, we rated differences between pre/post-CAMs concerning the frequency of ethical principles and the overall impression of the CAMs.

In Contributions 1 and 2, we focused on statistical network analysis[15]. The

[15] We are currently investigating the semantic content of all concepts from Contribution 2, which seems to provide insights into which topics matter to people during the corona crisis, how these are evaluated affectively, and to what extent the German and Canadian samples differ in this respect.

marginalization of the CAMs' semantic content in our studies can be explained by resource-related pragmatism since the analysis of rich text material is costly, and there are no standards for analyzing the content for large CAM datasets. However, the analysis of the semantic content of CAMs was part of several other studies in our department (e.g., Dörr, 2021; Kreil, 2018; Nothdurft et al., 2021; Sendtner, 2021). In the following, I will look closely at the mentioned concept categorization and ratings.

Analysis of Semantic Content. Different approaches for analyzing and summarizing text material have been developed in qualitative social research (Flick, 2007; 2018) and automated semantic network analyses (Yang & González-Bailón, 2018). The literature on cognitive maps provides less information on qualitative than on quantitative approaches to analysis. There, most analyses focus on quantitative approaches, such as automated aggregation mechanisms, learning algorithms, statistical models, and connection matrices (Stach, 2010). An exception is presented by Özesmi & Özesmi (2004), who sort individual concepts ("variables") of cognitive maps into categories to create a qualitatively aggregated map ("cognitive interpretation diagram").

In the following, I will refer to qualitative social research, in which various approaches are described to analyze textual material, for example, content analysis, grounded theory, or discourse analysis. In our studies, we referred to content analysis, a standard method that can be applied to different data materials[16] (Flick, 2018; Mayring, 2019; Mayring & Fenzl, 2020). Content analysis is traditionally attributed to qualitative research approaches but also includes quantitative analysis steps and enables frequency or cluster analyses (Carrera-Fernandez et al., 2014; Mayring, 2019). In contrast to single-case analysis, content analysis can be used to process a larger amount of data (Mayring & Fenzl, 2020). A

[16] For an overview of other qualitative analysis methods and the frequency of their use, see Carrera-Fernandez et al. (2014).

central procedure is assigning text material to categories, which are either developed inductively from the data or deductively from theory. Both types of category generation can be applied to CAMs. Starting with a list of all concepts mentioned in a CAM dataset, these can be sorted into predefined or inductively created categories. This allows an overview of the topics in the CAMs, how often they are mentioned, and how they are emotionally valuated. Especially for large datasets, it may be helpful to consider using an algorithm to detect word similarities and create initial categories in an automated way as a first step. In Contribution 1, we used synonym-matching algorithms and regular expressions to categorize the CAMs' concepts before manually checking and refining the resulting categories. The whole categorization procedure is similar to summarizing qualitative content analysis, which aims to reduce the amount of data while preserving important contents (Flick, 2018; Mayring, 2019).

Rating Analysis. Besides on the level of the individual concepts, CAMs can also be examined as a whole and rated by categories, inspired by structuring content analysis, where both formal and content structures are worked out from the material (Flick, 2018). In Contributions 1 and 3, we created categories to assess differences between pre/post-CAMs by two independent raters. In Contribution 1, the raters created the categories by noting their impression of each CAM pair in short sentences and then consensually decided on a selection of categories that captured the pre/post changes best. In Contribution 3, raters used predefined rating categories to assess characteristics of the pre/post-CAMs. The categories included affective dimensions (e.g., differences related to the CAMs' positivity) and structural ones (e.g., differences related to the CAMs' complexity). Further, the CAMs were rated based on ethical principles categories which we derived deductively from literature. For each CAM, we checked whether and which ethical principles they contained.

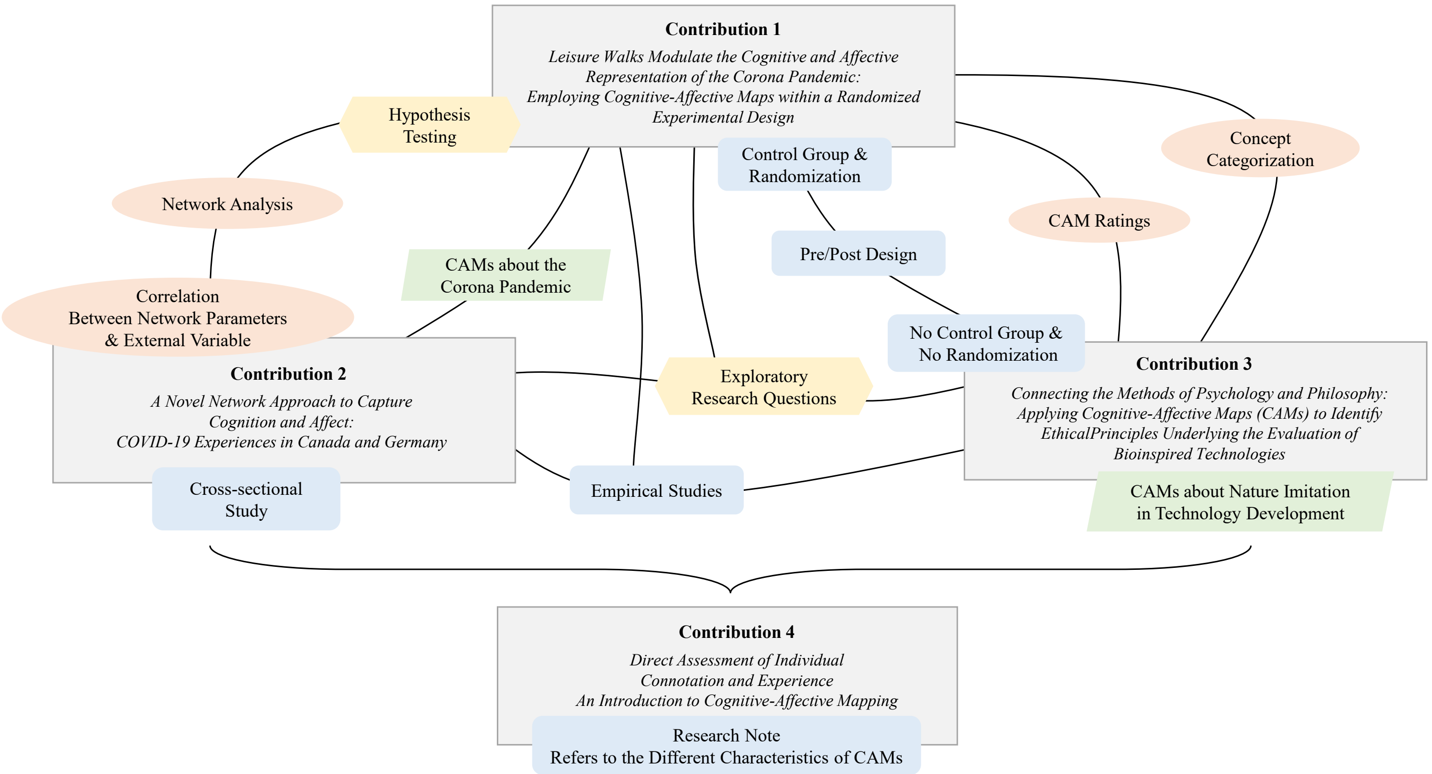
In Contribution 1, we decided to conduct a quantitative post-testing following the qualitative evaluation, which could not statistically validate the qualitative results. Generally, the questions arise about whether qualitative and quantitative approaches provide the same measuring results and to what extent these can be compared (Creswell et al., 2003). Further empirical research and theoretical examination are needed to get to the bottom of such issues.

With the presented approaches to evaluate CAMs with category systems, semantic contents of the individual CAMs were included and quantified. In some aspects, the procedure resembled qualitative content analysis. However, it differed as carrying out a content analysis follows a fixed schedule, the categories are more clearly defined, and coding strictly follows determined rules (Mayring & Fenzl, 2019). In principle, semantic CAM analyses could also be conducted in a more standardized manner with the advantage of increased intersubjective comprehensibility. However, aligning the qualitative approach more and more with the logic of quantitative analyses bears the risk of limiting the access to the material to a descriptive level (Flick, 2018; Froggatt, 2001). By applying standardized and text-reducing qualitative approaches in our studies, we took the risk of this limitation. Other qualitative approaches could open up more profound levels of meaning in the text, such as grounded theory or hermeneutics, which offer an exciting outlook for future CAM research.

The previous remarks explicitly refer to the application of CAMs in empirical research. Figure 2 illustrates differences and similarities in the design and analysis approaches of the contributions. In the following part of the discussion, I will address open questions and difficulties I encountered while working with CAMs. These issues could easily serve as the subject for further research projects and might seem slightly unconnected to the present structure of the thesis. I accept this as I consider the aspects to be important for a critical assessment of empirical work with CAMs, and for setting future research impulses.

Figure 2

Illustration of the Characteristics, Similarities, and Differences Between the Contributions



Note. The shapes and colors do not express any valence but sort various study characteristics by using the following coding: rounded blue rectangles = study/article design; yellow hexagons = exploratory/confirmatory approach; green trapezoids = topic of the CAMs; red ovals = analyses approaches.

3.4 Relating Empiricism to Theory

We propose Cognitive-Affective Mapping as a method suitable for mixed methods research. However, one criticism of mixed methods research is that it neglects scientific-theoretical arguments in favor of pragmatic-empirical approaches (Knoblauch, 2014; Völcker et al., 2019). Except for Contribution 3, this is also observable in our studies. Below, I open a reflection on quality criteria for quantitative and qualitative research and Cognitive-Affective Mapping. I then link the present empirical CAM data collection to theoretical foundations, focusing on remaining questions concerning CAMs' connections. I also address the combination of quantitative and qualitative elements in our studies.

3.4.1 Quality Criteria

Researchers commonly adhere to some criteria to assess the quality of research processes. However, different criteria in quantitative and qualitative research are usually found in the literature. This raises the questions which quality criteria should apply to mixed methods research and how the quality of Cognitive-Affective Mapping should be evaluated. Below, I will outline standard quality criteria in quantitative, qualitative, and mixed methods research in order to relate them to Cognitive-Affective Mapping.

Quantitative Research. Quality criteria in quantitative empirical research aim to perfect the measurement of human traits and cause-effect relations according to the mentioned criteria. They are typically applied in survey and experimental research. The standard primary quality criteria are *objectivity*, *reliability*, and *validity* (Döring & Bortz, 2020d; Moosbrugger & Kaleva, 2020). *Objectivity* means that the measurement results are independent of the researcher and can be divided into *implementation objectivity*, *evaluation objectivity*, and *interpretation objectivity*. *Reliability* is a standardized effect size measure to indicate that the results are reproducible when the measure is repeated. There is a differentiation between *retest*, *parallel test*, *split-half reliability*, and *Cronbach's alpha*.

Validity is often called the most crucial quality criterion and describes whether the instrument measures what it is supposed to measure. It can be further differentiated into *face*, *content*, *criterion*, and *construct validity* with additional subtypes, but sometimes such differentiations are abandoned, for instance, with the argumentation-based validation approach (Hartig et al., 2020). If applied to research designs, e.g., an experiment, it is referred to as *internal validity*, the unambiguousness of the interpretation of the results and *external validity*, the transferability of the results to a predefined population (Krebs & Menold, 2014).

Some authors (e.g., Bühner, 2021; Döring & Bortz, 2016e; Moosbrugger & Kaleva, 2020) refer to the following secondary quality criteria: *scalability* (adequate representation of the empirical characteristics), *standardization* (availability of representative test norms), *economical testing* (the instruments' cost-effectiveness), *utility* (practical relevance), *reasonableness* (burden on participants), *test fairness* (no systematic discrimination), and *non-fakeability* (no opportunities for participants to deliberately fake the measurement).

Qualitative Research. Flick (2014, 2020) explains why usual quality criteria of experimental-statistical quantitative research are difficult to be transferred to more phenomenological and subject oriented qualitative research. For instance, the identical repetition of a narrative interview, a typical qualitative standard (*retest reliability*), does not appear to be a suitable criterion for assessing the reliability of the statement or the method. Similarly, other aspects of quantitative research, such as the complete control of contextual conditions or the claim to objectivity, contradict the principles and logic of qualitative research. On the one hand, there are approaches to apply the quality criteria *validity*, *reliability,* and *validity* in a modified sense to qualitative research (e.g., Lincoln & Guba, 1985), and on the other hand, efforts are made to develop new quality criteria (e.g., Bohnsack, 2005; Tracy, 2010). However, some researchers also fundamentally question whether the definition of normative standards can be feasible (e.g., Schwandt, 1996; Smith &

Hodkinson, 2009). Researchers have developed many criteria catalogs without consensus (Flick, 2018). Frequently cited are the quality criteria according to Lincoln & Guba (1985) *credibility*, *transferability*, *dependability,* and *confirmability*, which are based on the quantitative quality criteria *internal* and *external validity*, *reliability*, and *objectivity* (Döring & Bortz, 2016c). They aim to ensure that the results and interpretations are trustworthy and transferable to other contexts, that the research process is comprehensible, and that the results are not biased by the researchers. Also, some authors have proposed triangulation approaches as a stand-alone quality criterion (Gabriel, 2019). Another common characteristic is the reflection of the researcher's subjectivity (Mortari, 2015), which, contrary to the quantitative paradigm, must not be neutralized but instead has to be acknowledged and disclosed (Döring & Bortz, 2016b).

Mixed Methods Research. Despite the popularity of mixed methods designs and the growing interest in specific quality criteria, there is no agreement on general quality criteria for mixed methods research (Heyvaert et al., 2013; Fàbregues et al., 2017). The most frequently referenced quality criteria for mixed methods studies can be found in reviews by Heyvaert et al. (2013) and Fàbregues et al. (2017). The Journal of Mixed Methods Research published a special issue on quality in mixed methods research, highlighting the distinct diversity of perspectives in mixed methods research, making consensus on quality criteria demanding (Fàbregues et al., 2021). According to Döring & Bortz (2016c), particularly those quality criteria should be pointed out that refer to procedures that exclusively concern mixed methods studies and thus the combination of quantitative and qualitative aspects and results of the study. The authors further refer to the following quality criteria for the entire mixed methods research process: *planning quality* (feasibility of the study), *design quality* (justification of the mixed methods design), *data quality* (choice of samples and data collection procedures), *interpretation quality* (relation of qualitative and quantitative evaluation and interpretation to each other), *inferential transferability* (transferability of results to other contexts), *presentation quality* (comprehensibility of the study presentation), *synthesizability* (suitability of the study presentation for research syntheses), *usefulness* (practical relevance of the study results).

3.4.2 Quality Criteria of Cognitive-Affective Mapping – A First Approach

To the best of our knowledge, no specific studies are yet available in the research literature that deal comprehensively with quality criteria. Researchers occasionally refer to quality criteria; e.g., Homer-Dixon et al. (2014) suggest that CAMs drawn by researchers can be *validated* by submitting them to others (e.g., participants or experts) for control or by simultaneously using other survey methods for comparison. The presented contributions were not intended to develop or test quality criteria for CAMs. Thus, it is difficult to make a general quality assessment of the method. Quality criteria might vary depending on the research question, design, analysis, and interpretation. The following remarks serve as a first step in reflecting the quality assessment of CAMs, specifically related to the presented empirical work (Contributions 1–3) and oriented towards the criteria just outlined.

The standardized instruction and data collection offer advantages to ensure *objectivity* and *reliability* by increasing the independence of the Cognitive-Affective Mapping process from the researcher. No *reliability* values can be derived from our work because repeated measurements only took place after the intervention, and accordingly, we expected no stability of the measurement results. From a general perspective, the stability of different characteristics of CAMs could diverge from each other. If and when differences between CAMs in repeated measurements should be regarded as measurement errors or whether this represents the dynamics of internal human representations cannot be answered at this point and requires further empirical and theoretical elaboration. I assume that the *objectivity* and *reliability* of quantitative research are rather applicable to statistical analyses of CAMs compared to the presented qualitative approaches, which require more room for evaluation and interpretation for the raters. Nevertheless, fully disclosing the applied categorization and rating mechanisms can increase *intersubjective comparability* for such methods. Concerning *validity* assessment, Contribution 1 stands out as the experimental design increases particularly the *internal validity*. In Contribution 2, we applied established statistical procedures to the CAM data, favoring *statistical validity*[17]. The CAMs generally exhibit high *face validity* as it is apparent to study participants that the CAMs capture their perspectives and attitudes through a network. To validate CAMs adequately according to standards of quantitative research, several empirical studies and calculations are necessary (Döring & Bortz, 2016e). Ambiguities concerning the relation between empirical data and the theoretical foundation of CAMs can be seen as a threat to *validity*[18].

Regarding *scalability*, it could be further examined whether the affective evaluation of a concept can be assessed similarly to a 7-point scale, which is often used for questionnaire items. Another question is to what extent the single affective valences of concepts can be combined to an adequate total value (e.g., CAMs' *mean valence*). With respect to *standardization,* no norm values are available for CAMs. While it is common to standardize questionnaires and tests with norms, it will be challenging to identify such universal norm values for Cognitive-Affective Mapping without imposing enormous restrictions on the design and the content. In terms of *economical testing*, we must admit that instructing and drawing a CAM took about 30-40 minutes in our studies, though this varies among participants. We argue that Cognitive-Affective Mapping is *economical* and practical (*utility*)

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[17] *Statistical validity* is given if the correct performance of the statistical analyses has demonstrated with a high degree of certainty that the effects found are (not) statistically random and have a relevant effect size (Döring & Bortz, 2016c).

[18] Such ambiguities are further elaborated in the following chapter (3.4.3).

because it combines the advantages of rather standardized procedures (allowing the collection and analysis of larger amounts of data) and more open procedures (allowing more creative freedom for participants to frame and express their personal experience). Participants' general feedback on the method suggests that the efforts are *reasonable*, except for occasional technical difficulties with the software. CAMs can be drawn by any group of people and thus feature a *fair* application. To this aspect, I add that we do not assume that Cognitive-Affective Mapping is dependent on specific cognitive skills. However, detailed instruction of the method is necessary, which we have implemented in a language-dependent textual-visual way that might be variously accessible to people. Further, specifically in our online study design, it should be considered that technical skills vary systematically among participants and therefore require different periods. We tried to compensate for this by calculating the time for participation spaciously and paying the same to all study participants. However, we could not prevent that some participants completed the study more quickly than others. It is also a matter of fact that CAM-drawers could intentionally distort the CAM, maybe due to social desirability. Here one could note a trade-off between *non-fakeability* and *face validity*.

The quantitative validity criteria are primarily designed for procedures such as tests and questionnaires. They are more likely to be applied to individual features of CAMs, e.g., network parameters or specific designs, such as experiments. Given the lack of consensus among many suggestions for quality criteria for qualitative approaches, it is difficult to decide on specific criteria for cognitive-affective mapping. As the presented data collection and evaluation approaches tend to be quantitative, I discuss the frequently cited and previously mentioned quality criteria according to Lincoln & Guba (1985), which are oriented towards quantitative quality criteria. Schou et al. (2012) presented a checklist based on the quality criteria of Lincoln & Guba and extended it by the *formal requirements* criterion, shown in Table 1. It presents an evaluation of Contributions 1–3, based on my personal judgment.

Table 1

Evaluation of Contributions 1-3, Using the Checklist by Schou et al. (2012) for the Quality Criteria Presented by Lincoln & Guba (1985)

Quality Criteria	Items according to Schou et al. (2012)	Contribution 1	Contribution 2	Contribution 3
		X = agree [X] = rather agree [–] = rather disagree – = disagree		
Credibility	Purpose is described clearly.	X	X	X
	Method is described.	X	X	X
	Arguments for choice of method were made.	X	X	X
	Methods suits the purpose.	X	X	X
	It is described how data were registered.	X	X	X
	Triangulation has been applied.	[X] [a]	[X][b]	X
	Research process is described.	X	X	X
Applicability	Selection of informants or sources is described.	X	X	X
	Description of the informants is included.	X	X	X
	It is argued why these informants are selected.	X	–	X
	Context (place & connection of research) is described.	X	X	X
	Relationship between researcher(s), context & informants is described.	[X][c]	[X][c]	[–][d]
Consistency	A logical connection between data & themes is described.	X	X	X
	Process of analysis is described.	X	X	X
	Clear description of the findings.	X	X	X
	Findings are credible.	X	X	X
	Quotations are reasonable/supporting the interpretation.	X	X	X
	Agreement between the findings of the study and the conclusions.	X	X	X
Neutrality	Researchers described their background/perceptions/preunderstanding.	–	–	–

Quality Criteria	Items according to Schou et al. (2012)	Contribution 1	Contribution 2	Contribution 3
		X = agree [X] = rather agree [–] = rather disagree – = disagree		
	Theories are referred to (clear who has inspired the analysis).	X	X	X
	It is described if themes were identified from data/pre-formulated.	X	X	X
	It is described who conducted the study.	[X][e]	[X][e]	[X][d,e]
	It is described how the researcher participated in the process.	[X][e]	[X][e]	[X][d,e]
	Description of the importance of the researcher's position for the findings.	–	–	[X][f]
Additional Formal Requirements of Scientificity	Background of the study is described through existing literature.	X	X	X
	It appears why the study is relevant.	X	X	X
	It is described how demands to informed consent have been met.	X	X	X
	It is described if there are relevant approvals.	X	[–][g]	[–][g]
	It is described whether the study can affect the informants.	[–][h]	–	–
	It is described what will be done if the study affects the participants.	[–][h]	–	–

Note. The final version of the checklist, according to Schou et al. (2012), contains a 4-point rating scale (*totally agree*, *agree*, *disagree*, *totally disagree*). In the present table, I changed the rating points to *agree*, *rather agree*, *rather disagree* and *disagree* in order to include expressions of uncertainty. I provided additional notes for the intermediate points.

[a]Though different analyses with the CAMs were conducted; [b] Possibly data triangulation, as questionnaire measures were correlated with network parameters of CAMs; [c]It was stated that participants were recruited and instructed anonymously via the online participant pool Prolific and how they were screened and paid – there was no direct contact between participants and researchers; [d]It was described how participants of an ethics seminar were instructed to use the CAMs in the context of the seminar, however it was not mentioned that one of the researchers hosted the seminar; [e]Authors of the study are named but without clearly breaking down the responsibilities; [f]Difficulties of interdisciplinary collaboration (philosophical & psychological background) were revealed, though less related to the research subjects but more to the research discipline and associated standards of methodological approaches; [g]There were no relevant approvals; [h]This was described in the application for ethical approval but not in the study

As seen in Table 1, the studies mainly fulfill criteria concerning the description and the coherence of the method, the procedure, the sample, and the results. Further improvements could be achieved by (more) triangulation and by a more detailed description of how researchers, participants, and the respective contexts relate to each other, who exactly conducted the study, and which role the researchers played in the process. Also, we did not specify whether the study might affect the participants and how we would deal with such an issue. However, in all studies, we informed the participants of their right to withdraw from the study at any time without providing a reason. Furthermore, the articles lack reflection on our role as researchers, our subjectivity, backgrounds, and presuppositions.

Other catalogs include further criteria such as the relevance of the research question, which was outlined in the articles in each case, or ethics (e.g., Tracy, 2010). In the present studies, we did not explore ethical aspects of the study in detail, except for Contribution 1, where our ethical application was approved, because we did not see any ethical risks. At the beginning of the study, all participants signed informed consent. The data was stored and published anonymously and only in the context of the scientific publication.

With regard to the aforementioned quality criteria for mixed methods, particular attention was paid to the quality of planning, design, data, representation, synthesizability, and usefulness. The results' transferability is limited, partly because of a small and specific sample (Contribution 3), the particular context of the corona pandemic (Contributions 1 and 2), and uncertainty about the meaning of the results (Contribution 2). In Contributions 1 and 3, we aimed to combine and relate the results of quantitative and qualitative approaches. In Contribution 2, we neglected qualitative approaches, which we are currently postprocessing in follow-up analyses on the same data material. Generally, more research is needed that investigates explicitly how qualitative and quantitative properties of CAMs interact and how these analyses can be related to each other. In doing so, it can be investigated whether and which quantitative and qualitative properties represent the same or different characteristics or whether they complement each other and how conflicting results can be dealt with.

I conclude that for some applications of CAMs, quantitative quality criteria and for others, qualitative ones might be used, depending on design, data, analysis, and interpretation approaches. The specification of which quality criteria are appropriate cannot be sufficiently discussed here. Presenting quality guidelines for Cognitive-Affective Mapping are beyond the scope of this thesis. However, our contributions show that it is possible to design studies according to quantitative quality criteria (e.g., the experimental design in Contribution 1) and qualitative criteria (e.g., the integration and reflection of different research backgrounds and assumptions in Contribution 3). We paid particular attention to making the research steps transparent and the data accessible. A limitation of the method's validity is that it has not yet been sufficiently elaborated on what Cognitive-Affective Mapping precisely measures and how the results can be validly interpreted. Some of these ambiguities are elaborated below.

3.4.3 Ambiguities Concerning the Connections Between Concepts

Throughout my work with CAMs, ambiguities repeatedly arose regarding the connections between the concepts. In the following, I specifically address the distinction between dashed and solid connections whereas, however, the distinction between unidirectional (arrows) and bidirectional connections can also be considered difficult. I observe uncertainties on two levels: First, there seems to be no consensus among researchers using CAMs about what the connections represent and by which rules they are guided (e.g., emotional coherence or semantic/logical connection, or both). Second, this fundamental theoretical question, in turn, affects practical-methodological aspects, especially when not only researchers draw CAMs but also study participants. This raises the question of how participants should be instructed to draw connections and how these connections should then be interpreted.

Theoretical Considerations on the Meaning of Connections. Thagard (2010a) introduced CAMs as an extension to his theory of *emotional coherence* (2006). Following this, CAMs illustrate human reasoning (inferences) in the form of a graphical and visual approximation of neuronal networks of the human brain. According to Thagard's theory, inference processes are characterized by striving to maximize emotional coherence. Connections in CAMs model the spread of emotions in the network (Homer-Dixon et al., 2014). They represent coherence between concepts of equal valences (solid link) or incoherence between concepts of opposite valences (dashed link). Accordingly, solid links are not used between concepts of opposite valence (a positive concept with a negative concept) and dashed links are not used between concepts of equal valence (a positive concept with a positive concept or a negative concept with a negative concept). Neutral and ambivalent valences are excluded from these rules and can be connected with any concept (Homer-Dixon et al., 2014). Assuming a person evaluates the concepts *eating meat* positively and *carbon emission* negatively and wants to connect those concepts, the link would have to be dashed due to the emotional incoherence of the concepts according to the presented rules.

To allow participants more freedom for drawing the CAMs, we have refrained from such restrictions in our studies. We only told participants that a solid link symbolizes that two concepts reinforce each other or go hand in hand and that a dashed link symbolizes that two concepts inhibit or exclude each other. The meaning of the unidirectional connections was adapted correspondingly. Further, our instruction contained an exemplary CAM with a solid link between a negative and positive node. Accordingly, regarding the example above, it would be possible to draw a solid link between *eating meat* and *carbon emissions*, e.g., because they are semantically/logically/linguistically linked (like, for example, *eating meat* goes along with *carbon emissions*). In our studies, participants have often drawn connections that would not be in accordance with Thagard's emotional (in)coherence rules but could be explained semantically. Presumably, the number of such connections would decrease if participants were explicitly instructed not to draw solid links between emotionally incoherent concepts and dashed links between emotionally coherent concepts. However, such connections could also point to participants' internal conflicts and thus provide important information. In the example above, *eating meat* might be valued positively because the person likes its taste. However, a conflict might occur because the person also might care about reducing *carbon emissions* and thus knows that meat production consumes a relatively large amount of carbon. This conflict could be resolved by changing the valence of one of the concepts, i.e., seeing *carbon emissions* as less harmful or *eating meat* as less favorable. Another way to solve the contradiction with Thagard's Cognitive-Affective Mapping principles could be to argue that the affective evaluation of the concepts might not be precise since *eating meat* could also be evaluated ambivalently. From this perspective, *eating meat* (ambivalent) could be connected with a solid link to *great taste* (positive) and *carbon emissions* (negative). While the second option does not resolve the conflict within the person but only the discrepancy with the emotional (in)coherence rules, the first option implies a resolution of the person's conflict and thus requires an inner change of evaluations. Building on the assumption that the mentioned connections might indicate conflicts, one can also argue that Thagard presents CAMs as the static result of a dynamic computational process (*HOTCO*) to maximize emotional coherence (Homer-Dixon et al., 2014; Thagard, 2010a). The CAMs we empirically collected might represent a snapshot of the participants' momentary experience, including current conflicts of coherence maximization.

As the CAMs, according to their theoretical anchoring, depict internal representations and processes in the brain, questions emerge on whether and which processes the connections represent and how they can be interpreted. The answer to that is still open. However, the above considerations show that the two ways of understanding connections, semantically or in terms of emotional (in)coherence, can interplay. The described issues with the rules concerning (in)coherent connections pose the question of how (in)coherence is to be defined with respect to CAMs. I notice a conceptual vagueness since (in)coherence, on the one hand, refers to single local connections between two concepts and the global CAM on the other. In line with the theory of emotional coherence, in my understanding, a dashed connection between a positive and negative concept can contribute to an overall coherent network, such as a dashed connection between a positively valued concept, e.g., *just society*, and a negatively valued concept, e.g., *social deprivation*[19]. However, dashed connections are generally referred to as incoherent since they symbolize the emotional incoherence between concepts of opposing valences. A more precise definition and conceptualization of (in)coherence in terms of local connections between concepts and the global CAM network could resolve such confusions.

Considerations on Arrows. Arrows (unidirectional links) were not included in Thagard's (2010a) original CAM conventions. In our contributions, we allowed participants to draw arrows to offer them more opportunities to contextualize CAMs' content in specific ways and provide more clarity for interpretation. If, for example, a person connects the concepts *smoking* and *arguing with the partner* with a solid link instead of an arrow, it is unclear whether the person wants to express that a) *smoking* leads to *arguing with the partner*, b) *arguing with the partner* favors the need for *smoking*, or c) both situations are mutually dependent. For semantic connections, examples are also conceivable where two concepts are connected with one inhibitory arrow in one direction and one reinforcing arrow

[19] Note: Mansell et al. (2021) calculate the network parameter *emotional dependence* as a proxy for *emotional coherence* using two different codings for an empirical-analytical approach. One calculation increases the coherence value if many concepts of the same valence are connected, regardless of the type of connection. In the second calculation, solid links between concepts of equal valence and dashed links between concepts of opposing valence increase the coherence value. The second approach corresponds to the conceptions I have outlined.

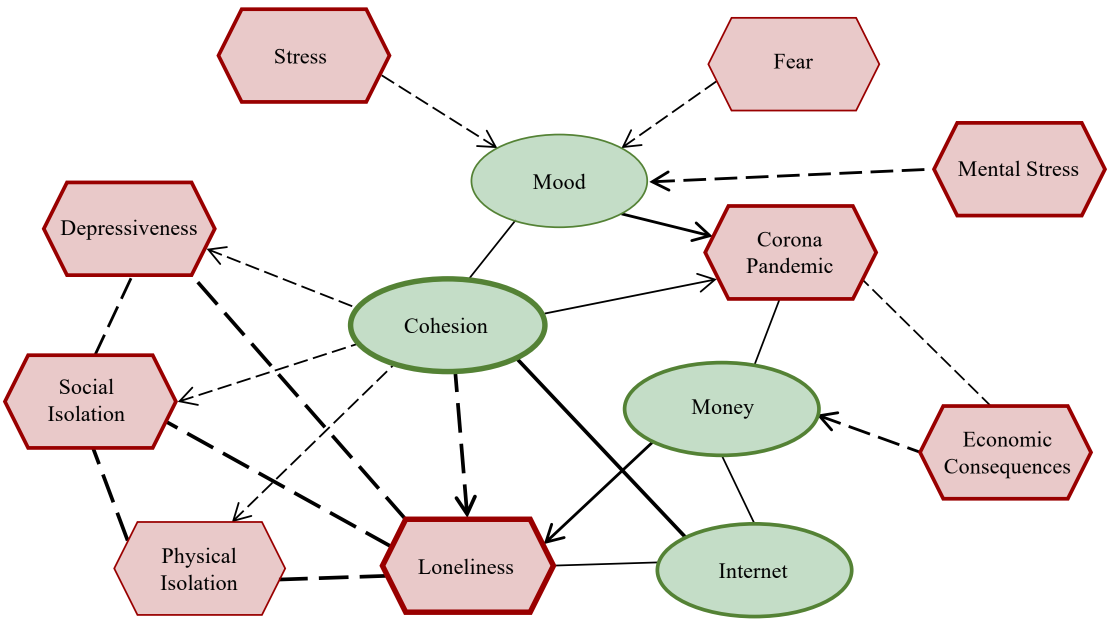
in the other. Assuming a person connects the negative concept *health risk due to corona* and the positive concept *vaccination*. If the person wants to express that people get vaccinated because of the health risk due to the coronavirus, a solid arrow from the concept *health risk due to corona* to the concept *vaccination* would be appropriate. Alternatively, if the person wants to express that vaccination reduces the health risk due to corona, a dashed arrow from the concept *vaccination* to the concept *health risk due to corona* would be appropriate.

How to handle such cases has not yet been discussed. Other practical implications arise in network analyses where CAMs can be treated as directed or undirected graphs. Theoretically, it can be discussed whether arrows are a suitable option for connecting concepts in CAMs. Again, there might be discrepancies concerning Thagard's theory of emotional coherence, according to which concepts affect each other emotionally in both ways and thus connections carry these emotional activations in both directions.

Practical Considerations on the Comprehension of Connections. A CAM represents the attitudes of a person or group of persons in the form of a vivid and comprehensible graph. Certain rules apply to the creation of CAMs, such as which shapes and colors of concepts represent the associated affective evaluation. If a person draws the concept *rain* in a green oval, it is assumed that they value *rain* positively in general, in relation to the topic of the CAM, or in relation to connected concepts. To date, we found no indications that people misunderstand the rules for evaluating concepts as positive, negative, neutral, and ambivalent. By this, I mean that the evaluation of concepts seemed comprehensible to us, either because of immediately available social norms (e.g., *death* as a negatively evaluated concept) or because of the overall CAM context. However, according to my experience, the comprehensibility of CAMs' connections appears to be more complicated. In all of our CAM surveys, numerous connections appear inconclusive to us. Since uncertainties appear independent of whether connections represent emotional or semantic (in)coherence, this problem might be located on another level. Figure 3 shows an example of such a CAM from Contribution 1. For example, the concept *physical isolation* connects with a dashed link to *loneliness* and *social isolation*. Since we did not confer with the participants, the following explanations must remain speculative. Sometimes, participants seemed generally to be more likely to choose dashed links for connections between negative concepts, although from our understanding, personally and based on the overall CAM, concepts should be more likely to be connected with a solid link, e.g., like in Figure 3.

Figure 3

CAM of a Participant with Connections that Appear Difficult to Understand to Our Team



Note. This CAM was created by an anonymous participant on the topic of the corona pandemic as part of the data collection for Contribution 1. I have translated the original German CAM into English. The participant seems to associate negative concepts, in general, more with dashed links, while solid links are more likely to be related to positive concepts.

One explanation could be that solid links might sometimes be scored as a *good connection* or *good influence* and dashed links as a *bad connection* or *bad influence*. Accordingly, it could be said that the valence of the concepts transfers to the (understanding of the) connection in a way for which no provision was made. However, as this pattern is neither consistent within a CAM nor across CAMs in general, it does not explain all the connections that seem contradictory to us. Another possibility may be that participants use dashed links when a connection between two concepts is ambiguous; for example, it could be both supportive and inhibitory. Clapp (2021) introduced a new type of dashed links for such cases. In a currently ongoing study on the understanding of connections in CAMs, the results suggest a similar explanation, according to which participants justified their choice of a dashed link by stating that the relationship between the two concepts can be supportive/inhibitory but not necessarily has to be so (Rothmann, 2022). Further research on the elaborated ambiguities in theory and practice could improve our understanding of the drawn connections and thus also the validity of Cognitive-Affective Mapping. In the event of lacking clarity concerning the question of what exactly is being measured and represented with the connections in CAMs, the validity of the interpretations and the method is limited.

Recapping the Concerns with Connections in CAMs. The connection rules we applied conflict with the theoretical concept of emotional coherence insofar as we allowed participants to draw solid links between concepts of different valence and dashed links between concepts of the same valence. Furthermore, we included causality-implicating arrows, whereas Thagard (2010a) only used bidirectional links since connections that align with the theory of emotional coherence (Thagard, 2006) symbolize the bidirectional spreading of emotional activation. The elaborated considerations and ambiguities regarding connections in CAMs may be understood as an expression of a somewhat unclear relationship between empirical practice and theoretical anchoring. Future researchers might deal with the basic theoretical assumptions and implications for the empirical use of CAMs as a data collection method in more detail.

Other unresolved issues regarding the participants' general comprehension of the connections are whether they understand them semantically, emotionally, or both, and whether they see links uni- or bidirectionally. We had decided to allow all mentioned connections because we see this as an advantage to let participants draw their CAM as freely as possible. On a practical level, the contributions showed that the different connection options (with/without arrow; solid/dashed) are generally used, though some people do not use arrows and others do not use dashed links. Whether this is because the default setting for connections is a solid, bidirectional link or whether it represents a conscious choice of the participants cannot be answered from our data. Future qualitative and quantitative studies could help to find out how connections are understood.

3.4.4 Balancing Quantitative and Qualitative Elements

The combination of quantitative and qualitative elements can be realized at all stages of research, from research design and data collection to data analysis and interpretation. From our perspective, Cognitive-Affective Mapping represents a data collection method that produces qualitative and quantitative data. One major challenge was to combine these data, analyses, and results. Mixed methods research aims to truly integrate different approaches (Schreier & Odağ, 2020). However, mixed methods research always bears the risk of presenting results of qualitative and quantitative analyses merely in parallel. Regrettably, there are no clear standards on what precisely an integration should look like. Plano et al. (2010) described three ways of integration in mixed methods studies. One of them is *merging in a discussion*, which means discussing the results in turns, one right after the other. This is how we proceeded in Contributions 1 and 3. Further, the authors mention *merging by data transformation*, meaning “quantitazing” qualitative data or/and “qualitizing” quantitative data (Plano et al., 2010, p. 157), whereby the first occurs more frequently. Many of our evaluation steps can be seen as quantifying qualitative data, especially if CAMs are considered as qualitative data. In a broader sense, also network parameters might then be such a quantification. In a narrow sense, counting ethical principles in Contribution 3 could describe such a process. One way of data integration mentioned by Plano et al. (2010) and not applied by us is *merging with a matrix*, namely the representation of quantitative and qualitative information in a matrix. Such a format would certainly support the overview of the results and may be considered in future research.

One criticism regarding mixed methods research is that qualitative elements are often dominated and marginalized by quantitative ones (Kuckartz, 2014; Schreier & Odağ, 2020). Central features of qualitative research, like interpretivity, subjectivity, and creativity, may conflict with the economic logic of quantitative research, standardization, and analysis automation. The present work confirms the dominance of quantitative research approaches. However, the use of CAMs in previous work could also be described as qualitative, for example, when CAMs were used as a representational tool for conflicts (e.g., in Thagard, 2010a; 2015a). Finally, CAMs do not seem to be better suited for either quantitative or qualitative research, and it would be worthwhile to implement research designs with a more balanced proportion of quantitative and qualitative elements.

3.5 Critical Self-Reflection

While critical self-reflection seems to be an exception to the rule in quantitative studies, it is a widely accepted quality criterion of qualitative social research (Breuer et al., 2002). The decision to include a self-reflective section is an expression of my rather constructivist understanding of science, according to which researchers' contextual conditions do influence research questions and processes. These include disciplinary backgrounds and research traditions, the respective spirit of the time, sociocultural epistemological conditions, and personal presuppositions which influence research decisions (Breuer et al., 2002; Mruck & Breuer, 2003). Such decisions are decisive for identifying the research topic and selecting the applied methods for data collection, analysis, and interpretation. I will reflect on possible interdependencies between my personal background and the research presented in this thesis.

My interest in Cognitive-Affective Mapping and my motivation to explore this method are related to my ambition to combine classical quantitative methods of empirical psychological research with more qualitative approaches. This is based on the premise of categorizing methodological approaches into quantitative and qualitative. I was more critical of this categorization at the end of my thesis than at the beginning of my research with CAMs, as I was confronted with difficulties in figuring out characteristics and analyses of the data as quantitative or qualitative. Still, the argumentation in my thesis is based on the simplified dichotomous division of methodological approaches into quantitative and qualitative, which I found omnipresent during my studies in psychology. Further, the dominance of quantitative approaches in psychology increased my desire for more qualitative research. However, I have also become aware of my knowledge gaps in these research areas. This circumstance and the institutionally structured collaboration with researchers whose expertise also relates to quantitative approaches characterized the study designs' focus.

Furthermore, my understanding of research is influenced by an understanding of science based primarily on Western concepts and cultures. This includes the urge to understand phenomena by examining and analyzing them, often interpreting and verifying them in cause-effect relations. To represent reality, researchers frequently use simplified systems, and much research is carried out on specific, isolated levels of analysis that often remain unrelated to each other. These descriptions and the frequently inherent neglect of holistic approaches relate particularly to approaches in natural sciences, which in turn dominated my work. Ideas about whether and how the human experience of the world can be appropriately researched, mapped, and communicated are closely related to cultural perspectives. I was virtually in exchange about my research only with people who were socialized in Europe, Canada, or the United States. I think this has influenced many of the premises of my research: that human experience can be represented in terms of a network, that humans have internal representations that can be externalized, that cause and effect can be clearly delineated temporally and that it is generally helpful to better understand, even measure (human) nature.

All studies were funded within the Freiburg Cluster of Excellence *Living, Adaptive and Energy-Autonomous Materials Systems* (*liv*Mats). *Liv*Mats is an interdisciplinary research consortium in which new materials systems are to be developed. The team I joined in *liv*Mats consisted of researchers affiliated with the research area *sustainability*, who combine the disciplines of psychology, philosophy, and environmental science. At the same time, I was closely tied to the department for *Cognition, Action and Sustainability* of the Institute for Psychology in Freiburg. The long-term interest for *liv*Mats researchers in CAMs is focused on the possibility of using them as a transdisciplinary bridge between society and the natural scientists who develop the materials systems. My research on CAMs was aimed at exploring Cognitive-Affective Mapping as a method, which is why Contributions 1, 2 and 4 are thematically independent of the topic of technology development. The thematic focus in Contribution 3, the study of attitudes toward nature imitation in technology development, the empirical study of ethical principles, and the interdisciplinary collaboration between psychology and philosophy, goes back to the *liv*Mats research context. For Contributions 1 and 2, we chose the topic of the corona pandemic since the pandemic spreading was proceeding concurrently with the data collection for our studies. We assumed it was a suitable topic for a wide range of study participants since it is a collective social experience. Indeed, the pandemic pushed us to determine the online setting since local data collection was not always possible due to protection measures. Although the online data collection proved to be feasible, an on-site setting would have allowed for interaction with study participants and could have helped to clarify questions arising concerning the method. The restriction to online-only data collection did not seem particularly disadvantageous to me at first. This may also be because I worked mainly on the computer and was very familiar with the digital handling of our software for creating CAMs since I was constantly involved in software development and testing. This may have reduced my awareness of technical difficulties with anonymous online data collection, which we then experienced.

The data collections of Contributions 1 and 2 were essentially facilitated by the financial resources provided by *liv*MatS. The fact that the open approach to the potentially innovative method Cognitive-Affective Mapping received this material support may be seen in the context of the current research zeitgeist. Over the last years, the demand for inter- and transdisciplinarity has increased, and mixed methods research has been gaining popularity.

3.6 Conclusion

I have investigated to what extent Cognitive-Affective Mapping is suitable as a mixed methods tool for empirical psychological research. Our studies have shown that CAMs can be used in different designs for data collection and that it requires comparatively little effort to instruct participants in a standardized way to map their cognitive-affective perspectives with CAMs. Cognitive-Affective Mapping offers participants great freedom in representing their manifold experiences, and researchers can collect large data sets. We showed that CAMs could be analyzed in various ways. We applied network analyses using latent and emotional parameters of the CAMs for statistical analyses. Further, we categorized the concepts of multiple CAMs and rated the CAMs' overall appearance. The main focus of our work was on quantifiable aspects of CAMs while we somewhat neglected the semantic content. I reflected that we had set aside the linkage between empiricism and theory to favor a pragmatic exploratory approach, leaving some important questions unanswered. In particular, the meaning and interpretation of connections in CAMs raise difficulties. In this regard, qualitative approaches aiming at a holistic and contextual reconstruction of subjective realities might offer exciting prospects for open questions. Further, I elaborated that quality criteria for CAMs have been hardly assessed, and I have taken first steps in this direction. However, I argue that Cognitive-Affective Mapping represents a promising method for bridging the gap between quantitative and qualitative research, especially if researchers give more weight to qualitative research approaches within a mixed methods approach with CAMs.

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5. Contribution 1: Employing CAMs within a Randomized Experimental Design

Leisure Walks Modulate the Cognitive and Affective Representation of the Corona Pandemic: Employing Cognitive-Affective Maps within a Randomized Experimental Design

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The supplementary study material and the data that support the findings of this study are openly available through OSF at: https://osf.io/zhysw/ ?view_only=f6b06 d165d 9640e 1a6fb 143b4 1824b55

Conflict of Interest & Ethics Statement
The authors declare that there is no conflict of interest. Authors adhere to the APAs' ethical principles of psychologists and code of conduct.

Abstract

In response to the corona pandemic, many leisure activities have been restricted while walking has been explicitly endorsed by health authorities. We investigated how leisure walking affects individuals' attitudes to the pandemic. We used *Cognitive-Affective Maps* (CAMs) to measure individual's cognitive and affective attitudes toward the corona pandemic and related issues. In a controlled randomized experiment, we asked (N = 66) participants to draw a CAM before and after a walk. Participants in a control group drew CAMs before and after any self-chosen activity at home. We found that walking led to a more negative evaluation of the pandemic itself, likely due to a more intense reflection, while in everyday routines one has already adapted to it. In further qualitative post hoc assessments of the CAMs, we observed that negative concepts other than corona disappeared after walking. We conclude that leisure walks have complex effects on individuals' cognitive and affective conceptualization of the corona pandemic. Hence, the exact mechanisms of these effects need to be examined in future research. Our study has also shown that CAMs are a promising tool for measuring experimental interventions in health psychology.

Keywords: Cognitive-Affective Mapping, corona pandemic, leisure walking

Introduction

In response to the corona pandemic, governments around the world have taken drastic measures to minimize transmission of the virus. Almost every country affected by the disease has imposed massive restrictions on public and private activities, including popular leisure activities such as traveling, public events, and private gatherings (Askitas et al., 2020; Burdett et al., 2021; Eckardt et al., 2020).

In many countries, recreational facilities like gyms, swimming pools, and playgrounds have been closed (González-Valero et al., 2020; Shahidi et al., 2020). The restrictions greatly differ between countries rendering their effectiveness an increasingly popular subject for comparative evaluations (Cheng et al., 2020; Desson et al., 2020). In some countries, for example Italy, gathering in public spaces was prohibited, including sports; additionally, social amenities like museums, cinemas, and theaters were closed (Lazzerini & Putoto, 2020; Mahmoudi et al., 2021; Signorelli et al., 2020).

Scientific evaluations of lockdown policies have not been limited to assessing their epidemiological effectiveness (Adhikari et al., 2020; Ferguson et al., 2020; Flaxman et al., 2020) but have also intensely scrutinized negative psychological and societal side effects of the pandemic. For example, previous studies indicate that common reactions to the pandemic are anxiety, depression, and stress (Rajkumar, 2020; Wang et al., 2020). However, while the vast majority of official governmental interventions regarded explicit bans or restrictions of certain leisure activities, some governments complemented these restrictions with positive recommendations of leisure activities which have been explicitly endorsed by public health organisations, such as the World Health Organization (2020). For instance, during the first pandemic wave in Europe at the end of March 2020, the Press and Information Office of the German Federal Government (2020) officially announced that assistance for others, individual sport, and exercising outdoors, as well as other necessary activities, were permitted. Likewise, the Belgian government (2020) allowed, and even explicitly recommended, outdoor exercise together with family members or one friend. While the problematic psychological effects of the lockdown restrictions and bans have been previously investigated (Brooks et al., 2020; Rossi et al.,2020), the present study focuses on the psychological effects of a leisure activity that has explicitly been recommended by authorities during the lockdown, namely going for a walk. In many countries, going for a walk was permitted—given that hygienic measures are taken—butnot explicitly recommended by public authorities. For example, the French government (2020) implemented local curfews, entailing that leaving one's residence was only permitted with an exemption certificate and only for specific reasons, including brief walks with a pet. In countries with particularly severe lockdown regimes, even going for a walk was prohibited; for example, the Argentine president warned people not to walk more than 500 m from home (Horvat, 2020), and the Italian government (2020) only allowed walks when absolutely necessary. Thus, the recommendations in Germany and Belgium differed from other countries, and they have indeed not been based on scientific research or explicitly justified by the stipulated positive effects of going for a walk. A balance must be achieved between the risk of increased infection associated with outdoor activities in general and the potential examined in future research. Our study has also shown that CAMs are a promising tool for measuring experimental interventions in health psychology physical, immunological, and psychological gains of leisure walking. Thus, it is important to estimate and predict these gains in as much detail as possible. Consequently, the present study investigates the psychological effects of leisure walking, specifically in relation to coping with the corona situation. There is abundant evidence that leisure walks have diverse effects on psychological health and well-being. For example, nature walks lead to a more positive body image (Swami et al., 2018) and increased creativity (Oppezzo & Schwartz, 2014) as well as self-esteem

(Barton et al., 2012; Roe & Aspinall, 2011). Other studies have shown that leisure walking can reduce rumination (Bratman et al., 2015) and symptoms of clinical depression (Berman et al., 2012; Iwata et al., 2016; Korpela et al., 2016). As a result, walking has become increasingly popular as a therapeutic tool (Cooley et al., 2020; La Torre, 2004; Revell & McLeod, 2016).

The present study aims to specifically investigate the effects of leisure walking on thoughts and attitudes toward the corona pandemic. Specifically, we investigate whether going for a walk affects how we cognitively and affectively represent the experience of the corona pandemic in our mental models of the world. At a first glance, one might expect that going for a walk leads to more positive attitudes toward the corona pandemic. This outcome would be in line with previous literature from various domains that revealed several indirect hints that leisure walks might have effects on cognitive representations and affective assessments. For example, there is abundant evidence that walking increases positive affect (Fuegen & Breitenbecher, 2018; Gidlow et al., 2016) even for walks as short as 10 min (Focht, 2009). This has also been confirmed in a recent study on walking during the corona pandemic (Lades et al., 2020).

The positive effects on mood and well-being are typically explained by beneficial effects from the moderate and pleasant physical activity that characterizes walking (Buecker et al., 2020; Reed & Ones, 2006), complemented by positive effects from the walking environment (Fuegen & Breitenbecher, 2018; Olafsdottir et al., 2020). The latter is commonly explained by the restorative characteristics of typical walking environments (see, e.g. Hartig et al., 1991; Martens et al., 2011). According to restoration theory, environments that direct attention effortlessly lead to the restoration of attentional capacities and induce a pleasant mood (Kaplan, 1995; Kaplan & Kaplan, 1989).

Such qualities have not only been demonstrated primarily for natural environments (see, e.g. Ehret et al., 2020; Korpela & Staats, 2014; Van den Berg et al., 2016) but also for certain types of buildings (e.g. museums, see Chatterjee & Noble, 2016; Kaplan et al., 1993a, 1993b; Packer & Bond, 2010) and some urban environments (Janeczko et al., 2020; Scopelliti & Giuliani, 2004; Subiza-Pérez et al., 2021).

When individuals have the choice between different environments – as is often the case when going for a walk – restorative landscapes are typically preferred to non-restorative ones (Hartig & Staats, 2006; Van den Berg et al., 2003). The mediating role of restorative experiences for the well-being effects of walking has recently been confirmed in a study by Korpela et al. (2016). With regard to the present study, one might speculate that the overall increase in positive affect by walking would lead to a more positive evaluation of any concepts in the individual's representation of the pandemic context, including the corona pandemic itself.

However, a closer look at the nature of restorative experiences also allows an alternative, more nuanced prediction. Research on the impact of restorative environments has shown that, in addition to positive affect, restorative experiences also lead to a reflected cognitive state (Herzog et al., 1997; Mayer et al., 2009). Accordingly, walking has often been described as a contemplative process enabling one to step outside of everyday routines and think in a more reflective way (Keinänen, 2016; Keinänen & Beck, 2017), often leading to a more existential perspective on one's own life than normal everyday experiences (Saunders et al., 2018; Stevenson & Farrell, 2018). Thus, walking might allow individuals to gain a more critically reflected evaluation of the corona pandemic and call into question their everyday habituation and adaptation to the situation. From this perspective, one might conjecture that a leisure walk could even lead to a more negative attitude to the corona pandemic due to a more distanced reflected perspective. Note that this would well be compatible with a generally positive affect, as restorative experiences often support both positive affect and more reflective states (Herzog et al., 1997).

In the present study, we tested the hypothesis that leisure walking affects the valence of the corona pandemic in a controlled randomized experiment, where a group of participants went for a walk at a place of their choice, and a control group performed a different self-chosen activity. We measured the cognitive and affective representations of the corona pandemic with so-called Cognitive-Affective Maps (CAMs). In both groups, participants drew such a map before and after the intervention, and we analyzed the differences between the pre-and post-intervention maps. We used CAMs as they combine the advantages of quantitative and qualitative approaches (Möller et al., 2021).

A CAM is a network that connects cognitive and affective elements. The network concepts (called *vertices*, *nodes*, or *points* in graph theory; Diestel, 2017) can display any content in text form, for example thoughts, knowledge, or events. Additionally, each concept conveys an emotional value, which is represented by the color and shape of the concept's border. These valences or affects can refer to emotions, mood, and motivation (Thagard, 2012b). The CAM method was initially developed and employed by the philosopher Thagard (2010) and has so far been used primarily in conflict research and conflict management to visualize contrary positions and derive possible solutions (Homer-Dixon et al., 2014; Thagard, 2015). Other applications included the graphic representation of attitudes and their changes (Thagard, 2012a, 2012b, 2018; Wolfe, 2012) or CAMs as a methodological supplement in addition to other tools, for example for a triangulation with coding techniques from discourse theory (Luthardt et al., 2020). To date, in most published studies, CAMs are drawn by the researchers themselves and are subsequently based on other data or analysis methods. In the present study, we instead instructed the participants to draw the CAMs, an approach which has successfully been employed in several previous investigations (Kreil, 2018; Mansell et al., in press; Ricken, 2020). A more detailed description of the CAM method can be seen in the Methods section.

Based on previous literature examining the potential effects of leisure walks as previously reviewed, we hypothesised that walks exert a characteristic effect on participants' attitudes. First, we expected that the pre/post-change in the affective assessment of the concept *corona pandemic* will be more pronounced in the walking condition than in the control condition (Hypothesis 1). Second, we expected that the pre/post-change in the average affective assessment of the corona pandemic depicted by the entire CAM will also be more pronounced in the walking than in the control condition (Hypothesis 2). As previous literature allows diverging predictions, it was not clear whether the direction is positive (due to walks increasing positive mood) or negative (due to walks fostering a more reflected view).

For the first time, CAMs were employed in an experimental design with repeated measures. Thus, the present study can be regarded as a first methodological test of the applicability of CAMs in such designs. We come back to this aspect in the discussion. In order to better estimate the usefulness of CAMs to randomized experimental designs, we complemented the hypotheses-driven analyses by several exploratory quantitative and qualitative evaluations (see the Results section for details).

Methods

Sample

Ethical approval for the study was granted by the ethics committee of the University of Freiburg (number 338/20). We recruited a sample of $N = 74$ participants from Prolific, an online recruitment platform for academic research. To register on Prolific, one must be an adult. We applied three filters in order to advertise the study only to individuals who indicated that they currently live in Germany (1), speak German fluently (2), and have not participated in any other of our CAM studies on Prolific (3). A participant pool of 1545 individuals remained. We also specified that a desktop computer or laptop was required for the study. Of the 98 people who signed up for the study, 24 (24.49%) withdrew during the study. The 74 (75.51%) remaining participants who completed the study were paid a compensation of GPB17 (approximately equivalent to EUR19 GER), based on the hourly minimum wage in Germany. The study was scheduled for about 120 min, and participants were asked to engage only if they can go for a walk within the next 2 h. Participants were randomly assigned to the walk or control conditions. Incomplete datasets and CAMs with less than three concepts and links were excluded, as well as two CAMs from one participant focusing on a topic other than the given one. This resulted in a final sample of $N = 66$ participants, 30 in the walking condition (age, M = 29.13, $SD = 9.13$; 46.7% female) and 36 in the control condition (age, M = 26.97, $SD = 4.86$; 30.6% female).

Data Collection and Storage. We collected the data of all participants on April 8, 2020. At that time, the German Federal Government (Press & Information Office of the German Federal Government, 2020) had ordered strict regulations to slow the spread of the coronavirus, for example a contact ban. On April 8, the John Hopkins University recorded 113,296 cumulative and 5633 active cases in Germany (Johns Hopkins University & Medicine, 2020). Part of the data was stored on the server of the Questback GmbH until the completion of the study. The other part of the data was stored on a server of the Albert-Ludwigs-University. After completion of the survey, all data were stored on the university's server. The dataset of this study is openly available through OSF (Reuter et al., 2021).

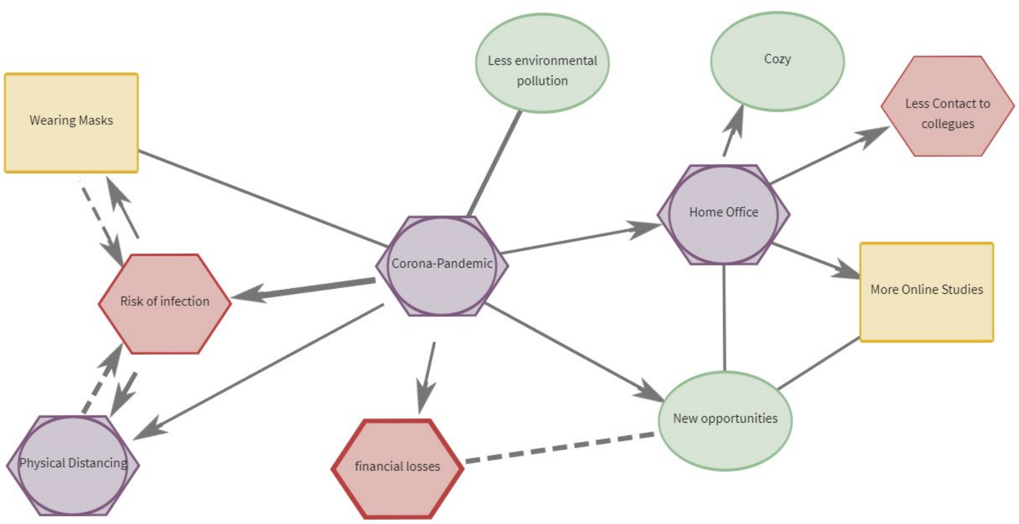
Measures

Before the actual implementation of the study is explained, a more detailed description of the CAM method follows.

Cognitive-Affective Maps. Figure 1 shows an exemplary CAM. The rules for drawing a CAM were adapted from Thagard (2010): Each concept in the CAM is affectively evaluated. Participants can choose between eight valence gradations, divided into four different colors and shapes. Green ovals stand for positive valence and red hexagons for negative valence. Yellow rectangles represent neutral valence, while the purple mixed form stands for ambivalent evaluation, meaning that the concept is evaluated both positively and negatively. There are three levels of intensity for positive and negative valence—the thicker the concept's border, the more intense the affect. The concepts are connected through links (called *edges* or *lines* in graph theory; Diestel, 2017). There are two types of links: A solid link between two concepts means that they are positively correlated, thus reinforcing each other; dashed lines mean that the two concepts are negatively correlated, thus inhibiting each other. According to Thagard's (2010) CAM rules, the links do not represent causality. In this study, however, we gave participants the opportunity to specify causal directions with arrows, contrary to the original CAM rules. Such an arrow link is interpreted as a one-sided effect of one concept on the other. The CAM data was collected with the freely available software *Valence* (Rhea et al., 2020). A detailed description of the instruction can be found in Appendix (S1, S3, S6, S7).

Figure 1

Exemplary CAM on the Topic of the Corona Pandemic



Results

Descriptive Analysis

Prior to the analysis, synonymous concepts were identified and collapsed into overarching terms, which reduced 480 terms to 131. The reduction steps (first going through online databanks to search for synonymous and regular expressions, then manually categorizing the terms) can be reconstructed in more detail in Appendix S3 and S4. On average, participants used 13.73 (SD = 3.97) concepts and 29.07 (SD = 12.08) links. The valence of a concept was numerically coded according to the border thickness as −3, −2, or −1 for negative concepts (−3 for the thickest negative border) and 1, 2, or 3 for positive concepts (3 for the thickest positive border); neutral and ambivalent concepts were coded as 0.

The mean valence of the *corona pandemic* concept was −1.26 (SD = 1.43) over all the CAMs. The average mean valence of these CAMs was −0.76 (SD = 0.76). Participants included most of the predefined concepts. The concepts most frequently left out were depressiveness (27%), mood (26%), and cohesion (22%). Furthermore, 92% of participants provided additional concepts. The average number of self-added concepts was 5.96 (SD = 1.98). A list with the frequencies of the most commonly used concepts, both predefined and self-added ones, can be found in Table 1 in Appendix S5.

Hypothesis-Driven Tests

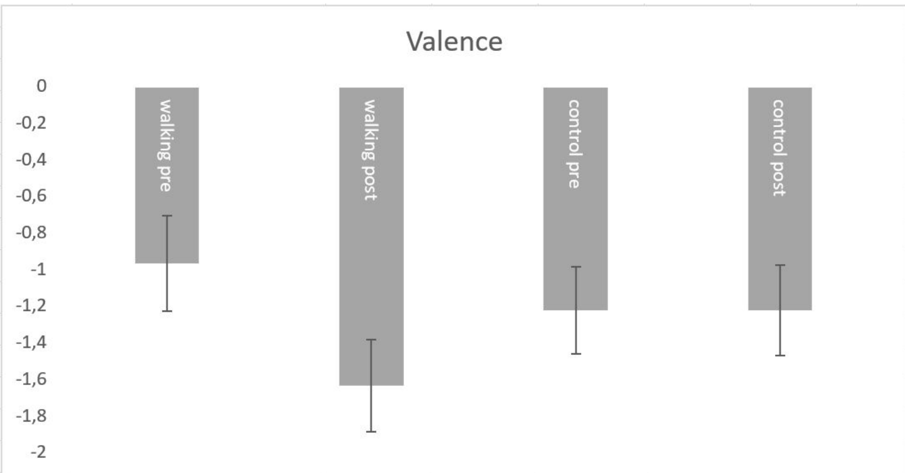
In testing the first hypothesis, we verified whether walking affected the affective valence in participants' representation of the corona pandemic. To this end, we conducted a two-factorial Mixed analysis of variance (ANOVA) with the between-subjects factor *group* (walking vs. control) and the within-subjects factor *time* (pre vs. post). The dependent variable was the valence assigned by participants to the concept *corona pandemic* in their CAM, coded by us from −3 to 3. The valence of the concept *corona pandemic* was not normally distributed in either of the groups, as assessed by the Shapiro–Wilk test ($p > .05$). However, simulation studies have revealed that the ANOVA is robust against violations of the normal distribution (Blanca et al., 2017). All other assumptions of the factorial mixed ANOVA, like not having any significant outliers and the homogeneity of covariance matrices, were met (Johnson & Wichern, 2002).

We observed a main effect of *time*, $F(1, 64) = 5.13$, $p < .05$, $\eta_p^2 = .07$, $\eta_G^2 = .014$, as well as a significant interaction of *group* by *time*, $F(1, 64) = 5.13$, $p < .05$, $\eta^2_p = .07$, $\eta^2_G = .014$. There was no statistical significance for the main effect of *group*, $F(1, 64) = 0.06$, $p = .81$.

In other words, participants who went for a walk assigned a less negative valence to the concept of *corona pandemic* before walking (M = −0.97, *SD* = 1.43) than afterward (M = −1.63, *SD* = 1.38), $t(29) = 2.88$, $p = .007$, $d = .53$ (Figure 2). In participants who did not go for a walk, the difference between the assigned valences for *corona* in the first CAM (M = −1.22, *SD* = 1.42) and the second (M = −1.22, *SD* = 1.48) was not significant.

Figure 2

Participants' Affective Assessment of the "Corona Pandemic" Concept.



Note. $N = 30$ in the walking group (pre and post); $N = 36$ in the control group (pre and post). Coding of the single concept rating ranges from –3 to 3 according to the 7 valuation options available in the CAM forms – due to the broadly more negative valence of the *corona pandemic* concept, here the range of the vertical axis is limited to the minus area

In a second hypothesis test, we verified whether walking affected the affective assessment across participants' entire CAM. To this end, we conducted a two-f actorial mixed ANOVA with the between- subjects factor *group* (walking vs. control) and the within-s ubjects factor *time* (pre vs. post). The dependent variable was the average valence, calculated by participants' valuations of all concepts over the entire CAM.

We observed a main effect of *time*, $F(1, 64) = 6.49$, $p < .05$, $\eta_p^2 = .09$, $\eta_G^2 = .02$, due to less negative CAMs after the intervention, M = −0.62, *SD* = 0.69, than before, M = −0.77, *SD* = 0.64. However, there was no significant interaction of *group* by *time*, $F(1, 64) = 0.12$, $p > .05$, nor statistical significance for the main effect of *group*, $F(1, 64) = 0.70$, $p > .05$ (Figure 3).

Figure 3

Average Valences of Participants' CAMs.

Note. *N* = 30 in the walking group (pre and post); *N* = 36 in the control group (pre and post). Coding of the single concept rating ranges from –3 to 3 according to the 7 valuation options of the CAM forms – due to the broadly more negative valence of the *corona pandemic* concept, here the range of the vertical axis is limited to the minus area

Quantitative Exploratory Tests

In the current research, graph theory was applied to quantitatively analyze CAMs, in addition to developing and evaluating a number of quantitative indicators (Borsboom & Cramer, 2013; Mansell et al., in press). Although these indicators fundamentally possess a structural nature, networks in general might offer psychological interpretations and are an important current field of research (Lynn & Bassett, 2020; Newman, 2018). Adapted from Mansell et al. (in press), we calculated the following parameters:

– Centrality: Number of connections on a concept, normalized by the total number of possible connections.

– Density: Proportion of links in a network divided by all possible links in a network.

– Diameter: Longest path in the graph (maximum distance from one concept to another)

– Triadic Closure: Number of triangles (three connected concepts) divided by the number of possible triangles.

– Number of Concepts; number of links; number of supporting (solid) links; number of contradicting (dashed) links.

Additionally, we calculated an assortativity value, which is a quantitative expression of how likely two vertices are connected if they are of the same type, in our case, have the same valence (Newman, 2018). The assortativity coefficient is positive if similar vertices (based on some external property) tend to connect and negative if otherwise. For each of these measures, we conducted a mixed ANOVA analogously to the aforementioned hypotheses-d riven tests. For none of these measures did we observe any main effect for *group*, all $p > .2$, or any interaction, all $p > .2$. However, there was a significant main effect for *time* on the *number of positive concepts* (for details, see Table 2 in Appendix S5). Additional qualitative exploratory analyses of the CAMs can be found in Appendix S6.

Discussion

Summary

We explored whether and how leisure walking affects participants' valence of the corona pandemic using CAMs. In a controlled randomized experiment, we assigned each participant to either the experimental group with the instruction to go for a 1- h walk or to the control group with the instruction not to go for a walk but to undertake any other activity. We hypothesised that participants who went for a walk would have a different perception of the corona pandemic afterward than before and that this change would be more pronounced than in the control group. We expected this effect for the valuation of the *corona pandemic* concept (Hypothesis 1) and for the average valuation of the entire CAM (Hypothesis 2). We measured potential changes with CAMs drawn by participants before and after the intervention. Additionally, we examined CAMs as a method using exploratory analyses.

Regarding Hypothesis 1, we discovered that participants rated the concept of *corona pandemic* more negatively after the walk than before, while no such difference was observed in the control group. As for Hypothesis 2, we found that generally the average valuation of the corona pandemic was less negative after the intervention than before. Nevertheless, contrary to our hypothesis, this difference was observed in the walking as well as in the control group. Our qualitative exploratory analyses (Appendix S6) revealed a tendency to omit negative concepts from the CAMs in the walking but not in the control condition. Furthermore, positive as well as negative concepts were introduced in the second CAM, although more were seen in the control than in the walking condition.

Leisure Walks and Cognitive- Affective Representation of the Corona Pandemic

Leisure walks seem to have a substantial and reliable effect on corona related cognition and affect, which is more complex than initially hypothesised. The specific evaluation of the *corona pandemic* concept evolved into a more negative valuation after walking. This is in accordance with literature stating that walking fosters reflection (Keinänen, 2016; Keinänen & Beck, 2017). Given the central theme of the pandemic, it is not surprising that an intensified contemplation on the latter has a negative effect on its evaluation. Thus, a walking induced, more distanced reflection on an initially negatively evaluated topic seems to sharpen walkers' views on negative aspects of the situation.

However, the leisure walks also allowed other negative topics to fade into the background (Appendix S6), so that they disappear from the cognitive-affective representation of the corona pandemic, which is likely due to the opportunity to contemplate and thereby positively resolving worries over the corona crisis. In summary, the cognitive processing during leisure walks had the somewhat ambiguous effect that the concept *corona pandemic* itself was evaluated more negatively, while negative issues disappeared.

In addition to this, the walking condition seems to have prevented new – positive and negative – concepts from entering the individual's representation of the corona pandemic (Appendix S6). We hypothesise that this might be because of a reduced variance of environmental stimuli during the walks. In the control condition at the participants' homes, participants were more likely to be stimulated by media, conversations, or greater variance in activities. The finding, contradictory at first sight, that the corona concept itself was evaluated more negatively after the walk, while other negative concepts tended to disappear and also fewer concepts were added, could be explained by coherence mechanisms. According to the theory of emotional coherence (Thagard, 2000), the valence of an element may be constrained by the valences of the elements surrounding it. Applied to our scenario, the negative valence of the corona pandemic in the post- walking CAMs could result from a containment of the negative valence on the corona concept, while peripheral concepts were less affected. Confirmation of such an effect is provided by individual CAMs, an example from the collected CAM data can be taken from Figure 4.1 and 4.2 (see Table 4 in Appendix

S5 for the original concepts in German).

Figure 4.1

Pre-CAM – before walking.

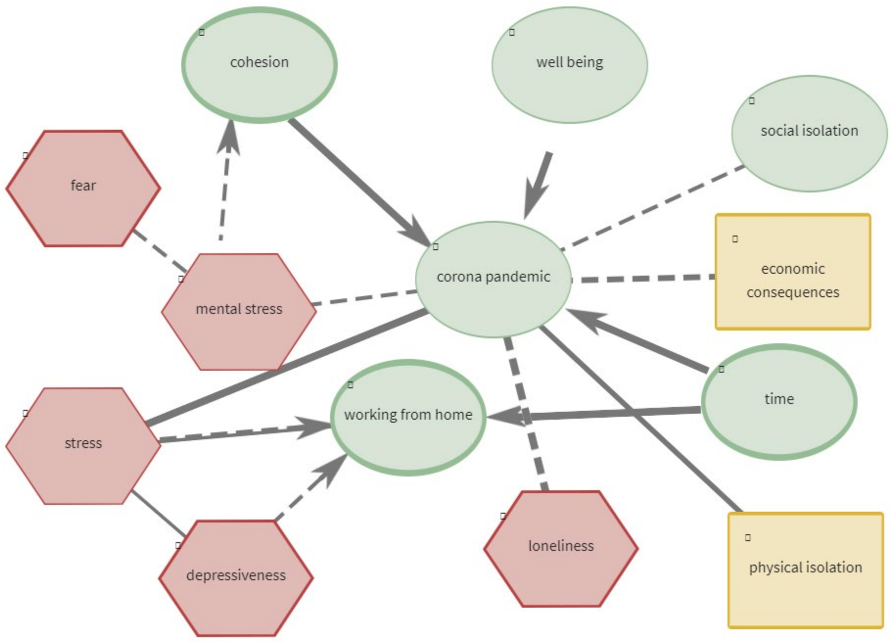
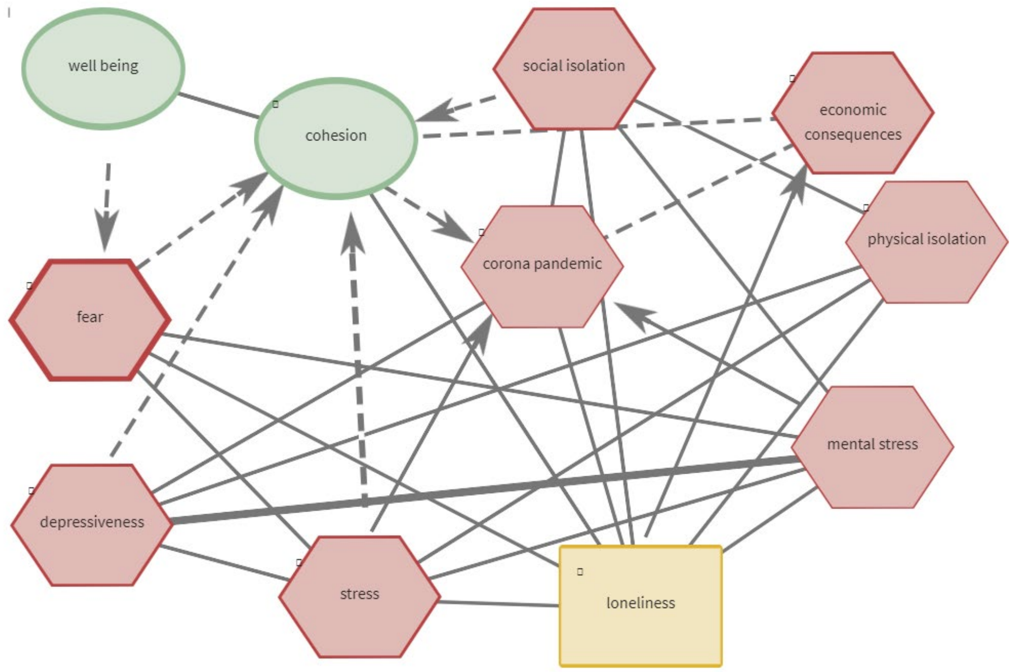


Figure 4.2

Post-CAM – after walking



Practical Implications

When evaluating how valuable leisure walks are in the time of corona, our findings provide a more nuanced picture than initially hypothesised. Our study does not question the well-e stablished antidepressant effect of walking in general (Bratman et al., 2015; Oppezzo & Schwartz, 2014; Swami et al., 2018), yet this effect does not lead to a more positive attitude toward the corona pandemic. On the contrary, also the well-established contemplating effects on reflecting cognition seem to impact CAMs here: lead to a more focused and probably more realistic evaluation of the pandemic, attributing the individual's negative affect on the pandemic, while reducing negativity toward other contextual factors. In spite of these findings, importantly, this modulation of affective distribution does not result in a generally more negative overall affective evaluation.

Thus, the present findings do not speak against the recommendation of walking as a leisure activity in the time of corona, although they clearly show that the effects of walking do not cause a general boost of positivity in participants' cognitive- affective evaluation of the corona pandemic. Leisure walking, in other words, focuses the distribution of negative evaluation on the corona pandemic.

Limitations and Future Research

The limitations of our study include the fact that participants in the control group pursued any self-c hosen activity. This choice was motivated by the applied perspective of our study because the alternative to an explicit recommendation to walk by health authorities was giving no recommendation at all. From this perspective, the most realistic condition to compare walking with was a condition with no instructed activity. However, future studies could assign control group participants to a specific suitable indoor activity, such as using an ergometer, which would allow researchers to pin down the walking effects to certain crucial parameters of an activity, like movement or rhythmicity. Furthermore, in our study, participants were instructed to go for a walk on their own – a walk together with companions could completely change the result pattern due to the content of the walkers' conversation. Thus, it would be interesting if future studies investigated whether differences were apparent between walking alone and walking with companions. It should also be noted that there was already a difference in CAM valence values between the walk and control groups when the first CAMs were drawn. This could be explained by the fact that at the time of the first CAM drawing participants already knew which condition they were in, which could have influenced their mood. Moreover, we could not verify whether participants really followed the instruction. We chose not to constrain the walking by control measures, as we aimed at making the experimental walks as unconstrained as possible with regard to the applied research question.

In our study, the majority of the pre-set concepts presented to the participants were likely to be assessed rather negatively. Thus, their thoughts may have been colored negatively during the intervention. Prospectively, the effect of assigned positive concepts could be investigated.

Regarding the different results of the quantitative and qualitative analysis, it should be noted that the study was originally designed to test hypotheses quantitatively. The qualitative analyses were of exploratory nature. It is indeed possible that the statistical power of the quantitative test was too low for a qualitatively observed effect.

Finally, it should be noted that the study cannot serve as a method validation, though we tested the method of Cognitive- Affective Mapping in a new design. The investigation of psychometric properties, such as validity, is still pending. Also, there is no information on reliability characteristics so far, although retest reliability, in particular, would be important for our repeated measures design. Also, it is possible that merely drawing a CAM changes the attitude toward the topic. We tried to prevent such changes from biasing the effect of leisure walking by using the break control condition. Future empirical CAM studies should examine such important psychometric properties in detail.

Also, the theoretical embedding of the CAM method in network and attitudinal models is not clear. This study cannot clarify such fundamental questions, but can only demonstrate as a first approach that its application in this kind of experimental design is possible.

CAMs for Pre/Post-Designs

In general, the present study found that CAMs are feasible to use by participants and may be suitable for an experimental pre/post-d esign. Despite this, with exploratory mixed ANOVAs for certain network measures, we found that generally the effect of *time* was more important than the effect of *group*. A number of main effects of time are remarkable in the ANOVAs, like the *number of positive concepts*, *assortativity*, and the *average CAM valence*. Interestingly, this suggests that there were generally substantial changes in CAM properties, regardless of whether the participants went for a walk or performed other self-c hosen activities. This means that drawing a CAM twice has in itself an effect independent of condition. This does not affect our results, as they focus only on the differences in changes between conditions. This, however, is a vital implication for CAM research in general. Future research should explore the effects of drawing CAMs twice on the same or different topics in isolated research designs.

It is also remarkable that participants included new positive concepts in the pre- and post- CAMs. It is possible that in extant literature on corona, positive aspects have been allocated less importance. Our data, however, indicate that such concepts can be identified with the method of CAMs.

Conclusion

We conclude that leisure walks in corona times lead to a more reflective and accentuated perspective on the corona pandemic. While the negative evaluation of the *corona pandemic* concept was intensified, other negative context aspects were shifted to the background. Our findings show that leisure walking, a currently widely practiced activity, has complex effects on how people cognitively represent the pandemic and its context. The findings also call for a more comprehensive investigation of the detailed impact of leisure walking on cognition and affect. We further recommend the use of CAMs in experimental designs.

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6. Contribution 2: A Novel Network Approach to Capture Cognition and Affect

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A Novel Network Approach to Capture Cognition and Affect: COVID-19 Experiences in Canada and Germany

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Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study

Author Contributions
JM was primarily responsible for the statistical analysis and results. LR was primarily responsible for the study programming and implementation. CR was responsible for the administration of the Valence software tool. AK was responsible for overseeing the project development and direction. All authors contributed to the study design, statistical analysis, and preparation of the manuscript.

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Conflict of Interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Abstract

We tested a novel method for studying human experience (thoughts and affect). We utilized Cognitive-Affective Maps (CAMs)–an approach to visually represent thoughts and their affective connotations as networks of concepts that individuals associate with a given event. Using an innovative software tool, we recruited a comparative sample of ($n = 93$) Canadians and ($n = 100$) Germans to draw a CAM of their experience (events, thoughts, feelings) with the Covid-19 pandemic. We treated these CAM networks as a series of directed graphs and examined the extent to which their structural properties (latent and emotional) are predictive for the perceived coronavirus threat (PCT). Across multiple models, we found consistent and significant relationships between these network variables and the PCT in both the Canadian and German sample. Our results provide unique insights into individuals' thinking and perceptions of the viral outbreak. Our results also demonstrate that a network analysis of CAMs' properties is a promising method to study the relationship between human thought and affective connotation. We suggest that CAMs can bridge several gaps between qualitative and quantitative methods. Unlike when using quantitative tools (e.g., questionnaires), participants' answers are not restricted by response items as participants are free to incorporate any thoughts and feelings on the given topic. Furthermore, as compared to traditional qualitative measures, such as structured interviews, the CAM technique may better enable researchers to objectively assess and integrate the substance of a shared experience for large samples of participants.

Keywords: COVID-19, cognition and affect, network approach, cognitive-affective mapping, Germany, Canada, network analysis

Introduction

Developed by the cognitive scientist and philosopher Paul Thagard, *Cognitive-Affective Maps* (CAMs) are a direct mental modeling approach for visually depicting the content of belief systems (Thagard, 2010). While CAMs contain several quantifiable properties, their feasibility as an empirical tool is yet to be tested. Using the COVID-19 pandemic as a test case, we explored the application of CAMs as a quantitative tool for the study of human experiences including thought and affective connotations. Specifically, we ask the question *can the network properties of CAMs be used to study similarities in individuals' thinking and experience surrounding an emotional life event?* To answer this question on the feasibility of CAMs, we recruited a sample of Canadian (n = 93) and German (n = 100) subjects to create CAMs encoding their experiences with the COVID-19 pandemic, we then assessed the resulting mental models, using a stepwise analysis of their network properties.

CAMs are visualized networks consisting of nodes and links that connect affective and cognitive elements. The nodes represent various content in text form, including goals, events, people, ideas or concepts, emotions, factual knowledge, or conclusions. Each node also conveys an emotional value, which is represented by the color and shape of the node. These valences or affects are broad assessments in terms of "positive" or "negative" and they can be related to emotion, mood, and motivation (Thagard, 2012b). CAMs also include links (sometimes called edges), that are lines connecting two nodes. Based on the computational theory of explanatory coherence (Thagard, 1989), there are two types of links between concepts in CAMs: supporting links and contradictory links. Applied to the study of attitudes and experiences, CAMs are a rich source of individual level data, however, the lack of an appropriate tool to encode and analyze this information is an ongoing constraint to their wider usage in research. Past applications of CAMs were limited to qualitative evaluations or discussions about the structure and function of belief systems (Thagard, 2010, 2011, 2012a,b,c, 2015, 2018; Wolfe, 2012; Homer-Dixon et al., 2013, 2014; Milkoreit, 2013; Findlay and Thagard, 2014; Luthardt et al., 2020). Within the published literature utilizing CAMs, exemplar CAMs were typically drawn by the researchers themselves, using a critical evaluation of a corpus of data (speech or written document, e.g., Luthardt et al., 2020). Unfortunately, when used exclusively, these qualitative methods are subject to several limitations including the introduction of subjective (reader) biases and the restriction to small sample sizes. In our opinion, the lack of a standardized method for the creation, analysis, and comparison of CAMs is significantly impeding their wider application across the social and psychological sciences. Fortunately, the increased accessibility of analytic tools for network analysis and the creation of online applications such as *Valence*[1] means that it is possible to use CAMs to analyze and compare how individuals perceive a single issue or experience.

CAMs contain a number of significant opportunities not provided by other research methods. In contrast to questionnaires, CAMs can directly capture the connection between the elements of interest to a specific individual participant. Furthermore, because they use an open response visualization tool, as opposed to structured survey items, their content is less susceptible to instrument biases. For example, CAMs' less structured response format provides participants an opportunity to elaborate on factors which are potentially overlooked or discounted by structured response items. Compared to qualitative interviews, larger amounts of data can be collected with less effort as participants are able to draw the CAMs themselves and the data analyses does not require a detailed transcription of the interview. Finally, CAMs can be combined with survey, interview, and experimental methods to generate richer datasets, conduct robustness checks or cross method comparisons, and explore

[1] https://cam1.psychologie.uni-freiburg.de/users/loginpage?next=/.

causal relationships.

We investigate the feasibility of using CAMs' network properties to study similarities in individuals' experiences with a shared emotional life event. To meet this objective, we administered an incentivized online study during the 2020 COVID-19 pandemic. We asked samples of Canadian and German participants to visually depict their experience with the ongoing viral out-break as a CAM, using the *Valence* application (Rhea et al., 2020). In detail, we asked participants to capture their experience, the events, thoughts, and feelings resulting from the current coronavirus outbreak and draw everything that comes to their mind concerning their experience with the coronavirus pandemic. We selected the pandemic as our case study to maximize the external validity in our assessment of individuals' experience (thought and affect). In contrast to laboratory manipulations which subjects often perceive of as artificial or unrelatable, the global nature of the pandemic emergence ensures that all individuals in our study have experienced some degrees of life disruption. Our design therefore relies on within sample variation on the perceived threat of coronavirus to test the predictive validity of CAMs as an empirical tool. Participants also completed demographic questionnaires capturing their experience with the viral outbreak, including a 3-item scale to assess perceived coronavirus threat (PCT) developed by Conway et al. (2020). For future research on the factors mediating or moderating the PCT, we administered questionnaires on the meaning of life (Breyer and Danner, 2015), control conviction (Kovaleva et al., 2012), need for cognition (Beißert et al., 2015), need for affect (Appel et al., 2012), and personal need for structure (Neuberg and Newsom, 1993). For future research on the social consequences of the PCT we also administered questions on socio-political attitudes.

To evaluate the predictive value of CAMs' network properties we operationalized and compared 14 network properties for each individual CAM (including centrality, density, average valence, and valence of central node) which capture both the emotional and latent properties of CAMs (Supplementary Table 6). Based on the principles of CAMs developed by Thagard (2010), our expectation is the emotional properties of CAMs should be correlated with the PCT. Specifically, participants who draw CAMs with a more negative valence should be more likely to perceive the coronavirus as threatening? Given the exploratory nature of the study, we have no expectations about the relationship between latent properties and PCT, however, a discussion of possible relationships is included in the Supplementary Material (page 9). Finally, we had no a priori expectations about the differences between Canadian and German samples.

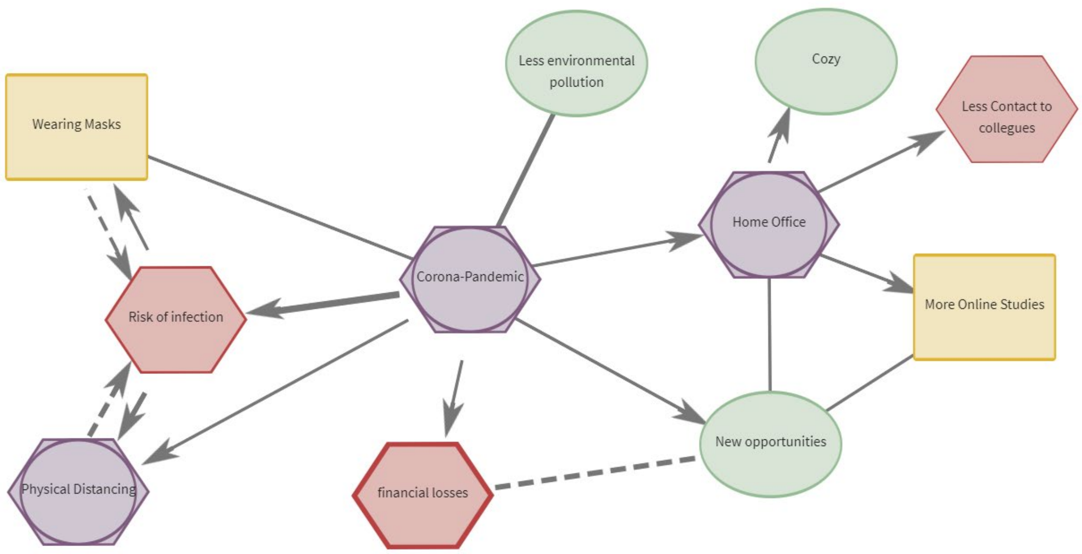
In reporting our results, across multiple models, we found a consistent and significant relationship between these network variables and the PCT in both the Canadian and the German sample. However, in the German sample we found an unexpected relation between valence and PCT. Our results demonstrate that a network analysis of CAM properties is a promising method to study the relationship of the overall assessment of a situation e.g., in terms of threat and the detailed assessment of the experience in terms of thoughts/concepts and their affective assessment.

Properties of CAMs

Outlined in Thagard (2010), the rules for drawing a CAM are illustrated as follows (Figure 1 for an exemplary CAM). Every node in the CAM can be evaluated affectively. There are eight valence gradations to choose from, which are divided into four different colors and shapes. Green ovals stand for positive valence, red hexagons for negative valence. Nodes can be coded as neutral and ambivalent. Neutral, represented as a yellow rectangle, means that the node is not associated with positive or negative affect. Ambivalent, represented by a purple hexagon superimposed over a circle, means that the node contains a mixture of positive and negative values. There are three intensity levels for both positive and negative values–the thicker the border, the more intense the affect. These different nodes are connected through lines (links or edges; in the following we use the term link to refer to these connecting lines). There are two different kinds of links to choose from: solid and dashed. Solid links indicate that the two elements are positively correlated, whereas dashed links mean that the two elements are negatively correlated.

Figure 1

Exemplary CAM on the Topic of the Corona Pandemic.



Note. Figure displays a summary of a CAM's properties: ambivalent (purple), negative (red), neutral (yellow), and positive (green) concepts. Solid lines indicate concepts which are mutually reinforcing, dashed lines indicate concepts which are oppositional. Thicker lines indicate stronger relationships. Arrows indicate the direction of a causal relationship between concepts. Two arrows between two concepts indicate a bidirectional or mutually reinforcing relationship. No arrows indicate there is no clear causal relationship.

According to Thagard's (2010) rules for drawing CAMs, the links do not represent causal directional effects. In our study, we modified the original format to allow participants to include arrows as a link property. We interpret these arrows as an indicator of a directed relationship where one concept contributes to the occurrence of another following the direction of the arrow e.g., A contributes to B if A → B. The outcome of this modification is that for the purpose of statistical analysis CAMs can be treated as directed (Markov) graph which allows us to generate a wider variety of network measures. These measures are valuable as they allow us to explore how different structural relations within the data contribute to a given perspective.

Exploratory Questions and Expectations

The COVID-19 pandemic has brought about a global health emergency (Sohrabi et al., 2020) broadly affecting people around the world. Responses to the pandemic such as social distance, self-isolation, travel restrictions, and school closures have farreaching effects on work, family life and leisure time behavior (Nicola et al., 2020). Reviews of COVID-19 studies show a considerable increase in anxiety, stress and depression levels and sleep disturbance (Rajkumar, 2020; Salari et al., 2020; Sandín et al., 2020; Usher et al., 2020; Vindegaard and Benros, 2020). Because of these severe and widespread consequences, the pandemic represents an ideal case to study human experience (thought and affect).

While the consequences of the pandemic vary by region and by person, the global characteristic of the pandemic means that all individuals, to varying degrees, are administered treatment. Our study exploits the variation in outcomes to study the relationship between individuals' structured thoughts and experience. In other words, we investigate whether similarities in individual structured thinking are predictive of similarities in individual experience.

In this study, we ask the following question: *Can the network properties of Cognitive Affective Maps be used to study similarities in individuals' thinking and experience surrounding an emotional life event, the 2020 COVID-19 pandemic?* To answer this question, we evaluated the following exploratory questions about the relationship between CAMs' network properties and the perceived threat of COVID-19 assessed by the 3-item PCT scale of Conway et al. (2020). A justification of these questions is provided in Supplementary Material ("Exploratory Question Rational").

s

Exploratory Questions

1. Do the emotional network properties of CAMs (e.g., averagevalence and valence of central node) predict the perceived threat of the coronavirus?
2. Do the latent network properties of CAMs (e.g., density, diameter, closure) predict the perceived threat of the coronavirus?
3. If so, to what extent are the network properties that predict theperceived threat of the coronavirus consistent across samples?

Method

Sample

Initially, we recruited (n = 106) Canadian and (n = 110) German participants from Prolific, an online participants recruitment tool for academic research. Due to the exploratory nature of the study, two independent samples (Canadian and German) are used to increase the generalizability and reliability of our findings. Study sample size was set by the availability of research funds. To demonstrate that our study is sufficiently powered, a separate one-sided *post-hoc* power analysis using the results of the conditioned statistical model (Model 2) is conducted for Canadian and German samples. Summarized in Supplementary Tables 80, 81, the results show that there is sufficient power to detect each of the significant effects but it is underpowered in the case of marginal effects.

During data cleaning, the data of 12 participants were dropped because they indicated that they prematurely stopped the CAM exercise, 11 additional participants were dropped for failing an attention check. For the purposes of the network analysis, we also restricted observations to participants whose CAM contain a minimum of three nodes or two links, this results in the exclusion of 1 additional participant. The final sample is (n = 93) Canadians and (n = 100) Germans. Due to the 2020 coronavirus pandemic, it was necessary to conduct our data collection online. The Prolific data collection platform was selected because it provides transparent information about the demographic composition of its subject pools by country and because it maintains subject pools in both Canada and Germany, representing the nationalities of the research team. The sample was restricted to Canadian and German residents over the age of 18 who had access to a laptop, notebook, or desktop computer. We further restricted participation to participants who speak fluent English (in Canada residents) or fluent German (in German residents). To incentivize participation, each participant was given a direct £8.50 payment for their participation. British pounds are the standard currency on Prolific, this payment converts to $14.50 CAN/ e9.50 GER. Participant compensation is based on an hourly minimum wage in Canada and Germany. The estimated length of the study was indicated with 60 min. Most participants completed the study in <60 min.

Data collection for this study was administered in two waves, the first from May 28th to May 29th (1), and June 21st to June 24th (2), 2020. During this time number of cases per 100,000 inhabitants differed greatly. According to Johns Hopkins University Medicine (2020), during the data collection periods the number of reported cumulative infection cases were as follows: Canada—May 28th [99,976], June 24th [104,087]; Germany—May 28th [182,196], June 24th [192,871]. In our sample, there are no significant correlations between time of data collection and the PCT (Supplementary Tables 7, 8).

The completion rates, measuring all participants who opened the study as compared to participants who completed the study, were 61.8% (CAN) and 64.4% (GER). All demographic data and questionnaire measures (Supplementary Tables 9–27) were collected after the CAM exercise. After the collection of demographic data, we fully randomized the order of attitudinal and psychological measures and the presentation of all questions within these measures.

Demographic Summary

The Canadian sample (n = 93) is 44.09% female, 53.76% male, 1.00% non-binary, and 1.00% prefer not to say. The mean age category of the sample is 26–32 years (SD = 1.17), and it is 58.84% White, 45.16% other groups; 58.06% of the sample obtained a minimum of a college undergraduate, and 48.08% of the sample identifies religion as being “Very important” or “Somewhat important” in their life. The German sample (n = 100) is 34.00% female, 65.00 % male, 1.00% non-binary. The mean age is 26–32 (SD = 0.83), 76.00% of the sample indicate that both of their parents are of German ancestry, 12.00% have at least one parent of German ancestry, and 12.00% have no parent of German ancestry; 80.00% of the sample obtained a minimum of a college undergraduate, and 24.00% of the sample identifies religion as being “Very important” or “Somewhat important” in their life.

Attitudinal and Psychological Measures

We administered a series of psychological measurements of the impact of COVID-19 developed by Conway et al. (2020). Drawing a CAM is a time intensive exercise (~30 min), to minimize survey fatigue we choose to administer short survey batteries whenever possible. The short version battery of Conway et al. (2020) consists of the following questionnaires: (1) *Perceived Coronavirus Threat* (PCT) Questionnaire with three items[2], (2) Governmental Response to Coronavirus Questionnaire with six subscales with two items each, (3) Coronavirus Impacts Questionnaire with three subscales with two items each, and (4) Coronavirus Experience Questionnaire with three subscales and seven items each (Supplementary Tables 18–26). We focus on the three item 7-point measure of PCT, Canada ($\alpha = 0.775$), Germany ($\alpha = 0.884$). We also administered a 10item measure of *need for affect* (Appel et al., 2012) which captures individuals’ differences in the need to approach or avoid emotions (Canada [$\alpha = 0.794$], Germany [$\alpha = 0.830$]), and a 6-item measure of *need for*

[2] Conway et al. (2020) 3-item Perceived Coronavirus Threat (PCT) Questionnaire: (1) Thinking about the coronavirus (COVID-19) makes me feel threatened; (2) I am afraid of the coronavirus (COVID-19); (3) I am stressed around other people because I worry I’ll catch the coronavirus (COVID-19).

structure (Neuberg and Newsom, 1993), which measures personal need for a structured, simple, and predictable environment Canada ($\alpha = 0.840$), Germany ($\alpha = 0.806$) (Supplementary Table 27). For readers not familiar with these scales, please note that for each measure larger measured values indicate more perceived threat, need for affect or need for structure.

CAMs – Network Properties

In total we operationalized 14 network properties, using the *CAM Network Analysis* tool (Rhea et al., 2021). These properties can be divided into two categories, emotional and latent. Emotional properties measure how the valence of individual nodes contributes to the overall CAM (Average Valence, Percentage of each node type, Central Node Valence). Latent properties refer to the number of nodes, links, and their interconnectedness (Centrality, Density, Diameter, Number of Nodes, Number of Links, triadic Closure). A definition of all network measures is listed in Supplementary Table 6. Of note, average valence incorporates the strength of an emotion weak—strong on a three-level categorical scale. This differs from the percentage of valence nodes (ambivalent, negative, neutral, positive) which only consider the number of nodes with a given valence relative to all other nodes. The properties and Pearson's correlations of these measures are summarized in Supplementary Tables 30–38.

Procedure

Participants drew their CAM using the *Valence* online application, an editable graphic space: https://cam1.psychologie. uni-freiburg.de/users/loginpage?next=/. Participants began the CAM-drawing exercise by reviewing a set of neutral visual instructions which guided them through the process of drawing a CAM using the online application (Supplementary Material "Instructions"). Participants were able to keep the CAM-drawing instructions open during the exercise. After completing the CAM instructions, we asked participants to draw a CAM which captures their experiences with the coronavirus outbreak. We used the wording: *We are interested in capturing your experience, the events, thoughts, and feelings, resulting* *from the current coronavirus outbreak. Using the mapping tool, please draw everything that comes to mind concerning your experience with the coronavirus. Think about what matters in the current coronavirus outbreak and please do your best to draw everything that comes to your mind concerning the coronavirus.*

Participants were also instructed not to spend more than 30 min on the mapping exercise. The full instructions as presented to all participants are listed in the Supplementary Material ("Instructions"). The instructions are also available via OSF: https://osf.io/8mxcz/?view_only= 750d8048ed6a4c629d03f11bcc03c454.

After completing their CAMs, participants answered a set of control questions and four attention checks which measured whether they correctly understood the properties associated with CAMs. The data of participants who answered incorrectly to more than one of these four questions were dropped from the analysis. The instructions for the study were originally written in German and then translated into English. The instructions were reviewed and edited by two native German and two native English speakers prior to data collection. After drawing the CAMs, participants completed all demographic and further questionnaire measures.

Approach to Analysis

To investigate whether the structural properties of individuals' CAMs are correlated with PCT we used the general linear statistical model (GLM) with robust standard errors. A GLM is used, as opposed to an Ordinary Least-Squares (OLS), to account for the non-normal distribution of errors in several network measures as well as the non-normal distribution of the measures themselves. The dependent variable in these regressions is the standardized measure of the PCT. For each regression we reported the Akaike Information Criterion (AIC) and Residual Deviance (D), deviance adjust for degrees of freedom. The independent variables are the emotional and latent network measures (Supplementary Table 6). To minimize skewedness and kurtosis in specific variables, we performed a logistic transformation on 6 measures: (i) density, (ii) number of nodes, (iii) number of links, (iv) number of contradicting links, (v) number of supporting links, (vi) triadic closure. To better compare their relative effect sizes all network variables are standardized.

As an exploratory study, we had limited evidence on which to base assumptions about the expected significance of each network measure. Consequently, we conducted our regression model using a stepwise approach. We began by including all network measures as covariates and then iteratively dropping the item with the lowest significance until all terms in the model are meaningful. Following Hosmer Jr et al. (2013) a meaningful covariate is one whose p-value is at, or below, $p \leq 0.250$. In addition to social and demographic characteristics Canada and Germany also differ in several direct factors which may influence the perceived threat of COVID-19 include the number of active cases, spread of the pandemic, and government response. To take account of these differences, we report our results with combined and separate Canadian and German samples. Cluster robust standard errors by country are used in the combined sample.

As a robustness measure, we ran the stepwise analysis with conditioned and unconditioned models for both the combined (German and Canadian) and the separate samples, these were labeled models 0, 1, 2, and 3. Model 0 was applied only in the combined sample and displayed the unconditioned correlations between the network measures and the PCT. Model 1 displayed unconditioned correlations between the network measures and the PCT, expect in the combined sample where model 1 included a control covariate for country. Model 2 included control covariables for age, education, gender. Model 3 included controls for: (i) need for affect, and (ii) need for structure. Need for affect and need for structure were included to rule out the possible mediating effects of traits previously associated with the sensitivity to threat or to life disruptions. In models 0, 1, 2, and 3, the control covariates were retained regardless of whether they met the $p \leq 0.250$ significant threshold.

Results

We found several consistent and significant correlations between network measures and the PCT. We focus on summarizing the meaningful and significant results with the full pattern of results reported in the Supplementary Tables 39–52. In each section, we report the result of the emotional network measures followed by the latent network measures. Of note, there is a significant difference in the PCT between samples (Supplementary Table 53), with German participants reporting lower levels of PCT than Canadians (Coefficient =−0.606; Std. 0.137; $p < 0.0001$).

German and Canadian Sample Combined

As summarized in Table 1, consistent with expectations, across models 0–3 *average valence* was negatively and significantly correlated with the PCT indicating that the more positive a CAM the lower the PCT. In models 0, 1, and 2 the *percentage of negative nodes* was retained and negatively correlated with PCT. This second result is contrary to expectations that more negatively valenced CAMs will positively correlate with PCT, however this variable only reaches significance in model 1, and drops out completely in model 3.

Looking at the latent measures, in models 0, 1, and 3, *centrality* was positively and significantly correlated with the PCT. This indicates that participants whose CAMs' structure is more dependent upon their central node (centralized), are more likely to perceive the virus as threatening. Similarly, in models 0, 1, and 3 *density* was negatively and significantly correlated with the PCT, indicating that higher levels of interconnectedness are associated with lower PCT. In model 2, the *number of nodes* was positively and significantly correlated with the PCT however, this variable was not retained in any of the other models. Finally, in model 3, *triadic closure* was positively and significantly correlated with PCT.

Table 1

General Linear Regression Model (GLM) with Robust Confidence Intervals in Combined Sample

Variable	Model 0	Model 1	Model 2	Model 3
Average Valence	-0.217**	-0.281**	-0.231**	-0.151***
	(0.088)	(0.091)	(0.084)	(0.012)
Central Node Valence				
Centrality	0.166***	0.078***		0.093***
	(0.10)	(0.006)		(0.012)
Density	-0.174**	-0.159**		-0.217***
	(0.058)	(0.070)		(0.059)
Diameter			-0.104†	
			(0.058)	
Number Nodes			0.204***	
			(0.009)	
Number Links				
Number Dashed				
Number Solid				
Percentage Ambivalent				
Percentage Negative	-0.120	-0.165**	-0.114	
	(0.078)	(0.078)	(0.072)	
Percentage Neutral				
Percentage Positive				
Triadic Closure				0.109**
				(0.055)
Age			-0.054**	-0.048**
			(0.024)	(0.021)
Education			-0.017	-0.002**
			(0.026)	(0.021)
Gender				
Female			-0.360**	-0.283
			(0.135)	(0.181)
Non-binary			-1.084***	-1.391**
			(0.272)	(0.508)
Pref Not Say			1.503***	1.478***
			(0.255)	(0.226)
Country		-0.654***	-0.652***	-0.634***
		(0.028)	(0.030)	(0.048)
Need for Affect				0.030
				(0.099)
Need for Structure				0.209***
				(0.025)
constant	0.000	0.339	0.800	0.649
	(0.303)	(0.014)	(0.146)	(0.351)
N	193	193	193	193
Residual *df*	192	192	192	192
Scale parameter	0.987	0.890	0.855	0.821
Residual D	0.967	0.867	0.810	0.770
A1IC	2.809	2.700	2.633	2.581

Note. Correlation between network measures and a standardized measure of the perceived threat of coronavirus in combined Canadian and German samples.

†p < 0.100. **p < 0.050. ***p < 0.001.

Overall, these results support the conclusion that latent properties are meaningful predictors of individual experience, however, the exact nature of this relationship remains unclear. For example, the observation that *density*, an alternative measure of connectivity, had an opposing relationship to PCT as compared to both *number of nodes* and *triadic closure* is important to the interpretation of our results. We discuss the limitation of the density measure in our discussion section.

Canadian Sample

As expected, in models 1 and 2 *average valance* was negatively and significantly correlated with PCT (see Table 2), indicating that participants who drew more positive CAMs were less likely to perceive the coronavirus as threatening. In model 3, *average valence* was dropped from the model and replaced by the *percentage of positive nodes* which was also negatively and significantly correlated with the PCT. Here, the dropping of *average valence* was a consequence of the stepwise process and the initial inclusion of multiple correlated covariates into a single overfit model. As shown in Supplementary Tables 51, 52, when *percentage of positive nodes* was replaced in the final model by *average valence,* average valence was significant at the 95% confidence level. It is also worth noting that the two variables, *average valence* and *percentage of positive nodes* where highly correlated (Pearson's correlation: 0.823, $p < 0.0001$), (Supplementary Tables 33–35). Lastly, contrary to expectations, the *percentage of negative nodes* in models 1–3 was negatively correlated with the PCT, indicating that the greater the number of negative nodes the lower the level of PCT. As with the same effect in the combined sample this effect reached significance in models 1 and 2.

Table 2

General Linear Regression Model (GLM) with Robust Confidence Intervals in Separated Samples

Variable	Model 1 Canada	Model 1 Germany	Model 2 Canada	Model 2 Germany	Model 3 Canada	Model 3 Germany
Average Valence	-0.418**		-0.399**			
	(0.132)		(0.139)			
Central Node Valence						
Centrality	-0.151					
	(0.122)					
Density$_c$		1.102†		0.332†		0.342†
		(0.448)		(0.193)		(0.192)
Diameter	-0.326**		-0.223†		0.188	
	(0.127)		(0.117)		(0.119)	
Number Nodes	0.649**	1.102**	-0.913***	0.444**	-0.760***	0.429**
	(0.225)	(0.448)	(0.303)	(0.177)	(0.316)	(0.168)
Number Links	-0.490**		1.092**		0.931**	
	(0.225)		(0.275)		(0.080)	
Number Dashed						
Number Solid						
Percentage Ambivalence						
Percentage Negative	-0.292**		-0.295**		-0.097	
	(0.123)		(0.128)		(0.080)	
Percentage Neutral						
Percentage Positive					-0.259**	
					(0.091)	
Triadic Closure			0.211†		0.185	
			(0.116)		(0.115)	
Age			-0.111†	-0.099	-0.101	-0.064
			(0.067)	(0.126)	(0.063)	(0.132)
Education			-0.046	0.001	-0.046	0.087
			(0.060)	(0.160)	(0.059)	(0.144)
Gender						
Female			-0.415**	-0.239	-0.340**	-0.099
			(0.171)	(0.219)	(0.168)	(0.220)
Non-binary			-1.843***	-0.763†	-2.083***	-0.879**
			(0.338)	(0.398)	(0.415)	(0.385)
Pref Not Say			1.821***		1.752***	
			(0.343)		(0.359)	
Need for Affect					0.163†	-0.070
					(0.095)	(0.094)
Need for Structure					0.160†	0.242**
					(0.091)	(0.093)
constant	0.371	-0.333	1.165	0.079	1.102	-0.593
	(0.090)	(0.098)	(0.453)	(1.063)	(0.448)	(0.971)
N	93	100	93	100	93	100
Residual *df*	86	97	83	94	81	92
Scale parameter	0.754	0.953	0.671	0.968	0.654	0.920
Residual D	0.754	0.953	0.655	0.957	0.638	0.910
AIC	2.628	2.819	2.516	2.853	2.508	2.820

Note. Correlation between network measures and a standardized measure of the perceived threat of coronavirus in combined Canadian and German samples.

†$p < 0.100$. **$p < 0.050$. ***$p < 0.001$.

Looking at the network properties, the *number of nodes* was positively correlated with the PCT in models 1–3. This indicates that participants who included more content into their CAMs were more likely to perceive the virus as threatening. In models 1–3 the *number of links* is negatively correlated with the PCT. This indicates that from a certain perspective the interconnectedness of a network is negatively correlated with the PCT, however, a limitation of this measure is that it does not correct for the total number of possible links. By comparison, *triadic closure*, which does correct for the total number of possible links, was positively correlated with the PCT, however, this measure was only retained in models 2 and 3, and was only marginally significant in model 2. Finally, in models 1–3 *diameter* is negatively correlated with the PCT, indicating that participants, whose networks are more expansive, are less likely to see the coronavirus as threatening. However, this term fails to reach significance in model 3. In summary, the results indicate that the latent properties of CAMs are a meaningful predictor of individual experience. Specifically, for the Canadian sample we see that CAMs that are expansive and more interconnected are associated with a greater perceived coronavirus threat. However, the relationship is not straight forward as the opposite relationship is observed in CAMs of the German sample.

German Sample

In contrast to the combined and Canadian sample, no significant correlations were observed between the emotionoriented network measures and PCT in the German sample. Looking at the latent measures, the *density* of the network and the *number of nodes* were both positively correlated with the PCT in model 1–3. While density remained marginally significant across all three models, the number of nodes reached significance at the 95% confidence level. Consistent with the combined and Canadian samples, this indicates that the amount of content and the interconnectedness of this content are significantly associated with the PCT in Germany. Taken together, the results provide good evidence that network properties of CAMs capture information significant to the larger study of individual experience (thought and connotation).

Additional Regressions: Interaction Between Emotional and Latent Network Measures

Noted in the discussion of our research questions (Supplementary Material, page 9), one data trend which may be observed in participants' CAMs is the interaction between emotional and latent network properties. Drawing similarities from research in human memory, it is possible that the PCT will be associated with the interaction between density (high density) and valence (negativity). To answer this question, we ran a regression with first-order interactions of the emotional and all the latent network measures (Tables 2–5). Again, we applied a stepwise approach, however, because of the large number of interactions, we used a stricter criterion of $p < 0.100$. The same $p \leq 0.250$ retention criterion was applied to individual covariates, except where a covariate contributed to a significant interaction. In general, we found similarities between the initial and interaction models, with both models including the same basic covariates. The largest difference was the retention of variables not included in the three previous regression models.

Combined Sample. Looking at the combined sample, two interaction terms were retained. First, there was a positive and significant interaction between *centrality* and *valence of the central node*. Contrary to expectations, this indicates that as networks become more dependent on the central node and more positive, the PCT increases. Second, the interaction between *density* and *valence of the central node* was positive and marginally significant. Once again contrary to our expectations, this indicates that as CAMs become denser (more interconnected) and more positive, the greater the PCT.

Table 3

General Linear Statistical Model (GLM): Interaction between Emotional and Latent Network and the Standardized Measure of the Perceived Threat of Coronavirus. Combined Sample

Variable	Coefficient	*SD*	Z	P>z	95% CI
Average Valence	-0.228	0.161	-1.410	0.158	[-0.544, 0.089]
Centrality	0.674	0.080	8.380	0.0001***	[0.516, 0.831]
Central Node Value	0.043	0.017	2.560	0.010**	[0.010, 0.076]
Density Log	-0.418	0.151	-2.760	0.006**	[-0.715, -0.122]
Number Nodes Log	-0.354	0.012	-28.690	0.0001***	[-0.378, -0.329]
Number Links Log	0.321	0.189	1.700	0.090†	[-0.049, 0.691]
Percentage Negative	-0.131	0.080	-1.630	0.103	[-0.289, 0.026]
Percentage Ambivalent	-0.015	0.001	-14.280	0.0001***	[-0.017, -0.013]
Centrality # Central Node Value	0.234	0.024	9.550	0.0001***	[0.186, 0.282]
Density# Central Node Value	0.086	0.044	1.950	0.051†	[0.000, 0.172]
Country	-0.674	0.005	-132.820	0.000	[-0.684, -0.664]
constant	-0.016	0.051	-0.310	0.753	[-0.115, 0.083]
N					193
Residual *df*					192
Scale P					0.842
Residual D					0.794
AIC					2.613

Note. †p < 0.100. **p < 0.050. ***p < 0.001.

Canadian Sample. Looking at the Canadian sample, there was a significant negative correlation between *number of nodes* and *percentage of negative nodes.* Difficult to interpret, this indicates that as the number of nodes and percentage of negative nodes increase, PCT decreases. Also observed was a significant negative correlation between *number of nodes* and *valence of the central node.* Consistent with our expectations this indicates that as the number of nodes increases, and the central node becomes more positive, the lower the PCT.

German Sample. Three interactions are observed in the German sample. First, there is a significant positive interaction between *density* and *valence of the central node.* Once again, and contrary to expectations, this indicates that as CAMs become more interconnected and the central node becomes more positive the PCT increases. Second, and contrary to expectations, there is a positive interaction between *number of nodes* and *valence of the central node* indicating that as the number of nodes increases, and the valence of the central node becomes more positive the greater the PCT. This is the opposite correlation as observed in the Canadian sample. Third, consistent with our expectations there was a negative interaction effect between *triadic closure* and *valence of the central node* indicating that as CAMs become more connected and the central node becomes more positive the lower the PCT.

Table 4

General Linear Statistical Model: Interaction between Emotional and Latent Network and the Standardized Measure of the Perceived Threat of Coronavirus. Canadian Sample

Variable	Coefficient	*SD*	Z	P>z	95% CI
Average Valence	-0.371	0.118	-3.140	0.002**	[-0.603, -0.139]
Diameter	-0.198	0.098	-2.030	0.042**	[-0.390, -0.007]
Number Links	-0.865	0.282	-3.070	0.002**	[-1.417, -0.312]
Number Solid	0.364	0.178	2.050	0.040**	[0.016, 0.712]
Number Nodes	0.823	0.201	4.090	0.0001***	[0.428, 1.217]
Percentage Negative	-0.219	0.110	-1.980	0.048**	[-0.435, -0.002]
Central Node Value	0.102	0.100	1.020	0.307	[-0.094, 0.299]
Number Nodes#Percentage Negative	-0.269	0.092	-2.920	0.004**	[-0.451, -0.088]
Number Nodes# Central Node Value	-0.337	0.088	-3.820	0.0001***	[-0.510, -0.164]
constant	0.351	0.087	4.030	0.0001	[0.180, 0.521]
N					93
Residual *df*					83
Scale P					0.662
Residual D					0.662
AIC					2.526

Note. †p < 0.100. **p < 0.050. ***p < 0.001.

Table 5

General Linear Statistical Model: Interaction between Emotional and Latent Network and the Standardized Measure of the Perceived Threat of Coronavirus. German Sample

Variable	Coefficient	*SD*	Z	P>z	95% CI
Density	0.388	0.250	1.550	0.121	[-0.103, 0.878]
Number Nodes	0.566	0.221	2.560	0.010**	[0.133, 0.998]
Triadic Closure	-0.044	0.120	-0.360	0.717	[-0.279, 0.192]
Central Node Value	0.100	0.099	1.000	0.315	[-0.095, 0.294]
Density Log# Central Node Value	0.793	0.255	3.110	0.002**	[0.293, 1.293]
Number Nodes Log#Central Node	0.495	0.229	2.160	0.031**	[0.046, 0.944]
Triadic Closure#Central Node	-0.530	0.120	-4.430	0.0001***	[-0.765, -0.296]
constant	-0.341	0.089	-3.820	0.0001	[-0.516, -0.166]
N					100
Residual *df*					92
Scale P					0.881
Residual D					0.881
AIC					2.788

Note. †p < 0.100. **p < 0.050. ***p < 0.001.

Discussion

Using the COVID-19 pandemic as a case study, we tested CAMs as a novel method for studying human experience (thought and affect). Specifically, we asked whether *the network properties of CAMs (emotional and latent) can be used to study similarities in individuals' thinking and experience surrounding an emotional life event?* To meet our objective, we operationalized and compared 14 network properties for each individual CAM. Our results yielded several interesting and significant network properties.

One immediate observation was a difference in significant emotional network measures between the Canadian and German sample. Looking at Table 2, in the Canadian sample, we found significant emotional and latent measures, while in the German sample we found only significant latent measures, yet no significant emotional measures. We conjecture that the German and Canadian sample differ regarding the emotional assessment of the COVID-19 pandemic. This assumption is backed up by our observation that scores on the PCT were significantly lower in the German than the Canadian sample. Please note that this finding is in line with other studies examining fearful reactions to the pandemic that also observed differences between countries (e.g., Lippold et al., 2020; Gruchoła and SławekCzochra, 2021). Lippold et al. (2020) for example reported that in terms of perceived fear of coronavirus Germany scores lowest among 96 countries, along with Austria and Sweden. Currently, we can only speculate why this is the case. It might be that variations in fear responses are a result of differences in government restrictions. However, data collected by University of Oxford[3], tracking restriction measures during the pandemic worldwide shows that the restrictions in Canada and Germany did not meaningfully differ in the first half of 2020. According to these data, measures in Germany tended to be tightened earlier than in Canada, but the two countries quickly converged and as of May 2020 (prior to our data collection) both countries are listing in the same category for stringency of government response (index 50–75). Still, even if the restrictions were outwardly similar in severity, they could be perceived differently in each country. A first pointer to this is provided by a look at the central nodes of the CAMs and their affective assessment: Supplementary Tables 82, 83 show a categorization of the central CAM concepts, according to which in Canada concepts such as “Quarantine” are put in the center more frequently, while in Germany terms like “Restrictions” are more frequently referred to as central node (of course like expected the most frequent category in both countries is “Pandemic” or “Coronavirus”). Yet, to make more concrete statements about different perceptions, the content of all CAM concepts would have to be examined more closely, which is beyond the focus of this study. Another explanation for the differences in PCT between the countries refers to cultural differences related to workplace protection. In comparison to Canada, Germany has stricter employment projection

[3] Blavatnik School of Government, University of Oxford. Data as of March 25. Data for the most recent seven days may not yet reflect government response changes implemented during that period. © FT Retrieved from: https://ig.ft.com/ coronavirus-lockdowns/

protections (Chen and Hou, 2019). The German state has implemented a worker protection program which protects workers from losing their job during the pandemic and enables them to work in short time instead. By comparison, the Canadian Federal government extended its unemployment program to provide financial assistance to workers laid off because of the pandemic but did not guarantee job security. This difference in public policy may contribute to the differences in PCT observed in this study. This assumption is supported by research by Gruchoła and Sławek-Czochra (2021), who did not find a high fear of job loss, unemployment, reduction or loss of income for Germans, but did find these effects in other European countries. Unfortunately, a limitation of the present study is that it lacks the necessary measures to understand these baseline differences regarding perceived threat of COVID-19. Future research on CAMs using multiple samples will need to give greater attention to how contextual factors affect the salience or significance of an emotional event.

Furthermore, as described in the Supplementary Material, German CAMs also show less variation on the percentage of positive and negative nodes and the average valence of their CAMs. This suggests that as compared to Canadian participants, the coronavirus pandemic is a less negative emotional experience for Germans. To test this, we explored the interactions between country and different percentages of nodes and average valence as a predictor of PCT. Listed in Supplementary Tables 50–54, the results show that as the percentage of positive nodes and average valence of the CAM increased, Germans showed a greater PCT than Canadians. Additionally, as the percentage of negative, neutral and ambivalent nodes and the valence of the central node increased, Germans were less likely to perceive PCT than Canadians (Supplementary Tables 54–60). A psychological interpretation of these network correlations is difficult without analyzing the content of the CAMs. For example, the positive nodes of a CAM could be negatively correlated with the pandemic and explain a higher PCT. Such analyses are beyond the scope of this study. Future studies should therefore consider a mixed method approach which incorporate content-based automated analyses. Despite these differences in the Canadian and German sample, our results may at least provide tentative answers to two of the three research questions. Taking these differences into account, we argue the answer to questions 1 is yes: The emotional properties of CAMs did capture the perceived threat of the coronavirus. In both the combined and Canadian sample, average valence reliably predicted PCT. While other measures, such as the percentage of different nodes (e.g., positive, or negative) were not consistent, we believe these deficiencies were likely due to structural limitations within these variables and the differences between samples. The ability of participants to select four nodes with six difference valences introduced a large amount of variation in the percentages of nodal valence. The result was that the percentages of nodal variances tended not to be normally distributed, displaying skewedness or kurtosis (Supplementary Table 60). By contrast, the measure of average valence of the CAM was calculated using both the valence and strength scores for nodes and resulted in a network property with normal distribution. Lastly, the valence of the central node did not appear to be a significant variable except when interacted with the measures of network centrality, density, number of nodes, and triadic closure. This result indicates that as the networks become larger or more interconnected, the valence of the central node becomes a more important predictor of PCT. We assume this effect could also be influenced by the instructional setting– in the instructional example, the central node (shopping at the market) remains neutral. In total, 51% (n=99) of the sample coded their central node as neutral, including 52 participants whose central node referenced the coronavirus, and a further 14 participants whose central node referenced restrictions, social distance, or stress concepts which might be otherwise expected to be defined as negative (see Supplementary Table 83 for the frequencies of affective assessments separately for both samples). To avoid this possible framing effect, future research utilizing CAMs will need to be explicit in informing participants that they are free to adjust the valence of all nodes in their CAM.

Turning to the latent network properties, we argue that the answer to question 2 is yes. Latent network properties captured the perceived threat of the coronavirus. All three samples show positive correlations between the *number of nodes* and the PCT. Furthermore, except for density in the combined sample, measures of network interconnectivity were also positively correlated with PCT. In other words, the results suggest an association between the salience or effect of an emotional event and levels of cognition and cognitive complexity. We note that while several other measures (centrality, diameter, triadic closure) were only periodically significant, these measures were highly correlated (Supplementary Tables 30–32) with the measures of density, number of nodes, and number of links, so it is not surprising that all the latent measures are not retained within the final model.

This is consistent with research on memory which demonstrates an association between the significance of an event and the retention and recollection of information. As noted in the Supplementary Material, the intensity of an event is a "more consistent predictor of autobiographical memory properties than was valence or the age of the memory" (Talarico et al., 2004, p. 2) and the effect of intensity on memory is independent of the valence of the emotion. Furthermore, Holland and Kensinger (2010) observed that emotional arousal and personal involvement in an event have a significant impact on "the likelihood that a vivid memory can be maintained over time" (Holland and Kensinger, 2010, p. 7). In other words, individuals retain and recall more information when an event is emotionally significant.

With respect to question 3, whether the network properties that predict the perceived threat of the coronavirus are consistent across samples, we are not able to make a definitive determination currently. Insofar the samples significantly differed in the PCT, it is not permissible to draw conclusions about whether the network measures are, or are not, equivalent across samples. Further data collection with additional independent samples is required.

A further consideration is the role of density in the PCT. As a measure of the CAM's interconnectedness, density was negatively and significantly correlated with the PCT in the combined sample but positively correlated with PCT in the German sample (while density was not significant in the Canadian sample its coefficient was also positive). Also challenging is that the interaction between density and valence of the central node was also positive and significant in the combined and German sample. This indicates that as graphs become denser and the central node becomes more positive, PCT increases. While this result is not easily interpreted, two statistical tendencies in the data are meaningful to its explanation. First, across the data we observed a large negative correlation between density and the number of nodes and links. This correlation indicates that dense CAMs have lower numbers of nodes (content) rather than a large number of highly interconnected nodes (Supplementary Tables 61–64). Second, the interaction between density and valence of the central node was negatively correlated with the percentage of positive nodes, and positively correlated with the number of negative nodes. In the German sample, these correlations reached significance at the 95% confidence level (Supplementary Tables 65–70). Counterintuitively, this suggests that CAMs with strongly positive central nodes contain a larger number of negative concepts while CAMs with strongly negative central nodes contain a larger number of positive concepts. While they did not reach significance, as we expected, the percentage of positive nodes in the German sample was negatively correlated with the PCT while the percentage of negative nodes was positively correlated with PCT (Supplementary Tables 71–76). This positive interaction between density and valence with PCT was contrary to expectations as the valence of the central node was positively correlated with the average valence of the CAM which, as shown, was negatively correlated with PCT (Supplementary Tables 77–79).

This relationship held across all samples and reached significance at the 95% confidence level in the combined and Canadian sample. This result is difficult to interpret purely on the basis of an analysis of CAM network properties. To explore this interaction effect, the content of the central nodes would need to be considered. One may assume that the source of the interaction is that the central nodes may disproportionately feature negative concepts such as “coronaavirus” while the CAMs themselves are populated with positive concepts such as “working from home” or vice versa. While a content analysis of all CAM nodes is beyond the scope of this study, a categorization of the central nodes is available in the Supplementary Tables 82, 83. Among the seven inductively created categories (*Coronavirus*; *Quarantine*; *Restrictions*; *Isolation*; *Stress*; *Freetime*; *Other*), the category “Coronavirus" is the most frequent in both samples, i.e., a large proportion of participants placed the term “Pandemic” or “Coronavirus” directly in the middle. Other frequent central nodes were “Quarantine” (Canada) and “Restrictions” (Germany), assumably also negative concepts. Future studies should elaborate more the valence of central nodes, as well as the content of all concepts of the CAMs. We suggest that CAMs are a very helpful tool to dive deeper into a research topic such as the coronavirus pandemic and allow participants to elaborate complex impressions, including affective connotations while at the same time CAMs give the possibility to collect large samples and apply network analyses. Yet, to enable this more work is needed to develop a content wise automated analyses which can be directly applied to CAM data.

Conclusion

We explored Cognitive-Affective Maps (CAMs) as a tool to capture peoples’ experiences with the ongoing coronavirus pandemic and to predict their perceived coronavirus threat (PCT) across the Canadian and German samples. Our findings showed consistent and significant relationships between emotional and latent network variables and PCT in both samples. The average valance of a CAM reliably predicted PCT. Also, there were consistent correlations between PCT and the latent structural variables centrality and density. The Canadian and German samples differed in their PCT value, which prevents a statement about the equality of correlation with network properties across samples. Further studies are needed to make clearer statements about differences and similarities of network measures between samples. It is currently difficult to draw specific psychological conclusions from the network data of the CAMs. In the future, methods should be found to automatically evaluate the contents of the CAMs and to relate them to the network properties. Yet, we suggest that CAMs can bridge several gaps between qualitative and quantitative methods. Unlike when using quantitative tools (e.g., questionnaires), participants' answers are not restricted by response items as participants are free to incorporate any thoughts and feelings on the given topic. Furthermore, as compared to traditional qualitative measures, such as structured interviews, CAMs may better enable researcher to objectively assess and integrate the substance of a shared experience for large samples of participants.

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7. Contribution 3: Applying CAMs to Identify Ethical Principles

Connecting the Methods of Psychology and Philosophy: Applying Cognitive-Affective Maps (CAMs) to Identify Ethical Principles Underlying the Evaluation of Bioinspired Technologies

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The Supplementary Material and the original data can be found on OSF: https://osf.io/brp9t/?view_only=9c98c736aee743baacfd5bb2a85af57c

Abstract

One major challenge of the 21st century is the increasingly rapid development of new technologies and their evaluation. In this article we argue for an interdisciplinary approach to meet this demand for evaluating new and specifically bioinspired technologies. We combine the consideration of normative principles in the field of ethics with psychological-empirical research on attitudes. In doing so, the paper has a twofold concern: first, we discuss how such an interdisciplinary collaboration can be implemented by using the method of Cognitive-Affective Mapping. Cognitive-Affective Maps (CAMs) enable a graphical representation of attitudes, including cognitive and affective aspects. Second, we argue that CAMs can be helpful to remedy the deficits of traditional ethical approaches. We applied CAMs in the context of an ethics seminar in which students were instructed to create CAMs based on bioinspired technologies twice – prior to the seminar to assess their evaluation on bioinspired technologies per se (pre-assessment) and after the seminar to assess how their evaluation might have changed and especially which normative ethical principles might have been additionally considered (post-assessment). As could be shown, CAMs can visualize the students' attitudes, including the valence of ethical principles. Further, comparing pre- and post-CAMs indicated students' attitude change.

Keywords: evaluation of bioinspired technologies, ethical principles, interdisciplinarity, cognitive affective mapping, empirical ethics

Introduction

In view of the ecological challenges of our present age, bioinspired technologies, i.e. technologies that imitate functional principles of nature, and the associated research fields of biomimetics or biomimicry, are increasingly important as future technologies (Benyus, 2002). Yet, the transfer of functions from biological models to technical applications does not guarantee that the applications are good for humans or for the environment. Therefore, this transfer is not well-suited considering normative aspects – biomimetic products are not per se better, more ecological and less risky technical solutions. To determine whether the 'biomimetic promise' (von Gleich et al., 2010) of better, more ecological and less risky technical solutions is kept, it is necessary to implement a second step of reflection, which considers the products independently of their pure imitation of biological functions (Möller et al., 2020). For this reflection, ethical principles must be identified, as is done in particular in the context of ethics and technology assessment (Grunwald, 1999; Jonas, 1984). Yet, abstract ethical principles are usually no longer sufficient to rate new technologies (Kibert et al., 2012) because technologies are being developed ever faster and at the same time penetrate the natural and social life world ever more comprehensively. Therefore, in addition, the normative perspectives of users and affected laypersons are increasingly included in the process of adequate normative decisions about these technologies (Molewijk et al., 2004; Paulo & Bublitz, 2020).

In this article, we endorse an interdisciplinary approach to meet this double standard for new and, in our case, bioinspired technologies. We combine psychological-empirical acceptance research with the consideration of normative principles by ethics and technology assessment to address the far-reaching challenges of new technologies. Here, the methods of psychology appear promising in capturing normative concerns from users and affected persons who exhibit attitudes on a culturally specific, group- specific or even individual-specific level. This should be taken into account in the development of new bioinspired technologies (Höfele, 2022).

In the following, we discuss such an interdisciplinary cooperation in the application of the method of Cognitive-Affective Mapping (Thagard, 2010). Cognitive-Affective Maps (CAMs) allow to connect beliefs, impressions, ideas, and emotions about a particular topic in a network-like structure. While in questionnaires and interviews the researchers' item and question formulations often prescribe specific linguistic-semantic thought structures, the CAM method allows for a very free collection of individual attitudes, less influenced by suggestive wordings. One advantage with respect to other types of cognitive modeling of knowledge is that each CAM concept carries an affective value, involving three gradations of positivity and negativity, and one option each for neutrality and ambivalence. A more detailed description of the method of Cognitive-Affective Mapping follows in the methods section. By using this method, we explore two central questions:

First, we test the extent to which moral evaluations and ethical principles are explicitly or implicitly reflected in CAMs created by laypersons (students) on the topic of bioinspired technologies.

Second, we want to find out whether a scholarly engagement with issues around 'ethics of nature' in the context of an ethics seminar leads to changes in the individual CAMs of the students.

In the following, the theoretical background about the role of psychology as well as that of philosophy, especially its subfield of ethics, will be presented first. We will then suggest the methodology of Cognitive-Affective Mapping for ethical reflections, while at the same time serving to remedy a deficit of traditional ethics. Traditional ethics often take a top-down approach and do not take into account different contexts and concerns of groups of people (chap. 2). We elaborate on this issue by discussing the application of the Cognitive-

Affective Mapping method in the context of an ethics seminar. Here the students were given the task of drawing a CAM on the subject of bioinspired technologies twice – once at the start of the semester and once at the end of the semester (chap. 3 and 4). Subsequently, we reflect on the methods of psychology and philosophy more fundamentally. Our aim is to illustrate the interdisciplinary cooperation of both disciplines in the context of the evaluation of bioinspired technologies as an interplay of hypothesis-guided and hermeneutical procedures. This interplay is intended to remedy the aforementioned deficit of traditional ethics in that psychology helps to establish empirically informed ethics (chap. 5). A short outlook concludes the article (chap. 6).

Psychological Research on Attitudes and Attitude Change as a Methodological Enrichment of Empirical Ethics

CAMs represent various cognitive and affective aspects of a topic, in other words, they visualize individuals' attitudes as a network of relevant concepts (also referred to as nodes), their respective affective connotation, and certain relationships between the concepts (links). The notion of attitude has been extensively researched in social psychology for decades, although the distinction from other terms, for example, *beliefs*, *opinions*, *values*, is often ambiguous (Seel, 2012). According to Ajzen (2001), an attitude represents the summarized evaluation of a psychological object. With respect to the neurosciences, conceptions of attitudes envision a network of nodes with affective and cognitive connotations connected by associative pathways (Seel, 2012). Here we work with one specific form of such networks – the CAMs introduced by Thagard (2010). Thagard's Cognitive-Affective Mapping method builds on his computational HOTCO model, which uses artificial neural networks to explain inferences influenced by emotions (Thagard, 2006, 2012, 2015).

Numerous researchers have attempted to model not only attitudes, but also their change. Some theories are called consistency theories, e.g., Festinger's *cognitive dissonance theory* (1957), Heider's *balance theory* (1958), or Bem's *self-perception theory* (1967). These theories do not imply that attitudes are unchanging, but rather state that people strive for consistency in their cognitions and are motivated to resolve inconsistencies, e.g., by changing individual attitude components.

Similarly, Thagard's theory of emotional coherence states that people strive for such a coherence, not only for cognitive but also for emotional coherence, since reasoning is based not only on logical arguments, but also on emotions (Thagard, 2006). Consequently, Thagard distinguishes between cognitive incoherence and emotional incoherence. In detail, incoherence may arise from the fact that two actions or goals contradict each other, i.e., it is not possible to perform or achieve both. And incoherence may also result due to a connection between elements in which a good feeling about one element simultaneously comes along with bad feelings about the other element (Thagard, 2010).

An attitude change can then be explained by the motivation to increase coherence. Please note that other researchers have also developed and empirically tested theories on attitude change (for an overview, see Lorenz et al., 2021, and Seel, 2012). Although these theories offer different explanations for the mechanisms of attitude change, they overlap in saying that attitude change is possible and arguably influenced by an interplay of cognitive, emotional, and behavioral elements, and that attitudes can vary in strength (Seel, 2012). One factor influencing attitudes is knowledge, also referred to as attitude-relevant knowledge (Fabrigar et al., 2006). Fazio (2007) refers to attitudes themselves as evaluative knowledge, as a sum of evaluations, influenced among other things by the information available. At this point we consider it important to note that the impact of information on attitudes is mutual: the influence of attitudes on availability of information (in terms of retrieving information from memory) or search for information (in terms of encoding information) is widely researched and well-known as confirmation bias (e.g., Festinger, 1957; Hart et al., 2009; Wason, 1960).

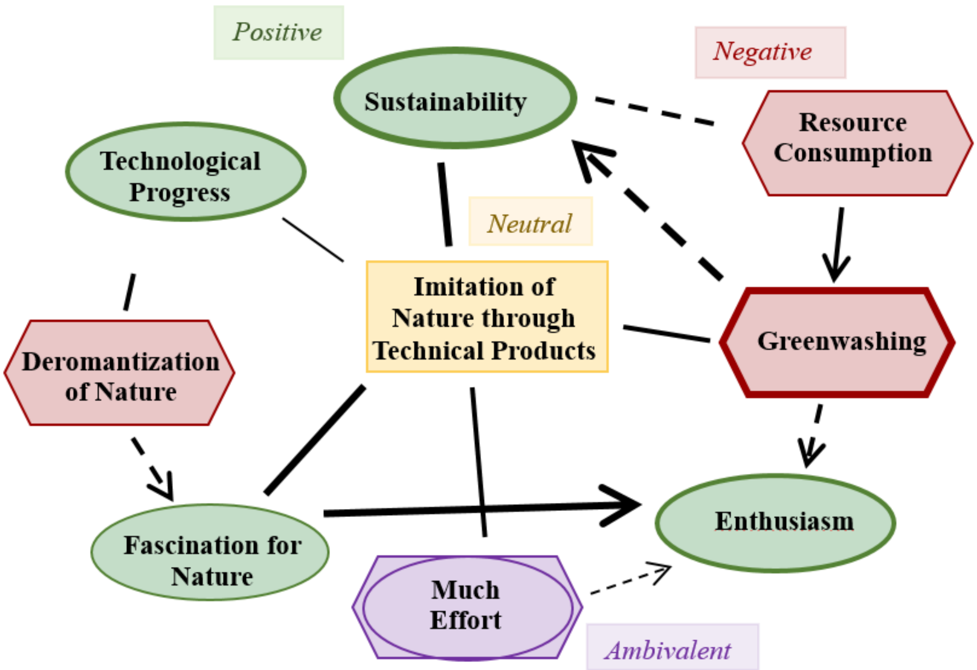
As stated above, one goal of our study is to explore the influence that information about the 'ethics of nature' (in the form of philosophical considerations in an ethics seminar) can have on students' attitudes toward bio-inspired technologies, i.e., nature imitation in technology development. To our knowledge two recent studies used related methods. In these studies, the influence of ethical values in the case of different stakeholders has been mapped by value-informed mental models (ViMMs) in the context of climate risk management (Bessette et al., 2017; Mayer et al., 2017). The difference of their approach to the ethical application of the CAMs in our study, is that CAMs are drawn by each member of the investigated group himself and that CAMs also depict emotional attitudes.

CAMs have already been used in practical-political and ethical contexts. Thagard introduced CAMs in the context of conflict research and explains how they can help to better understand the conflicting positions of opponents. Homer-Dixon et al. (2014) demonstrated that CAMs can be used to represent the beliefs of individuals in disputes as diverse as the dispute over German housing policy, disagreements among Israelis over the meaning of the Western Wall, disputes over the exploitation of Canadian bitumen deposits, as well as the dispute between proponents and opponents of action on climate change. In our study, however, we used a slightly different variant of CAMs. Specifically, we added the ability to connect concepts by arrows to depict a unidirectional connection (connections are also referred to as links). Figure 1 shows an exemplary CAM on nature imitation in technology development.

Initially, CAMs were mostly drawn by the researchers themselves to visualize specific perspectives or existing data material (e.g., Findlay & Thagard, 2014; Homer-Dixon et al., 2013, 2014; Luthardt et al., 2020; Wolfe, 2012). More recently, CAMs have also been used as a survey method by having participants draw CAMs themselves on a particular topic (e.g., Mansell et al., 2021; Reuter, Mansell et al., 2021).

Figure 1

Exemplary CAM on the Topic "Imitation of Nature through Technological Products".



Note. Valences of the concepts are represented by the nodes' shapes and colours. Green ovals = positive affect; red hexagons = negative affect; yellow rectangles = neutral affect; purple superimposed hexagons with ovals = ambivalent affect. For green and red shapes, strength of the shape's border denotes a grading of the affective connotation (range = 1, 2, 3) – the thicker the frame, the more positive/negative the concept. Two types of links indicate the relations between concepts. Solid lines = supportive connections; dashed lines = inhibiting connections; arrowheads = one-sided/unidirectional influence; without arrowhead = mutual influence.

Livanec et al. (2022) proposed CAM as a vivid, practical tool of collaborative knowledge production between scientific and nonscientific stakeholders in the context of technology acceptance prediction. Thagard (2015) used CAMs to visualize attitudes of students in an ethics seminar and concluded that the method is suitable for this purpose. He explained how philosophy students were instructed to draw CAMs on seminar topics. We will describe Thagard's (2015) study in more detail since we modified his approach for our application of CAMs.

The students of an environmental ethics course and a medical ethics course taught by Thagard were asked to draw CAMs on one of seven yes/no ethical questions they could choose from. Questions included ‘Are publicly funded drug injection sites morally right? Yes or no.’ (Medical Ethics) or ‘Is the use of genetically modified organisms morally wrong? Yes or no?’ (Environmental Ethics). Each student was asked to draw one map in favor of the position, as well as one map against it. Ultimately, they were asked to rate their experience with the method in a post-survey. The results of this survey suggest that on average students found the method helpful, both for their general understanding of the topics as well as for gaining other perspectives on them. Students also supported the use of the method in future seminars. One question referred to how often the students’ opinion changed as a result of drawing the CAMs (answer options: 0, 1, 2, 3). More than 80% of the students stated that they had changed their opinion at least once – the mean values were 1.08 (Medical Ethics) and 1.13 (Environmental Ethics). According to Thagard, the method is easy to use and informative about the structure of ethical conflicts. Thagard thus also indirectly shows that ethical laypeople, or at least undergraduate students in ethics, can use CAMs to make their ethical principles explicit.

This approach stands partly in contrast to classical ways of approaching ethics. Many classical approaches intend to consider ethical principles for action that are not dependent on subjective or individual attitudes, but can apply in a universally accepted manner (Pieper, 2007). Furthermore, these approaches often seek to strictly separate ethical rationality and emotions (e.g., Kant, 2019; van Roojen, 2009), whereas Thagard (2015) used CAMs to make a connection visible, emphasizing that rational judgments imply emotional reactions. Furthermore, it has been shown, especially in the context of medical ethics (Musschenga, 2005, 2009), but increasingly also in other areas of ethics (Birnbacher, 1999), that ethics must integrate sociological and psychological data. This is the only way to ensure that ethical principles of action are applicable to specific realities. Therefore, '[e]mpirical ethics combines doing empirical—usually qualitative—(social) research with philosophical (normative ethical) analysis and reflection' (Musschenga, 2005, p. 468). Of course, this raises the question of how such empirical-qualitative research can be conducted and how the implicit normative beliefs and judgments of persons can be made visible. For example, empirical ethics assumes that many moral judgments are made intuitively, and the individuals are not able to take a reflective position on their judgments (Paulo & Bublitz, 2020). CAMs represent a method to make such moral judgments or conflicts and the accompanying values visible, which is why Thagard (2015) also speaks of 'value maps'.

In the following, this is demonstrated by means of an ethics seminar in which CAMs were also used as in Thagard's case. While Thagard's students were instructed to draw CAMs on morally difficult yes/no-questions and used only negative and positive evaluations, we made some changes that will be explained in detail in the next chapter.

In summary, the specific questions of our study are: 1a) Can CAMs be used to map students' attitudes toward nature imitation in technology development? 1b) Can ethical principles be identified in such CAMs? 2a) Do the attitudes represented in CAMs change over the course of the seminar? 2b) Are these changes specifically related to the content of the seminar? The example of the ethics seminar also illustrates the extent to which interdisciplinary cooperation between psychology and philosophy in particular can put the concern of empirical ethics into practice.

CAMs in the Context of an Ethics Seminar: Application of the Method

CAMs Data Collection

Data collection took place as part of a winter term seminar 2020/21, entitled '*Sustainability and its Ethical-Philosophical Foundations*'. The seminar reflected on the ethical-philosophical foundations of the concept of sustainability. Its content was closely related to the topics of natural and environmental philosophy, the ethics of responsibility, as well as approaches of biocentrism and deep ecology (Krebs, 2016a; Muraca, 2016; Schopenhauer, 2004; cf. in detail Supplementary Material 1). Students taking part in this seminar mainly pursued degrees in philosophy, and tended to be at the beginning of their bachelor studies. We assumed that they did not have intensive contact with such topics before the seminar and considered them as laypersons when drawing the first CAM on the topic of nature imitation in technology development at the beginning of the semester. We conjectured that engaging with the themes of the seminar might influence their attitude toward nature imitation in technology development. The students were asked to create one CAM at the beginning of the semester (pre-CAMs) and one at the end of the semester (post-CAMs) on the topic of nature imitation in technology development. While Thagard's students were instructed to create two CAMs (one pro/one con) and advised not to include two perspectives in one CAM, we asked students to draw only one CAM at a time and this CAM was to reflect their own perspective. While Thagard gave further specific guidelines (for example, a minimum of positive/negative nodes; no ambivalent nodes, etc.), we gave only a general instruction on drawing a CAM without restrictions or minimum requirements.

In detail, students were instructed online using Unipark before the first content-related seminar date (full instructions can be found in the Supplementary Material 2a & 2b) on how the Cognitive-Affective Mapping method and the Valence[1] software (Rhea, Reuter, Thibeault et al., 2021) work. Valence is a freely available online tool for creating CAMs. Next, students read a text with information about nature imitation in technology development (Appendix) and were asked to create a CAM with the Valence software based on the question 'What are your thoughts and evaluations regarding nature imitation by technological

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[1] https://cam1.psychologie.uni-freiburg.de/users/loginpage?next=/

products?'. When starting Valence with their personal software access, a central node with the content 'Nature Imitation through Technical Products' was shown and the students were asked to create their own CAM around this concept. Students were free to choose the time of CAM creation in the period Oct. 27– 2 November 2020. The same procedure was repeated at the end of the semester (period of CAM creation: Jan. 21– 8 February 2021). The anonymous data collection was unable to trace back the CAMs to the students. The pairing of pre- and post-CAMs was realized by an individual code. 32 students were assigned to the seminar. We received N = 62 (nt1 = 34; nt2 = 28) assignments to the software, of which we could match N = 36 CAMs, which resulted in N = 18 CAM pairs that could be analyzed. The remaining CAMs could not be used because they either showed deficiencies (for example, no connections between nodes; wrong topic), or codes could not be matched.

CAMs Analyses

There is no gold standard for the analysis of CAMs, instead different approaches have been explored by researchers, both quantitative and qualitative (Reuter, Fenn et al., 2021). The high degree of freedom while creating CAMs resulted in rather heterogeneous CAMs. We therefore decided to use a two-part rating procedure. One rating was related to the ethical-normative principles in both pre- and post-CAMs, the other rating concerned the general differences of the nodes' content and valence. Both rating procedures will now be described.

Ethical Principles. To investigate whether we can use CAMs not only to map students' attitudes regarding nature imitation in technology development (research question 1a), but also to identify ethical principles relevant to students (research question 1b), we created a list of 20 ethical principles (Supplementary Material 3). This list was mainly based on a text on the ethics of nature by Angelika Krebs and a text on the sustainability discourse by Barbara Muraca (Krebs, 2016b; Muraca, 2010).[2] The list was only definitively established after reviewing all CAMs drawn by students. Only those of Krebs' (2016b) principles concerning the ethics of nature that were mentioned in the CAMs were then included in the list; principles from Krebs (2016b) that were not mentioned in the CAMs were omitted from the list. In addition, other principles were identified, particularly those of the ethics of sustainability, which are mentioned in the text by Muraca (2010). These were also included in the list. Methodologically, we followed the approach of the hermeneutic circle (cf. below chap. 5.3.) to ensure that the CAMs did not only show the ethical principles pre-selected by the raters and that no ethical principles were left out.

Subsequently, the CAMs were rated by noting which principles appeared in each individual CAM. Initially, to answer research question 1b, no attention was paid as to whether a single CAM was created before the start of the seminar (pre-CAMs) or at the end of the seminar (post-CAMs). To allow for some sort of inter-rater reliability, two raters were instructed independently. Both raters, graduate students of philosophy and research assistants at the Department of Philosophy, received the list of the ethical principles, as well as the text on the ethics of nature (Krebs, 2016b), which contained explanations of the principles. The raters were instructed to pick out ethical principles explicitly mentioned in the CAM nodes, i.e., ethical principles that were more or less precisely mentioned in the wording of Krebs (2016b) and Muraca (2010). They were also asked to name nodes in the CAMs that they thought implicitly addressed ethical principles – without being precisely mentioned in the wording of Krebs (2016b) and Muraca (2010). In addition, no further instructions for categorization were given, contrary to the usual procedure in content analysis. Definitions of and distinctions between the categories emerged from the description of the principles

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[2] Krebs, 2016b is a shortened German version of the English text by Krebs (1999), which, however, mentions the same principles of the ethics of nature.

themselves in Krebs (2016b). After the individual ratings, the raters exchanged ideas to discuss differences and, if possible, to reach a joint judgment (see also Mayring, 2020; Scott, 1955). Raters quickly came to agreement on the few differences in their ratings.

CAMs Differences Results from Using the CAMs in the Context of an Ethics Seminar. To analyze systematic differences between the pre- and post-CAMs (research question 2a), we formed deductive categories according to which we evaluated differences between the CAMs. The creation of deductive categories is mainly known from qualitative content analysis (e.g., Mayring, 2020). However, our procedure differs fundamentally from the typical application of deductive categories, which is primarily designed for text material, such as interviews. Our categories are not semantic-based but focus on the structure and the affectivity of the CAMs (Table 1). In order to grasp differences between the pre- and post-CAMs on different scales, the categories were created by the research team. Then two raters, a graduate student of psychology and a bachelor student of education, both research assistants of the Psychological Department, independently rated each pair of CAMs according to the categories. Since the raters had the option to inductively add categories, the two categories 'wordiness' (How wordy are the concepts?) and 'complexity' (How complex is the overall representation of the CAM?) were added. There were only slight differences between the raters' scores, which could be eliminated in the exchange.

In addition to the rating, we analyzed each CAM regarding network parameters with an open source code (Rhea, Reuter, Tecza et al., 2021). This software features the assessment of emotional parameters such as the mean valence of a CAM map as well as structural parameters such as density. For the full list of parameters that we assessed see chap. 4.1., Table 2.

Table 1

Template for the Rating of Differences Between the Pre- and Post-CAMs

<table>
<tr><td colspan="6">Content:</td></tr>
<tr><td colspan="6">Are there new terms in the second CAM?
Are terms omitted in the second CAM?
Do terms remain the same?
Response Categories:</td></tr>
<tr><td colspan="2">None</td><td colspan="2">Some</td><td colspan="2">Many</td></tr>
<tr><td colspan="6">Valence:</td></tr>
<tr><td colspan="6">Does the overall valence change?
Does the valence of the original concept (nature imitation in technical products) change?
Does the valence of the consistent terms (if existing) change?
Response Categories:</td></tr>
<tr><td>No</td><td>Yes, more positive afterwards</td><td>Yes, more negative afterwards</td><td>Yes, more neutral afterwards</td><td>Yes, more ambivalent afterwards</td><td>Neither, but…</td></tr>
</table>

Note. The template was translated into English, see Supplementary Material 4 for the original version.

Finally, the pre- and post-CAMs were also compared regarding the ethical principles mentioned in them. It was not only evaluated which and how many ethical principles were mentioned in the pre- and post-CAMs, but also examined whether ethical principles were mentioned only implicitly or explicitly (i.e., in the wording of Krebs, 1999; Muraca, 2010) in the pre- and post-CAMs.

Results from Using the CAMs in the Context of an Ethics Seminar

In general, it can be stated that the CAMs reflect the students' attitudes regarding nature imitation in technology development (research question 1a). Indeed, most of the CAMs entailed many concepts (ranging from 4 to 24, on average ca. 12) and different emotional evaluations of the nodes. In addition, when evaluating the CAMs, numerous implicitly or explicitly mentioned ethical principles could be identified in the students' CAMs (research question 1b). In addition, significant differences in the pre- and post-CAMs could be detected (research question 2a) in both the evaluation based CAM differences and based on hermeneutic analyses of ethical principles, as will be discussed in more detail below. Furthermore, these differences could be attributed to the contents of the seminar (research question 2b).

CAMs Differences

In general, it can be stated that students' CAMs differed substantially in pre/post comparison. Regarding the terms used in both CAMs, many new concepts were added, while others were dropped and, in comparison, few concepts remained the same. An overview of the final rating of differences between the CAMs is presented in Table 2, the detailed ratings per CAM can be found in the Supplementary Material 5.

Regarding the concepts' valence, both raters from the Department of Psychology identified a tendency that CAMs were more ambivalent, neutral and positive in their overall valence at the post-assessment compared to the pre-assessment. The valence of the original concept ('Nature Imitation through Technical Products') remained the same, which is likely due to the fact that the majority of original concepts were drawn neutrally. This particularity could in turn be attributed to the effect of the exemplary CAM in the instruction, in which the central/original concept was represented as a neutral node. Also, when the students logged into the software, the original concept was neutral and it might not have been clear for them that they could change the valence of the central concept.

Two categories give an idea of the extent to which the pre-/post-CAMs are similar in appearance. The category wording indicates some sort of formal stability in the CAMs, as students did tend to express themselves with similar words in each of the CAMs according to both raters. In terms of complexity, both raters noted a slight reduction in complexity.

For the mentioned categories the raters' most frequent response options corresponded to each other. For the following categories the ratings differed: Regarding the evaluation of the valence of the unchanged terms only one rater had the impression that a majority of these concepts' valences changed to ambivalent while both raters noted no changes for a large proportion of remaining concepts.

Table 2

Frequency of Rating Categories Used per Rater

New Terms	**0 (None)**	**1 (Few)**	**2 (Many)**
Rater 1	1	2	15
Rater 2	3	8	7
Omitted Terms	**0 (None)**	**1 (Few)**	**2 (Many)**
Rater 1	0	8	10
Rater 2	3	7	8
Remaining Terms	**0 (None)**	**1 (Few)**	**2 (Many)**
Rater 1	6	11	1
Rater 2	12	5	1

Overall Valence *Second CAM more…*	**Neutr.**[a]	**Amb.**[b]	**Pos.**[c]	**Neg.**[d]	**Same**
Rater 1	3	5	5	2	3
Rater 2	6	5,5	5,5	1	0

Valence Remaining Concepts *Second CAM more …*	**Neutr.**[a]	**Amb.**[b]	**Pos.**[c]	**Same**	**No Remaining Concepts**	**More Extreme**	**Other**
Rater 1	-	2	-	8	6	1	amb. + pos.
Rater 2	1	7	1	6	2	-	amb. + pos.

Valence of Original Concepts *In second CAM more…*	**Same**	**Deleted**	**Amb.**[b]	**Missing (in both CAMs)**
Rater 1	9	4	3	2
Rater 2	11	4	3	-

Wordiness *Second CAM is…*	**Much Less Wordy**	**Less Wordy**	**Equally Wordy**	**More Wordy**	**Much More Wordy**
Rater 1	3	3	10	-	2
Rater 2	3	4	6	4	1

Complexity *Second CAM is…*	**Much Less Complex**	**Less Complex**	**Equally Complex**	**More Complex**	**Much More Complex**
Rater 1	3	6	5	3	1
Rater 2	3	7	2	5	1

Note. [a]Neutr. = Neutral; [b]Amb. = Ambivalent; [c]Pos. = Positive; [d]Neg. = Negative. Most frequent categories are highlighted.

Although the ratings were similar in their frequency concerning (un)changed terms, the difference could be due to the fact that, the raters sometimes rated different terms as remaining the same and this could be reflected in the (ambivalence) valence ratings of these terms.

The calculated parameters (Table 3) support the raters' impression that ambivalent and neutral nodes appeared more frequently in the post-CAMs than in the pre-CAMs. The parameters also reveal that the post-CAMs contained more solid links but fewer dashed links. The CAMs' mean valence and amount of nodes was slightly increased in post-CAMs. The decrease of negative nodes in post-CAMs was higher than the decrease of positive nodes. For the latent parameters of density and diameter there was almost no change, indicating that latent parameters show more stability than emotional parameters.

Table 3

Calculated Network Parameters of Pre-CAMs and Post-CAMs and the Difference Between Them

Network Parameters	Pre-CAM Mean Value	Post-CAM Mean Value	Difference (Post –Pre)
		Increase	
Nodes (All)	12,67	12,83	0,16
Nodes Ambivalent	0,94	2	1,06
Nodes Neutral	2,89	3,67	0,78
Links (All)	15,28	15,83	0,55
Links (Solid)	12,61	14,06	1,45
Mean Valence	0,24	0,45	0,21
Density[a]	0,23	0,26	0,03
		Decrease	
Negative Nodes	3,83	2,33	-1,5
Positive Nodes	4,94	4,83	-0,11
Links (Dashed)	2,67	1,78	-0,89
Diameter[b]	4,5	4,44	-0,06

Note. [a]All Links of a CAM divided by the number of possible links in the CAM; [b]Longest path in the CAM without repeated visits of nodes.

Ethical Principles

The ethical-philosophical evaluations of the students' CAMs likewise indicate differences between the pre- and post-CAMs regarding three aspects: First, more principles from the ethics of nature were mentioned by the students in the post-CAMs. Second, explicitly mentioned principles were found exclusively in the post-CAMs, i.e., principles that more or less correspond in wording to the principles from the ethics of nature listed in Krebs (2016b); Muraca (2010), which may be due to the preoccupation with these principles in the context of the ethics seminar. Third, and in general, it can be stated that slightly more implicitly and explicitly mentioned principles could be identified in the post-CAMs than in the pre-CAMs. Table 4 shows in detail the frequency of individual principles in the pre- and post-CAMs and also identifies CAMs where ethical principles were explicitly mentioned by students (in or close to the wording of Krebs, 2016b and Muraca, 2010). A full overview over principles mentioned in the CAMs can be found in the Supplementary Material 6. Supplementary Material 7a & 7b contains a precise mapping of all CAMs' nodes to ethical principles, which lists nodes identified as implicitly naming ethical principles.

Due to the large number of only implicitly mentioned principles, especially in the pre-CAMs, the independently evaluating raters from philosophy delivered different evaluation results in view of some CAMs. Frequently, only the subsequent discussion of the evaluation results among the two raters could lead to a uniform evaluation result. The problem described here also refers back to the difficulty that CAMs represent mental structures only on the basis of briefly formulated concept nodes. Thus, an interpretative effort on the part of the raters is required.

Table 4

Illustration of the Frequency of Implicitly and Explicitly Stated Ethical Principles in CAMs

Ethical Principles	Quantity of naming a principle in pre-CAMs	Quantity of naming a principle in post-CAMs	Explicitly named principles *(only in post-CAMS)*
1. Anthropocentric argument / value of rationality / human beings	2	5	5
2. Aisthesis argument / multifunctionality of nature	1	3	1
3. Argument of aesthetic contemplation	4	3	0
4. Argument of the capability approach / of the good life	1	2	1
5. Argument of human hybris	1	4	2
6. Argument of weak sustainability / three-pillar model	1	3	2
7. Argument of strong sustainability / dependency argument / biosphere as resource / boundary	2	4	2
8. Autonomy argument	2	2	1
9. Basic needs argument / argument of 'survival'	0	3	1
10. Biocentrism argument / value of life	0	2	1
11. Design argument	6	1	0
12. Harmony argument	2	3	0
13. Holism argument	1	2	0
14. *In dubio pro malo* argument (Jonas''heuristic of fear')	7	3	0
15. Intergenerational justice	0	3	1
16. Intragenerational / social justice	2	2	0
17. Naturam sequi argument	9	6	0
18. Pedagogical argument	2	2	0
19. Pathocentric argument / value of sentient beings	2	1	0
20. Physiocentric argument / value of being / nature	1	5	4
Total	**46**	**59**	**21**

Note. Participants mentioned more principles in the post- than in the pre-CAMs. Additionally, the principles (according to Krebs, 2016b and Muraca, 2010) are mentioned explicitly only in the post-CAMs.

Discussion: The Advantages of an Interdisciplinary Approach to the Evaluation of Bioinspired Technologies

With our open, interdisciplinary empirical approach, we were able to gain more insight into the attitudes of philosophy students toward bioinspired technologies, which are discussed below. Subsequently, we reflect on the process of how we brought together the disciplinary different patterns of thinking and research.

Exploring Attitudes with CAMs

Our research question 1a) was whether it is possible to use Cognitive-Affective Mapping to represent students' attitudes toward the topic of nature imitation in technology development. Based on the fact that students drew rich CAMs (on average about 12 nodes and 15 connections per CAM) and used the opportunity to affectively evaluate the concept nodes, we conclude that the CAMs were useful for the students to create a vivid representation of their perspectives. Further, we asked in question 1b) whether ethical principles can be identified in such CAMs. This was clearly the case as the raters of philosophy were able to identify implicitly and explicitly named ethical principles in pre- and post-CAMs. Question 2a) addressed whether attitudes represented in the CAMs differed from the first data collection at the beginning of the semester to the second one at the end of the semester. Here the CAMs changed from the first to the second time point of data collection: The ratings showed that the overall impression of the post-CAMs was more ambivalent and neutral. The network analyses confirmed this impression as the post-CAMs contain on average more neutral and ambivalent nodes than the pre-CAMs. One explanation for the change toward more neutrality and ambivalence could be the exposure to topics of ethics of nature in the seminar, which might have changed the students' initial attitudes toward the topic and thus might confirm our research question 2b). Since the philosophical-ethical articles discussed the topics in a less judgmental manner, this may have changed the students' perspectives in the observed direction. Among the abundant research on attitude change through information, most focus is put on the effect of persuasion (Richardson et al., 2017), implying a specific direction of attitude change, usually toward (dis)agreement. However, the students in our study were not to be persuaded of a specific position – rather, they were encouraged to engage with heterogeneous positions. Studies in ambivalence research show that being embedded in a heterogeneous environment (for example, talking to oppositional political camps) is associated with more ambivalent political attitudes (Huckfeldt et al., 2004). Furthermore, Rudolph (2011) analyzed ambivalence as a dynamic experience and found that heterogeneous information increased individual attitudinal ambivalence. In addition to ambivalent nodes, there was also an increase in neutral nodes. In contrast to ambivalence as an activation of positive and negative impressions, affective neutrality is used to describe the absence of positive and negative affect. Taken together with the significant decrease in negative nodes we presume that previously negative affect was neutralized by engagement with the topic. The decrease of negative nodes and increase of mean valence corresponds with the raters' impression that the post-CAMs were more positive. Overall, according to the raters and network parameters, the post-CAMs seem to be more neutral, ambivalent and more positive.

Moreover, the post-CAMs contain slightly more ethical principles than the pre-CAMs. In addition, in the post-CAMs we could detect explicitly mentioned ethical principles, while the pre-CAMs only contained implicitly stated ethical principles. The wording of ethical principles is also likely related to what was learned in the ethics seminar since the wording strongly resembles the ethical principles of Krebs (2016b) and Muraca (2010). Please note that the analyses regarding ethical principles was restricted to these principles that were taught in the ethics seminar. We conjecture that the list of ethical principles derived from Krebs (2016b) and Muraca (2010) contains the most important principles, yet, other ethical principles would have remained unconsidered in the evaluation, even if they had been named by the students in the CAMs. Within this regard it is noteworthy that the work of Krebs (2016b) represents a summary and discussion of the principles from the ethics of nature found in the literature on the ethics of nature. Thus, it seems is unlikely that other ethical principles beyond the ethics of nature and sustainability would be named by the students. Indeed, the instructional text and the sample of nature imitation in technology development underlying our study deliberately focuses on problems of the ethics of nature and sustainability. Moreover, even when creating the pre-CAMs, the students already had in mind that they were creating them in the context of a seminar that focuses on the ethics of nature and sustainability. Finally, the principles for the ethics of nature given by Krebs were slightly extended by certain principles of the ethics of sustainability according to Muraca (2010). And this was done just after a first review of the ethical principles given in the CAMs (cf. in detail above chap. 3.2.1.). Methodologically, we followed the approach of the hermeneutic circle (cf. below chap. 5.3.).

Reflection of the Methods: Hypotheses vs. Hermeneutics

The present work tries to unite two scientific disciplines, psychology and ethics, taken as a subfield of philosophy. Through the interdisciplinary approach we see the potential for broadening perspectives and an emergent gain of knowledge. Interdisciplinary cooperation presupposes a disciplinary self-understanding (Eckardt, 2010) and is habitually confronted with difficulties, from differences in subject-specific terminology to methodologies to epistemological convictions (Möller et al., 2021). Philosophy and psychology share deep roots in the history of science. However, after psychology developed independently from philosophy at the end of the 20th century, the two scientific branches evolved as individual disciplines and today function largely independently of each other in research and teaching (Murray & Link, 2021). In this section, we reflect on our different research backgrounds and outline how we have dealt with them for this project.

The most popular conception of academic psychology portrays it as a science of describing, explaining, and predicting human experience and behavior. In its self-conception, psychology today sees itself primarily as an empirically oriented individual science (Eckardt, 2010). After paradigm shifts on the one hand and school formations on the other, different psychological tendencies coexist today, in terms of both epistemology and methodology. Academic psychology at German universities is generally considered to have a comparatively homogeneous self-image, in which it sees itself more clearly belonging to the natural sciences than to the humanities, since it conveys an understanding of science according to the falsification principle, in the sense of critical rationalism (Plischke, 2016). Thus empiricism plays a central role in academic psychology. Through qualitative and quantitative data collection and analysis, psychological models and theories are confirmed, further developed, or discarded.

Even if empirical research is gaining more and more importance in various fields of philosophy (e.g., ethics of artificial intelligence), a rather deductive ('top down') approach is predominant, especially regarding ethical questions. Gaining knowledge is more likely to take place through reasoning and rationalism that is independent of empiricism. In the case of ethics, this rationalist rejection of empiricism has to do with the fact that its primary purpose is to formulate normative prescriptions for action. If, however, these prescriptions were derived from empiricism beforehand, this would result in an inadmissible circularity (Kant, 2019) or even a naturalistic fallacy, according to which one would conclude what ought to be from an actual state of affairs (Hume, 2011). It is true that applied ethics works empirically and takes data input from other sciences and societal contexts, but only the newer approach of empirical ethics, as already mentioned above (chap. 2), refers to empiricism and more precisely culturally specific, group-specific or even individual-specific attitudes as an essential part of ethical reflection and thus opens a more or less new paradigm.

Despite these different emphases, there are also overlaps in the objects of research and methods as well as mutual influence between psychology and philosophy or ethics, for example in the field of moral psychology. In the following, we reflect on the occasions in our collaboration where we noticed different approaches.

Hypotheses vs. Hermeneutics

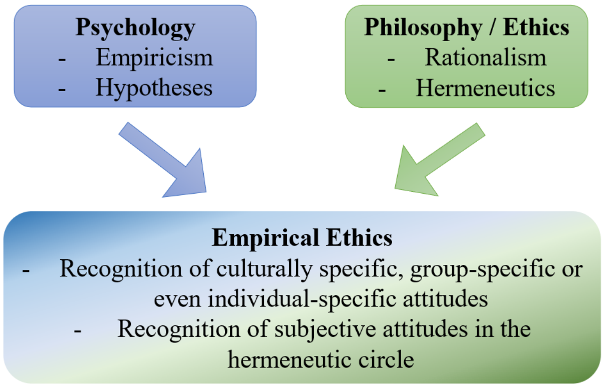
In empirical psychological research, the research questions are first specified, then the methods are determined, the data are collected and analyzed based on the research question and the hypotheses that have been established. Hermeneutic approaches are rare and most likely to be found in qualitative psychological research. There are quality criteria and methodological standardizations for both quantitative and qualitative psychological research approaches.

In philosophy, on the other hand, there is no consensus on clear methodological guidelines for answering a research question (Reichling, 1996). Often, there is methodological agreement at best in the fact that the various philosophical approaches do not start from empirical data collection. One of the most influential attempts in the 20th century to justify the methods of the humanities and thus also of philosophy was undertaken by Gadamer (2006). In his view, the hermeneutic procedure of the humanities is characterized precisely by a positive circular structure, the 'hermeneutic circle'. According to him, the understanding of a topic starts from a previous knowledge or 'prejudice' (*Vorurteil*) about the thing to be interpreted, which is essential in the process of understanding and at the same time must be constantly revised in the experience of a topic to be interpreted (Gadamer, 2006). Hermeneutics understood in this way does not simply operate in contrast to scientific research based on empirical data, which ideally proceeds inductively, 'from the bottom up'. A hermeneutic understanding (of philosophy) does not proceed deductively, 'from top to bottom'. Rather, it combines both approaches in a certain way, by confronting general patterns of understanding derived from a 'history of effects' (*Wirkungsgeschichte*) with concrete contexts to be interpreted, and bringing both into 'conversation' with each other.

Precisely because of this background, philosophy and ethics which proceed in a hermeneutic manner can be fruitful for the hypothesis-guided procedure of psychology in some scientific questions. In the context of the analyses of the CAMs drawn in the context of the ethics seminar (cf. chap. 3.2.), this can be seen in the two-fold evaluation of the CAMs by psychologists as well as philosophers, which seeks to interlock the two disciplines. While too much freedom for CAM drawers in the context of a hypothesis-guided evaluation by psychology can lead to raters producing overly subjective evaluation results, this is precisely where hermeneutic evaluative ethics can help. The 'hermeneutic circle' is applied here in a modified form in such a way that the raters exchange information with each other again and thus reduce their subjective 'prejudices' that flow into the evaluation. One could insert further 'circles' or 'loops of conversation' here, for example by discussing the results of the raters again with the CAM drawers themselves, whether they recognize their implicit positions in the evaluations or not. In this way, we complement the psychological approach, guided by empirical hypotheses, with the hermeneutic method stemming from philosophy and ethics. This gives rise to a form of empirical ethics which, on the one hand, is able to reflect culture-specific, group-specific or individual-specific attitudes and, on the other hand, is able to methodically deal with and recognize subjective attitudes by applying the hermeneutic circle, as Figure 2 shows.

Figure 2

Sketch of Constructive Collaboration Between Psychology and Philosophy/Ethics in the Context of Empirical Ethics.



Note. The empirical hypothesis-driven approach of psychology complements the methodology of philosophy/ethics through the recognition of culturally specific, group-specific or individual-specific attitudes. Hermeneutic philosophy/ethics complements the methodology of psychology by the methodological recognition of subjective attitudes in the hermeneutic circle.

Conclusion and Outlook

We used CAMs as an empirical tool to detect changes in philosophy students' attitudes regarding bioinspired technologies and found that affective evaluation changed as well as the consideration of ethical principles. Our study within an ethics seminar showed that affective evaluations and, perhaps more interestingly, ethical evaluations were not stable variables. We assume that the learning content of the seminar contributed to students articulating ethical principles more explicitly in the second CAMs.

With this work, we aim to strengthen the collaboration between philosophy or more precisely ethics and empirical psychology to open new research perspectives. We see the unification of the different methodological approaches of both disciplines as a necessary challenge and broadening of perspectives. We have combined the empirical approach with a conceptual-normative approach, descriptive analyses and hermeneutic interpretations. We see CAMs as a suitable tool to combine philosophical or ethical and psychological approaches.

In this respect, we consider the procedure presented here as merely a first promising step in the context of an interdisciplinary collaboration between psychology and philosophy or ethics, which may lead to a form of empirical ethics. The increasingly rapid development of new technologies, and bioinspired technologies in particular, necessitates an ethical assessment that can keep pace with this ‘Great Acceleration’ (Steffen et al., 2015) and adequately incorporate the perspectives of all those who are and will be involved with these technologies as early as possible.

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Appendix: Information Text About Nature Imitation in Technology Development

This text was translated into English – the original version in German can be found in the Supplementary Material 8.

The CAM should depict your thoughts and evaluations regarding the imitation of nature by technical products. Before doing so, please read a short text on this topic:

In our everyday life we often encounter things that are called ‘organic’ or ‘biological’. This does not only mean food from ecologically sustainable cultivation, i.e., GMO-free natural products. Cosmetics, clothing, garbage bags, cleaning agents, building materials, fuels or electricity are also referred to as ‘bio(logical)’ or ‘ecological’, i.e., technical products which are of artificial origin and which are ascribed a closeness to nature by means of this ‘label’. However, technical products are not usually perceived as natural or nature-like, i.e., they are distinguished from plants, animals and other natural entities. The distinction is based on the fact that technical products, unlike natural ones, are, for example, manufactured and consist of materials that do not occur in nature and are therefore artificial.

At the same time, in view of environmental problems, we are placing more and more emphasis on sustainable technologies. Sustainability is to be ensured, for example, by the use of regenerative and non-hazardous materials or the degradability of broken and discarded technical products, so that the environment is not adversely affected to the detriment of present and future human and non-human life. In a normative sense, it is precisely such technologies that are described as future-proof and good. This is accompanied by an increasing preference for technical products that imitate nature and are thus similar to nature. This imitation of nature does not refer so much to the appearance of the technical products, but rather to the use of nature-like materials or the imitation of mechanisms found in nature.

Outline your thoughts, arguments, and evaluations regarding the imitation of nature by engineered products as explained in the instructions.

8. Contribution 4: An Introduction to Cognitive-Affective Mapping

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Direct Assessment of Individual Connotation and Experience

An Introduction to Cognitive-Affective Mapping

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Abstract

We introduce cognitive-affective maps (CAMs) as a novel tool to assess individual experiences and belief systems. CAMs were first presented by the cognitive scientist and philosopher Paul Thagard as a graphical representation of a mental network, visualizing attitudes, thoughts, and affective connotations toward the topic of interest. While CAMs were originally used primarily to visualize existing data, the recent release of the new software tool Valence has facilitated the applicability of CAMs for empirical data collection. In this article, we explain the concept and the theoretical background of CAMs. We exemplify how CAMs can be applied in research practice, including different options for analysis. We propose CAMs as a user-friendly and versatile methodological bridge between qualitative and quantitative research approaches and encourage incorporating the method into studies to access and visualize human attitudes and experience.

Keywords: cognitive-affective mapping, attitudes, network analysis, mixed methods

We introduce cognitive-affective mapping as a novel, innovative method for data collection that can bridge gaps between quantitative and qualitative research methods. A cognitive-affective map (CAM) is a graphical representation of a network, visualizing attitudes and thoughts toward the topic of interest. Unlike other network representations, such as mind maps or directed acyclic graphs, CAMs capture not only the interconnectedness of cognitive concepts but also their affective valences. The method was developed and introduced by the philosopher Paul Thagard (2010) and used primarily in conflict research as a tool to depict and communicate divergent perspectives. In this regard, CAMs might be considered an extension of cognitive maps (e.g., Boukes et al., 2020) that allow the integration as well as the differentiation of cognitive concepts (Conway et al., 2014; Neumann, 1981; Suedfeld, 2010; Tetlock, 1983). While these cognitive maps are able to depict the "cognitive complexity" of a given topic, CAMs additionally allow one to depict the affective valences—that is, whether a concept is considered as positive, negative, neutral, or ambivalent. As we discuss later, the inclusion of affective valences makes it possible to calculate a number of cognitively meaningful network properties.

Recently, Rhea et al. (2020) developed *Valence*, an open-source browser-based drawing tool for CAMs that records each graph's network properties. This dual innovation in practicality and quantifiability allows CAMs to be used for large-scale empirical research. Through the *Valence* application, CAMs can be created in field or lab settings with research assistance available and in online studies after standardized instructions. Furthermore, *Valence's* data exporting allows for qualitative, quantitative, and mixed-method data analyses. In this article, we first provide a detailed explanation of the concept of CAMs (1), followed by the method's theoretical background (2). Then we exemplify CAMs' utility as a research tool with an example (3) before discussing export and analysis possibilities of CAMs' network properties (4). We conclude by discussing the larger implications of CAMs for scientific research progress, particularly the opportunities to bridge gaps between qualitative and quantitative research (5), and we present methodological application examples (6). We end with a summary of our CAM presentation (7).

What is a CAM?

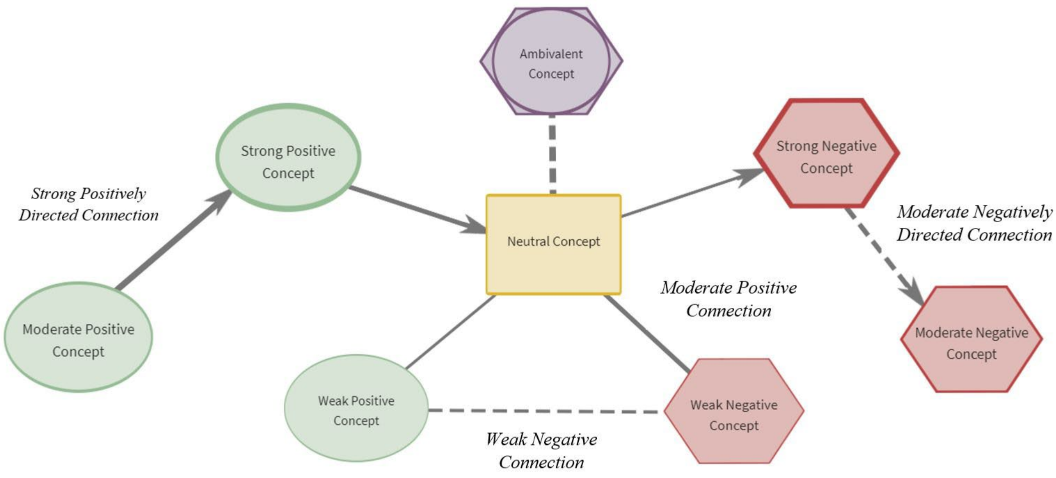
A CAM is visualized as a network consisting of nodes (vertices; concepts) and edges (links between the nodes). Figure 1 summarizes the properties of a CAM. The nodes can represent any content in text form, for example, thoughts, events, emotions, or factual knowledge. Each node also conveys an affective valence, represented by the color and the shape of the node. There are four different colors and shapes: green ovals represent positive valence; red rectangles represent negative valence; neutral is represented by yellow rectangles, meaning that the node is linked to neither positive nor negative affect; ambivalent is indicated by a superimposed oval and rectangle in purple and means that the content of the node is emotionally ambivalent—in other words, there are simultaneously positive and negative feelings. There are three valence levels to choose from for both positive and negative valence; the thicker the border, the more intense the affective connotation. The neutral and ambivalent evaluations are without intensity levels.

The network's nodes can be linked via edges. Edges are connecting lines that are either solid or dashed. Solid lines imply that the two nodes are positively correlated (or mutually reinforcing concepts), whereas dashed lines imply a negative correlation (or concepts in conceptual opposition). In the original CAM model developed by Thagard (2010), edges were undirected and did not imply causality. In more recent studies, solid and dashed arrows were (optionally) added to imply causal directionality allowing CAMs to be analyzed as directed Markov graphs.

The combination of qualitative information captured by conceptual nodes and quantitative information captured by network properties makes CAMs a unique tool to study individual connotation and experience. While other mapping approaches incorporate both conceptual content and quantifiable network properties, such as fuzzy cognitive maps (Kosko, 1986), the CAM method can be distinguished for its applicability to study individual-level differences.

Figure 1

Summary of CAM Properties



Theoretical Development

Thagard (2010) introduced the concept of CAMs in his workshop paper "EMPATHICA: A computer support system with visual representations for cognitive-affective mapping." The method is based on his theories about the relationship between individuals' perspectives and their network's structure and valences. In his book *Coherence in Thought and Action*, Thagard (2000) combined philosophy and cognitive science to explain how people unify their thoughts and experiences coherently. He also referred to constraint satisfaction in networks of connected representations that coherently fit together (positive constraints) or incoherently do not fit together (negative constraints). In 2006, Thagard revised and expanded his coherence theory in his book *Hot Thought*. He elaborated on the emotional component of human thought to explain how cognition and emotion interact in everyday human thinking. In his extended HOTCO (hot cognition) model, Thagard (2006) included emotional coherence and assigned a valence value to the network elements.

Synthesizing these ideas, Thagard (2010) presented the software application EMPATHICA, with which CAMs can be created, along with an example of how CAMs can be used for conflict resolution by increasing mutual understanding. Using EMPATHICA, two different parties can create visual representations of their perspectives that can be qualitatively compared to identify points of conflict. In the study of conflict reconciliation, several studies have applied the CAM approach to visualize contrary positions and derive possible solutions for stakeholders (Homer-Dixon et al., 2014; Thagard, 2015a) or to graphically represent attitudes and changes in attitudes in response to interventions (Thagard, 2012a; 2018; Wolfe, 2012). As a secondary application, CAMs were often used to visualize data obtained in interviews or text analysis; for example, Luthardt et al. (2020) used CAMs in their research on social innovation for early childhood education, while Homer-Dixon et al (2013) used CAMs to map conceptual structures in ideological research.

A limitation of past applications of CAMs was that in most instances, researchers drew CAMs themselves based on a critical assessment of collected data, such as interviews or written text. This research-centered approach suffers from two limitations: (1) the development of a single CAM based on a critical assessment of collected data is time-consuming, and (2) the reliance on critical assessment introduces bias from subjective (author) assessment into the results. To overcome these limitations, the previous EMPATHICA software was modified into a new version called *Valence*, which has a freely available code (Rhea et al., 2020). Unlike EMPATHICA, *Valence* records the network statistical properties of CAMs providing researchers with a mechanism to objectively study and compare individual CAMs. A further feature of the *Valence* update is the development of a web-based browser interface, which instructs participants to draw CAMs themselves while allowing data collection in both an online and offline environment. In the proceeding section, we demonstrate the applicability of CAMs using a visual example.

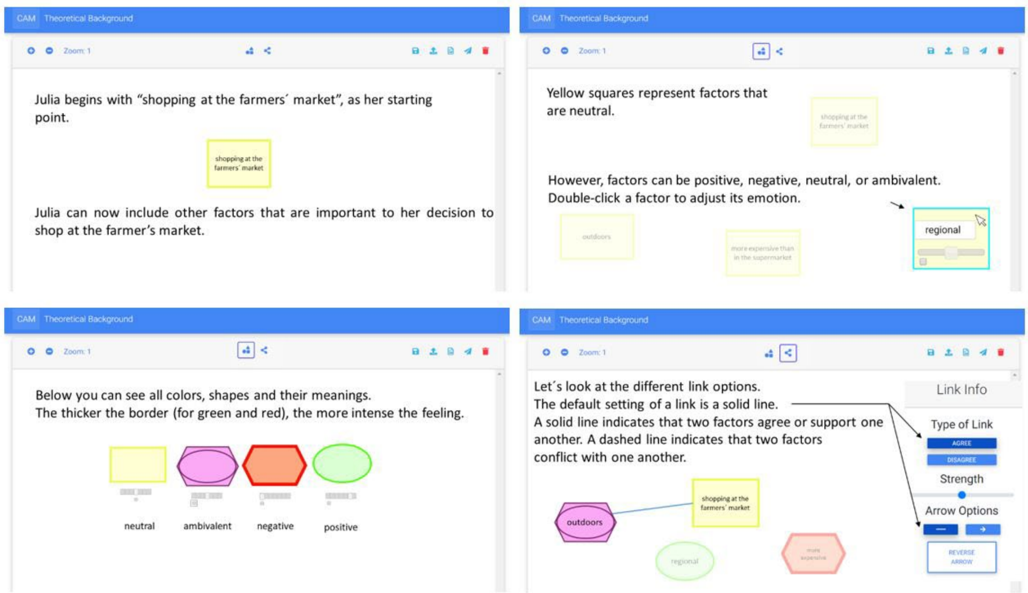
Applicability and Example

CAMs can capture complex attitudinal interrelationships to gain essential insights into human decision criteria and motivational structures. Because of the adaptability of its content and design, the method can be used in diverse disciplines and can contribute to interdisciplinarity. To date, while CAMs have been used primarily in a practical sense to access or represent cognition, the method is applicable to scientific research—for example, CAMs can be used to study variations in individual motivation and decision processes or the interplay between cognition and emotion. Therefore, the method can be used in many different contexts, for instance, in psychiatric treatments or assessments. For example, in treating psychological disorders CAMs can be used to map emotional change in psychotherapy (Thagard & Larocque, 2020).

Here we demonstrate the applicability of CAMs using an example taken from a CAM study about individuals' experience with the coronavirus pandemic (Mansell, Reuter, et al., 2021). Participants were first instructed how cognitive-affective mapping works and how they can draw a CAM with *Valence*. Note that attention checks can be used to improve response validity. Figure 2 shows sample slide excerpts from the instruction set for the Valence application using a neutral example topic, while the complete sample instruction is available in the supplementary materials. Then participants were instructed to draw a CAM on the topic of the coronavirus pandemic. Figure 3 shows the CAM of one participant as an example.

Figure 2

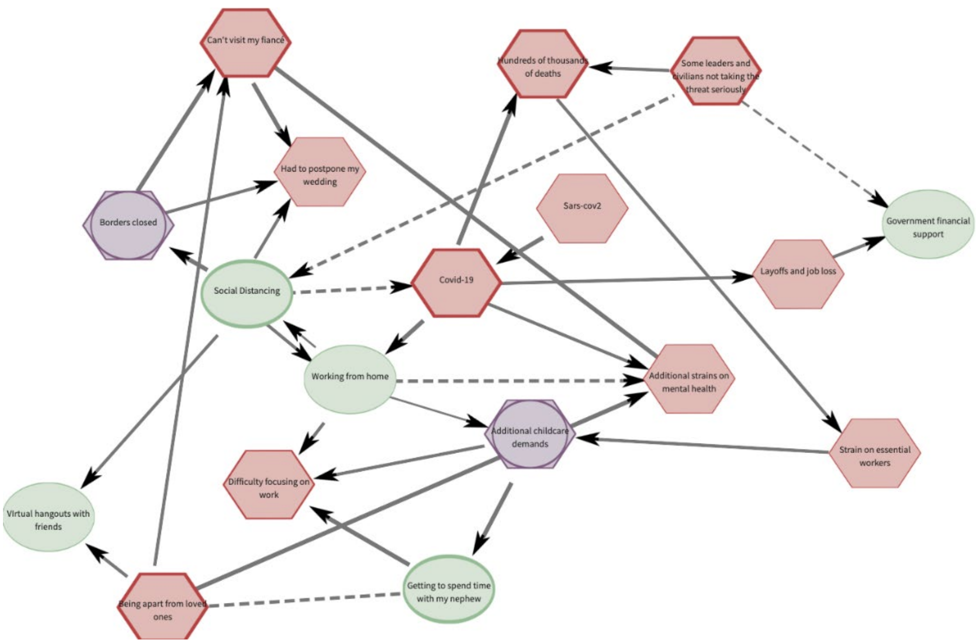
Exemplary Instruction Slides for Drawing a CAM with the Valence Application



Note. that these are only excerpts. For detailed instructions, please see the supplementary materials.

Figure 3

Exemplary CAM Capturing the Experience of one Participant with the Coronavirus Pandemic



Note. The academic instruction was as follows: "We are interested in capturing your experience, the events, thoughts, and feelings resulting from the current coronavirus outbreak. Using the mapping tool, please draw everything that comes to mind concerning your experience with the coronavirus. Think about what matters in the current coronavirus outbreak, and please do your best to draw everything that comes to your mind concerning the coronavirus" (Mansell, Reuter, et al., 2021).

In summary, the vivid appearance and transparent rules of CAMs make them accessible to laypersons. As most people have some familiarity with mind mapping methods like directed acyclic graphs, word bubbles, or decision trees, the approach of cognitive-affective mapping is perceived as familiar and agreeable. Also, CAMs benefit from their high degree of face validity: what is represented by a CAM, including the interconnections between concepts, is immediately recognizable for most participants. In our experience, this transparent character increases the acceptance and willingness to participate in CAM studies. Furthermore, their latent and valence network properties make them applicable for research on cognition, emotion, and experience, or studies on individual beliefs, perceptions, and evaluations. Research using CAMs may be further supplemented with experimental or longitudinal (repeated) research designs.

The analysis of connotation and experience using CAMs using network properties is a recent methodological development; therefore, further validation is required to ensure that the interpretation of CAMs by researchers are consistent with the interpretation by participants. As an initial assessment of CAMs' validity, Mansell, Mock, et al. (2021) calculated the probability of randomly replicating each CAM obtained in their study using a Bayesian inference algorithm. Their results provide evidence that the CAMs in their study are a result of intentional decisions by participants and not random imputation.

Previous CAM studies raised fundamental questions regarding CAM analyses and interpretations that need to be clarified in future studies. In particular, there is the question of how ambivalent nodes are interpreted and coded for further calculations. For example, Mansell, Mock, et al. (2012) used two different codings for ambivalent nodes when calculating the affective network parameters: one time they treated ambivalent like neutral nodes (coded 0), and one time they omitted ambivalent nodes (and only included positive and negative nodes). Another issue comes with the interpretation of the connecting links. The two qualitatively different kind of links, supportive and inhibitory, do provide a more accurate representation of the nature of the connections; however, there is currently a lack of research on the extent to which participants understand the distinction between the connections in the way intended by the researcher. Specifically, establishing an understanding of inhibitory connections proves challenging. To ensure the validity of CAMs as a research tool, future studies will need to investigate these issues.

Export and Analysis of Network Properties

The content of any single CAM can be exported as a set of simple network properties, node values, and edge values, allowing the data to be analyzed using graphical analysis. The data can be downloaded as tabular files (.csv). Image files (.png), suitable for qualitative analysis, can be exported for each CAM and include a participant ID that can be matched to the tabular files. The tabular data include both latent (structural) and valence (emotional/nodal) properties of CAMs. This includes the affective valence and strength of each node and information about which nodes are connected, and the strength and potential directionality of these connections. While the x- and y-positions of each node in the graphical space are recorded, other calculations such as the physical distance between nodes (e.g., 1 cm) are not recorded, as this information is not relevant for network analysis. Using this tabular information, a variety of network properties can be calculated to analyze and compare the properties of CAMs, including measures of affective content such as the average valence of a network, the dependency of the network to a specific emotion, the diversity of emotional properties and connections (Simpson's diversity index), or structural measures such as centrality, diversity, and transitivity. For an overview of CAMs' network parameters, see Table 1.

Table 1

Exemplary Network Parameters of a CAM

Measure	Description	Scale
Average Valence	Mean value of all node valences of a CAM.[a]	-3-3
Valence Percentages	Percentages of the individual valence options (e.g. for positive; negative; neutral or ambivalent).	0-1
Central Node Valence	Valence of the most central node.[a]	-3-3
Centrality	The number of links on a node normalized by the total number of possible link.	0-1
Density	The number of a CAM's links, divided by the total numeber of possible links.	0-1
Diameter	Maximum distance from one node to another.	
Number of Nodes	Total number of nodes.	
Number of Links	Total number of links (measure can be subdivided in number of supporting/contradicting links/arrows).	
Triadic Closure /Transitivity	Total number of triangles (three nodes connected with each other by links) divided by total number of possible triangles.	0-1
Simpson's Diversity	The extent to which a network employs heterogeneous properties.	0-1

Note. [a]Neutral nodes are usually counted as zero, while ambivalent nodes could be counted as zero (one value) or as −1,5 +1,5 (zero in sum, but two values).

Currently, two versions of the *Valence* software are freely available to access online. One is operated by the Cascade Institute, the other by the University of Freiburg. The University of Freiburg software version supports arrows (directedness) as graphical features. The software code for *Valence* is freely available (Rhea et al., 2020). A code for analyzing the original CAM data sets is also freely available. With this code, it is easily possible to clean and combine data sets and calculate the aforementioned network parameters, such as density. An interactive website, with which such calculations can be automated in a user-friendly way, is in progress.

Bridging Gaps in Qualitative and Quantitative Research

Nowadays, both qualitative and quantitative research methods are recognized as significant to scientific research, however, after many paradigmatic controversies about scientific advancement, gaps still exist between qualitative and quantitative research. Recent developments in mixed-methods designs have bridged many of these gaps, yet some are more enduring. While structured interviews can provide detailed accounts of individual experiences, it is difficult to directly contrast the substance of these accounts in an objective and quantifiable manner. Instead, researchers must insert themselves into the discussion to provide meaningful context at the cost of risking subjective interpretive bias. Also problematic, survey responses are highly constrained and can be influenced by factors such as question order, wording, and scale (see Tourangeau et al., 2000).

When incorporated into a mixed-method design, CAMs contain a number of properties that can assist researchers in reducing these biases. In contrast with interviews, CAMs' properties allow unbiased comparisons of quantitative and qualitative data between subjects. Compared with closed-response questions, CAMs allow participants to express themselves openly without the constraints of instrument bias. In this regard, CAMs mimic interviews but also capture quantifiable information. Additionally, for large-scale projects, CAMs are faster to implement than structured interviews as they can be administered to multiple participants at a time. A further benefit of CAMs' accessibility, or "face value," is that CAMs' content is easy to visualize and useful to facilitate communication both during and after data collection.

The simplicity of the CAM method can also be viewed critically, considering the reduction of emotions to mere affective connotation—that is, to the four categories *positive*, *negative*, *neutral*, and *ambivalent*. Various disciplines, including philosophy and neuroscience in addition to psychology, have come up with theories and models of emotions.

Prominent are two-dimensional (dual process) models that emphasize valence/(un)pleasantness and arousal/(de)activating as basic dimensions of emotion, also named core affect (Russell, 2003). However, other researchers propose additional and different dimensions (e.g., Fontaine et al., 2007; Scherer et al., 2006). Hence, the CAM categorization entails a loss of information regarding the specifics and nuances of emotions. Thus, researchers using the CAM method should be aware that CAMs cannot be a decided explanation and differentiated consideration of discrete and specific emotions—instead, they offer the possibility to incorporate simple and fundamental valence information, to identify cognitive and emotional coherence and to strengthen interdisciplinary collaboration. We emphasize for readers that we are not advocating the abolition of structured interviews or survey response measures; rather, we argue that CAMs can be incorporated into studies to provide an objective comparative measure that was not previously available.

Examples for Specific Research Designs

In this section, we point out different methodological approaches for the application of CAMs: They can be used to visualize existing information (6.1.), be integrated into experimental studies to measure the effect of interventions on attitudes and beliefs (6.2.), collect and analyze individual-level data (6.3).

Experts Draw CAMs to Visualize Pre-Collected Data

The original primary application of the CAM method was conflict resolution (Thagard, 2010). Findlay and Thagard (2014) presented the Camp David negotiations in 1978 as a specific example. They used CAMs to visualize the change of attitudes of the two negotiators. The descriptions in Jimmy Carter’s memoirs served as the basis for the mapping. Findlay and Thagard drew multiple CAMs for both conflict parties to depict the emotional changes that were central to conflict resolution over the course of the negotiation.

Other studies have used CAMs to represent disparate worldviews of different cultures (Thagard, 2012a); to signify values in scientific thinking (Thagard, 2012b); to illustrate social conflict (Homer-Dixon et al., 2013); to capture the cognitive-affective structures of ideologies (Homer-Dixon et al., 2014), ethical conflicts (Thagard, 2015b), or political beliefs (Thagard, 2018); as well as to represent analogical and emotional aspects of allegory structures (Thagard, 2011). Thagard and Larocque (2020) also suggested that CAMs can be used in psychotherapy to help patients better understand and positively change their emotional states. Wolfe et al. (2012) suggested using CAMs to mediate between stakeholders in water policy, and Luthardt et al. (2020) used CAMs to visualize perceptions and values related to innovation transfers in early childhood education as part of a triangulation approach.

Using CAMs for Experimental and Correlation Studies

CAMs can be used in quasi-experimental and experimental designs to investigate cause-effect correlations. Here, the focus of investigation is the change in structural properties between treatment and control groups. Because individual CAMs have the potential to vary significantly in both emotional and latent structures, researchers may wish to consider implementing a within-subjects design. For example, Reuter et al. (2021) had participants draw a CAM on the topic of the coronavirus pandemic. After completing this task, participants in the experimental group were instructed to go for a one-hour walk, while the control group pursued any activity at home for one hour. Afterward, all participants were asked to draw a second CAM on the same topic. Differences in pre/post-CAM change were quantitatively examined through overall CAM valence, valence of the central coronavirus pandemic concept, and other structural measures such as the number of positive/negative nodes. The results showed substantive differences between the control and treatment group that appear to be related to higher levels of introspection and reflections among the treatment group. On the basis of these differences, CAMs may be useful to study how different activities influence attitude formation and change.

CAMs are also highly applicable for survey research. A classic cross-sectional design considers the correlation between two or more characteristics from a single sample data collection. In addition to correlations within the network (between specific network parameters, e.g., between density and number of nodes), external variables, such as questionnaire data, can also be collected and correlated with network structures. To test correlations inferentially, classical significance tests, especially correlation and regression analysis, can be used. Mansell, Reuter, et al. (2021) collected CAMs on the topic of the coronavirus pandemic and, at the same time, questionnaires on attitudes toward the pandemic. A central questionnaire scale was the perceived threat of the coronavirus. They examined the extent to which this score could be predicted by structural features of the network. In a second independent study, Mansell, Mock, et al. (2021) examined the relationship between CAMs' emotional and network structures and the introduction of the federal Canadian carbon tax. Both studies show significant correlations between participants' attitudes and CAMs' network structures.

Furthermore, the Valence software allows for flexible project planning in that participants can be presented with a list of predefined concepts, which can be arranged into a CAM (as in Reuter et al., 2021) or asked to generate and relate their own unique set of concepts (as in Mansell, Reuter, et al., 2021).

Analyzing the content of CAMs

The previous example studies focused on structural network parameters and took less account of the content of the different nodes of the CAMs. Various approaches to capture the nodal level information are possible. A common way to examine individual-level data is qualitative content analysis, which aims to identify manifest content through category formation. Analogous to usual approaches (e.g., Mayring, 2014), CAMs can be coded inductively and deductively; that is, researchers look at the individual CAMs and rate them according to specific categories. In the earlier example study by Reuter et al. (2021), the pre- and post- CAMs were also examined qualitatively by having two raters independently form categories to rate the within-subjects CAM changes; example categories are *positive development* or *similar to before*. The ratings of each CAM were summarized separately for the experimental and control group, and then compared.

Another option is to focus more on the semantic content of the CAMs, with a thematic analysis. This involves examining which key themes or aspects emerge regarding the research topic. Such a thematic analysis can be implemented, for example, by automatically creating a list of all concepts mentioned in the CAMs and then categorizing these concepts. An example approach can also be found in Reuter et al. (2021), where the authors first performed an automated categorization (e.g., using word databases) and then manually completed the remaining categorization to create a frequency list for the most emerging topics. However, as the tabular data include the information recorded in each node, the process can be implemented using existing research tools like LegislatoR, Lexicoder, Linguistic Inquiry and Word Count (LIWC), or Python. Finally, this combination of qualitative and quantitative evaluations allows CAMs to be used as part of method triangulation or a mixed-methods approach.

Summary

We introduced the method of cognitive-affective mapping as a tool to assess cognitive and affective mental representations as a network. The method was first presented by Thagard (2012) as an extension of his theory of emotional coherence, and in subsequent years, it was used primarily by researchers to restructure and visualize existing data by drawing CAMs. Recently, the release of the new user-friendly software tool called *Valence* has extended the applicability of CAMs as a research tool, allowing individuals to draw CAMs to visualize their experience and impressions on a given topic in a cognitive-affective network.

This development opens up new study design options, such as experimental approaches, but also new possibilities for network analysis. Because of larger data sets, classical network parameters from graph theory, such as density or centrality, gain importance. In addition, the original qualitative analysis options are still available, but with added analytic potential attributable to the updated data exporting capability. The method thus bridges gaps between quantitative and qualitative paradigms and combines advantages from both worlds: CAMs are vivid and easily understandable, while at the same time capable of representing complex relationships. Furthermore, a free response format is possible, freeing participants from the restrictions of traditional closed survey measures, while at the same time generating large amounts of accessible and analyzable data. The CAMs are thus versatile and a promising tool to access and visualize human experience.

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9. Declaration on Oath

I hereby declare that I have written the submitted dissertation independently and that all the sources that I have used or quoted have been acknowledged by means of complete references. I have not used any paid help from intermediaries or counseling services (thesis advisors or others).

I have not presented the thesis to another university as the subject of an examination or qualification achievement neither in Germany nor abroad.

I also hereby declare that I have not already applied for the doctoral degree at another German or foreign university or that I am applying in parallel.

I understand the significance of this declaration, and I am aware of the criminally punishable consequences of making a false or incomplete declaration on oath.

Freiburg, 17.10.2022

Place and Date

Signature

10. Appendix: Zusammenfassung (German Summary)

Mit Hilfe von Cognitive-Affective Maps (CAMs) lassen sich Perspektiven und Überzeugungen in Form von Netzwerken darstellen, wobei die jeweiligen Konzepte affektiv als positiv, negativ, neutral oder ambivalent bewertet werden können. CAMs wurden bislang überwiegend von Forschenden gezeichnet um konfligierende Perspektiven zu visualisieren. In dieser Arbeit untersuche ich, inwiefern Cognitive-Affective Mapping sich für die empirische und Mixed Methods Forschung eignet. Die Dissertation umfasst vier Artikelbeiträge, die durch eine umfassende Synopse eingerahmt werden. In dem ersten Beitrag untersuchten wir mit 66 Studienteilnehmenden, ob sich die in CAMs dargestellten kognitiv-affektiven Repräsentationen zur Corona Pandemie durch Spazierengehen verändern. Dazu verwendeten wir ein experimentelles Prä/Post-Design mit Kontrollgruppe und Signifikanztests zur Überprüfung unserer Hypothesen. Darüber hinaus untersuchten wir die CAMs explorativ mit qualitativen und quantitativen Auswertungsansätzen. Der zweite Beitrag stellt eine Querschnittstudie dar, in der wir mit Allgemeinen Linearen Modellen prüften, ob sich Netzwerkparameter von CAMs zur Corona Pandemie dazu eignen, die externe Fragebogenvariable *Angst vor dem Coronavirus* zu prädiktieren. Indem wir CAMs sowohl von Teilnehmenden aus Deutschland (N=100) als auch aus Kanada (N=93) erhoben, konnten wir zusätzlich Unterschiede und Gemeinsamkeiten bei den Stichproben ermitteln. In dem dritten Beitrag zeichneten 18 Studierende eines Ethikseminars zu Beginn und am Ende des Semesters CAMs zum Thema *Nachahmung der Natur durch technische Produkte*. Mithilfe von Kodierungs- und Ratingverfahren analysierten wir Prä-/Post-Unterschiede der CAMs in Bezug auf darin vorkommende ethische Prinzipien sowie hinsichtlich des gesamten Erscheinungsbildes der CAMs. Der vierte Beitrag gibt einen Überblick über verschiedene Arten der Anwendung und Auswertung von CAMs, wobei einzelne Aspekte aus den empirischen Studien aufgegriffen werden.

Wir konnten zeigen, dass Studienteilnehmer ohne entsprechende methodische Vorerfahrung online instruiert werden können, CAMs zu erstellen, und dass die Methode vielfältige Möglichkeiten für quantitative und qualitative Auswertungsverfahren eröffnet. Wir argumentieren, dass Cognitive-Affective Mapping Vorteile quantitativer und qualitativer Ansätze verbindet, da einerseits große Datensätze erhoben werden können, und andererseits den Teilnehmenden Freiraum bei der Darstellung ihrer subjektiven Perspektiven ermöglicht wird. Die Erforschung neuer methodischer Anwendungsmöglichkeiten für CAMs lässt einige Fragen offen, die im weiteren Sinne das Verhältnis zwischen empirischer Praktikabilität und theoretischer Einbettung der Methode betreffen. Insbesondere diskutiere ich Unklarheiten hinsichtlich der Verbindungsmöglichkeiten zwischen Konzepten, einerseits in Bezug auf das Konzept der emotionalen Kohärenz, als theoretischer Wurzel der CAMs, sowie andererseits hinsichtlich Schwierigkeiten bei der Instruktion. Darüber hinaus unternehme ich erste Schritte, um Gütekriterien der quantitativen und qualitativen Forschung auf CAMs zu beziehen. Ich reflektiere, dass die methodischen Ansätze der vorliegenden empirischen Untersuchungen vorrangig quantitativ geprägt waren, obwohl qualitative Ansätze tiefere Bedeutungsebenen des subjektiven Inhalts von CAMs erschließen könnten. Ich betrachte die genannten Aspekte nicht nur als methodische Einschränkungen, sondern sehe sie auch als impulsgebend für zukünftige Forschungsprojekte. Insgesamt trägt diese Arbeit zur Weiterentwicklung der empirischen Anwendungsmöglichkeiten des Cognitive-Affective Mapping bei. Die Möglichkeiten, mit CAMs quantitative und qualitative Elemente zu verknüpfen, stellt einen vielversprechenden Ansatz für die Mixed-Methods Forschung dar.