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A Step towards Sustainable Development: Predicting the Acceptance of life-like Materials Systems with Cognitive-Affective Mapping

Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science Psychology

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Abstract

This exploratory study investigates whether the ratings of basal attributes of new materials systems are context-dependent, and whether they differ depending on the survey methods. The study is part of a larger investigation and part of the Cluster of Excellence *Living, Adaptive and Energy-autonomous Materials Systems* (*liv*MatS). One aim of this project is to predict the acceptance of life-like materials systems even before their implementation. To investigate the context dependency, 32 basal attributes were set in two different scenarios of materials systems. In total $N = 107$ test persons took part and should rate all 32 attributes after reading one of the scenarios. The ratings were surveyed using either *Cognitive-Affective Mapping* (CAM) or a questionnaire.

The results of the Bayesian ANOVA can only be generalized with limitations but show that 21 of the 32 attribute ratings did not differ significantly between the scenarios and 24 of the 32 attribute ratings did not differ significantly between the survey methods. The calculations are complemented by Bayesian factors which, in addition to discussed suggestions for methodological improvements, may be used for future studies of the *liv*MatS project.

Keywords: Acceptance research, Attribute rating, Cognitive-Affective Mapping, Context dependency, Scenarios

Zusammenfassung

In dieser explorativen Studie wird untersucht, ob die Bewertungen grundlegender Eigenschaften von neuen Materialsystemen kontextabhängig sind und ob sie sich abhängig von der Erhebungsmethode unterscheiden. Die Studie ist Teil einer größeren Untersuchung im Rahmen des Exzellenzclusters *Living, Adaptive and Energy-autonomous Materials Systems* (*liv*MatS). Das Projekt verfolgt unter anderem das Ziel, die Akzeptanz von lebensähnlichen Materialsystemen bereits vor deren Implementierung vorherzusagen. Zur Untersuchung der Kontextabhängigkeit wurden 32 grundlegende Eigenschaften ausgewählt und jeweils in zwei unterschiedliche Szenarien potenzieller Materialsysteme implementiert. Insgesamt haben $N = 107$ Testpersonen an der Online-Untersuchung teilgenommen. Nachdem die Testpersonen eines der zwei Szenarien gelesen haben, sollten sie jeweils alle 32 Eigenschaften bewerten. Erhoben wurden die Bewertungen entweder mittels *Cognitive-Affective Mapping* (CAM) oder per Fragebogen.

Die Ergebnisse der Bayesian ANOVA sind nur mit Einschränkungen generalisierbar, zeigen jedoch, dass 21 der 32 Eigenschaftsbewertungen sich nicht signifikant zwischen den Szenarien und 24 der 32 Eigenschaftsbewertungen sich nicht signifikant zwischen den Erhebungsmethoden unterschieden haben. Zu den Berechnungen werden jeweils auch Bayes Faktoren angegeben, die, zusätzlich zu diskutierten Vorschlägen zu methodischen Verbesserungen für zukünftige Studien des *liv*MatS Projekts genutzt werden können.

Schlüsselwörter: Akzeptanzforschung, Eigenschaftsbewertung, Kontextabhängigkeit, Cognitive-Affective Mapping, Szenarien

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1 Introduction

Any novel technology will contribute to a change in lifestyles and impact the environment (Coates, 1982). History tells that implementation of technical novelties without considering cultural consequences can lead to changes which cannot be undone. Examples of such disruptive technologies are e.g., cars, computers and smartphones. The disruptive character of these new technologies is reflected in both, the individual habits they have changed and the previously used technologies they have replaced. Another example of disruptiveness is the new trend of digital detox, which attempts to decimate the omnipresent influence of digital technologies and media on daily life. This also raises the question of why these technologies were implemented, even though they have far-reaching negative effects on society and environment.

It is part of sustainable development to satisfy present needs without restricting the ability for future generations to meet their needs. The practicability of this principle has already been stated by the Word Commission of Environment and Development (WCED, 1987). In order to follow this principle in the field of the development of new technologies, it is important to consider effects of novel technologies before their implementation. Contradictory, pre-evaluation of consequences of new technologies, before their implementation, often lacks behind (Albert-Ludwigs-Universität Freiburg, 2018).

The speed of technological development is increasing significantly over time and potential threats which may arise through these new technologies can impact the society dramatically (Sharan, 2018). Technology acceptance research should examine the social embedding of technologies and identify potential benefits and risks before they occur (Petermann & Scherz, 2005). Recent examples are the debate about autonomous driving (Fraedrich & Lenz, 2016) and limitations in genetical engineering (Kotze, 2018). The possibilities in these areas are available and constantly developing, while at the same time the demand for ethical guidelines is increasing. The Freiburg Cluster of Excellence *Living, Adaptive and Energy-autonomous Materials Systems* (*liv*MatS) attempts to work with more foresight.

1.1 *liv*MatS

*liv*MatS is an interdisciplinary research project driven by the University of Freiburg, the Öko-Institute of Freiburg and two Frauenhofer Institutes, one for Mechanics of Materials (IWM) and the other for Solar Energy Systems (ISE). Researchers from disciplines like microsystems and biomimetics engineering as well as from psychology and philosophy are united to develop novel, bio-inspired, adaptive and energy-autonomous materials systems. These will be purely technical but, in a behavioural sense, life-like and combine nature and technology (Albert-Ludwigs-Universität Freiburg, 2019).

The project comprises four interlinked areas to organize the research with each one having one of the following foci: (A) energy autonomy, (B) adaptivity, (C) longevity or (D) sustainability and societal implications. The latter is dedicated to hold ethical, social and sustainable discourse to model guidelines for the development of new technologies. To this end, pre-evaluation of sustainable and societal implications is performed at an early stage of development (Albert-Ludwigs-Universität Freiburg, 2018).

The psychological research within *liv*MatS is based in area D. Its goal is to predict human's evaluation and behaviour towards life-like materials systems by means of a computational model. Insights into social acceptance may then serve as a basis for future developments. To reach this, investigations of attitudes towards material-specific parameters must be carried out (Albert-Ludwigs-Universität Freiburg, 2018). In a previous study, the first step towards the societal evaluation of technologies attributes has been performed. In this study Reuter (2019) interviewed 14 experts of *liv*MatS to compile a list of basal attributes which are likely to be part of novel technologies. Furthermore, this list of attributes has been sent to and rated by these experts. The next step, to which this thesis is dedicated, is to investigate the cognitive and affective evaluation of these basal attributes to pave the way predicting the acceptance of life-like materials systems (Livanec, Reuter, Müller, Stumpf, & Kiesel, 2019).

1.2 Acceptance – a research field with several approaches

Acceptance is explained as a "general agreement that something is satisfactory or right" (Cambridge University Press, 2020). It holds an active component, a sense of willingness, which distinguishes acceptance from tolerance and simple acquiescence (Fraedrich & Lenz, 2016). Acceptance is also explained as the "willingness of people to use a new product or service or to believe a new idea" (Cambridge University Press, 2020). "Acceptance is the result of processes of perception, evaluation and decision and can be represented in a specific attitude or a certain behaviour" (Schäfer & Keppler, 2013, p. 25). Acceptance of technology or rather technology acceptance, however, is not an easy concept to grasp. It is influenced by social processes, subjective norms and attitudes. It depends on social change and therefore changes over time (Hasse, 1998; Petermann & Scherz, 2005; Rammert, 1990, nach Hasse, 1998; Schäfer & Keppler, 2013).

The history of acceptance research for new technologies goes back to the 1970s, when the developments and risks of nuclear energy technology began to be viewed with scepticism (Petermann & Scherz, 2005). In the 1990s there were intense debates about the conceptualization of technology acceptance. Social scientists argued empirically and fact-based. They investigated acceptance of technology and its relevant factors in the society. Philosophers argued ethically and normatively. They investigated the acceptability of technology in the society and conditions under which this could be normatively expected. The debate came to no conclusion, except that the implementation of technology comes with a range of impositions onto the society and that through further technical progress some impositions are inevitable (Grunwald, 2005).

Fraedrich and Lenz (2016) describe two aims of technology acceptance research and assigns them to the scientific approaches. The first is to better understand acceptance itself (social science/ empirical analysis) and the second is to shape technology development in a way that leads to acceptance (normative-ethical approaches).

1.2.1 Current state of research

There are various theories and models with each having own determinants to investigate technology acceptance (Venkatesh, Morris, Davis, & Davis, 2003). However, there is no model that meets the requirements of livMatS to predict the acceptance of technologies which have not been developed yet. “Therefore, one of the objectives of *liv*MatS is to develop a theoretical framework for a computational model that predicts human attitudes and behavior [sic] towards living materials systems based on their attributes” (Reuter, 2019, p. 8). Accordingly, two basic assumptions must be made. First, that life-like materials systems can be described by their basal attributes. Second, that predictions of acceptance based on the cognitive and affective evaluation of basal attributes are applicable (Livanec et al., 2019).

The *Theory of Reasoned Action* (TRA, Fishbein & Ajzen, 1975), describes a person’s attitude towards an object as the position on a bipolar dimension of affect. Consistent with this, Pelegrín-Borondo, Reinares-Lara, & Olarte-Pascual (2017) argue, that for very early acceptance research of novel technologies, it is crucial to investigate affective, normative as well as cognitive factors, and that affective and normative factors explain the most variance. The authors proposed the Cognitive-Affective-Normative (CAN) model, to investigate the acceptance of novel technologies. Within the CAN model, the cognitive variables are perceived usefulness and perceived ease of use. The affective variables are positive affect, negative affect and anxiety. Venkatesh and colleagues proposed the *Unified Theory of Acceptance and Use of Technology* (UTAUT, 2003). But the UTAUT does not include the affective factor. In order to integrate the important affective factor in the framework, *Cognitive-Affective Mapping* will be used as a research tool to visualise the mindset and to investigate the acceptance of life-like materials systems (Albert-Ludwigs-Universität Freiburg, 2018).

1.3 Cognitive-Affective Mapping

Cognitive-Affective Mapping has been implemented for the first time by Thagard (2010). The products created with this method are called *Cognitive-Affective Maps* (CAMs). They represent an individual's complex network of cognitive and affective concepts about a subject in a visuo-spatial way (Homer-Dixon, Milkoreit, Mock, Schröder, & Thagard, 2014; Kreil, 2018). CAMs are built up by interconnected concepts whereby the nature and strength of connection and emotional value can vary. They can be drawn with the help of computer programs such as EMPATHICA, which was developed by Thagard. Originally CAMs were used to resolve conflicts in the way that each conflict partner draws e.g., two CAMs about the conflict. One CAM from their own perspective and one from the perspective of the conflict partner. Doing so, key similarities and differences between the diagrams can be found and EMPATHICA can help to indicate the points to focus on to resolve the conflict (Homer-Dixon et al., 2014; Thagard, 2010).

CAMs consist of boxes and connections, which can be seen in Figure 1. The boxes are called nodes and their valence is represented by their frame as shape and colour. Green ovals denote positive affect, red hexagons denote negative affect, yellow rectangles denote no or neutral affect and purple hexagons within purple ovals denote ambivalent affect. The width of the box frame also allows to display three different importance levels whereby a thicker frame indicates a higher importance. The connections can either be solid lines denoting supportive connections or dashed lines denoting inhibiting connections. Analogous to the frame, these connections can also have three different width levels, which denote their influence. In addition, a one-sided connection can be indicated by a line with an arrowhead. A line without an arrowhead indicates a mutual connection.

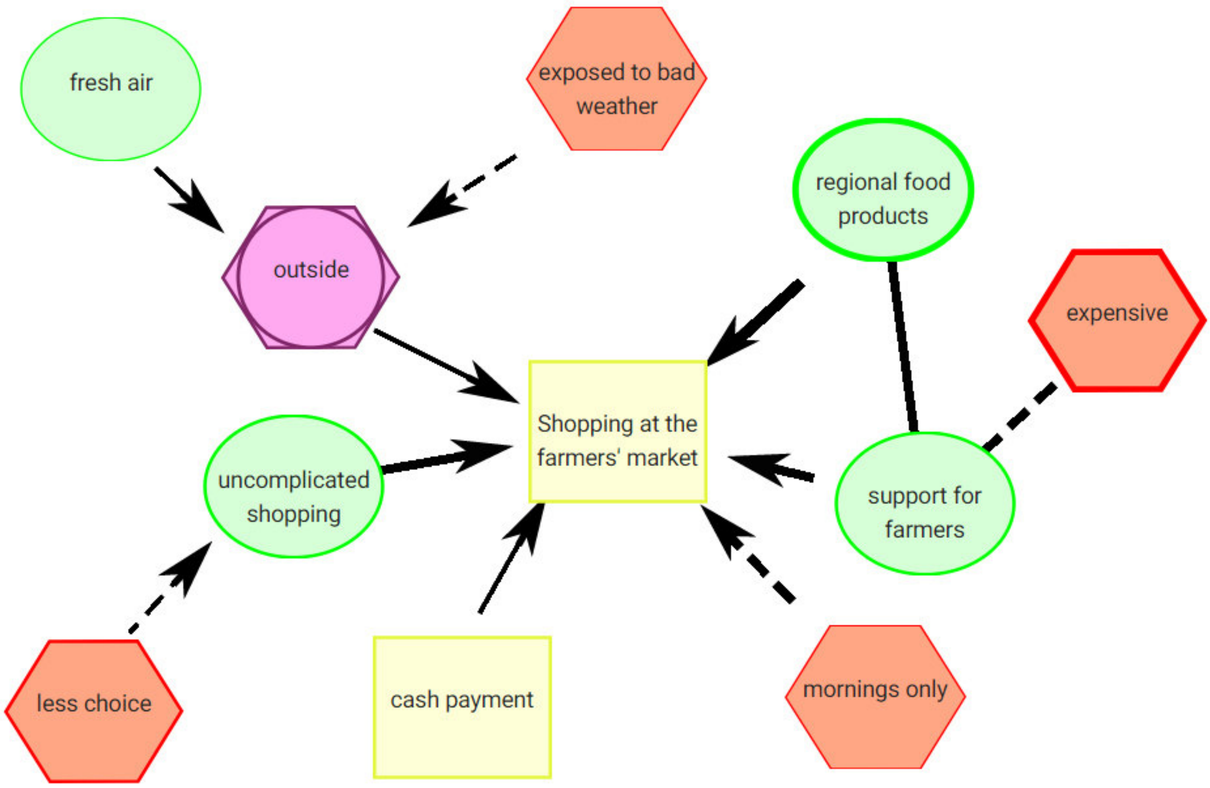

Figure 1. Example of a cognitive-affective map (CAM). This figure illustrates different mental concepts to the topic *Shopping at the farmers' market*. Concepts are in boxes (nodes) and their valence is represented by their frame as shape and colour. Green ovals denote positive affect, red hexagons denote negative affect, yellow rectangles denote no or neutral affect and purple hexagons within purple ovals denote ambivalent affect. The width of the frame denotes the importance level, ranging from one to three. The thicker the frame, the higher the importance. Solid lines denote supportive connections and dashed lines denote inhibiting connections. Respective to the frame, the width of a line represents the level of influence ranging from one to three. Lines with an arrowhead denote one-sided connection and lines without an arrowhead denote a mutual connection.

1.3.1 Application of Cognitive-Affective Mapping as a research tool

To investigate the acceptance of life-like materials systems, we want test persons to create CAMs with potential basal attributes of materials systems. Therefore, it is necessary to introduce Cognitive-Affective Mapping as a research tool. Kreil (2018) already stated the utility of the CAM method as a research tool in empirical psychological research to obtain data directly from test persons. In the study by Kreil, undergraduate students were instructed to use this method to visualise their choice between elevator or staircase use. It was concluded, that "CAMs can be used effectively to investigate people's motivations for engaging in clearly defined behaviors [sic] such as stair climbing, and that the results this method generates are comparable to those yielded by qualitative interviews" (Kreil, 2018, p. 28).

Furthermore, the use of CAM as a research tool has various advantages over solely qualitative interviews. Kreil (2018) states, that "it combines features of qualitative and quantitative methods" (p. 3), allowing CAMs to be evaluated according to both methods. There is no transcript to be made, therefore the researcher safes time and effort. Moreover, as the data the test person creates is visualised and editable, there is more control on the site of the test person e.g., the person is able to give a second thought about a concept and correct it if applicable (Kreil, 2018). During a narrative, descriptions of concepts and their interconnections can only be made linear with consecutive statements. "CAMs, however, provide an immediate gestalt of the whole system and of the simultaneous interactions between, and relationships among, its parts" (Homer-Dixon et al., 2014, p. 2). Thus, the cognitive and affective evaluation of basal attributes of potential materials systems can be visualized by CAMs.

1.4 Normative and context depending evaluation of attributes

As we want to investigate the cognitive and affective evaluation of basal attributes, it is important to consider how humans evaluate attributes and how attitudes are formed. According to the above-mentioned TRA, Fishbein and Ajzen (1975) assume, that beliefs about an object link it with attributes and the evaluation of these attributes results in the attitude towards this object. Fazio (1995) writes, that the attitude towards an object can be viewed as "an association in memory between a given object and a given summary evaluation of the object" (p. 247). The accessibility of an attitude can vary with the likelihood, that the association is activated. The likelihood, that the association is activated depends on the strength of the association between object and evaluation (Bargh, Chaiken, Raymond, & Hymes, 1996; Fazio, 1995). The strength of the association, in turn, might be influenced too, e.g., positively by emotional connections or the frequency of retrieval (Fazio, 1995; Fazio, Chen, McDonal, & Sherman, 1982). Fazio and colleagues (1982) term attitudes towards an object as *object-evaluation associations*. Two decades later Fazio (2007) argues, that the attitude towards an object is like knowledge, a so-called *evaluative knowledge*, that exists in our memory just as any other knowledge. The appraisal of this evaluative knowledge determines the current attitude towards the object. It may stem from various factors that we characterise with the object, such as experiences with the object, one's past behaviours, emotional reactions, conditional learning or a combination of these factors (Fazio, 2007). Regarding the contextual influence on the attitudinal rating, Fazio (2007) writes that it depends on the strength of the object-evaluation association in memory. Someone who does not have a strong object-evaluation association is more likely that this association is not activated and so to be influenced by salient contextual information.

The basal attributes which are to be evaluated are single words. Single words by themselves can have an emotional valence and influence the language processing (Hölzer, Scheytt, & Kächele, 1992; Kanske & Kotz, 2010; Schmidtke, Schröder, Jacobs, & Conrad, 2014). Hölzer and colleagues (1992) term words which have an emotional connotation as *affective vocabulary*. In more recent literature they are termed *affective norms* or *semantic orientation of words* (Köper & Im Walde, 2016; Turney & Littman, 2003). In order to facilitate further reading, I will use the term affective norms. With the aim to list affective norms, different affective dictionaries have been created. Most of them use dimensions of valence and arousal to let test persons rate the affective norms and give each word a numeric value within the categories (Lehmann, Mittelbach, & Schmeier, 2017). Through possibilities like crowdsourcing the ease of creating an affective dictionary rises and so does the size of words within a dictionary which is by now up to 14.000 (Lehmann et al., 2017).

Köper and Im Walde (2016) assembled a list of 3.500 German affective words. They integrated four existing affective dictionaries and trained an algorithm to rate the words on dimensions of abstractness, arousal, valence and imaginability. The dimension imaginability is "important for understanding the relations between emotion and language" (Schmidtke et al., 2014, p. 1109). Within the list from Köper and Im Walde, more than half of the basal attributes that will be assessed within this study have been rated by the algorithm. However, most of the affective dictionaries used context-free word lists to evaluate the ratings. As we want to predict the acceptance of life-like materials systems, it is of great importance, to examine the human evaluation of basal attributes while these are set in a probabilistic context of potential materials systems.

To this end, one objective of this study is to check whether the evaluation of attributes of life-like materials systems is normative or depending on the context. To investigate this, we present the basal attributes in two different contexts.

1.5 Expertise and survey method as moderators of attitude accessibility

A further aim of this thesis is to investigate the ratings of the attributes depending on the survey method and to compare the test person's ratings with those of the experts. We expect to have ratings of the attributes from lay persons using either the CAM method or filling in a questionnaire. Besides this, we have ratings from experts who evaluated the attributes with a questionnaire from Reuter (2019). Therefore, we consider general differences between ratings surveyed with the CAM or the questionnaire and between experts and lay persons.

So far, one can state that the frequency of retrieval and the experience with the object can influence the object-evaluation association and therefore the attitude towards the object (Fazio, 2007). Furthermore, experts tend to have a stronger object-evaluation association in the areas of their specialisation (Czellar & Luna, 2010). Consistent with Fazio's (2007) proposal of evaluative knowledge as the attitude towards an object, Czellar and Luna (2010) describe expertise as a personal factor, which influences the availability and accessibility of the attitude representation in memory. This description, in turn, is consistent with considerations of Anderson (1974), who investigates the influence of prior knowledge onto the retrieval of information in memory. Anderson finds that response time increases as test persons quantity of information about the requested content in memory increases. The findings represent the so-called *fan effect*, whereby the fan of associations of a concept in memory increases due to expertise. Therefore, the activation and the likelihood of retrieving specific information in the association network decreases (Anderson, 1983). The fan effect is discussed considering memory access models and different theories like the *Adaptive Control of Thought Theory* (ACT, 1983) by Anderson (Anderson & Reder, 1999; Radvansky, 1999).

In a more recent study by Czellar and Luna (2010), the fan effect has been found as well. They focused on implicit and explicit attitude measures and investigated expertise as a moderator. During explicit evaluation, experts and novices differ in that experts in specific domains have a deeper knowledge of object attributes whereas novices rely on their global, stereotypical attitudes. When experts explicitly evaluate an object in their specific domain of expertise, the relative weight of global attitudes in the overall object-evaluation associations decreases due to the quantity of detailed attribute-level information. This effect was not constantly found and depended on the type of evaluation and the object specificity (Czellar & Luna, 2010).

A study investigating ratings by expert and novices found that experts used multiple technical terms whereas novices used more everyday words (Bucher, Hartmann, Rollo, & Collins, 2017). Corresponding to this observations, recent examinations on how semantic memory is organised by mushroom experts compared to novices show different cognitive processing and organisation. Among others, it was observed, that experts relied on conceptual and perceptual information to form categories whereas novices used more superficial features to form categories. Experts were able to perform analytical and relational processing simultaneously and used better recall strategies (Megalakaki, Crimet, Ballenghein, & Gounden, 2019). Due to the mentioned findings I assume, that the expert ratings compiled by Reuter (2019) differ from the ratings we collect from test persons, granted that those are lay persons.

The ratings of the attributes by experts were collected using questionnaires. In the present study, the ratings will be surveyed using the CAM method as well as questionnaires. We assume that this approach might give us a deeper insight into the CAM method in terms of an added value in attribute evaluation. Using the CAM method allows to interconnect attributes on different levels. According to this, it is possible to picture attributes on a higher level, which have an influence onto attributes on a lower level, they are related to. Those attributes on a higher level which influence other attributes may be termed as *moderator attributes*. The influence or rather the weight of a moderator attribute can be considered when calculating the valence of a lower level attribute. This, in turn, is relative to the weight of other influencing moderator attributes. Because the consideration of the influence of moderator attributes in the calculation of attribute evaluation is very complex, we will evaluate the valences of the attributes alone, without considering their interconnections to each other. Accordingly, another aim of this study is to examine whether the CAM method, despite this evaluation process, still has an added value compared to a questionnaire survey. CAMs might share big advantages with questionnaires compared to other survey methods like interviews, e.g., cost efficiency and scalability due to online surveying (Brace, 2018). Whereas surveying the attribute valence via questionnaire might safe time compared to the effort of creating a CAM. CAMs, in turn, represent the network of attribute valences as a whole (Homer-Dixon et al., 2014) and therefore provide a context, which in turn, grants a better activation of the object-evaluation association in memory (Fazio et al., 1982). According to this, I assume, that the valence ratings of attributes between CAMs and questionnaires differ.

To rate an attribute, the questionnaire we use requires the test persons to give a rating of positivity, negativity and importance on a 4-point scale (0 = neutral and 3 = strong). The questionnaire does not offer the option to rate an attribute as ambivalent. As explained in section 1.3, the CAM method, in contrast, does offer this option. When rating the valence of an attribute in the CAM, test persons can rate it on a 7-point scale (-3 = strong negative valence and 3 = strong positive valence) or choose to rate it as ambivalent. The ratings might be biased through the *central tendency*, which is described as a common bias within questionnaires, whereby respondents rather be conservative and avoid the ends of a scale (Choi & Pak, 2005). To identify such biases, we are going to analyse the distribution of the ratings from the questionnaires and the CAMs.

1.6 Scenarios – A rough idea of life-like materials systems

To deliver basal attributes in a probabilistic context and to identify possible context-dependent differences in the evaluation of these attributes, we developed two exemplary scenarios of life-like materials systems. In the scientific literature there are various definitions of scenarios (Greeuw et al., 2000). Moreover, there is no consistent theoretical scenario development methodology, so that the application of scenarios is based rather on implicit understanding (Jain & Dannenberg, 2018; Kosow & Gaßner, 2008). The basic assumption when creating a scenario is that many different futures are possible. A scenario itself is a hypothetical construct which may only picture one part of one possible future (Kosow & Gaßner, 2008).

Area D of *liv*MatS attempts to offer "'out of the box' perspectives on living materials systems" (Albert-Ludwigs-Universität Freiburg, 2018, p. 74). Those perspectives can be provided by developing scenarios, which is a process of formal and innovative steps, where the writer needs to be creative but also convincing (Sharan, 2018). Furthermore, scenarios are the gold standard to communicate possible future developments, threats attendant and offer a basis for public discourses (Kosow & Gaßner, 2008; Peperhove, 2018a; Sharan, 2018). Therefore, scenarios are the method of choice, as one goal of *liv*MatS is to evaluate possible societal consequences arising from *liv*MatS research (Albert-Ludwigs-Universität Freiburg, 2018).

The editors of the book *Envisioning Uncertain Futures* (Peperhove, Steinmüller, & Dienel, 2018) collected projects of different topics in which scenarios were used in a broad range of contexts. Moreover, the process of developing these scenarios is presented so that readers can understand and learn how scenarios are developed (Peperhove, 2018a; Sharan, 2018). According to Sharan (2018), scenarios should be consistent, coherent, plausible and perceivable in order to be convincing. The most projects developed scenarios which picture various possible problems in the future with the aim to find solutions in the present. In contrast, within our project we aim to develop scenarios which picture possible life-like materials systems in the future or present daily life, to collect and evaluate valence ratings of their basal attributes.

Peperhove (2018a) describes narrative scenarios as short stories which picture relevant aspects in an everyday context. They are easy to perceive whereby leaving space to the reader to form an individual imagination (Peperhove, 2018b). The scene which is illustrated by the scenario provokes the reader to think and to react to it (Peperhove, 2018a). Therefore, we assume that the test persons will be able to evaluate life-like materials systems or rather their associated attributes after they have been presented in a narrative scenario.

1.7 Aim of this thesis

The main objective of this thesis is to investigate the societal evaluation of life-like materials systems attributes. As there is only little known about this topic, the aim of this pilot study is to generate more knowledge and provide a basis for future investigations. To this end, I will exploratory estimate the following assumptions which are, in turn, based on the theoretical assumptions mentioned above. My assumptions are, that basal attributes are evaluated differently depending on:

1. The context in which they are presented.
2. The method used to assess the attribute rating.

As we have access to the ratings of the experts working for *liv*MatS, I will compare these to the ratings of novices (the test persons in this study). At the end of this thesis the CAM method will be discussed in general as a research tool to survey the societal valence ratings of basal attributes. For this purpose, I will give an account of the distribution of valence ratings within the CAM method and visually compare these to the distributions within the questionnaire.

2 Method

Before describing the approaches of estimating these explorative hypotheses, I give a general overview of the study and the materials we created for this purpose. This thesis is part of a study, which is conceptualized with two other researchers, Niklas Koloczek and Lisa Reuter. We designed this study and all materials within an iterative process together. My colleague Niklas Koloczek focused on the instructions to the CAM method. He examined what kind of instruction leads to a better usability of the CAM method. Parameters for this are e.g., the complexity of the CAMs which were created by the test persons as well as the feedback within the final questionnaire. Whereas I focused on the basal attributes, their contextual embedding into the scenarios and the investigation of their evaluation.

2.1 Sample

There were two samples. First, we recruited test persons through social media, e-mail distribution lists and flyers. We advertised the participation in the study with the opportunity to participate in a raffle of 10 vouchers for 25€ when finished. Hence, this sample will be referred to as the *raffle sample*. Additionally, we recruited a second sample of test persons through Prolific (www.prolific.co). The participants of the second sample were rewarded with 7£ (7.82€) per participation. In the following, this sample will be referred to as the *prolific sample*.

Both samples were treated as one. However, a short overview of demographic data for both is given separately.

Table 1 displays the distribution of the included test persons along the analysis conditions. In total $N = 107$ test persons ($M_{age} = 27.82$ years, $SD = 8.75$) were included and $n = 59$ (55.14%) of the test persons were female. Basal attributes were evaluated by $n = 51$ (47.66%) test persons with the CAM method and by $n = 56$ (52.34%) with the questionnaire. Mean age of the raffle sample was 30.30 ($SD = 11.80$) years and of the prolific sample mean age was 26.66 ($SD = 6.46$) years. All test persons of the raffle sample ($n = 34$) indicated German as their mother tongue. Of the prolific sample, most test persons $n = 24$ (32.88%) indicated German as their mother tongue. Second most frequent was Polish $n = 18$ (24.66%), third most frequent Greek $n = 5$ (6.84%) and $n = 26$ (35,62%) test persons indicated several other languages as their mother tongue. The different native languages were spread across the sample almost evenly.

Table 1

Overview of the included test persons and their allocation to the analysis conditions

Analysis Condition[a]	Raffle[b]	Prolific[c]	Total (∑)	Gender (f)[d]	M_{age}	SD
1 (NanoPat_CAM)	8	17	25	11	25.56	4.43
2 (PlastGat_CAM)	7	19	26	14	26.58	6.71
3 (NanoPat_Questionnaire)	9	19	28	17	27.75	8.71
4 (PlastGat_Questionnaire)	10	18	28	17	31.07	12.19
Total (∑)	34	73	107	59	27.82	8.75

Note. [a]Analysis conditions are named after their distinctive feature: First the scenario type (Nano-Pat-Parka or PlastGat), followed by the survey method (CAM or questionnaire); [b + c] We first acquired test persons through advertising with a raffle and then in a second step with Prolific (www.prolific.co); [d]Gender (female), all other male except of one test person in analysis conditions 3 and 4 indicating a divers gender.

The inclusion criterion was that at least 25% of the basal attributes were rated as valent (different from neutral). In total, $n = 21$ records did not meet this inclusion criterion. Of these, eleven records did not hold any valent rating of the basal attributes. Further dropout reasons were no available data ($n = 42$ records), duplicated data sets due to technical problems ($n = 6$

records) and the lack of the user-defined variable which led to a non-assignability of that test person to one of the scenario types ($n = 1$ record). Therefore, there were $n = 70$ dropouts in total.

2.2 Materials

The study took place at two internet platforms. Besides the actual creation of the CAMs, the study took place at EFS Survey (Questback GmbH, 2020). For the part in which the test persons created a CAM, we used the program EMPATHICA (Thagard, 2010) in a slightly modified form at the platform (http://cam.psychologie.uni-freiburg.de). To provide a proper use of this program, it was necessary for test persons to access this platform with the internet browser Opera, Google Chrome or Safari. We informed participants about this precondition and gave the opportunity to download the Opera or the Google Chrome browser when they were guided to EMPATHICA. The study was conducted in German; therefore, I translated all following text and material examples verbatim except for the materials in the appendix.

2.2.1 Instructions to Cognitive-Affective Mapping

The instructions were either text- or video-based. For the text instruction see appendix A, the video instruction is available in German language on request. Throughout the instruction an example of a fictive person called *Julia*, which created a CAM to the topic *shopping at the farmers' market*, was used to explain the rules and function of the CAM method. The instructions based on the *Rapid Assessment* method. This method's principle is to test learner's knowledge rapidly after the leaning material was presented and give a feedback as testing itself grants a growth in learning (Yeh, 2006). For this purpose, we divided both instructions into two parts. After each part, we asked a question to test the newly learned. In the first part of the instruction we describe the different possible valences and the corresponding width, shapes and colours of nodes. This was followed by a drag-and-drop question in which the test persons were asked to assign the four different shapes and colours to the corresponding values. The width of the shape, i.e. the intensity of the nodes, was not included in the assessment. Following this, we gave a feedback whether the test persons were right or wrong and showed the correct answer in either case.

During the second part of the instruction the test persons should learn about the different connection types. Within the subsequent drag-and-drop question we asked them to assign the four different pictured connection types to four given statements about connections. Analogue to the first part, the strength of the connections was not part of the assessment. We gave feedback instantly while also showing the right answer. Finally, we showed the test subjects the previously presented CAM (Figure 1). This was created according to the example in the instructions and we asked the test persons if they could understand it. In case of limited understanding we gave them the opportunity to tell us about it.

We adopted most of the rules, which we introduced to the test persons for creating a CAM, from Thagard (2010). We followed the recommendations of Kreil (2018) and dropped a restriction made by Thagard regarding the linking of nodes. This was recommended to adapt the CAM method for psychological research and now allows test persons to use both solid and dashed lines to connect nodes, regardless of their valence. In doing so, test persons can "express themselves as freely as possible" (Kreil, 2018, p. 31). Further, we considered a recommendation made by a test person from Kreil (2018) and added the option to choose links with arrowheads to indicate one-sided connection between two nodes as asymmetrical influence.

2.2.2 Scenarios

The idea behind the scenarios was to set the basal attributes of possible materials systems into different contexts. To this end, we decided that one of the scenarios should be spatially close to the human, so that interactions are inevitable. In contrast, the other scenario should provide a context in which the materials system is far away from human reach. Further, both example materials systems were built upon the idea of *liv*MatS to build demonstrators which are either a proof-of-concept in terms of the nature-technology-fusion or oriented towards practical applications in terms of shape-adaptive objects (University of Freiburg, 2019). Therefore, we created the Nano-Pat-Parka (NP), a scenario, that primarily represents shape-adaptivity as well as closeness and interaction with humans.

The other example of a life-like materials system is the PlastGat. This scenario was inspired by a flesh-eating plant. In this connection the PlastGat is described as a sustainable and autonomous materials system that nourishes itself form microplastic in the oceans. Accordingly, this scenario reflects a possible nature-technology-fusion, far from human reach. Both scenarios can be found in Appendix B and C, respectively.

Like all materials used for this study, the scenarios were designed in an iterative process. They were based on Reuter's (2019) list of rated basal attributes which were rated by the *liv*MatS experts on a 5-point scale (-2 = negative valence and 2 = positive valence). The number of attributes should be about 30 to 40 and the ratio of the average attribute valences should be about 2:2:1 (positive/ negative/ neutral). For this purpose, I defined attribute valence with the help of cut-offs as follows. Given that the average valence of basal attribute ratings of experts is X, then: $X < -0.5$ = negative; $-0.5 \leq X \leq 0.5$ = neutral and $X > 0.5$ = positive. Hence, I have selected 32 basal attributes, 12 positive, 12 negative and 8 neutral. For two of the negatively defined attributes I reversed the polarity in order to fulfil the intended ratio of the attribute valences and to be able to include suitable attributes.

In order to assess the suitability of the basal attributes for creating the scenarios, I considered the above-mentioned deliberations about possible materials systems and the four areas of *liv*MatS; energy-autonomy, adaptivity, longevity and sustainability and social implications. Moreover, in line with the necessity of creativity and persuasion while developing a scenario (Sharan, 2018), I tried to imagine these materials systems and picked those basal attributes which were part of these mental images and in line with the ratio of attribute valence defined. The chosen attributes and their rating by the experts can be found in Appendix D. The average valence of the used positive, negative and neutral basal attributes is listed in Table 2.

Table 2

Average valence of the used attributes

Valence category	*n*	$\sum^{a}$	*M* ($\sum/n$)
Negative	12	-13,66	-1,14
Neutral	8	0,99	0,12
Positive	12	16,86	1,41

Note. [a] ∑ represents the sum of all *N* attributes used in this valence category. Used attributes can be found in Appendix D.

At first, I wrote the scenarios without great concern of possible biasing effects by filler sentences. Within the review process, I shortened the scenarios to avoid biasing effects by filler sentences of any kind. In addition, I kept the scenarios general and not group specific. Furthermore, I considered using comparable sentences between both scenarios with similar words and phrases to put the basal attributes into a plausible context. For this purpose, I paid attention to the independence of the basal attributes and an even distribution of negative and positive attributes along the scenarios. Moreover, I have tried to use only attributes from the list to describe the materials systems. I used each attribute only once except for the attribute *anpassen* (adapt), from the adjective *anpassungsfähig* (adaptive), which I used twice. Altogether, it was a converging process, in the area of tension between objectivity, creativity and credibility.

2.2.3 Questionnaires used

The questionnaire we used to survey the attribute ratings was designed by Lisa Reuter. It consisted of 96 questions, three per attribute. Test persons indicated on 4-point scales (0 = neutral and 3 = strong) the positivity and negativity of the attributes. On top of this, the importance of the attributes for the overall valance of the materials system was queried using the same 4-point scale. An excerpt of the questionnaire can be seen in Appendix E.

After drawing the CAMs, each test person was asked to return to the EFS Survey platform and fill in the final questionnaire. This consisted of nine questions, mainly concerning the representativeness of the drawn CAM and the usability of the method. The first question for example was: "How well does the finished chart represent your attitudes in this issue?". We primarily used 7-point scales (1 = very good and 7 = very bad) to survey the answers. Three times we offered a text field for further completion. Finally, we asked the test persons about their self-assessment of their affinity for technology on a seven-point scale (1 = very strong and 7 = not at all), and whether they have ever created such a map before.

2.3 Procedure

An overview of the experimental design is given in Table 3. Note, that the questionnaire was solely used to survey conditions with text instruction whereas the CAM method was used to survey each option once. To this end, survey conditions one to four differ solely within the instruction type and the scenario type. Whereas survey conditions five and six differ in that the attribute ratings were surveyed with the questionnaire and had a slightly different procedure.

Table 3

Overview of the experimental design and the different conditions

Instruction type	Scenario	Survey method	Condition (survey) [a]	Condition (analysis) [b]
Text	Nano Pat	CAM	1	1
		Questionnaire	5	3
	PlastGat	CAM	2	2
		Questionnaire	6	4
Video	Nano Pat	CAM	3	1
	PlastGat	CAM	4	2

Note. [a] Survey conditions represent the conditions the test persons were allocated to within the survey platform. [b] Analysis condition in contrast are the conditions I formed regardless of instruction type for assessing my assumptions.

After the test persons gave their informed consent, we asked them to fill in the query of demographic data. We surveyed their age, gender, native language and the primary activity. When the demographic data page was finished, a trigger was activated to allocate the test persons to one of the six survey conditions. The allocation was not fully random, as the trigger was programmed to reach an equal distribution throughout the six conditions. Survey conditions one to four started with the instruction for the CAM method. After the instruction and before the participants were guided to one of the scenarios, we presented the following information to help them understand their task:

> *[…] In the following part of the study you will read a text that will inform you about a specific topic. Afterwards you will be asked to rate certain attribute terms from the text and to arrange them in a chart like the one Julia has created. You won't have to remember all the attributes - they will be shown to you again after reading. The rules for creating the mind map chart will also be shown again later*. (Translated from the original instruction in German language).

After reading the scenario they were asked to give an overall rating of the Nano-Pat-Parka or the PlastGat on a seven-level Likert scale. As already mentioned, the drawing of the CAMs took place on a different internet platform than the survey itself. Before the test persons were led to EMPATHICA, we provided a summary of the rules and functions of the program (Appendix F). In order to be able to access this summary while creating the CAM, the test persons were asked not to close the survey page. We presented all 32 attributes within neutral rated nodes. An overview of the EMPATHICA interface as it appeared for the test persons is given in Appendix G. Once they were finished with their CAM, test persons were asked to return to the previous survey platform and fill in the final questionnaire. The test persons of the raffle sample could then participate in the raffle.

Test persons in conditions five and six ran through similar tasks, except that they were asked to rate the attributes within the questionnaire instead of drawing a CAM. They were additionally asked to create a CAM about Corona (COVID-19). Here, we did not provide any nodes or key points, so that the test persons could create their own models.

2.4 Data processing and analysis

The CAM data were exported from EMPATHICA. I transformed the valence descriptions which were given to the test persons for creating the CAMs into valence values using Table 4. Note, that I did not include the links between the nodes and, consequently, I did not include the assessment of importance in the analysis. I transformed the questionnaire data the same way, also not including the assessment of importance.

Table 4

Assignment of the valance value

Valence of nodes	Valence value
Strong negative	-3
Negative	-2
Weak negative	-1
Neutral	0
Weak positive	1
Positive	2
Strong positive	3
Ambivalent [a]	(-1,5+1,5)/2 = 0

Note. [a] Ambivalent ratings were processed as two ratings, +1,5 and – 1,5. When aggregating ratings of the same attribute, ambivalent ratings were considered as one rating. To this end, the valence of ambivalent ratings was calculated as $\frac{(-1{,}5+1{,}5)}{2} = 0$.

Since this is a pilot study, data analysis was exploratory. I did all calculations with SPSS version 26 (IBM Corp., 2019). Analysis focused on test person's valence ratings (dependent variable) of the 32 basal attributes. Therefore, I split all calculations according to the 32 basal attributes. As these basal attributes were presented in two different scenarios (Nano-Pat-Parka and PlastGat) and surveyed by two different methods (CAM and Questionnaire), the type of scenario and type of method represented the independent variables, with two groups each. Due to the complexity and still unclear inclusion of the interconnections between the nodes of a CAM into the calculation of the attribute rating, I have not considered them. Further, I have not considered any possible effects of the instruction type onto the attribute rating. Therefore, I formed the four analysis conditions which can be seen in Table 3, neglecting the instruction type.

To test my assumptions, that the scenario type or the method used to survey the attribute rating have an influence onto the valence rating of the attributes, I calculated two Bayesian one-way analysis of variance (Bayesian ANOVA). One with type of scenario as a factor and a second with type of method as a factor. In this analysis, I used the Zellner-Siow's approach (JZS-method), to estimate the Bayesian Factor (BF). The BF_{01} is the BF in favour of the alternative hypothesis (H_1: Factors [type of scenario, type of method] have an influence on the valence rating of the attributes). The BF_{10} is the BF in favour of the null hypothesis, respectively. The interpretation of the BF's indication of evidence strength are "spaced out in exponential half steps of 10, $10^{0.5} \approx 3$, $10^1 = 10$, $10^{1.5} \approx 30$, etc." (Keysers, Gazzola, & Wagenmakers, 2020, p. 789). Consequently, it is considered that a $BF_{01} > 3$ indicates moderate and a $BF_{01} > 10$ indicates strong evidence in favour of the alternative hypothesis. As $BF_{01} = 1/BF_{10}$, it is also considered that a $BF_{01} < 1/3$ indicates moderate and a $BF_{01} < 1/10$ indicates strong evidence in favour of the null hypothesis (Keysers et al., 2020).

To detect possible interactions between the scenario type and the survey method onto the attribute ratings, I performed a 2 x 2 (Scenario [Nano-Pat-Parka, PlastGat] x Method [CAM, Questionnaire]) analysis of variance (ANOVA). To obtain Bayes Factors for those attributes, where the ANOVA showed an interaction effect at $p < .2$ level, I calculated *t*-tests for independent samples. Therefore, I compared the mean values of the attribute ratings of the following pairs of analysis conditions: 1 x 2 (NanoPat x PlastGat [CAM]), 3 x 4 (NanoPat x PlastGat [Questionnaire]), 1 x 3 (CAM x Questionnaire [NanoPat]) and 2 x 4 (CAM x Questionnaire [PlastGat]). To calculate the Bayes Factors for these *t*-tests, I used the calculator provided on the internet platform of the University of Missouri (http://pcl.missouri.edu/bf-two-sample) by Rouder, Speckman, Sun, Morey and Iverson (2009). Thereby I set the scale *r* on effect size to default at .707.

3 Results

Before I report the results of the analysis, I will first give an overview on the missing data and how I proceeded with it. Afterwards I will present the results regarding the assumptions of context dependence as well as the influence of the method on the attribute valuation. I will also present results of the comparisons between expert and novice evaluations. Further, the distributions of ratings along the questionnaire and CAM method will be illustrated.

All $N = 107$ records were included into the analysis. Gender and age were spread almost equally among the analysis conditions as shown in Table 1. Within the CAM conditions, there were in total $n = 5$ test persons with missing data, of these, $n = 4$ with one attribute missing in their CAM. Two of these missing attributes emerged due to changes of an attribute within the scenarios before the study started. The transfer of the change to the specified attributes in EMPATHICA, however, was delayed. Thus, $n = 2$ test persons of the raffle sample evaluated the old attribute *enthält Quecksilber* (contains mercury) instead of *giftig* (toxic). Furthermore, $n = 1$ test person evaluated only eight attributes which lead to 24 attributes missing in the CAM. When investigating the corresponding CAM, it is noticeable that the attributes within the nodes have been rewritten by the test person (every word is written uncapitalized). Consequently, the nodes were not those we had specified in EMPATHICA. The missing attributes of the CAM conditions were not replaced, and no further cases were excluded than listed above in the sample section. Missing attributes of the CAM conditions are listed in Appendix H.

Within the Questionnaire conditions, there were $n = 3$ test persons with missing data. Of these, $n = 1$ test person did not evaluate one attribute. A second test person did not evaluate 16 attributes regarding either their positivity or negativity. Particularly the ratings of positivity were missing when the respective attribute was rated maximal high on the negative scale. Therefore, I assumed that these ratings were non-random missing (NRM). In these cases, I replaced the missing attribute ratings with the means of the respective condition and attributes. The third test person did not evaluate 20 attributes regarding their positivity, negativity or importance and another one only in terms of positivity. This test person did not reach the last page of the survey nor created a CAM. Moreover, I could not identify any connection between the missing ratings and other variables. Therefore, I assumed that the data was missing completely at random (MCAR). These 21 cases I deleted pairwise and excluded all 21 ratings from the analysis. All missing attribute evaluations in terms of positivity and negativity are listed in Appendix I.

3.1 Influences of scenario and method

Bayesian one-way ANOVAs were conducted to estimate the BF for the comparison of attribute evaluation between the type of scenario (Nano-Pat-Parka x PlastGat) and between the type of method (CAM x Questionnaire). All results of the Bayesian ANOVAs are summarized in Table 5. Notice, that of the 32 attribute evaluations, there were eight significant differences between the two groups of scenarios ($p < .05$). Of these eight significant differences, test persons in the PlastGat conditions rated seven attributes significantly more positive than they were rated by test persons in the Nano-Pat-Parka conditions ($p < .05$). Only the attribute *reflektierend* (reflective) $F(1,104) = 11.43$, $p = .001$, $BF_{01} = 16.59$, was rated significantly more positive by test persons in the Nano-Pat-Parka conditions ($M = 1.26$, $SD = 1.33$) than by test persons in the PlastGat conditions ($M = 0.38$, $SD = 1.35$). Of these eight significant different evaluations between the scenario conditions, there were five attributes for which the corresponding BFs could support the findings. For the attribute *energieautonom* (energy-autonomous), the BF_{01} was > 3, indicating at least moderate evidence in favour of the H_1. For the attributes *reflektierend* (reflective) and *unförmig* (bulky), the BF_{01} were > 10, indicating strong evidence in favour of H_1. For the attribute *autonom* (autonomous), the BF_{01} was > 30, indicating very strong evidence and for the attribute *fernsteuerbar* (remote controllable) the BF_{01} was > 100, indicating extreme evidence for H_1.

For 24 attributes, the Bayesian ANOVA showed no significant differences between the two groups of scenarios ($p < .05$). Of these 24 non-significant differences, 12 could be confirmed by their corresponding BFs ($BF_{01} < 0.33$), indicating moderate evidence for H_0. Nine could be confirmed by their BFs indicating strong evidence for H_0 ($BF_{01} < 0.1$). For the other three attributes *bio-inspiriert* (bio-inspired), *innovativ* (innovative) and *nicht kompostierbar* (non-compostable), the corresponding BFs indicated a lack of evidence ($0.33 < BF_{01} < 3$).

Between the two groups of method on the valence evaluation of attributes, there were seven significant differences. For example for the attribute *giftig* (toxic) $F(1,103) = 7.95$, $p = .006$, $BF_{01} = 3.43$, with significantly more negative ratings in the CAM conditions ($M = -2.69$, $SD = 0.65$) than in the questionnaire conditions ($M = -2.05$, $SD = 1.49$). Of the seven significant differences between the two groups of method, only the attribute *lernfähig* (capable of learning) $F(1,102) = 4.39$, $p = .039$, $BF_{01} = 0.65$, was rated significantly more positive by test persons in the CAM conditions ($M = 1.88$, $SD = 0.98$) than by test persons in the questionnaire conditions ($M = 1.37$, $SD = 1.38$). Of these seven significant differences between the methods, there were five differences for which their corresponding BF indicated a lack of evidence ($0.33 < BF_{01} < 3$). For 25 attributes, the ANOVA showed no significant differences between the two groups of methods ($p < .05$). All except of one corresponding BF supported these findings: Fifteen BF_{01} were < .33, indicating moderate evidence and nine BF_{01} were < 0.1, indicating strong evidence for H_0. The corresponding means are presented in Appendix J to

Table 5

Results of Bayesian ANOVAs split by the factors Scenario and Method

		Scenario				Method			
Attribute	*df*	*F*	*p*	BF_{01}	*M* >	*F*	*p*	BF_{01}	*M* >
Adaptiv	[1,103]	0.98	.324	0.13	PG	0.68	.411	0.11	Quest
Autonom	[1,105]	13.65	<.001***	44.33	PG	0.17	.684	0.08	Quest
Bio-inspiriert	[1,103]	3.88	.051	0.51	PG	9.28	.003**	6.32	Quest
Dynamisch	[1,103]	1.71	.194	0.18	PG	4.69	.033*	0.75	Quest
Energieautonom	[1,103]	8.24	.005**	3.93	PG	0.79	.377	0.11	CAM
Enthält Cadmium	[1,104]	0.01	.918	0.08	PG	0.26	.613	0.09	Quest
Fernsteuerbar	[1,104]	21.53	<.001***	1249.34	PG	0.07	.786	0.08	CAM
Giftig	[1,103]	0.24	.622	0.09	NP	7.95	.006**	3.43	Quest
Innovativ	[1,103]	3.16	.078	0.36	PG	3.68	.058	0.46	Quest
Intelligent	[1,104]	0.40	.527	0.09	PG	0.94	.334	0.12	CAM
Klackend	[1,103]	0.00	.946	0.08	NP	1.81	.182	0.19	Quest
Komplex	[1,103]	0.01	.93	0.08	NP	6.20	.014*	1.53	Quest
Langsam	[1,104]	0.00	.974	0.08	PG	0.25	.616	0.09	Quest
Laut	[1,104]	0.78	.381	0.11	NP	2.73	.101	0.29	Quest
Lernfähig	[1,102]	2.30	.133	0.24	PG	4.39	.039*	0.65	CAM
Mikroelektromechanisch	[1,104]	2.80	.098	0.30	PG	0.01	.937	0.08	Quest
Molekular	[1,103]	2.46	.12	0.26	PG	1.99	.161	0.20	Quest
Nanopartikel enthaltend	[1,105]	1.08	.301	0.13	PG	0.78	.380	0.11	Quest
Nicht An-/ Ausschaltbar	[1,103]	0.02	.886	0.08	NP	0.00	.995	0.08	Quest
Nicht kompostierbar	[1,103]	3.47	.065	0.42	NP	0.04	.837	0.08	CAM
Ökologisch	[1,105]	1.75	.188	0.18	PG	1.88	.173	0.19	CAM
Reflektierend	[1,104]	11.43	.001**	16.59	NP	1.27	.262	0.14	Quest
Selbstleuchtend	[1,103]	0.93	.336	0.12	NP	0.85	.359	0.12	Quest
Steif	[1,103]	7.43	.008**	2.70	PG	1.50	.223	0.16	Quest
Surrend	[1,103]	0.40	.528	0.09	PG	0.50	.482	0.10	Quest
Unangenehm riechend	[1,104]	7.48	.007**	2.76	PG	0.70	.405	0.11	Quest
Unbekannt	[1,103]	0.55	.461	0.10	NP	0.95	.332	0.12	Quest
Unerwartet	[1,103]	0.06	.802	0.08	PG	2.75	.100	0.30	Quest
Unförmig	[1,103]	11.74	<.001***	19.06	PG	4.15	.044*	0.58	Quest
Verlässlich	[1,103]	5.03	.027*	0.88	PG	0.31	.579	0.09	Quest
Vielseitig verwendbar	[1,104]	1.66	.201	0.17	PG	0.13	.715	0.08	Quest
Wartungsintensiv	[1,104]	0.62	.432	0.10	PG	6.68	.011*	1.90	Quest

Note. Lines with significant *p*-values are in yellow, lines with $p < .2$ are in grey. BF_{10} Bayes Factor in favour of H_1 (Factors [type of scenario, type of method] have an influence onto the valence rating of the attributes). Method used to estimate the Bayes Factor: JZS; *M* > illustrates the valence direction of the ratings, with NP (Nano-Pat-Parka), PG (PlastGat), CAM (Cognitive-Affective-Mapping) and Quest (Questionnaire). The corresponding means are presented in Appendix J.
$*p < .05$; $**p < .01$; $***p < .001$.

illustrate the valence direction of the ratings. Note, that the standard deviations of the ratings in the scenario conditions range between 0.74 and 1.60 (M_{SD} = 1.20). In the method conditions the standard deviations range between 0.54 and 1.73 (M_{SD} = 1.19).

To examine whether there are interaction effects between the scenario and the method conditions, I performed a 2 x 2 (Scenario [Nano-Pat-Parka, PlastGat] x Method [CAM, Questionnaire]) analysis of variance (ANOVA). This ANOVA revealed no significant interaction effects between scenario and method ($p < .05$). With the descriptive observation of six attributes, possible interactions could be suspected. Nevertheless, they are not significant with classical statistics ($p < .05$) but show potential trends with $p < .2$ (Table 6). These six attributes [*klackend* (clicking), *komplex* (complex), *langsam* (slow), *laut* (loud), *unangenehm riechend* (unpleasantly smelling), *unbekannt* (unknown)] are plotted in Appendix K. Note, within each plot, no lines are parallel to each other.

Table 6

Potential trends of interaction effects at p < .2 level

Attribute	*df*	*F*	*p*	η_p^2
clicking	[1, 101]	1.70	.195	.017
complex	[1, 101]	2.51	.116	.024
slow	[1, 102]	3.46	.066	.033
loud	[1, 102]	3.13	.080	.030
unpleasantly smelling	[1, 102]	2.59	.111	.025
unknown	[1, 101]	2.00	.161	.019

Note. Factor scenario*method onto the valence rating of attributes; η_p^2 is the effect size (partial eta square).

To further verify whether the corresponding main effects for both subgroups can be interpreted, *t*-tests and their corresponding BFs for the individual comparisons are considered like mentioned above in the method section. For example for the attribute *unangenehm riechend* (unpleasantly smelling), the ANOVA showed no significant interaction between scenario and method $F(1,102) = 2.59$, $p = 0.111$, $\eta_p^2 = .025$. Considering the corresponding *t*-tests, there was a significant difference in mean valence rating of this attribute between the Nano-Pat-Parka

(*M* = -2.28, *SD* = 0.89) and the PlastGat (*M* = -1.20, *SD* = 0.82) when it was surveyed with the CAM method $t(48) = -4.47$, $p < .001$, $BF_{01} = 417.19$. When the attribute was surveyed with the questionnaire, this difference between the Nano-Pat-Parka scenario (*M* = -1.68, *SD* = 1.70) and the PlastGat scenario (*M* = -1.38, *SD* = 1.30) could not be found $t(54) = -0.74$, $p = .464$, $BF_{10} = 2.95$. The two other corresponding *t*-tests, which compared the mean valence of the attribute *unangenehm riechend* between the survey methods CAM and questionnaire, once compared within the Nano-Pat-Parka scenario conditions and once within the PlastGat scenario conditions, both showed no significant difference ($p < .05$). The finding of a non-significant difference between the methods within the PlastGat conditions could be supported by the corresponding ($BF_{10} = 3.1$). The BF for the non-significant difference between the methods within the Nano-Pat-Parka conditions indicates too little evidence but is still in favour of the H_0 ($BF_{10} = 1.21$). All results of the *t*-tests and their corresponding BFs which were calculated for the six attributes with a potential trend of an interaction effect ($p < .2$) are compiled in Appendix L. Note that of the 24 *t*-tests, three showed significant differences ($p < .05$), of which two could be supported by their corresponding BF ($BF_{01} > 3$). Of the 21 non-significant differences, 17 corresponding BFs indicated a lack of evidence ($0.33 < BF_{10} < 3$). Further, it is important to note that the standard deviations of the estimated mean valences range between 0.65 and 1.76.

As we surveyed the overall rating of the scenario after the test persons have read it, I also estimated the difference of the overall ratings between the Nano-Pat-Parka and PlastGat scenario. Therefore, I calculated a *t*-test for independent samples. The result reveals a significant difference of the overall rating between the scenarios $t(102) = -5.39$, $p < .001$, $BF_{01} = 30568.06$, with significant more positive ratings of the PlastGat scenario (*M* = 1.02, *SD* = 1.266) than the Nano-Pat-Parka scenario (*M* = -0.42, *SD* = 1.473).

3.2 Differences between expert and novice valence ratings

I received the raw data of the expert ratings from Reuter (2019) and excluded cases with missing data for the corresponding attribute. Reuter surveyed the valence ratings of attributes from experts in a questionnaire on a 5-point scale. In this study we surveyed the ratings within the questionnaire on a 7-point scale. Therefore, I first z-transformed the variable, which contains the valence ratings, once for the expert and once for the novice sample. I then calculated *t*-tests for independent samples with these z-transformed valence ratings to compare the means of expert and novice ratings for each of the 32 basal attributes.

The *t*-tests showed four significant differences between expert and novice valence rating ($p < .005$). Once for the attribute *adaptiv* (adaptive) $t(49) = -4.13, p < .001$, $BF_{01} = 208.35$, with significant more positive ratings from experts ($M = 1.16$, $SD = 0.31$) than from novices ($M = 0.66$, $SD = 0.65$). For the attribute *giftig* (toxic) $t(48) = 2.61$, $p = .012$, $BF_{01} = 4.41$, with significant more negative ratings from experts ($M = -1.58$, $SD = 0.29$) than from novices ($M = -1.23$, $SD = 0.78$). For the attribute *wartungsintensiv* (high-maintenance) $t(68) = 2.85$, $p = .006$, $BF_{01} = 7.32$, with significant more negative ratings from experts ($M = -1.33$, $SD = 0.49$) than from novices ($M = -0.64$, $SD = 0.86$). And finally for the attribute *unförmig* (bulky) $t(65) = 2.19$, $p = .032$, $BF_{01} = 2.03$, with significant more negative ratings from the experts ($M = -0.83$, $SD = 0.43$) than from the novices ($M = -0.35$, $SD = 0.73$). For this latter significant difference, the corresponding Bayes Factor indicates a lack of evidence ($BF_{01} < 3$).

In total, there were 28 non-significant findings of which in 21 cases, the corresponding Bayesian factors indicated a lack of evidence ($BF_{10} < 3$). All *t*-tests and their corresponding Bayes Factors are compiled in Appendix M.

3.3 Distribution analysis

In order to better discuss CAM as a suitable method for surveying the valence evaluation of attributes, I explored the distribution of valence ratings. I plotted a histogram with the distribution of valence ratings for each attribute and for both methods separately. The aim was to visually compare the distributions of the valence ratings between the CAM and the questionnaire method and to detect possible central tendencies in the CAM evaluations. Six of these histograms, for the attributes *komplex* (complex), *langsam* (slow), *mikroelektromechanisch* (micro-electro-mechanical), *Nanopartikel enthaltend* (containing nanoparticles), *surrend* (buzzing) and *unbekannt* (unknown), are presented in Appendix N. Note, that within the histograms of the CAM method, the ratings as ambivalent are enclosed here as +1,5 and -1,5 at the same time and are treated as two ratings. The number of ratings included in the histograms and means are presented in Appendix O.

After the visual analysis of the histograms I could not identify any differences between the distributions of the CAM and the questionnaire method. Further, I could not observe any central tendencies within the ratings of the CAM method.

4 Discussion

The aim of the current study was to exploratorily investigate the affective valence ratings of certain basal attributes of potential quasi living materials systems. To this end, I formed two assumptions. To examine the first assumption regarding the contextual dependence of the valence ratings, the attributes were set in two different scenarios with potential quasi living materials systems. To examine the second assumption regarding the dependence of the valence ratings on the survey method, and to further investigate the usability and applicability of CAM as survey method, the attribute ratings were surveyed with two different methods (CAM and questionnaire). A secondary analysis was the comparison between the ratings of experts and novices. In the following, I will evaluate and reflect the results in this order. At the end, I will discuss general biases of the findings and improvement suggestions. An appraisal of the applicability of the CAM method is given at last.

4.1 Context dependence of valence ratings

The overall rating of the materials systems showed that the PlastGat was rated significantly more positive than the Nano-Pat-Parka. Therefore, it can be assumed that both contexts in which the basal attributes were set differ significantly. The results, however, do not support my assumption of context dependency in the valence rating of attributes. The Bayesian ANOVA revealed that only five of 32 attribute ratings differ significantly between the scenarios ($p < .05$) with a $BF_{01} > 3$. For the attribute *unangenehm riechend* (unpleasantly smelling), on closer analysis of potential trends of interaction effects, the corresponding *t*-tests showed that the scenario conditions differed only when surveyed with the CAM method, but not when surveyed with the questionnaire. Overall, these results are not conclusive, but indicate that the valence ratings of the attributes tend to be rather normative than context dependent.

This normative attribute rating could be explained by considering that most of the rated basal attributes are everyday words and not technical terms. Hence, I assume that the frequency of retrieval and experience with these words is high. According to Fazio (2007), this leads to strong object-evaluation associations, which in turn, reduces the contextual influence onto the attitudes towards these words. This might be supported by the fact, that the contexts in form of the scenarios were read probably only once and might thus have too little influence on the retrieval of the attitudes towards the attributes.

Since, to my knowledge, there are no theoretical approaches yet to explain the eight significant differences in the valence rating of attributes, I will briefly reflect on this below. The attempt to use the same words and phrases when creating the scenarios in order to maximise the comparability of them, could have decimated plausibility, coherence and consistency. But these latter characteristics are described as important for a scenario to be convincing (Sharan, 2018). In my opinion, the PlastGat scenario and its context are more plausible and more consistent, which may have led to the better overall assessment and consequently to the higher rate of positive attribute evaluations. It was not my intention that the scenarios would differ in this respect. In my opinion, however, a coat as a materials system with micro- and nanotechnology is less plausible than a plastic gathering materials system with the same attributes. Furthermore, I believe that this partly implausible context of the Nano-Pat-Parka scenario might have led to a reactance. Reactance in the sense that the test persons may have rated the attributes more negatively, also due to a likely limited comprehensibility or questionable usefulness of the materials system.

It is important to notice, that the scenarios do not only depict different technologies on a superficial level. In my opinion, the introduced technologies differ also in their normative (social and ethical) value. As it is common knowledge, that there are vast areas full of plastic floating in the oceans, the PlastGat scenario may seem far more ethically justifiable than the Nano-Pat-Parka. Normative factors are important for the acceptance of new technologies (Pelegrín-Borondo et al., 2017; Petermann & Scherz, 2005) and could therefore influence the evaluation of attributes regardless of the superficial characteristics of a technology. Another possible reason for the different evaluation of the scenarios and the eight different attribute ratings could be the different distances and possibilities of body contact of the introduced technologies to the human. Due to the different influencing factors that have potentially affected the valence ratings between the scenarios, there are several ways to explain and interpret the results of this analysis.

To give examples of these and to reflect further, I will distinguish between the *specific context* and the *overall context* of an attribute. The latter describes the context or rather the technology in which an attribute is set based on the scenario as a whole. The *specific context* is given by a sentence or a paragraph of the scenario, which contains the attribute and describes its exact context. Test persons may not always have remembered the specific contexts in which each of the 32 basal attributes were set. Consequently, they may have evaluated the attributes in the overall context of the scenarios. Generally, the Nano-Pat-Parka could have been roughly remembered as a multifunctional jacket which is close to the human body and the PlastGat as a plastic gathering technology which swims in the oceans, far away from humans. Considering this, it seems obvious to me that the attributes *autonom* (autonomous), *energieautonom* (energy autonomous) and *fernsteuerbar* (remote controllable), are evaluated more positive when linked to the PlastGat, because they seem to be more useful in their overall context. As the Nano-Pat-Parka is described to directly interact with the human and its environment, it could e.g. pose a more immediate risk if it is autonomous or remote controllable. Moreover, the Nano-Pat-Parka could be charged at home and does not have to be energy autonomous. Pursuing this further, it also seems obvious to me, that the attributes *steif* (stiff), *unangenehm riechend* (unpleasantly smelling) and *unförmig* (bulky) are rated more negatively and the attribute *reflektierend* (reflective) is rated more positively when linked to the Nano-Pat-Parka.

Following these reflections which are built on the roughly remembered overall context, I cannot explain the significant difference between the scenarios regarding the attribute *verlässlich* (reliable). I believe this attribute should have been evaluated equally among the scenarios, as it seems to be important in both materials systems. Nevertheless, the attribute *verlässlich* was rated more positive in the PlastGat scenario.

Considering the specific context in which the attribute *verlässlich* (reliable) was set, the difference becomes more plausible. In the Nano-Pat-Parka scenario, the attribute *verlässlich* is mentioned merely along with other attributes in the first paragraph to introduce the materials system. Therefore, it may seem negligible. “The bio-inspired Nano-Pat-Parka consists of an ecological down inner jacket and a *reliable* and versatile weather protective outer jacket” (translated from the original scenario in Appendix B). In the PlastGat scenario, in contrast, the attribute is used to describe an essential security aspect. “Due to the contained nanoparticles, a *reliable* distinction is made between plastics and biomass” (translated from the original scenario in Appendix C). Thus, for example, the factor of nature conservation might have been addressed, which in turn leads to greater ethical justifiability.

The inconclusive findings and the possibility of interpreting the differences in multiple ways raise several questions. An important question that needs to be addressed is, how good the specific contexts can be remembered and retrieved by the test persons when evaluating each of the 32 basal attributes. If the specific contexts are not well remembered, the evaluations can be biased by various associations. Moreover, the analysis of context dependence is built on the comparison of each single attribute between the scenarios (a_i [NP] x a_i [PG], with a_i as each single attribute of the 32 basal attributes). Therefore, the corresponding specific contexts of each attribute pair being compared, should be comparable, in order to ensure a comparability of the respective attributes. In my opinion, however, as exemplified above, the two scenarios within this study do not provide the same specific contexts for all compared attributes. Consequently, the attribute rating comparisons may be biased. Other questions are how the different characteristics of the technologies (distance from humans or normative value) influence the overall rating of the technologies and to what extend the single attributes are weighted in the evaluation. Generally, an interesting question would be why the overall ratings differ significantly, but only 25% of the associated attributes.

4.2 Influence of the survey method

The findings regarding my second assumption of attribute ratings depending on the survey method are not confirming. Instead, the results rather indicate that there is no difference in the valence ratings of the attributes between the two survey methods ($p < .05$). Only two of the seven attribute ratings, which differed significantly between the method conditions, were supported by their corresponding BFs. Further, all except of one of the 25 non-significant differences were clearly supported by their corresponding BFs. It is important to consider here, that for the two attributes *komplex* (complex) and *laut* (loud), the *t*-tests for individual subgroup comparisons showed that the main effect of the method should not be interpreted without considering the subgroups. Considering this, the main effect of the attribute *komplex* is only significant if test persons have read the Nano-Pat-Parka scenario. The same applies to the attribute *laut*, although the main effect of the method was not significant at this point without taking the subgroups into account.

Undeniably, the CAM method enables the test persons to display their network of attitudes towards the attributes and to link these attributes to each other at different levels (Homer-Dixon et al., 2014). This led me to the assumption, that the activation of the object-evaluation association in memory is better in the CAM conditions and therefore differs from the questionnaire conditions. In the analysis, however, I solely included the ratings of the single attributes without considering their interconnections and possible moderator attributes. Therefore, it is possible that the true added value of the CAM method and the difference to the questionnaire could not be shown by this analysis.

In addition, it was important to investigate the distribution of the ratings within the CAM and questionnaire conditions as the ratings surveyed with the CAM method could be biased through the central tendency. The graphical analysis, however, did not confirm this bias. Interestingly, although it was not tested for significance, the standard deviations of the ratings surveyed with the CAM method are always smaller than those surveyed with the questionnaire method. This might be due to the fact, that the affective variables within the attribute ratings in the questionnaire conditions were surveyed on two separate 4-point scales (0 = neutral and 3 = strong), one for the positive affect and one for the negative affect. In the CAM conditions, these affective valences were surveyed on one single 7-point scale (-3 = strong negative and 3 = strong positive). The large standard deviations might also be the reason why the two-way ANOVA showed no interaction effects ($p < .05$) although the graphical outputs in Appendix K and the statistics in Table 6 show potential trends of interaction effects between method and scenario.

4.3 Influence of expertise

A secondary aim of this thesis was to compare expert ratings which were collected by Reuter (2019) with those ratings surveyed in the current study. The results are more likely to suggest no differences between expert and novice valence ratings ($p < .05$). Whereas one should notice, that only 31.25% of the findings could be supported by their corresponding BF. Further, there are some remarkable differences in the standard deviations of the ratings between experts and novices. An explanation for the difference in the variance could be the small number of experts, which all work in the same project. This could have biased the expert ratings to higher coherence. Another explanation could be that novices rate objects more based on global attitudes, which may be broader (Czellar & Luna, 2010).

It is important to consider, that the attributes which the experts have rated were not set in a scenario of a probable life-like materials system. Therefore, those comparisons were solely for explorative matter. Nevertheless, experts tend to have a stronger object-evaluations association in their area of specification (Czellar & Luna, 2010). Therefore, I assume, that the contextual influence would have been relatively small on expert ratings.

4.4 Limitations of the study

Several limitations of the study must be considered when interpreting the findings. Problems with the comparability of attitude ratings and resulting implications for the interpretation have already been discussed above.

Further, general biases which may have influenced the findings of the study are for example the fatigue effect. First, the total duration of the study was about 45 minutes, which may have led to a loss of concentration and motivation when evaluating the attributes. This holds true especially in the two CAM conditions, as these test persons have also learned a new method before evaluating the attributes. Moreover, a total of 32 attributes had to be rated by the test persons, which again might have influenced their motivation and concentration. Some test persons stated in the final questionnaire, that they were not familiar with all attributes, that it was difficult to form an attitude towards these attributes and that there were too many attributes at once.

Another probable bias could be that I did not distinguish between the text- or video-based instruction types. Although my colleague Niklas Koloczek did not find any significant differences between both instruction types regarding the usability of the CAM method, there might be a difference between them regarding the attribute rating. In addition, I did not include the information on self-reported technical affinity of the test persons into the analysis that we queried in the final questionnaire. I believe that the technical affinity could correlate with the valence rating of the attributes, so its neglect may have biased the results.

Finally, it is important to mention that the software EMPATHICA, with which the test persons created the CAMs, is still in development. Several problems with the software which have been reported by the test persons, such as the need to perform a triple click instead of a double click or that the program crashed, may have biased the attribute ratings in the CAM conditions.

Despite these limitations and the accompanying restriction of generalizability, the results of this study may provide a direction for future research in this project. For this purpose, I have summarized several suggestions in the following chapter.

4.5 Suggestions for future investigations

When investigating the context dependency of attribute ratings based on two scenarios, it is important to ensure that the scenarios create different overall contexts (technologies) with similar normative values and simultaneously create the same specific contexts for each attribute being compared. The two scenarios created for this study can be used as a basis, but the Nano-Pat-Parka should be partially re-described in order to reflect a greater normative value. For example, it could be presented in such a way that it is able to monitor vital parameters or form a large scaffold to protect a group of people from an avalanche. In addition, the specific contexts among the scenarios should also be described more equally. This might not be easy but would lead to a better comparability of the single attributes.

Further, since the acceptance of technology is linked to social and ethical values (Pelegrín-Borondo et al., 2017; Petermann & Scherz, 2005), it might be helpful if the scenarios facilitate the formation of an opinion in this respect and provide an appropriate, maybe more complex context. Pursuing this further, it would have been interesting to ask test persons about their values and norms. Another important aspect would be to ask for an overall imaginability rating of the scenarios additional to the overall rating of the scenarios. As imaginability is an important factor for the emotional language processing (Schmidtke et al., 2014), I believe it might influence the ratings of the affective valence of words.

To the end that test persons better remember the exact context and to draw their attention to them while reading the scenario, the attributes could be written in bolt print. Furthermore, one should contemplate to provide the scenario text to the test persons during the evaluation process. This was noted by one test person as potentially helpful. A scenario that contains fewer attributes and instead places more emphasis on their explanation or their corresponding contexts could also improve the test persons' remembrance of the exact contexts and to develop a corresponding attitude. Some test persons gave the feedback that the attributes were too unspecific or too similar. For example, the attributes *dynamisch* (dynamic), *adaptiv* (adaptive) and *vielseitig verwendbar* (versatile) or intelligent and *lernfähig* (capable of learning). As the results of this study indicate no context dependence of attribute ratings, an interesting investigation would be to compare the valence ratings of this study with the valence of the automatically generated affective norms by Köper and Im Walde (2016).

If possible, the evaluation of the attribute rating should include the interconnections of the nodes and therefore also possible moderator attributes within the CAMs. This could not only provide great insights into human acceptance of life-like materials systems but also enables a better comparison of the CAM and questionnaire method. Additionally, the Bayes Factors of the reported findings may be used as priors in future studies.

4.6 Applicability of the CAM method

The surveying of test person's ratings of attributes with the CAM method proves to be useful. Results reveal no conclusive difference to the questionnaire and no central tendencies. Nevertheless, I assume that the CAM method has an added value if the interconnection of nodes is considered in analysis. Most importantly, by working with the method and through feedback of test persons we gained several improvement suggestions for the CAM method itself, its instruction and for the EMPATHICA software to create CAMs. This feedback was partly analysed by my colleague Niklas Koloczek and could eventually be available on request. Altogether, the CAM method has a great potential whose further areas of application are yet to be explored.

5 Summary

This exploratory study provides some indications towards enhancing our knowledge about the valence ratings of attributes of new material systems. The results are not conclusive but indicate several trends.

First, the analysis of the attribute valence ratings showed, that the test persons overall attitudes towards the potential materials systems differed, but that not more than 25% of all associated attributes differed between both scenarios.

Secondly, the comparison of the attribute valence ratings between the survey methods showed that only 7 of 32 attribute ratings differed, and one further attribute differed depending on what scenario was read. Therefore, not more than 25% of the attribute ratings differed between the survey methods used.

Finally, it should be noted that this study was part of a larger investigation that was conducted as part of the *liv*MatS project. Therefore, the significance of the current study should be assessed in relation to the overall *liv*MatS research project. In this respect it provides a basis for the development of a computational model that predicts the acceptance of novel material systems and could prevent possible disruptive implementations. To sum up, the present study makes a step towards sustainable development.

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Appendix A

Text instruction in original language (German)

Anleitung

Herzlich willkommen zur Anleitung für unsere Studie!

Du kennst bestimmt sogenannte Mind-Maps. Die Methode, die wir Dir beibringen möchten ist dieser recht ähnlich. Dazu wollen wir uns ein Beispiel anschauen.

Nehmen wir an, es gibt eine fiktive Person namens Julia, welche einen Text zum Thema "Auf dem Markt einkaufen" gelesen hat. In diesem Text wurden die Vor- und Nachteile zu dem Thema dargestellt. Nun soll sie diese Informationen bewerten und miteinander verknüpfen – wie in einer Mind-Map. In der folgenden Grafik sind alle Argumente aus dem Text nochmal aufgelistet:

Wie Du sehen kannst, sind bisher alle Argumente in einem gelben Rechteck. Bisher sind sie noch nicht bewertet. Generell stehen gelbe Rechtecke aber für neutrale Argumente. Julia bewertet nun, welche Argumente für sie positiv, negativ oder ambivalent sind und welche neutral bleiben.

Des Weiteren kann sie für positive und negative Argumente festlegen, wie schwer das jeweilige Argument für sie wiegt. Dies kann sie anhand der **Dicke der Umrandung** der Form darstellen. Dafür gibt es jeweils eine **3-stufige** Unterteilung. Dabei gilt: **Je dicker die Umrandung, desto schwerer wiegt das Argument**!

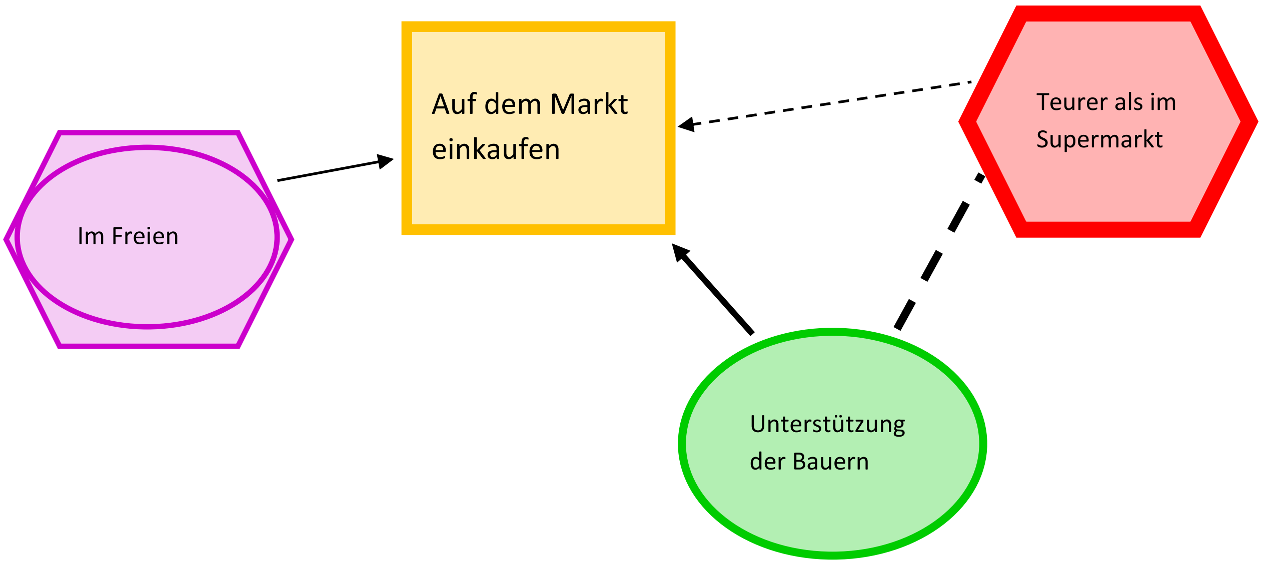
Zurück zu unserem Beispiel. Julia hat sich daran gemacht, verschiedene Argumente zu bewerten:

Links siehst Du, dass sie das Argument „Unterstützung der Bauern“ positiv bewertet hat. Positive Argumente werden als grüne Ovale dargestellt. Sie hat dafür die **2. Stufe** der Dicke der Umrandung gewählt. Das bedeutet, dass der Wert des Arguments für sie im mittleren Bereich liegt.

In der Mitte befindet sich das Argument „Teurer als im Supermarkt“. Dieses empfindet Julia als negativ. Negative Argumente werden wiederum als rote Sechsecke repräsentiert. Julia hat dafür die **3. Stufe** der Dicke der Umrandung gewählt, da sie es als stark negativ empfindet.

Rechts befindet sich das Argument „im Freien“. Julia findet dieses Argument sowohl positiv als auch negativ. Vermutlich hängt es u.a. für sie davon ab, wie das Wetter ist. Solche Widersprüchlichkeiten werden als violette übereinander gelegte Ovale und Sechsecke angezeigt.

Als nächstes möchte Julia die Argumente miteinander in Beziehung setzen. Dabei kann sie die Argumente sowohl direkt auf das Thema „auf dem Markt einkaufen“ beziehen als auch aufeinander, nur mit indirektem Bezug zum Thema. Es ist außerdem möglich, dass ein Argument sowohl indirekt als auch direkt mit anderen in Beziehung stehen kann:

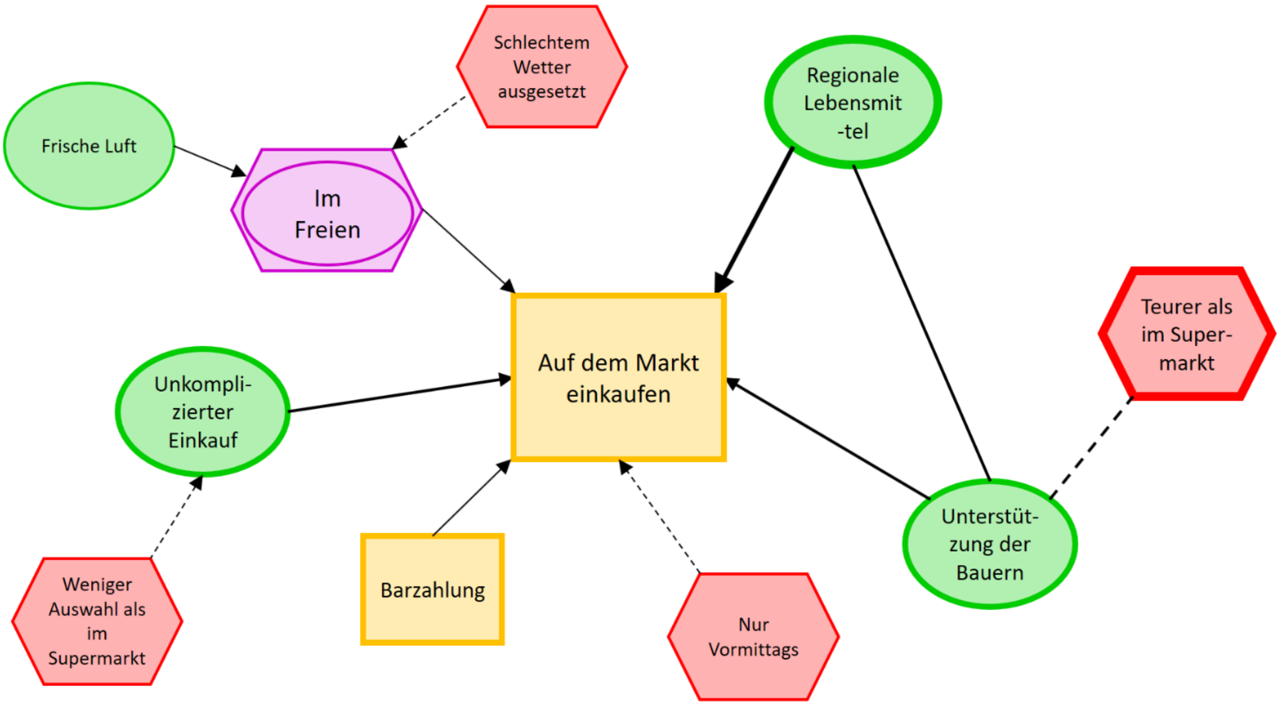


Wie Du in der Grafik erkennen kannst, hat das Argument „Unterstützung der Bauern“ für Julia einen unterstützenden Einfluss auf das Thema „auf dem Markt einkaufen“. Dieser wird durch eine *durchgezogene Verbindung* und eine Pfeilrichtung repräsentiert. Auch das Argument „Im Freien“ hat einen leicht unterstützenden Einfluss.

Im Gegensatz dazu gibt es zwischen den Argumenten „Unterstützung der Bauern“ und „Teurer als im Supermarkt“ eine *gestrichelte Verbindung* ohne Pfeilspitzen. Dies stellt daher eine hemmende, sowie wechselseitige Wirkung dar. Einen weiteren, einseitig hemmenden Einfluss gibt es zwischen dem Argument „Teurer als im Supermarkt“ auf das Thema „auf dem Markt einkaufen“.

Julia kann also wählen, ob sich Argumente unterstützen oder hemmen und ob dieser Einfluss einseitig oder wechselseitig ist. Außerdem kann es sein, dass ein Argument sowohl indirekt als auch direkt mit anderen in Beziehung steht. Bestimmt ist Dir außerdem aufgefallen, dass die Linien unterschiedlich dick sind. Wie bei der Umrandung der Argumente kann damit die Stärke der Verbindungen dargestellt werden. Dafür gibt es ebenfalls jeweils eine **3-stufige** Unterteilung. Dabei gilt: **Je dicker die Linie, desto stärker die Verbindung**!

So weit so gut! Das Ergebnis von Julia zum Thema „auf dem Markt einkaufen“ könnte so aussehen. Kannst Du ihre Einstellungen auf dem Schaubild verstehen?



Damit ist die Anleitung zu Ende. Im folgenden Teil der Studie wirst Du einen Text zu lesen bekommen, der Dich über ein bestimmtes Thema informieren wird. Im Anschluss daran wirst Du gebeten, bestimmte Eigenschaftsbegriffe aus dem Text zu bewerten und in einer Art Mind-

Map anzuordnen. Du wirst Dir die Eigenschaften nicht alle merken müssen – sie werden Dir nach dem Lesen wieder gezeigt.

PS: Als Hilfe gibt es auf der nächsten Seite eine Legende mit allen Erklärungen in Kurzfassung und Erläuterungen zu wichtigen Funktionen des Programms, mit dem Du gleich arbeiten darfst.

Appendix B

Scenario Nano-Pat-Parka in original language (German)

Nano-Pat-Parka von Vimmerby

Angeregt von den Eigenschaften der Pomelo-Frucht entwickelte die Albert-Ludwigs-Universität Freiburg in Kooperation mit weiteren Instituten den Nano-Pat-Parka.

Der bio-inspirierte Nano-Pat-Parka besteht aus einer ökologischen Daunen-Innenjacke sowie einer verlässlichen und vielseitig verwendbaren Wetterschutz-Außenjacke. Die Außenjacke enthält Cadmium, einen Stoff der giftig ist. Daher ist der Nano-Pat-Parka nicht kompostierbar.

Der Nano-Pat-Parka ist innovativ und autonom. Er kann sich mithilfe komplexer Technologien an verschiedene äußere und innere Bedingungen anpassen. Dabei können laute, klackende Geräusche entstehen und es kann unter Umständen unerwartet zu unförmig aussehenden Erscheinungen kommen.

Bei Reibung, z.B. durch das Tragen eines Rucksacks, wird das verwebte, molekulare N100pX-Laminat steif, dies kann zu unangenehmen Gerüchen führen. Kommt es zur Berührung von Felsen oder Gegenständen, können die mikroelektromechanischen Einsätze im Unterarm und Rückenbereich dynamisch als Protektoren dienen.

Durch die intelligente Technologie und enthaltenen Nanopartikel ist der Nano-Pat-Parka lernfähig. Das Anpassen an die äußeren Gegebenheiten ist fernsteuerbar und zunächst langsam. An- und Ausschaltbar sind diese Prozesse nicht. Was mit fortlaufendem Gebrauch der Jacke möglich wird, ist bisher unbekannt. Durch ihre selbstleuchtende und reflektierende Oberfläche ist die Außenjacke gut sichtbar, dabei ist sie vollkommen energieautonom. Der Nano-Pat-Parka ist relativ wartungsintensiv. Beispielsweise kann es sein, dass die eingebaute Technologie zu surren beginnt, was man beheben muss.

Appendix C

Scenario PlastGat in orignial language (German)

PlastGat von Vimmerby

Angeregt von den Eigenschaften fleischfressender Pflanzen, insbesondere der Venusfliegenfalle, entwickelte die Albert-Ludwigs-Universität Freiburg in Kooperation mit weiteren Instituten den PlastGat.

Der bio-inspirierte PlastGat steht für Plastic Gathering und dient dem Zweck, das Mikroplastik aus den Meeren der Welt aufzusammeln. Dabei bezieht er seine benötigte Energie aus dem gesammelten Plastik und ist somit komplett energieautonom. Dahinter stecken komplexe, mikroelektromechanische und molekulare Vorgänge.

Der PlastGat ist autonom und kann sich durch kleine Motoren an Kunststoffe verschiedener Zusammensetzungen und Formen anpassen. Dies geschieht oft unerwartet. Unter Wasser führt dies zu lauten, klackernden Geräuschen. Diese intelligente Technologie ist wartungsintensiv. Beispielsweise kann es sein, dass die eingebaute Technologie zu surren beginnt, was man beheben muss. Durch enthaltene Nanopartikel wird verlässlich zwischen Kunststoff und Biomasse unterschieden.

Der Abbauprozess des gesammelten Plastiks ist ökologisch, wenngleich auch unangenehm riechend. Die dabei abfallenden Produkte sind für den Stoffwechselkreislauf im Meer vielseitig verwendbar. Der PlastGat enthält Cadmium, einen Stoff der giftig ist. Daher ist der PlastGat nicht kompostierbar.

Der PlastGat ist fernsteuerbar. An- und ausschaltbar ist er nicht, da er sonst sinken würde. Aufgrund innovativer Technologie ist er lernfähig und dynamisch. Das Anpassen an die äußeren Gegebenheiten geschieht zunächst langsam, jedoch ist bisher unbekannt, was mit zunehmendem Einsatz möglich wird. Um im Meer gut sichtbar zu sein, ist er selbstleuchtend und seine unförmige, steife Oberfläche reflektierend.

Appendix D

*Table of basal attributes with ratings of liv*MatS *experts*

Basal attribute	*n*	Valence rating					*M*	miss
		-2	-1	0	1	2		
Adaptiv	15	0	0	0	3	12	1,80	0
Autonom	15	0	1	2	5	7	1,20	0
Bio-inspiriert	14	0	0	1	5	8	1,50	0
Dynamisch	15	0	0	2	5	6	1,31	2
Energieautonom/geladen	15	0	0	1	6	7	1,43	1
Enthält Cadmium	15	3	3	4	0	0	-0,90	5
Fernsteuerbar	14	0	1	0	11	0	0,83	2
Giftig	14	10	2	0	0	0	-1,83	2
Innovativ	15	0	0	0	6	9	1,60	0
Intelligent	15	0	0	2	6	6	1,29	1
Klackend	15	2	3	4	0	0	-0,78	6
Komplexität	14	0	2	9	1	2	0,21	0
Langsam	15	1	5	7	0	0	-0,54	2
Laut	15	6	5	1	0	0	-1,42	3
Lernfähig	15	0	0	0	11	4	1,27	0
Mikroelektromechanisch	5	0	1	2	1	0	0,00	1
molekular	9	0	0	4	3	0	0,43	2
Nanopartikelenthaltend	14	1	3	8	1	0	-0,31	1
nicht An-/Ausschaltbar	15	0	0	1	7	6	-1,36	1
nicht kompostierbar	15	0	0	0	6	5	-1,45	4
Ökologisch	15	0	0	1	7	7	1,40	0
Reflektierend	15	0	2	4	7	1	0,50	1
Selbstleuchtend	15	0	0	6	6	0	0,50	3
Steif	14	0	4	7	1	0	-0,25	2
Surrend	15	2	7	3	0	0	-0,92	3
Unangenehmriechend	15	5	5	1	0	0	-1,36	4
Unbekannt	15	3	4	1	1	1	-0,70	5
Unerwartet	15	1	2	6	1	1	-0,09	4
Unförmig	15	1	8	3	0	0	-0,83	3
Verlässlich	15	0	0	1	4	9	1,57	1
Vielseitigverwendbar	15	0	0	0	5	10	1,67	0
Wartungsintensiv	15	9	4	1	0	0	-1,57	1

Note. The attributes are listed in original language (German); Adapted reverse polarity of *kompostierbar* (compostable) and *An-/ Ausschaltbar* (on/off switchable) to *nicht kompostierbar* (not compostable) and *nicht An-/ Ausschaltbar* (not on/off switchable). *n* = Number of experts who filled in the list; *M* = mean valence rating; miss = Number of experts who did not specify the valence. Adapted from Reuter, L. (2019). Collection and evaluation of basal attributes of living materials systems. https://doi.org/10.13140/RG.2.2.27832.90889

Appendix E

An excerpt of the questionnaire used to survey attribute ratings

Zu jeder Eigenschaft bitten wir Dich anzugeben, wie positiv und wie negativ Du diese Eigenschaft findest. Außerdem fragen wir Dich wie wichtig diese Eigenschaft für Dich ist, das heißt wie stark die jeweilige Eigenschaft Deine Gesamtbewertung des PlastGats beeinflusst.

Dafür stellen wir Dir zu jeder Eigenschaft drei Fragen:

1. Wie positiv ist diese Eigenschaft für Dich? (0=neutral; 1=eher positiv; 2=positiv; 3=sehr positiv)

2. Wie negativ ist diese Eigenschaft für Dich? (0=neutral; 1=eher negativ; 2=negativ; 3=sehr negativ)

3. Wie wichtig ist diese Eigenschaft für Dich? (0=nicht wichtig; 1= ein bisschen wichtig; 2= wichtig; 3=sehr wichtig)

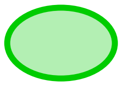
	0	1	2	3
Wartungsintensiv: Positive Bewertung	○	○	○	○
Wartungsintensiv: Negative Bewertung	○	○	○	○
Wartungsintensiv: Wichtigkeit	○	○	○	○

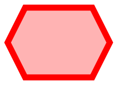
Note. Here only for the attribute *wartungsintensiv* (high-maintenance).

Appendix F

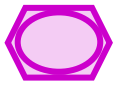
Summary of the rules for drawing CAMs and functions of EMPATHICA

Emotionale Bewertung


= Positiv


= Negativ


= Neutral


= Ambivalent (Positiv & Negativ)

Je wichtiger das Argument, desto dicker sollte dessen Umrandung sein!

Falls Du bezüglich eines Arguments etwas anmerken möchtest, nutze die Kommentarfunktion im Programm

Verbindungen

Eine Verbindung zwischen zwei Argumenten bedeutet, dass sie für Dich in Beziehung stehen

Eine *durchgezogene Verbindung* symbolisiert einen unterstützenden Einfluss

Eine *gestrichelte Verbindung* symbolisiert einen hemmenden Einfluss

Eine Pfeilspitze bedeutet, dass die Wirkung einseitig ist!

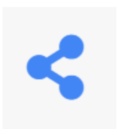
Eine Verbindung ohne Pfeilspitzen bedeutet, dass die Wirkung wechselseitig ist!

Je stärker dieser Einfluss, desto dicker sollte die Verbindung sein!

Funktionen im Programm

Mit dieser Funktion kannst Du die Eigenschaftswörter bewerten. Klicke dazu auf das Symbol und dann auf die Eigenschaft, die Du bewerten möchtest.

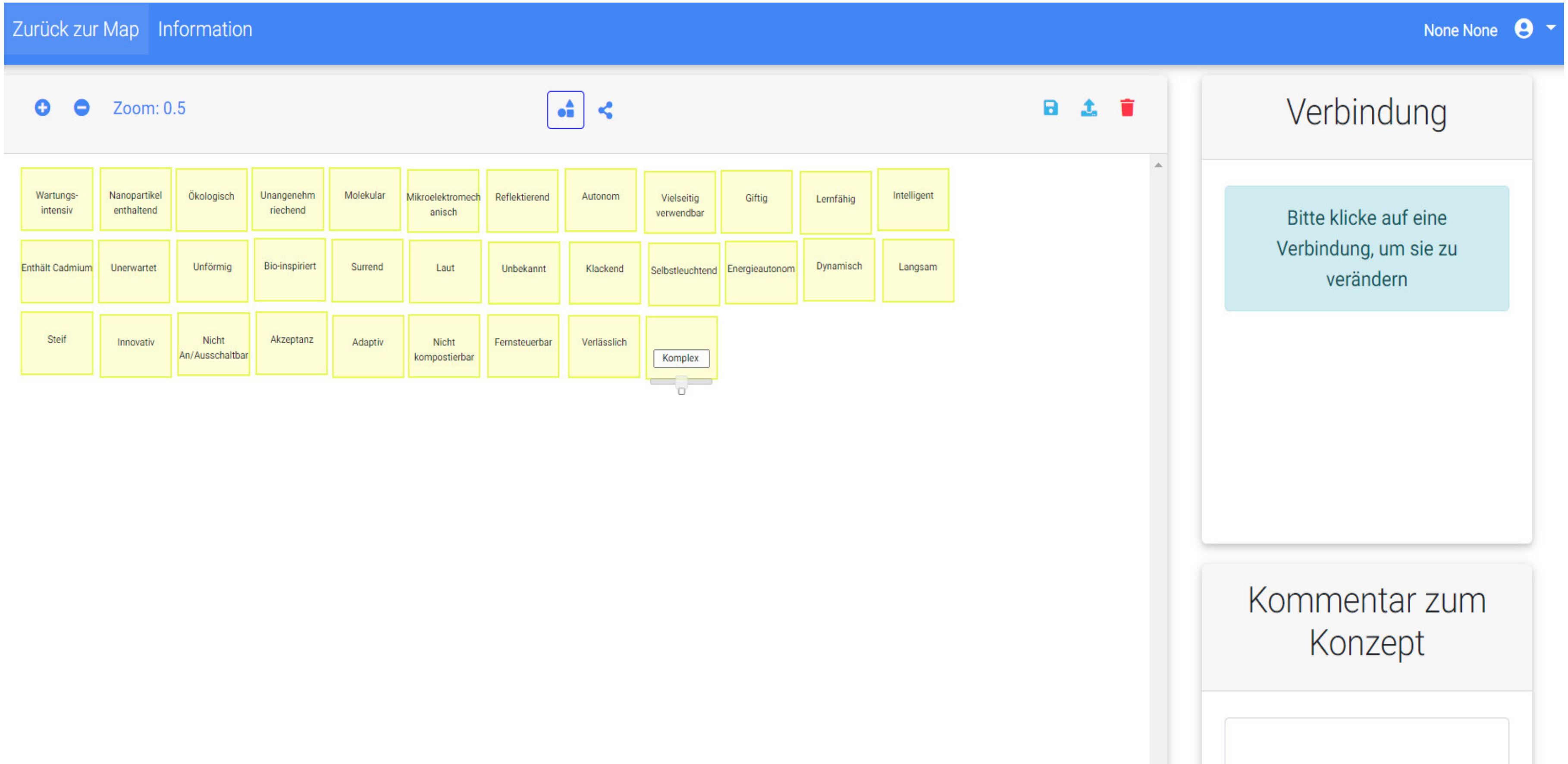
Achtung: Es kann sein, dass Du versehentlich einen neuen Knoten erstellst. Wenn das passiert, bitten wir Dich, diesen neuen Knoten wieder zu löschen. Das kannst Du, indem du den Knoten auswählst und auf deiner Tastatur auf „Entf" drückst.



Mit dieser Funktion kannst Du die Eigenschaften miteinander verbinden. Klicke dazu auf das Symbol und wähle dann die zwei gewünschten Eigenschaften aus, die Du miteinander verbinden möchtest. Danach kannst du die Verbindung nebenan im rechten Fenster anpassen.

Appendix G

Interface of EMPATHICA, how the test persons found it



Appendix H

Missing data in analysis conditions 1 and 2 (CAM)

Test Person	Missing Attribute
A33	Lernfähig
A34	Lernfähig
AU56	Giftig (dafür „Enthält Quecksilber“) [a]
AU67	Giftig (dafür „Enthält Quecksilber“) [a]
A44	Adaptiv
	Bio-inspiriert
	Dynamisch
	Energieautonom
	Enthält Cadmium
	Innovativ
	Klackend
	Komplex
	Lernfähig
	Mikroelektromechanisch
	Molekular
	Nicht an-/ ausschaltbar
	Nicht kompostierbar
	Reflektierend
	Selbstleuchtend
	Steif
	Surrend
	Unangenehm riechend
	Unbekannt
	Unerwartet
	Unförmig
	Verlässlich
	Vielseitig verwendbar
	Wartungsintensiv

Note. [a] The attribute *Enthält Quecksilber* (contains mercury) was changed to *Giftig* (toxic) within the Scenarios whereby the change to the given attributes in EMPATHICA was delayed, so that two test persons evaluated the old attribute *Enthält Quecksilber* instead of *Giftig*.

Appendix I

Missing data in analysis conditions 3 and 4 (questionnaire) of A45, A68 and A69

Test person	Attribute rating	Test person	Attribute rating
A45	Wartungsintensiv_1	A68	Molekular_1
A69	Wartungsintensiv_1	A68	Molekular_2
A69	Nanopartikelenthaltend_1	A68	Unerwartet_2
A69	Ökologisch_1	A68	Unförmig_1
A69	Unangenehm riechend_1	A68	Unförmig_2
A69	Mikroelektromechanisch_1	A68	Bio-inspiriert_1
A69	Reflektierend_1	A68	Bio-inspiriert_2
A69	Autonom_1	A68	Surrend_1
A69	Giftig_1	A68	Surrend_2
A69	Lernfähig_1	A68	Laut_1
A69	Enthält Cadmium_1	A68	Laut_2
A69	Unerwartet_1	A68	Unbekannt_1
A69	Bio-inspiriert_1	A68	Unbekannt_2
A69	Surrend_1	A68	Klackernd_1
A69	Energieautonom_2	A68	Klackernd_2
A69	Steif_2	A68	Selbstleuchtend_1
A69	Nicht kompostierbar_1	A68	Selbstleuchtend_2
		A68	Energieautonom_1
		A68	Energieautonom_2
		A68	Dynamisch_1
		A68	Dynamisch_2
		A68	Steif_1
		A68	Steif_2
		A68	Innovativ_1
		A68	Innovativ_2
		A68	Verlässlich_1
		A68	Verlässlich_2
		A68	Nicht kompostierbar_1
		A68	Nicht kompostierbar_2
		A68	Fernsteuerbar_1
		A68	Fernsteuerbar_2
		A68	Langsam_1
		A68	Langsam_2
		A68	Intelligent_1
		A68	Intelligent_2
		A68	Komplex_1
		A68	Komplex_2
		A68	Adaptiv_1
		A68	Adaptiv_2
		A68	Nicht an-/ ausschaltbar_1
		A68	Nicht an-/ ausschaltbar_2

Note. Attribute followed by the rating of positivity (_1) or negativity (_2); without rating of importance.

Appendix J

Table of attribute rating means for the scenario and method analysis conditions

	Scenario				Method			
Attribute		*n*	*M*	*SD*		*n*	*M*	*SD*
Adaptiv	NanoPat	52	1.37	1.14	CAM	50	1.38	1.01
	PlastGat	53	1.58	1.13	Quest	55	1.56	1.24
Autonom	NanoPat	53	1.00	1.26	CAM	51	1.37	1.11
	PlastGat	54	1.84	1.09	Quest	56	1.47	1.36
Bio-inspiriert	NanoPat	52	1.40	1.27	CAM	50	1.28	1.09
	PlastGat	53	1.84	0.96	Quest	55	1.93	1.10
Dynamisch	NanoPat	52	1.02	1.09	CAM	50	0.92	0.92
	PlastGat	53	1.30	1.12	Quest	55	1.38	1.22
Energieautonom	NanoPat	52	1.75	1.25	CAM	50	2.18	1.08
	PlastGat	53	2.39	1.02	Quest	55	1.98	1.26
Enthält Cadmium	NanoPat	53	-1.64	1.43	CAM	50	-1.70	1.22
	PlastGat	53	-1.61	1.35	Quest	56	-1.56	1.53
Fernsteuerbar	NanoPat	52	0.44	1.41	CAM	51	1.14	1.36
	PlastGat	54	1.72	1.43	Quest	55	1.05	1.73
Giftig	NanoPat	52	-2.29	1.43	CAM	49	-2.69	0.65
	PlastGat	53	-2.41	0.97	Quest	56	-2.05	1.49
Innovativ	NanoPat	52	1.48	1.13	CAM	50	1.46	0.95
	PlastGat	53	1.83	0.87	Quest	55	1.84	1.05
Intelligent	NanoPat	52	1.60	1.12	CAM	51	1.78	0.88
	PlastGat	54	1.74	1.22	Quest	55	1.56	1.38
Klackend	NanoPat	52	-1.10	1.45	CAM	50	-1.28	0.90
	PlastGat	53	-1.11	1.10	Quest	55	-0.95	1.53
Komplex	NanoPat	52	0.00	1.24	CAM	50	-0.28	0.83
	PlastGat	53	-0.02	0.93	Quest	55	0.24	1.23
Langsam	NanoPat	52	-0.69	1.06	CAM	51	-0.75	0.84
	PlastGat	54	-0.69	1.16	Quest	55	-0.64	1.31
Laut	NanoPat	52	-1.56	1.46	CAM	51	-1.88	0.99
	PlastGat	54	-1.78	1.09	Quest	55	-1.47	1.49
Lernfähig	NanoPat	52	1.42	1.24	CAM	48	1.88	0.98
	PlastGat	52	1.79	1.21	Quest	56	1.37	1.38
Mikroelektromechanisch	NanoPat	53	0.17	1.14	CAM	50	0.34	0.77
	PlastGat	53	0.53	1.07	Quest	56	0.36	1.35
Molekular	NanoPat	52	0.27	1.10	CAM	50	0.28	0.54
	PlastGat	53	0.60	1.08	Quest	55	0.58	1.42
Nanopartikel enthaltend	NanoPat	53	-0.04	1.40	CAM	51	-0.02	1.29
	PlastGat	54	0.26	1.60	Quest	56	0.24	1.68
Nicht An-/ Ausschaltbar	NanoPat	52	-1.00	1.47	CAM	50	-1.02	0.96
	PlastGat	53	-1.04	1.22	Quest	55	-1.02	1.63
Nicht kompostierbar	NanoPat	52	-1.40	1.38	CAM	50	-1.60	0.97
	PlastGat	53	-1.84	1.02	Quest	55	-1.65	1.43
Ökologisch	NanoPat	53	1.81	1.44	CAM	51	2.16	1.01
	PlastGat	54	2.14	1.12	Quest	56	1.82	1.50
Reflektierend	NanoPat	53	1.26	1.33	CAM	50	0.66	1.10

(continued)

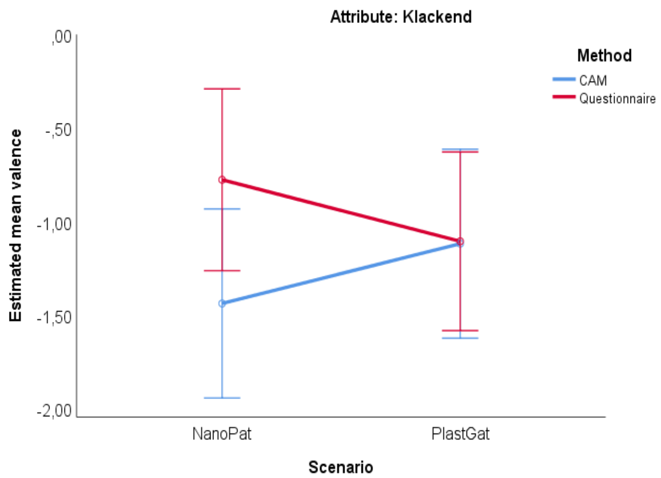
Table of attribute rating means for the scenario and method analysis conditions (continued)

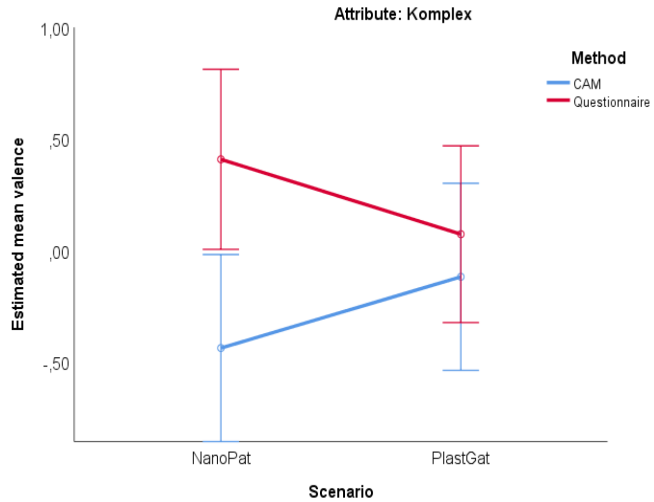
Attribute		Scenario				Method		
		n	*M*	*SD*		*n*	*M*	*SD*
	PlastGat	53	0.38	1.35	Quest	56	0.97	1.63
Selbstleuchtend	NanoPat	52	1.23	1.25	CAM	50	0.98	1.13
	PlastGat	53	0.98	1.39	Quest	55	1.22	1.47
Steif	NanoPat	52	-0.88	1.44	CAM	50	-0.72	0.95
	PlastGat	53	-0.26	0.85	Quest	55	-0.43	1.41
Surrend	NanoPat	52	-1.29	1.29	CAM	50	-1.30	0.91
	PlastGat	53	-1.14	1.05	Quest	55	-1.14	1.37
Unangenehm riechend	NanoPat	53	-1.96	1.40	CAM	50	-1.74	1.01
	PlastGat	53	-1.30	1.09	Quest	56	-1.53	1.51
Unbekannt	NanoPat	52	-0.37	1.22	CAM	50	-0.56	0.76
	PlastGat	53	-0.53	1.03	Quest	55	-0.35	1.38
Unerwartet	NanoPat	52	-0.29	1.23	CAM	50	-0.46	0.86
	PlastGat	53	-0.23	1.18	Quest	55	-0.08	1.42
Unförmig	NanoPat	52	-0.98	1.46	CAM	50	-0.84	0.93
	PlastGat	53	-0.21	0.74	Quest	55	-0.36	1.39
Verlässlich	NanoPat	52	1.75	1.10	CAM	50	1.92	0.90
	PlastGat	53	2.21	0.99	Quest	55	2.04	1.20
Vielseitig verwendbar	NanoPat	53	1.87	1.26	CAM	50	1.96	0.97
	PlastGat	53	2.13	0.81	Quest	56	2.04	1.14
Wartungsintensiv	NanoPat	53	-1.38	1.46	CAM	50	-1.64	1.08
	PlastGat	53	-1.16	1.44	Quest	56	-0.93	1.64

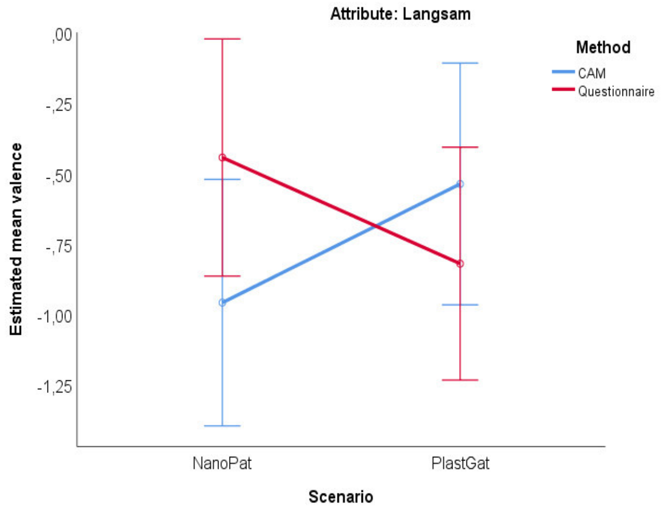
Note. Mean valence ratings to illustrate the valence direction of the results from the Bayesian ANOVAs shown in Table 5 within this study. Lines with significant *p*-values are in yellow, lines with $p < .2$ are in grey;

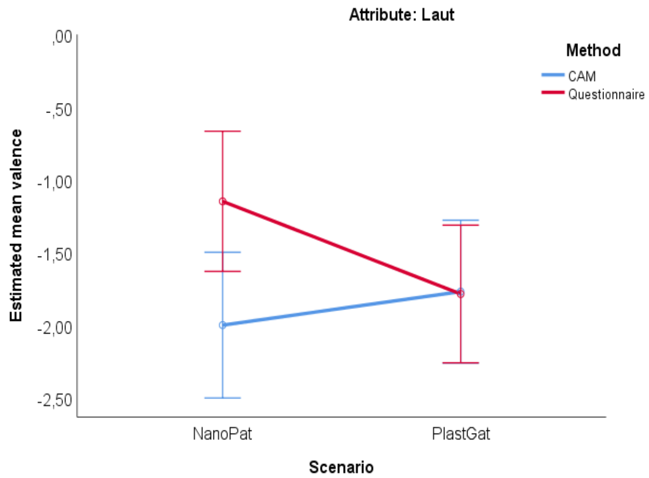
Appendix K

Graphical presentation of the six attributes with potential trends of interaction effects (p < .2)



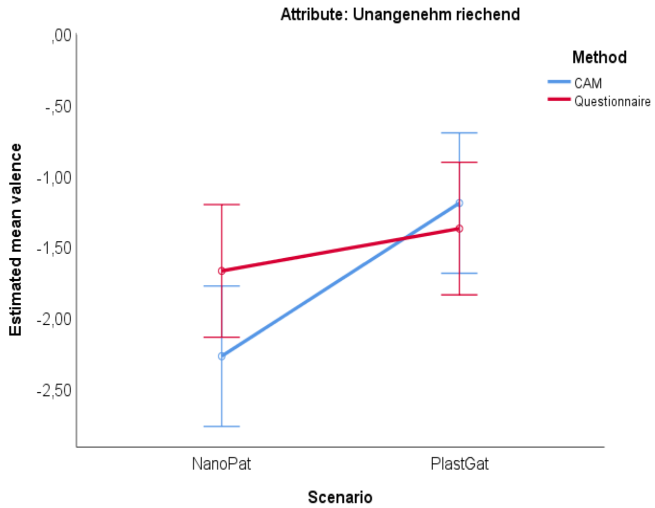


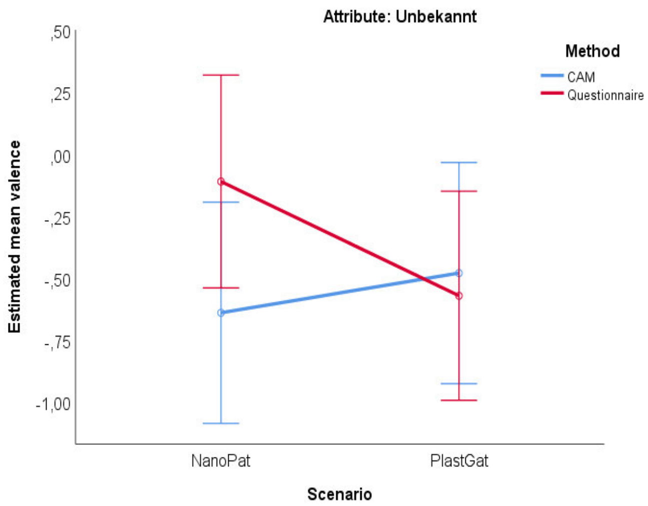




(continued)

Graphical presentation of the six attributes with potential trends of interaction effects (p < .2) (continued)





Note. Error bars indicate the 95% confidence interval; Corresponding group statistics can be seen in Appendix L.

Appendix L

Table of t-tests and corresponding Bayes Factors for nearly significant interaction effects (p < .2)

		t-test			Bayes Factor		Group statistics			
Attribute	Analysis conditions	*T*	*df*	*p*	BF_{10}	BF_{01}	Analysis condition	*n*	*M*	*SD*
Klackend (clicking)	CAM vs. Quest [NP]	-1.72	40	.094	1.08		CAM [NP]	25	-1.44	0.92
							Quest [NP]	27	-0.78	1.76
	CAM vs. Quest [PG]	-0.04	48	.966	3.61		CAM [PG]	25	-1.12	0.88
							Quest [PG]	28	-1.11	1.29
	NP vs. PG [CAM]	-1.26	48	.214	1.85		NP [CAM]	25	-1.44	0.92
							PG [CAM]	25	-1.12	0.88
	NP vs. PG [Quest]	0.79	53	.431	2.83		NP [Quest]	27	-0.78	1.76
							PG [Quest]	28	-1.11	1.29
Komplex (complex)	CAM vs. Quest [NP]	-2.66	42	.011*		4.61	CAM [NP]	25	-0.44	0.82
							Quest [NP]	27	0.41	1.42
	CAM vs. Quest [PG]	-0.74	51	.460	2.88		CAM [PG]	25	-0.12	0.83
							Quest [PG]	28	0.07	1.02
	NP vs. PG [CAM]	-1.37	48	.177	1.65		NP [CAM]	25	-0.44	0.82
							PG [CAM]	25	-0.12	0.83
	NP vs. PG [Quest]	1.01	47	.320	2.42		NP [Quest]	27	0.41	1.42
							PG [Quest]	28	0.07	1.02

(continued)

Table of t-tests and corresponding Bayes Factors for nearly significant interaction effects (continued)

	t-test				Bayes Factor		Group statistics			
Attribute	Analysis conditions	*T*	*df*	*p*	BF_{10}	BF_{01}	Analysis condition	*n*	*M*	*SD*
Langsam (slow)	CAM vs. Quest [NP]	-1.83	40	.074		1.09	CAM [NP]	25	-0.96	0.68
							Quest [NP]	27	-0.44	1.28
	CAM vs. Quest [PG]	0.89	52	.377	2.62		CAM [PG]	26	-0.54	0.95
							Quest [PG]	28	-0.82	1.33
	NP vs. PG [CAM]	-1.83	45	.073		1.10	NP [CAM]	25	-0.96	0.68
							PG [CAM]	26	-0.54	0.95
	NP vs. PG [Quest]	1.07	53	.290	2.29		NP [Quest]	27	-0.44	1.28
							PG [Quest]	28	-0.82	1.33
Laut (loud)	CAM vs. Quest [NP]	-2.23	40	.032*		2.05	CAM [NP]	25	-2.00	0.91
							Quest [NP]	27	-1.15	1.75
	CAM vs. Quest [PG]	0.05	52	.956	3.64		CAM [PG]	26	-1.77	1.07
							Quest [PG]	28	-1.79	1.13
	NP vs. PG [CAM]	-0.83	49	.412	2.69		NP [CAM]	25	-2.00	0.91
							PG [CAM]	26	-1.77	1.07
	NP vs. PG [Quest]	1.60	44	.117	1.28		NP [Quest]	27	-1.15	1.75
							PG [Quest]	28	-1.79	1.13

(continued)

Table of t-tests and corresponding Bayes Factors for nearly significant interaction effects (continued)

	t-test				Bayes Factor		Group statistics			
Attribute	Comparison	*T*	*df*	*p*	BF_{10}	BF_{01}	Analysis condition	*N*	*M*	*SD*
Unangenehm riechend (unpleasantly smelling)	CAM vs. Quest [NP]	-1.64	42	.109	1.21		CAM [NP]	25	-2.28	0.89
							Quest [NP]	28	-1.68	1.70
	CAM vs. Quest [PG]	0.61	46	.545	3.10		CAM [PG]	25	-1.20	0.82
							Quest [PG]	28	-1.38	1.30
	NP vs. PG [CAM]	-4.47	48	<.001***		417.19	NP [CAM]	25	-2.28	0.89
							PG [CAM]	25	-1.20	0.82
	NP vs. PG [Quest]	-0.74	54	.464	2.95		NP [Quest]	28	-1.68	1.70
							PG [Quest]	28	-1.38	1.30
Unbekannt (unknown)	CAM vs. Quest [NP]	-1.58	50	.120	1.29		CAM [NP]	25	-0.64	0.86
							Quest [NP]	27	-0.11	1.45
	CAM vs. Quest [PG]	0.33	41	.743	3.46		CAM [PG]	25	-0.48	0.65
							Quest [PG]	28	-0.57	1.29
	NP vs. PG [CAM]	-0.74	48	.463	2.82		NP [CAM]	25	-0.64	0.86
							PG [CAM]	25	-0.48	0.65
	NP vs. PG [Quest]	1.25	53	.218	1.94		NP [Quest]	27	-0.11	1.45
							PG [Quest]	28	-0.57	1.29

Note. *t*-tests to compare valence ratings of certain analysis conditions with NP (Nano-Pat-Parka), PG (PlastGat), CAM (Cognitive-Affective-Mapping) and Quest (Questionnaire); Lines with significant *p*-values are in yellow, lines with $p < .2$ are in grey; Method used to estimate the Bayes Factor: JZS, BF_{10} is the Bayes Factor in favour of H_1, BF_{01} is the Bayes Factor in favour of H_0.
*$p < .05$; **$p < .01$; ***$p < .001$.

Appendix M

Results from comparison of expert and novice ratings

	t-test			Bayes Factor			Group statistics			Original means	
Attribute	*df*	*T*	*p*	BF_{10}	BF_{01}	Condition	*N*	*M*	*SD*	*M*	*SD*
Adaptiv	49	-4.13	<.001***		208.35	Novices	55	0.66	0.65	1.56	1.24
						Experts	15	1.16	0.31	1.80	0.41
Autonom	69	-0.69	.492	2.85		Novices	56	0.62	0.71	1.47	1.36
						Experts	15	0.76	0.60	1.27	0.80
Bio-inspiriert	67	-0.11	.910	3.36		Novices	55	0.86	0.58	1.93	1.10
						Experts	14	0.88	0.49	1.43	0.65
Dynamisch	66	-0.83	.412	2.51		Novices	55	0.57	0.64	1.38	1.22
						Experts	13	0.73	0.55	1.23	0.73
Energieautonom	67	0.29	.769	3.27		Novices	55	0.88	0.66	1.98	1.26
						Experts	14	0.82	0.56	1.36	0.74
Enthält Cadmium	63	-0.68	.500	2.47		Novices	56	-0.97	0.80	-1.56	1.53
						Experts	9	-0.78	0.63	-0.78	0.83
Fernsteuerbar	54	-1.29	.204	1.67		Novices	55	0.40	0.90	1.05	1.73
						Experts	12	0.55	0.00	1.00	0.00
Giftig	48	2.61	.012*		4.41	Novices	56	-1.23	0.78	-2.05	1.49
						Experts	12	-1.58	0.29	-1.83	0.39
Innovativ	68	-1.31	.194	1.73		Novices	55	0.81	0.55	1.84	1.05
						Experts	15	1.01	0.38	1.60	0.51
Intelligent	67	-0.51	.615	3.04		Novices	55	0.66	0.73	1.56	1.38
						Experts	14	0.77	0.55	1.29	0.73
Klackend	61	0.06	.951	2.83		Novices	55	-0.65	0.80	-0.95	1.53
						Experts	8	-0.67	0.56	-0.63	0.74
Komplex	67	0.03	.977	3.38		Novices	55	-0.03	0.65	0.24	1.23
						Experts	14	-0.04	0.67	0.21	0.89
Langsam	66	0.57	.572	2.90		Novices	55	-0.49	0.69	-0.64	1.31
						Experts	13	-0.60	0.50	-0.54	0.66
Laut	65	1.17	.248	1.88		Novices	55	-0.93	0.78	-1.47	1.49
						Experts	12	-1.20	0.49	-1.33	0.65
Lernfähig	49	-1.45	.155	1.48		Novices	56	0.57	0.73	1.37	1.38
						Experts	15	0.76	0.34	1.27	0.46
Mikroelektromechanisch	58	0.12	.907	2.28		Novices	56	0.03	0.71	0.36	1.35
						Experts	4	-0.01	0.38	0.25	0.50
Molekular	60	0.09	.930	2.70		Novices	55	0.15	0.75	0.58	1.42
						Experts	7	0.12	0.40	0.43	0.53
Nanopartikel enthaltend	27	2.04	.052		1.57	Novices	56	-0.03	0.88	0.24	1.68
						Experts	13	-0.43	0.57	-0.31	0.75
Nicht An-/ Ausschaltbar	67	1.77	.082		1.03	Novices	55	-0.69	0.85	-1.02	1.63
						Experts	14	-1.11	0.53	-1.21	0.70
Nicht kompostierbar	63	1.26	.211	1.65		Novices	55	-1.02	0.75	-1.65	1.43
						Experts	10	-1.33	0.40	-1.50	0.53

(continued)

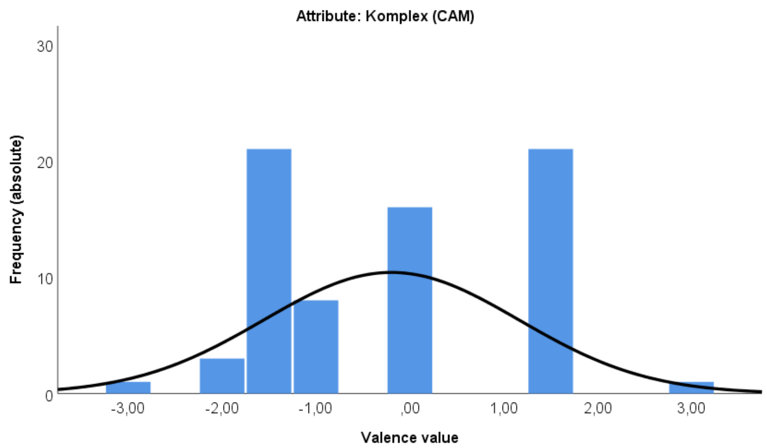
Results from comparison of expert and novice ratings (continued)

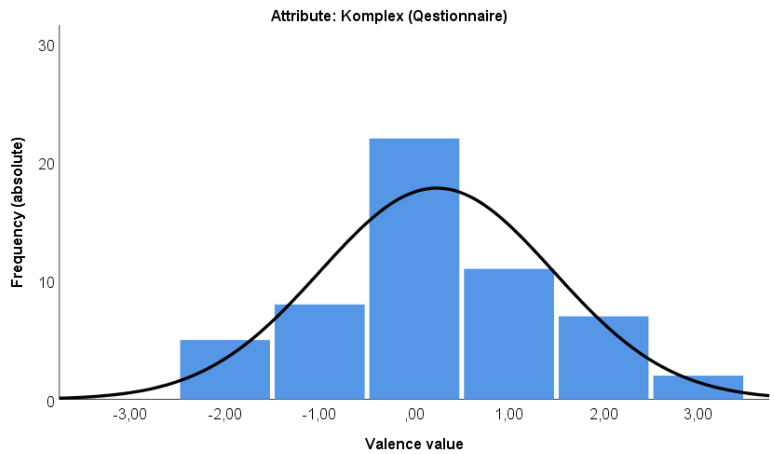
	t-test			Bayes Factor			Group statistics			Original means	
Attribute	*df*	*T*	*p*	BF_{10}	BF_{01}	Condition	*N*	*M*	*SD*	*M*	*SD*
Ökologisch	69	-0.51	.609	3.11		Novices	56	0.80	0.79	1.82	1.50
						Experts	15	0.91	0.48	1.47	0.64
Reflektierend	67	0.80	.426	2.56		Novices	56	0.35	0.86	0.97	1.63
						Experts	13	0.15	0.66	0.46	0.88
Selbstleuchtend	64	1.41	.162	1.45		Novices	55	0.48	0.77	1.22	1.47
						Experts	11	0.14	0.39	0.45	0.52
Steif	65	0.03	.979	3.22		Novices	55	-0.38	0.74	-0.43	1.41
						Experts	12	-0.39	0.47	-0.25	0.62
Surrend	65	0.62	.535	2.77		Novices	55	-0.75	0.72	-1.14	1.37
						Experts	12	-0.89	0.50	-0.92	0.67
Unangenehm riechend	64	0.85	.400	2.30		Novices	56	-0.96	0.79	-1.53	1.51
						Experts	10	-1.18	0.51	-1.30	0.67
Unbekannt	62	1.02	.312	1.98		Novices	55	-0.34	0.72	-0.35	1.38
						Experts	9	-0.62	1.00	-0.56	1.33
Unerwartet	64	0.57	.569	2.76		Novices	55	-0.19	0.74	-0.08	1.42
						Experts	11	-0.34	0.74	-0.18	0.98
Unförmig	65	2.19	.032		2.03	Novices	55	-0.35	0.73	-0.36	1.39
						Experts	12	-0.83	0.43	-0.83	0.58
Verlässlich	67	-0.40	.690	3.17		Novices	55	0.91	0.63	2.04	1.20
						Experts	14	0.98	0.49	1.57	0.65
Vielseitig verwendbar	69	-0.89	.378	2.51		Novices	56	0.91	0.60	2.04	1.14
						Experts	15	1.06	0.37	1.67	0.49
Wartungsintensiv	68	2.85	.006**		7.32	Novices	56	-0.64	0.86	-0.93	1.64
						Experts	14	-1.33	0.49	-1.50	0.65

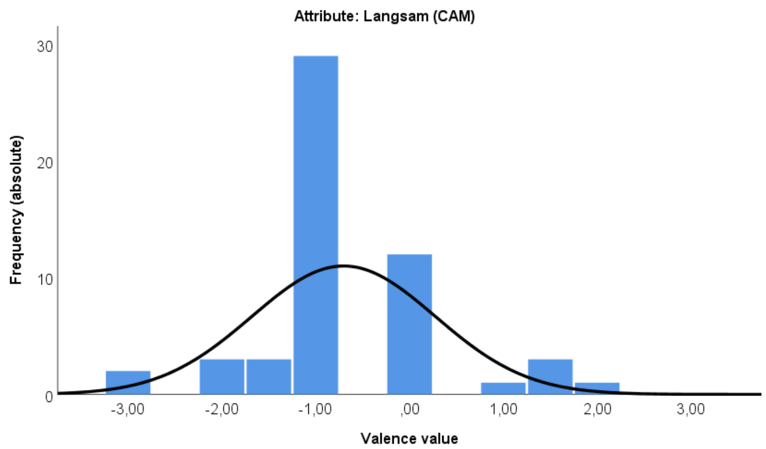
Note. *t*-tests to compare z-transformed mean valence ratings of attributes form experts with those from novices; Expert ratings received in raw data from Reuter, L. (2019). Collection and evaluation of basal attributes of living materials systems. https://doi.org/10.13140/RG.2.2.27832.90889; which were surveyed on a 5-point scale (-2 = negative valence and 2 = positive valence); Novice ratings are analysis conditions 3 and 4 of this study (Nano-Pat-Parka and PlastGat [Questionnaire]), which were surveyed on a 4-point scale (0 = neutral and 3 = strong); Original means before z-transformation, as I excluded all cases with missing data, some of the original mean valence ratings of the experts calculated here may vary slightly from the means that were calculated by Reuter; Lines with significant p-values are in yellow, lines with $p < .2$ are in grey; Method used to estimate the Bayes Factor: JZS, Scale r on effect size: 0.707; BF_{10} is the Bayes Factor in favour of H_1, BF_{01} is the Bayes Factor in favour of H_0.
**p* < .05; ***p* < .01; ****p* < .001.

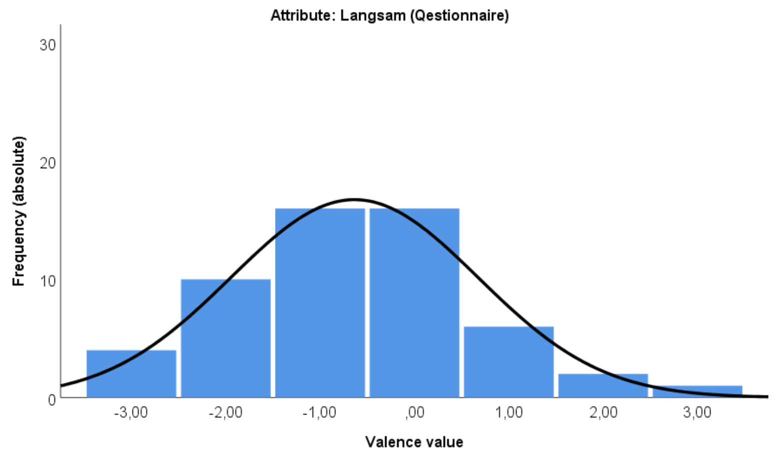
Appendix N.

Histograms of the valence evaluation distributions of six attributes, separated for the CAM and questionnaire method



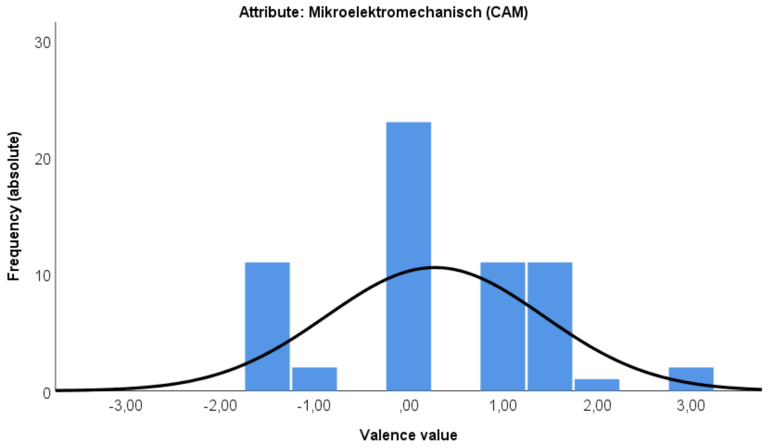


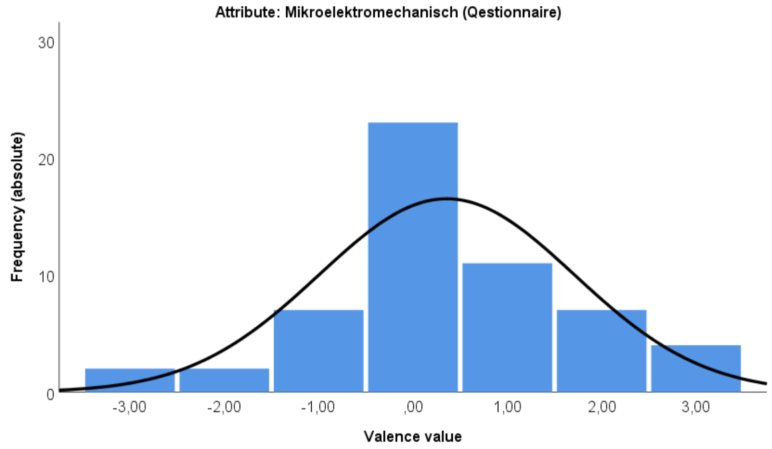


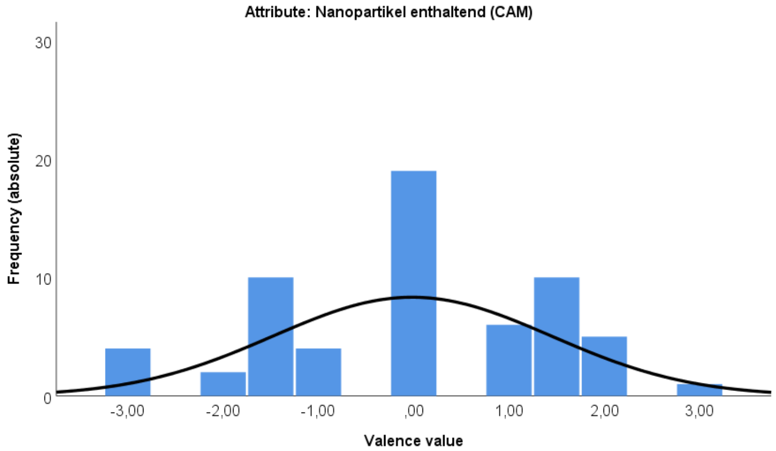


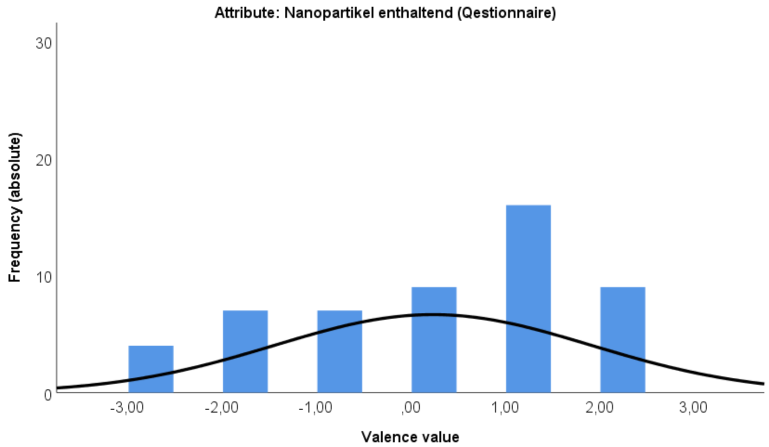
(continued)

Histograms of the valence evaluation distributions of six attributes, separated for the CAM and questionnaire method (continued)



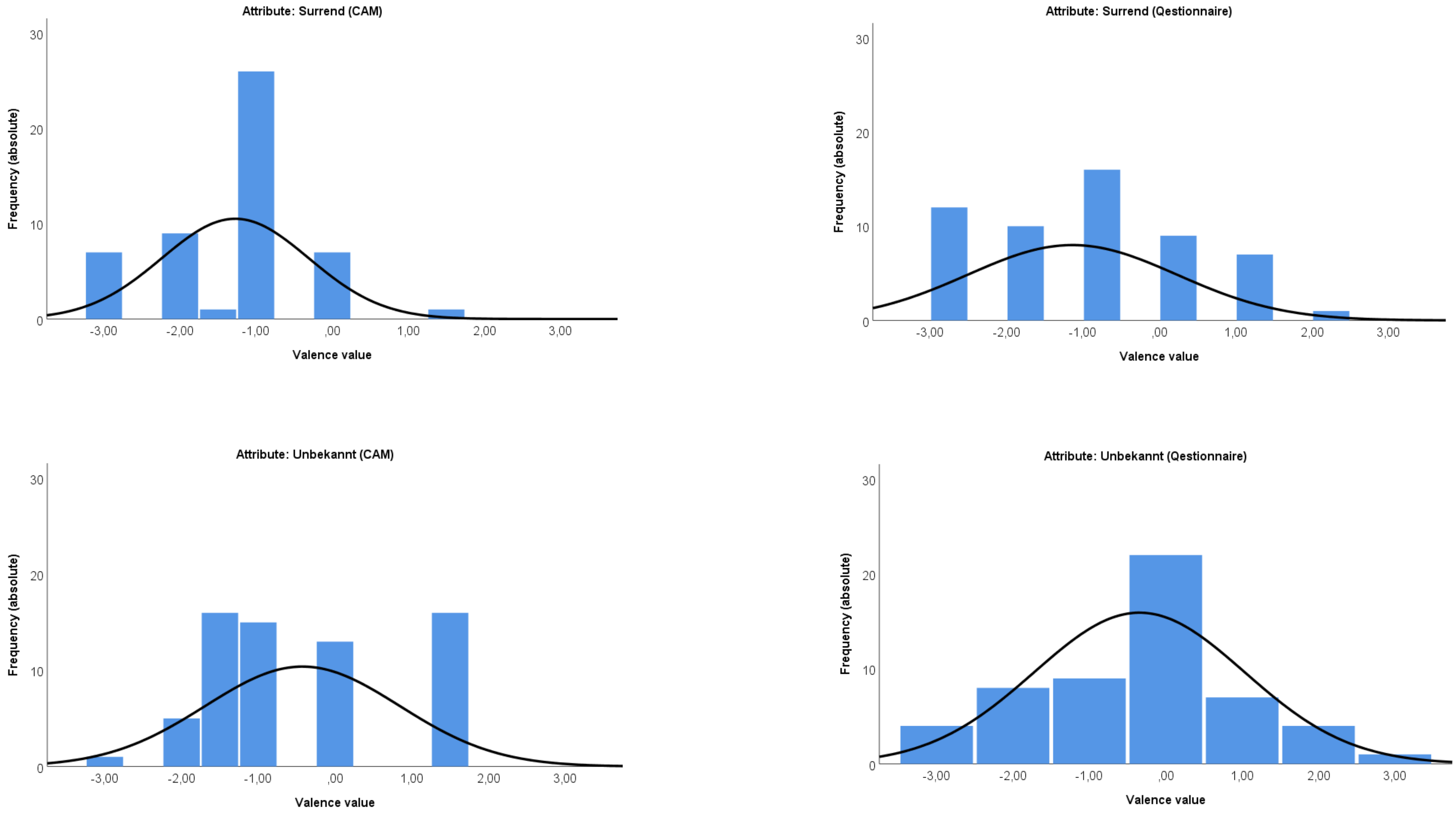






(continued)

Histograms of the valence evaluation distributions of six attributes, separated for the CAM and questionnaire method (continued).



Note. Number of ratings included in these histograms and means are presented in Appendix O; Histograms include the normal distribution curve.

Appendix O

Number of ratings included in the histograms of Appendix N

Attribute	n^a	M^b	*SD*
Nanopartikel enthaltend (CAM)	61	-0.02	1.46
Nanopartikel enthaltend (Quest)	56	0.24	1.68
Komplex (CAM)	71	-0.20	1.36
Komplex (Quest)	55	0.24	1.23
Langsam (CAM)	54	-0.70	0.98
Langsam (Quest)	55	-0.64	1.31
Mikroelektromechanisch (CAM)	61	0.28	1.15
Mikroelektromechanisch (Quest)	56	0.36	1.35
Surrend (CAM)	51	-1.27	0.97
Surrend (Quest)	55	-1.14	1.37
Unbekannt (CAM)	66	-0.42	1.27
Unbekannt (Quest)	55	-0.35	1.38

Note. [a + b] An evaluation as ambivalent is simultaneously included as +1.5 and -1.5 and is counted as two ratings.

Erklärung

Ich versichere hiermit, dass ich die beiliegende Arbeit mit dem Thema:

A Step towards Sustainable Development:
Predicting the Acceptance of life-like Materials Systems with Cognitive-Affective Mapping

selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.
Die Stellen, die anderen Werken dem Wortlaut und dem Sinn nach entnommen sind, habe ich in jedem einzelnen Falle durch Angabe der Quelle, auch der benutzten Sekundärliteratur, als Entlehnung kenntlich gemacht.

Mir ist bekannt, dass die Prüfung für nicht bestanden erklärt wird und dass ich von der Wiederholungsprüfung ausgeschlossen werden kann, falls sich die Unwahrheit der abgegebenen Versicherung erweist.

Ich bin damit einverstanden, dass meine beiliegende Arbeit öffentlich einsehbar ist (Bibliothek) und der wissenschaftlichen Forschung zur Verfügung steht.

Freiburg, den 04.08.2020

D.Ricken
(Unterschrift)