OSNABRÜCK UNIVERSITY

DOCTORAL THESIS

Digital Assistance for Goal-Setting and Goal Pursuit in Higher Education

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A thesis submitted in fulfillment of the requirements for the degree of Dr. rer. nat.

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Cognitive Science

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Declaration of Authorship

I, Felix WEBER, declare that this thesis titled, “Digital Assistance for Goal-Setting and Goal Pursuit in Higher Education” and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself (see Appendix G.

Signed:

Date:

“If you trust in yourself. . .and believe in your dreams. . .and follow your star. . . you’ll still get beaten by people who spent their time working hard and learning things and weren’t so lazy.”

Terry Pratchett, The Wee Free Men

OSNABRÜCK UNIVERSITY

Abstract

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Digital Assistance for Goal-Setting and Goal Pursuit in Higher Education

by Felix WEBER

This doctoral thesis investigates how data and AI-driven digital assistants can support university students in goal setting, goal pursuit, and achievement. The first chapter introduces contextual information about higher education, human-machine interaction, self-regulated learning, digital study assistants, and constructivism. The first chapter also clarifies the aims and motivation, states the main research questions, and concludes with an outlook on the content and structure of the text. In the second chapter, goals are introduced as a concept in the Cognitive Sciences, ranging from motor control, human-machine interaction, AI algorithms, planning, games, navigation, and human motivation. The second chapter also disambiguates the *goal* construct from related terms and constructs. The third chapter summarizes two approaches to measuring goal characteristics that have been taken during the dissertation research: An external approach was based on extensive tagging of goals by six raters, while an internal approach was based on self-assessment with a Likert-scale questionnaire. The fourth chapter centers around the *Hierarchical Goal Systems (HGS)* concept. It starts with a theoretical foundation, including a review of hierarchical goal structures in the literature, formal and functional definitions of Hierarchical Goal Systems, and potential advantages and disadvantages of such representations. The central part of chapter four describes the development process and a row of formative field studies with a hierarchical goal-setting assistant called "GoalTrees", publicly available as open-source software under an MIT license. In the productive database of the field study server, a significant amount of hierarchical goal system data and goal characteristics scores has been accumulated. Chapter five outlines how this data can be utilized to reproduce previous findings and increase knowledge about goal types, based on the theoretical concept of *Conceptual Spaces*, combined with goal data in goal characteristics space. Clustering in a high-dimensional conceptual space of goal characteristics can potentially work as a data-driven, bottom-up process in the proposed approach. Chapter six summarizes the findings and insights from this line of research on an ontological and epistemological level, reflects on the applied methods and scientific practice, and concludes with an outlook on future research and possible next steps. Due to the high interaction costs for users to answer questionnaires to measure goal characteristics, a reliable prediction procedure for characteristics based on goal formulations in natural language, for instance, a pre-trained and fine-tuned BERT neural network, could significantly improve the usability and user experience of *GoalTrees* in the future.

Zusammenfassung

Diese Doktorarbeit untersucht, wie daten- und KI-gestriebene digitale Assistenten Universitätsstudenten bei der Zielsetzung, Zielverfolgung und -erreichung unterstützen können. Das erste Kapitel stellt Kontextinformationen zu Hochschulbildung, Mensch-Maschine-Interaktion, selbstreguliertem Lernen, digitalen Studienassistenten und Konstruktivismus vor. Das erste Kapitel verdeutlicht zudem Ziele und Motivation, nennt die zentralen Forschungsfragen und schließt mit einem Ausblick auf Inhalt und Struktur des Textes. Im zweiten Kapitel werden Ziele als Konzept in den Kognitionswissenschaften eingeführt, welche von Motorik, Mensch-Maschine-Interaktion, KI-Algorithmen, Planung, Spielen, Navigation und menschlicher Motivation reichen. Das zweite Kapitel grenzt zudem das *Ziel*-Konstrukt von verwandten Begriffen und Konstrukten ab. Das dritte Kapitel fasst zwei Ansätze zur Messung von Zielcharakteristika zusammen, die während der Dissertationsforschung verfolgt wurden: Ein externer Ansatz basierte auf einer ausführlichen Kennzeichnung von Zielen durch sechs Rater, während ein interner Ansatz auf einer Selbsteinschätzung mit einem Fragebogen mit einer Likert-Antwortskala. Das vierte Kapitel dreht sich um das Konzept von *Hierarchischen Zielsystemen*. Es beginnt mit den theoretischen Grundlagen, einschließlich einer Literaturrecherche zu hierarchischer Zielstrukturen, den formalen und funktionalen Definitionen hierarchischer Zielsysteme und moeglicher Vor- und Nachteile hierarchischer Repräsentation von Zielsystemen. Der zentrale Teil des vierten Kapitels beschreibt den Entwicklungsprozess und eine Sequenz formativer Feldstudien mit einem digitalen Studienassistenten auf der Basis hierarchischen Zielsysteme namens „GoalTrees“, der als Open-Source-Software unter MIT-Lizenz veröffentlicht wurde. In der produktiven Datenbank des Feldstudienservers wurde eine beträchtliche Menge an hierarchischen Zielsystemdaten und Zielkennwerten gesammelt. Kapitel fünf skizziert, wie diese Daten verwendet werden können, um frühere Erkenntnisse zu reproduzieren und das Wissen über Zieltypen zu erweitern, basierend auf dem theoretischen Konzept von *Conceptual Spaces*, kombiniert mit Zieldaten in einem Raum von Zielcharakteristika. Es wird der Ansatz skizziert, dazu Clustering in einem hochdimensionalen konzeptionellen Raum von Zielmerkmalen als datengesteuerten Bottom-up-Prozess zu verwenden. Kapitel sechs fasst die Ergebnisse und Erkenntnisse dieser Forschungsrichtung auf ontologischer und epistemologischer Ebene zusammen, reflektiert angewandte Methoden und wissenschaftliche Praxis und schließt mit einem Ausblick auf zukünftige Forschung und mögliche nächste Schritte. Aufgrund der hohen Interaktionskosten für die Beantwortung von Fragebögen zur Messung von Zielcharakteristika könnte ein zuverlässiges Vorhersageverfahren für Merkmale auf Basis von Zielformulierungen in natürlicher Sprache, beispielsweise ein vortrainiertes und fein-getunetes neuronales Netz, basierend auf BERT, die Usability und UX von *GoalTrees* in der Zukunft deutlich verbessern .

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The research documented in this doctoral thesis would not have been possible without the support of colleagues, partners, friends, mentors, and beneficial circumstances. The Joint Project for Individualization of Studies through Digital, Data-Driven Assistants, "SIDDATA" formed a temporarily safe material foundation in the form of funding, provided a significant amount of inspiration from the vision outlined in the project proposal, and many challenges in the annual software development cycles with an interdisciplinary team of experts in Higher Education Research, Information Systems, Cognitive Science, and Software Development, at the universities of Bremen, Hannover, and Osnabrück, and the HIS-HE Institute for Higher Education in Hannover. Especially I would like to thank Tim Brauner, Kai-Christoph Hamborg, Jeroen van Kempen, Claudia König, Peter König, Kai-Uwe Kühnberger, Maren Lübcke, Debora Nolte, Yildiary Ogurol, Sebastian Osada, Funda Seyfeli, Katharina Schurz, and Klaus Wannemacher.

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Much of my dissertation project work has relied on open-source software, such as, for instance, Stud.IP, d3.js, and various Python libraries. My programming routines included a lot of online searches with search engines, such as Startpage or Qwant, which do not exploit users' personal data for profits as Google and other evil search engines do. Many of the searches led to Stack Overflow, where answers to my questions, which most often had been asked by others before me, helped me to solve my programming tasks. Thanks a lot to the open-source and programming communities worldwide.

Of course, I have to thank Springer and Elsevier for printing my works for a bit of funding from taxpayers, who allowed me to read scientific literature for a bit of funding from taxpayers, and now are so incredibly freehanded to allow me to publish parts of their literary property in my dissertation. I cannot wait to express my gratitude through some unsalaried reviews.

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Thanks to Marianne Schneider, who did a final review with the precision of a Swiss clockmaker.

Last but not least, I want to thank my supervisor Tobias Thelen, not only for being the mastermind behind the SIDDATA project, among others but also for being an inspiring example of how to successfully shape digitalization in higher education and make the most out of 24 hours a day.

Contents

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Listings

List of Abbreviations

AI	Artificial Intelligence
ANOVA	Analysis of Variance
APA	American Psychological Association
API	Application Programming Interface
BERT	Bidirectional Encoder Representations from Transformers
CD	Critical Distance
CMS	Campus Management System
CS	Conceptual Space
CSF	Conceptual Spaces Framework
CSS	Cascading Style Sheets
DB	Database
DBSCAN	Density-Based Spatial Clustering of Applications with Noise
DFN	Deutsches Forschungsnetz
DSA	Digital Study Assistant
D3.js	Data-Driven-Documents JavaScript Library
edSMA	Educational Social Media Application
FAIR	Findability, Accessibility, Interoperability, and Reusability
GAMMA	General Approach, Attainment, Maintenance, and Avoidance Motivation Scale
GC	Goal Characteristics
GCQ	Goal Characteristics Questionnaire
GDPR	General Data Protection Regulations
GUI	Graphical User Interface
GST	Goal-Setting Theory
HCI	Human-Computer Interaction
HGS	Hierarchical Goal System
HTN	Hierarchical Task Networks
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
IKW	Institut für Kognitionswissenschaft
IP	Internet Protocol Adress
IQR	Interquartile Range
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
KDE	Kernel Density Estimation
LT	Logic Theorist
LUH	Leibniz University Hannover
LMS	Learning Management System
MAC	Media Access Control
MAD	Median Absolute Deviation
MD	Median
MDS	Multidimensional Scaling

MIT	Massachusetts Institute of Technology
ML	Machine Learning
MPI	Max-Planck-Institut
MR	Median Rank
NGO	Non-Governmental Organization
NLP	Natural Language Processing
OCEAN	Openness to Experience, Conscientiousness, Extroversion, Agreeableness, Neuroticism
ORM	Object-Relational Mapping
PCA	Principal Component Analysis
PCoA	Principal Coordinates Analysis
PHP	Personal Homepage Scripting Language
PPA	Personal Projects Analysis
PSM	Public Service Motivation
PLOC	Perceived Locus of Causality
RAC	Relative Autonomy Continuum
RAI	Relative Autonomy Index
REG	Rationality Enhancement Group
REST	Representational State Transfer
RZ	Rechenzentrum
SD	Standard Deviation
SDC	Self-Determination Continuum
SDT	Self-Determination Theory
SGP	Symbol Grounding Problem
SRL	Self-Regulated Learning
SMART	Smart, Measurable, Achievable, Realistic, Time-Bound
SQL	Standardized Query Language
SSL	Secure Sockets Layer
SUS	System Usability Scale
SWB	Subjective Well-Being
TLS	Transport Layer Security
UB	University Bremen
UI	User Interface
UOS	University Osnabrück
URL	Uniform Resource Locator
UX	User Experience
WOOP	Wish, Outcome, Obstacle, Plan

List of Symbols

α	Krippendorffś α
γ	effect size
p	p-value
ρ	Spearmanś rank correlation coefficient
n	sample size or number of entities

Chapter 1

Introduction

This chapter has partially been published in "Goal Trees as Structuring Element in a Digital Data-Driven Study Assistant" (Weber, 2019).

1.1 Humans and Machines in Higher Education

Higher Education at the beginning of the 21st century, as almost any other area of human life, is strongly determined by digitalization, automatization, and dependence on technology. It is hard to imagine that an individual, who, for whatever reason, maybe subjective beliefs or the like, rejects the use of electronic tools, could achieve any university degree today. The benefits of the constantly increasing symbiosis between humans and assistive technologies can be found in efficiency and effectivity gains, in augmentation of human abilities in terms of data processing capacity, speed, and precision, and almost unlimited communication channels connecting humans over distances and time. For instance, a computer can efficiently process millions of database entries to match a predefined sub-string, check the spelling and grammar of books within seconds, with a precision that outperforms any human, or connect a set of humans at different locations on the planet, with virtual reality glasses in three-dimensional virtual reality, including sound. The computer, in forms ranging from servers to smartwatches, has become the universal information processing tool of humankind and has assimilated all types of data storage media and communication media, from books, letters, movies, and DVDs, to telephones, fax machines, radio, to television; almost everything is stored on or communicated between computers, today. Therefore, the computer is a perfect multimedia player and universal communication device.

For educational purposes, the author identifies at least the following three central functions:

- They make learning content available in the form of media.
- They connect learners with educational institutions, learning partners, learning groups, and educators.
- Learners can use them for self-regulation and self-organization.

1.1.1 Structure of the Introduction

In this introductory chapter, conceptual knowledge related to Higher Education, Artificial Intelligence (AI), and Human-Computer-Interaction (HCI) is provided. The chapter clarifies education-related concepts, such as *Future Skills*, *Constructivism*, *Personal Educational Goals*, and *Self-Regulated Learning (SRL)*, as well as technology-related concepts, such as *weak and strong Artificial Intelligence*, and the central concept of *Digital Study Assistants (DSA)*.

1.2 Artificial Intelligence

Artificial intelligence, or *AI* refers to the field of computer science dedicated to creating intelligent machines capable of simulating human cognitive processes and performing tasks that typically require human intelligence. *AI* can be broadly categorized into *strong AI* and *weak AI* (Russell and Norvig, 2021, p. 1032). *Strong AI*, also known as *general AI*, aims to develop machines that possess human-level intelligence across various domains and can perform tasks as proficiently as humans (Russell and Norvig, 2021, p. 1032). *Weak AI*, on the other hand, focuses on building systems that are designed for specific tasks without possessing human-like general intelligence (Russell and Norvig, 2021, p. 1032). Examples of *weak AI* include voice assistants like Siri [1] and Alexa[2], which can understand and respond to specific user commands but lack comprehensive understanding or consciousness. AI's relevance in higher education lies in its potential to revolutionize teaching and learning processes, personalize education, automate administrative tasks, and enhance student services, ultimately transforming the educational landscape. The research in this doctoral thesis aims to develop a digital assistant with weak AI for the specific domain of educational goal pursuit in higher education.

1.3 Future Skills

In the book *Future Skills - The future of learning and higher education*, the author Ehlers defines "future skills" "the ability of individuals to act in future highly emerging contexts" (Ehlers, 2020, p.XI). As future skills relate to the learners and their individual development, Ehlers identifies autonomy, self-initiative, self-management, need or motivation for achievement, personal agility, autonomous learning competence, and self-efficacy as crucial. The authors predict a change in higher education toward active learning and autonomy and a trend toward personalized curricula. Such learning conditions challenge the learner to set individual learning goals, maintain and pursue them, and self-regulate their behavior based on success or failure in goal achievement. Given the set of crucial future skills, constructivism, a perspective on learning that has been around for decades, seems highly relevant today.

1.4 Constructivism

Constructivism is an established conceptualization of learning, which shares a set of aspects with *future skills*. Loyens and Gijbels (Loyens and Gijbels, 2008) state the core assumption of constructivism: Knowledge is constructed by an active learner. They further characterize the process of knowledge generation as "active sense-making and knowledge construction" (Gijbels and Loyens, 2009). We assume that personal interest and commitment to an education goal form a more solid foundation for active sense-making and knowledge construction than a commitment by curricular

[1] A virtual assistant that Apple integrated into iOS, which can be controlled by speech.
[2] A virtual assistant owned by Amazon, which is controlled by speech.

obligations. Personal interest and commitment cannot be prescribed but must originate in the learner. Therefore, individually meaningful learning goals should be the roots of education.

1.5 Self-Regulated Learning (SRL)

Self-Regulated Learning (SRL) intersects with the *Future Skills* defined by Ehlers, 2020, and *Constructivism*. SRL is explainable from different theoretical perspectives. Today, there is a variety of models of SRL (Panadero, 2017), for instance, layered models (Wirth et al., 2020; Boekaerts, 1999), and cyclic models (Zimmerman, 1989). Cyclic models of SRL have a self-oriented feedback loop as a central feature (Zimmerman, 1989). In this Thesis, a cyclic model with three phases is assumed. In the first part of this loop, learners actively develop and apply learning methods and strategies. Those techniques and actions are used in the second part, and in the third part, a reflective process arises when goals and plans are evaluated (see figure 1). Such self-regulative processes can occur on cognitive, and also meta-cognitive processes. The question arises, how can assistive software implement support functionalities related to learners' self-regulatory feedback loop? This thesis investigates the first part of the loop, namely actively formulating learning methods, strategies, and specific actions, in detail. In contrast, the second and third part remains to be investigated in future research.

Definition 1 : ***Self-regulated learning (SRL)*** *is a learner-centered perspective on learning, including cognitive, meta-cognitive, behavioral, motivational, and emotional/affective aspects (Panadero, 2017). In this thesis, a cyclic model of SRL, with pre-actional goal-setting phases, actional phases of goal-pursuit, and post-actional phases of evaluation, is referred to.*

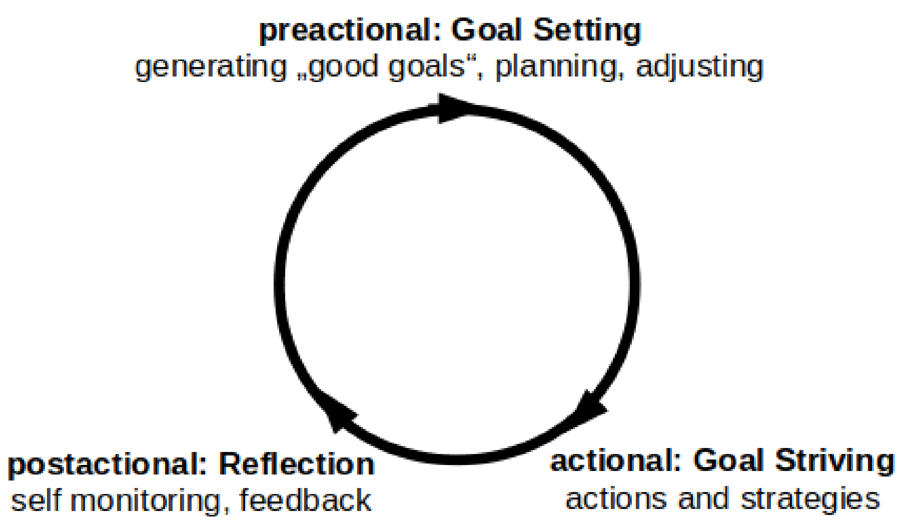

FIGURE 1.1: Cyclic Model of Self-Regulation with Three Phases.

1.6 Personal Educational Goals

For the autonomous, active learners, postulated by the *Future Skills* book, *Constructivism*, and *Self-Regulated Learning*, personal educational learning goals are of significant relevance. They function as guidance, motivators, orientation, and benchmarks for evaluation and readjustments. Olos, Hoff, and Härtwig, (Olos, Hoff, and Härtwig, 2014) have found that today, students entering the higher education system may often not even be able to name their personal education goals. This observation may originate from the fact that throughout elementary, middle, and high school, students often do not have many choices concerning learning content. Ex-cathedra teaching and other formats limiting exploratory learning are still prevalent. Thus, there is still a considerable gap between the ideal and reality of the educational system. The paradox question arises of how a university can support students in developing autonomy, self-management, and self-efficacy.

1.7 Digital Study Assistants (DSA)

The last years have seen an increased interest in Digital Study Assistants (DSA), which combine modern, often web-based, software development approaches, data from various sources and algorithms from artificial intelligence (AI) to support activities related to learning. This increased interest is due to technological advances in processing capacities, accelerating digitalization of higher education infrastructure, and the central role of computers and mobile devices in learning scenarios.

We define Digital Study Assistants as software systems that combine data and artificial intelligence to support students. DSAs have the potential to improve learning processes by providing guidance and augmenting human data processing capacities. They can preprocess large databases containing educational resources and derive recommendations fitting the user's individual needs by leveraging AI technology (Alexander et al., 2019).

> **Definition 2** ***: Digital Study Assistants (DSA)*** *are, often web-based, software systems that use data from various sources and possibly artificial intelligence to support learners.*

DSAs can serve many purposes, and various types will most probably emerge in the near future. The following list shows three types:

1. Navigation tools that find optimal paths through curricula minimize individual costs (effort, time..), and maximize utility (grades, expertise in specific domains,...)

2. Self-monitoring tools that help to track goal progress and refine strategies provide rewards, possibly with gamification elements.

3. Data-based self-reflection tools that confront learners with data of their education past to increase self-realization.

The *GoalTrees* DSA, implemented during this doctoral research, is intended as a self-monitoring and self-realization tool that allows one to track and dynamically adjust educational goal systems to stay focused on personal educational goals. The data consists of historical user inputs, and in the future, AI algorithms may operate on historical user data to generate recommendations for the goal pursuit of current users.

1.8 Goal-Setting Programs in Higher Education

Personal and educational goals play a central role in user-centered and self-regulated learning, where they serve as benchmarks (see chapter 2). Therefore, it is no surprise that many digital and analog interventions have been developed already. The following subsections introduce a set of representative examples to elucidate the field.

1.8.1 Digital Tools for Goal-Pursuit

As humans always tend to strive for goals, and digitalization has been around for a significant amount of years already, the market for digital tools is full of applications centering around goals. In table 1.1, an exemplary list of digital goal-setting tools, can be found. *Habitica* is a habit-tracking tool that can be used for daily self-monitoring with goals and habits as benchmarks, enriched with many playful and colorful gamification elements. *Complice* is a web-based self-organization tool centering around personally meaningful life goals and proactive goal-pursuit. Like Habitica, it is intended for regular use for self-monitoring and reflection on the process of goal progress. The *day zero* project encourages a community of users to set challenging goals and share lists of goals and their progress with other users. *Lifetick* is a web-based tool that starts with the assessment of core values, derives **S**mart, **M**easurable, **A**chievable, **R**ealistic, **T**ime-bound goals (Doran, 1981), allows for progress-tracking and self-monitoring. In addition, it encourages users to reflect on subjective experiences and dreams related to their goals and allows users to select goals and related data for sharing with friends. *Joe's Goals* is a simple online habit tracker, using matrices with the dimensions of habit and time to monitor behaviors over time. The **W**ish-**O**utcome-**O**bstacle-**P**lan technique is based on the research by Gabriele Oettingen and Peter Gollwitzer on Implementation Intentions and Mental Contrasting (Gollwitzer et al., 2011; Krott, Marheinecke, and Oettingen, 2019; Oettingen and Reininger, 2016; Oettingen et al., 2009; Kappes and Oettingen, 2014; Weichs, Krott, and Oettingen, 2021; Houssais, Oettingen, and Mayer, 2013; Oettingen et al., 2005), and is available as an online version. In digital tools for goal-setting, *gamification* elements can help to overcome mental barriers (Lieder, Chen, and Griffiths, 2018). Not only explicitly goal-related tools but also others, such as, for instance, collaboration tools for professional contexts, such as GitHub, a software development and code management platform, work with milestones and issues representing desirable states in the future and concrete tasks and actionable goals to be achieved. Insofar this collaboration tool, and many others, can also be understood as tools for collective goal-setting, goal-pursuit, and goal achievement.

tool	functions	URL
Habitica	goal-setting, habit-tracking, self-monitoring, gamification	https://habitica.com
Complice	personal goals, self-monitoring, pro-activity	https://complice.co/
Day Zero	personal goals, public challenges, community interactions	https://dayzeroproject.com/
Life Tick	core values, S.M.A.R.T. goals, self-monitoring, reflection on dreams, sharing with friends	https://lifetick.com/
Joe's Goals	simple habbit tracking	http://www.joesgoals.com/
WOOP	wish-outcome-obstacle-plan implementation intentions	https://woopmylife.org/de/practice
GitHub	milestones, issue-tracking, collective goal-pursuit	https://github.com/

TABLE 1.1: Exemplary Digital Tools with Goal-Setting Functions.

1.8.2 Analog Goal-Setting Programs in Higher Education

Aside from digital goal-setting tools, there are interventions, such as individual coaching or group coaching programs for goal-setting in Academia. Three illustratory examples are the *Future Authoring* Program by Morisano (Morisano, 2008; Morisano and Shore, 2010; Morisano et al., 2010; Schippers et al., 2020) at the University of Toronto or the *Professional Goal Clarification and Self-Regulation* Program at the Technical University of Berlin (Olos, Hoff, and Härtwig, 2014), or the *Goal Effectiveness Training* (Brunstein et al., 2008) at the Justus Liebig University in Giessen. In schools, similar interventions have been tested, and are constantly applied, such as, for instance, mental contrasting with school children (Gollwitzer et al., 2011). Findings from such interventions that have been reported in peer-reviewed publication formats are a valuable foundation for developing innovative digital interventions. For instance, in a recent study (Schippers et al., 2020), the authors find that the written elaboration on individual goals increases university students' academic performance, indicating that a digital intervention stimulates students to clarify and elaborate on personal, educational goals may unfold similar effects.

1.9 Funding Context: The SIDDATA Project

Parallel to the line of research summarized in this thesis, the SIDDATA project, funded as part of the "Innovation Potentials of Digital Higher Education" funding line, the Federal Ministry of Education and Research since November 1, 2018, has developed a more general DSA, which assist pro-active learners in goal pursuit. Within annual agile software development cycles, we developed a series of assistant prototypes (Schurz et al., 2021; Weber and Thelen, 2022a), we trained a Neural Network to match educational resources and learners (Schrumpf, Weber, and Thelen, 2021) and published data sets from field experiments with prototypes (Schrumpf et al., 2022; Weber and Thelen, 2022b).

1.10 Aims and Motivation

This line of research combines methods and insights from Educational, Motivational, Experimental Psychology, Human-Machine Interaction, Usability Research, and Artificial Intelligence to develop a Digital Study Assistant for educational goal-setting. In parallel, data about the characteristics of university students' goals and their characteristics accumulate. This data can serve as training data for AI algorithms to be applied in the goal-setting intervention. Therefore the project inweaves scientific theory and practice and derives insights and a helpful digital tool simultaneously.

1.11 Research Questions

This thesis centers around how university students can be supported in setting personally meaningful educational goals, and monitoring their progress towards such goals, by digital assistants. The research questions it aims to answer are:

1. Which methods can be applied to measure goal characteristics?
2. Which characteristics of goals are relevant in educational contexts?
3. How are goals and goal systems represented mentally, and how can they be represented in human-machine interfaces?
4. How can findings from former research on constructivism, goal-setting, self-regulation, and self-monitoring be applied in a digital data-driven study assistance software?
5. Which characteristics do the goals of students show, and which conclusions can be derived?
6. How can insights on the nature of educational goals be derived from high-dimensional goal data?
7. How can Machine Learning models be trained to predict goal characteristics from goals formulated in natural language?
8. How can methods from Artificial Intelligence be applied in Digital Study Assistants for goal-setting and pursuit?

In the final chapter these questions will be repeated and answered.

1.12 Results and Contribution

The line of research reported in this doctoral thesis is an ongoing, dynamically evolving project. Among the goals and milestones in the scientific dimension and the practical dimension that have been reached so far are the following:

- Two methods for measuring goal characteristics from an external and an internal perspective have been established and applied.
- The concept of hierarchical goal systems has been established on a solid theoretical foundation.
- The web-based software *GoalTrees* for academic goal-setting has been developed and refined in a row of formative studies.
- Four visualization types for hierarchical data have been tested and evaluated in usability studies. The dendrogram has been identified as the best solution for the graphical user interface.
- A data collection with hundreds of participants, thousands of goals, and their characteristics has accumulated and has partially been analyzed and published.
- Clustering techniques can potentially derive insights into the nature of educational goals in the high-dimensional data. How this can be achieved has been outlined on the foundation of conceptual spaces, and preparations for dimensionality reduction of the data have been undertaken.

In a subset of the studies, for instance the study on visualization type comparisons, inferential statistics have been applied. In another subset, for instance the study on structural characteristics of HGS, and the study on goal characteristics, explorative analyses were conducted to elucidate previously unknown research areas. Due to the high number of measured variables, Bonferroni corrections to counteract the multiple comparison problem (Dunn, 1961), would certainly increase p-values to non-significance. Future studies have to be conducted to verify the tendencies already found.

1.13 Structure of the Thesis

The chapters subdivide this dissertation into semantic units corresponding to the temporal order within which the research has developed. Consequently, this text resembles a project report. Chapter two provides definitions of the central term *goal* across the cognitive sciences and disambiguates it from related other terms. In the third chapter, goal characteristics and two approaches to their measurement are dealt with. The fourth chapter introduces the concept of hierarchical goal systems (HGS), on the one hand, as a conceptual perspective on goal-directed behavior and, on the other hand, as a blueprint for a digital goal-setting intervention. Subsequently, it gives an overview of the GoalTrees software development, the underlying web-based software architecture, and its current functionality state. Chapter five outlines how clustering and the conceptual spaces framework can be used to identify types of goals in high-dimensional data. The thesis concludes with chapter six, which summarizes central findings and insights and outlines how semi-supervised learning methods, in particular, BERT, can be used to predict goal characteristics scores from goal formulations to improve the GoalTrees intervention in the future. Finally, the chapter summarizes the insights on epistemological and ontological dimensions, reflecting upon the scientific methods used during the dissertation project and good scientific practice.

Chapter 2

The Goal Concept in the Cognitive Sciences

Goals are exciting objects of investigation in educational research because they can be understood as a concrete manifestation of motivation. Considering goals as "internal representations of desirable states" (Vancouver and Austin, 1996, p.338), almost every human behavior can be viewed as being goal-directed. Humans will more likely be able to elaborate on their goals than their abstract motivations. Another reason goal setting is of significant relevance in higher education is that they have been shown to affect outcomes such as performance, activity, academic performance, well-being, and vitality (Locke and Latham, 2002; Locke and Latham, 2019; Morisano et al., 2010; Morisano, 2008). This chapter introduces the meaning and significance of goals in the Cognitive Sciences.

Definition 3 ***: Goals*** *are internal representations of desired states in natural and artificial agents and predispositions for action.*

Goals as states of valence, or as reference frames for action, occur in all disciplines of the Cognitive Sciences, from Neurobiology (Dezfouli and Balleine, 2013; Southgate et al., 2014; Zwosta et al., 2018; Eppinger et al., 2013; Saito et al., 2005), to Philosophy (Kline and Schmidtz, 1996; Adams, 1979), Psychology (Vancouver and Austin, 1996; Kruglanski and Higgins, 2007), as goal states in Symbolic Artificial Intelligence (Ghosh, Gupta, and Levine, 2019), and in Robotics (Braubach et al., 2005; Stock, Günther, and Hertzberg, 2014; Rockel et al., 2013).

In a postmodern world in which existentialist philosophers have convincingly argued against universally valid standards, there is a vital necessity for humans to fulfill their needs for meaning and purpose in life. In this context, explicit and personally meaningful goals can be functional substitutes for the metaphysical truths of former times. From a more pragmatic perspective, goals guide behavior toward intended directions. The aspect of desirability and collateral effects of the consequences of human strivings raises a philosophical or even metaphysical question humans have asked themselves since ancient times: What should we strive for?

In this chapter, definitions from the disciplines mentioned above are gathered, interpreted, and integrated into a coherent picture. The length of the corresponding sections emphasizes the disciplines of Psychology and Artificial Intelligence. In contrast, contributions from other disciplines, such as Philosophy, Neuroscience, and Cognitive Science in general, are subsumed in the following section on *Goal Definitions in the Cognitive Sciences*.

2.1 Goals in Cognitive Science

The German "Wörterbuch der Kognitionswissenschaft" (Dictionary of Cognitive Science), Klaus Opwis[1] (Strube and Becker, 1996), defines the term *Ziel* (*Goal*) as follows[2]:

(1) In the area of motivation, goal refers to the "anticipated idea of the effect of our actions" (W.Wundt[3]) or the "intent to act in a certain way" (N. Ach[4]). Important aspects relate to the genesis of goals or the choice of action goals, the degree and direction of goal-drivenness, and the question of which processes are used to implement goals in action.

(2) In the field of problem solving, the goal is usually a state to be aimed for ("solution") that is specified in the problem. Goals can be general or specific, positive or negative, explicit or implicit. Important aspects concern the reformulation of goals as well as strategies for coping with the cognitive demands that arise when dealing with multiple goals (↑hierarchy of goals).

These two definitions show the interdisciplinary presence of the concept, the former emphasizing motivational psychology and the latter the subdomain of problem-solving in symbolic AI. The first definition emphasizes a close relation to action, on the one hand, as the purpose of actions and, on the other hand, as the driving force initiating actions.

In the "Dictionary of Cognitive Science" by Houdé[5] (Houdé et al., 2004), Joëlle Proust[6] provides the following detailed and abstract definition that allows us to identify and distinguish types of goal-directed behaviors:

"Intuitively, a *goal-directed behavior* is one that is executed in view of attaining a certain goal. The realm of living things exhibits innumerable examples of goal-directed behavior, such as web spinning by spiders, courtship rituals in birds, dam building by beavers, and so on (→ ANIMAL COGNITION). The difficulty inherent in this concept, however, is that it seems to imply a type of final causality in which the desired result is what orients and guides the action)→ ACTION, CAUSALITY AND MENTAL CAUSATION). Goal-directed behaviors can be manifested independently of any type or representation. The first attempt to *naturalize* the idea of purpose dates back to the work of Arturo Rosenblueth[7], Norbert Wiener[8], and Julian Bigelow[9] (→ NATURALIZATION). They showed that purpose can be understood without recourse to the idea of a final cause, and that it does not require considering the cause of a goal-oriented action to inhere in an event that comes after the action itself. They proposed seeing goal-directed behaviors as behaviors that require negative *feedback* coming from the goal. There is feedback when the system can use part of its output as input. It is positive when it has the same sign as the output, and negative if it is not. Negative feedback in goal-directed behavior consists of signals emitted by the goal that constrain the output in order to reduce the object's error margin as the goal is being pursued. Based on the analysis of Rosenblueth and his

[1]Klaus Opwis, born 1957, German Psychologist

[2]Translated by Google Translate.

[3]Wilhelm Maximilian Wundt, 1832 –1920, German Physiologist, Philosopher, and Professor, known today as one of the fathers of modern psychology.

[4]Narziß Kaspar Ach, 1871 –1946, German Psychologist

[5]Olivier Houdé, born 1963, French Psychologist

[6]Joëlle Proust, born 1947, French Philosopher

[7]Arturo Rosenblueth Stearns ,1900–1970, was a Mexican Researcher, Physician, and Physiologist.

[8]Norbert Wiener, 1894–1964, American Mathematician and Philosopher

[9]Julian Bigelow, 1913–2003, was a pioneering American Computer Engineer.

collaborators, the behavior of servo-mechanical devices (like the ones used to control torpedoes) can be defined as goal-directed (→ ROBOTICS). However, this initial definition suffers from two shortcomings. First, one cannot distinguish a strictly physical system from a goal-oriented system; for example, a liquid in a vase, that returns to a state of equilibrium seems to manifest a self-regulated behavior. Second, it seems to imply that a behavior cannot be goal-directed unless it makes use of an information that enables the *target event* to be accomplished by means of adaptive corrections (the *target element* is the object upon which the action must be performed; the target event is the final phase of the behavioral process that must be reached for the action to be successful). To remedy this state of affairs, one needs to bring to bear an additional set of conditions, which Gerd Sommerhoff[10] analyzed as follows:

(1) A goal-directed behavior continues to be executed until it reaches a certain state of completion. It is the attainment of this state, often called a *state of equilibrium*, that interrupts the behavior.

(2) The agent must be in a physical nonnomological relationship with the target element at time t in the target event. In other words, physical system A (made up of the agent and its environment) is connected to physical system B (the target event and its possibility conditions) by a causality link, granted, but one that does not have the force of law.

(3) The agent must reach the target event at least in part by virtue of the way in which he, she, or it initiated and/or carried out the action. This condition guarantees that the action sequence is not the result of chance or of a physical causality that cannot help but produce the concerned effects.

(4) If the properties that are causally relevant to the action exerted upon the target element had been different, the target event-directed action required by those properties would nevertheless have been accomplished.

(5) Physical systems consisting respectively of the agent and the instrument of his, her, or its action, and the process that leads to the target event, share the causal determinants that affect the dynamic at certain crucial points in the unfolding of the goal-directed process *(correction devices)*.

There are types of behaviors that satisfy properties 1 to 5 only partially; they are referred to as *weakened* goal-directed behaviors. The most elementary class is the class of *goal-seeking behaviors* (David McFarland[11]). The system engaged in this type of behavior does not achieve the target event by virtue of its own correctional devices, nor can it determine, whether the action succeeded or failed: it is designed to reach the goal without that goal being explicitly represented in the system. A second class, *goal-achieving behaviors* (McFarland), includes behaviors in which, like goal-directed behaviors, the system is capable of recognizing that the goal has been attained when it has, but is incapable of modifying the pathways of the action." (Houdé et al., 2004)

This extensive definition o *behaviors*(!) entails a row of interesting aspects: First, it provides a set of five criteria that have to be fulfilled for *goal-directed behaviors* and defines two types of *weakened goal-directed behaviors*, namely *goal-seeking behaviors*, and *goal-achieving behaviors*, from which the former does *NOT* have an explicit representation of a goal, and the latter can recognize goal-achievement but does not actively contribute to goal-pursuit.

[10] Gerd Walter Christian Sommerhoff, 1915–2002, German Pioneer of Theoretical Neuroscience.

[11] David McFarland is a contemporary Scientist interested in Animal Behavior, Artificial Ethology, and Robotics.

In artificial intelligence, forms of sub-symbolic AI, which rely on error functions or reward functions, can be understood as *goal-seeking agents*, because they strive towards hypothetical goal states with infinitely high rewards or infinitely low errors.

Nature has implemented reward functions on a biological level that lead to corresponding goal-directed behaviors. There are *goal-seeking* behaviors in biological agents with hard-wired reward functions and implicit goals. For instance, teenagers in love, have a natural tendency to become parents, although it is not their explicit goal.

2.1.1 Goals in Psychology

In psychology, *goals* have been defined as "internal representations of desired states" (Vancouver and Austin, 1996). This definition entails a set of general goal properties: At first, goals are subjective due to their intra-personal nature. A goal primarily exists in a person's mind and not in the external world. Even if a group of humans expresses goals in identical terms, the individual mental representations will most likely not be identical. Second, a goal is directed towards a state, most likely in the future. This aspect holds substantial implications for behavior because of the attractiveness of goal states projected to the external world. The third important aspect is desirability, which is subjective by definition, too. A person having a goal assumes, for some reason, that acting towards a future in which the goal state becomes a reality leads to positive consequences, such as, for example, well-being. Interestingly this is not necessarily the case. Research has shown that the characteristics of the goals we chose have a much more substantial impact on subjective well-being than goal achievement itself (Ehrlich, 2012).

The American Psychological Association Dictionary of Psychology (American Psychological Association, 2020) defines the term *goal* in the following way:

(1) the end state toward which a human or nonhuman animal is striving: the purpose of an activity or endeavor. It can be identified by observing that an organism ceases or changes its behavior upon attaining this state.

(2) a target of proficiency to be achieved in a task within a set period of time. See goal setting.

While the former definition includes nonhuman animals (but not artificial agents!), and states an abstract description of goal-directedness, similar to cybernetic perspectives, the latter entails aspects, such as time-boundedness and proficiency, that are emphasized in goal-setting research related to organizational psychology, for instance, by Doran, Latham, and Locke (Doran, 1981; Locke and Latham, 2019).

Goals as Drivers towards Organismic Equilibria

A simple organismic perspective on goals is based on the concept of biological and psychological equilibria, closely related to Maslow's[12] pyramid of needs (Maslow, 1943). A crucial aspect of this model is that needs build upon each other, and the deprivation on lower layers of the pyramid disables processes related to higher layers. If a human or other animal is searching for food and an existential threat arises, the need for safety immediately overwrites all nutrition-related processes and allocates processing capacities to ensure re-establishing the equilibrium on the safety level. Transferred into an educational setting, this thought implies that many distractions can surprisingly interrupt learning-goal-related behaviors based on organismic or social equilibria moving out of balance, apparently requiring immediate responses.

[12] Abraham Harold Maslow, 1908–1970, American Psychologist

The Oxford Handbook of Philosophy and Neuroscience (Bickle, 2009) devotes chapter 15 *The Emerging Theory of Motivation* to motivational states, and explains goal-directed behaviors on an abstract and a concrete biological level. The relation between motivational states and goals is defined as follows: "A motivational state provides an agent with at least one goal. Typically, the way we individuate motivational states suggests that each provides what we might call a basic goal. The basic goal of hunger is to be fed. The basic goal of lust is to have sex." (Bickle, 2009) Further, "..motivational states depend on specific control systems in the brain. These systems supply us with goals for thought and action, as well as the drive to act on behalf of those goals." (Bickle, 2009, p. 381) On a neuroscientific level, the handbook outlines how in biological agents, dopamine as a reward signal in the brain, plays a central role in the physiological implementation of goal-directed behaviors (Bickle, 2009, p. 288-400). In combination with the definition of *goal-seeking behaviors*, humans can be understood as goal-seeking biological agents, following implicit goals, programmed by a reward function, physiologically implemented in the dopaminergic system.

Goals as Benchmarks in SRL

Actions and goals co-occur because they are tied by causality: Goals lead to actions that are expected to cause a desirable goal state in the future, and actions are usually goal-directed and do not occur without a goal, except for reflexes. In Heckhausen's[13], and Gollwitzer's[14] modell of action phases, also known as *Rubikon-Modell*, (Heckhausen, Gollwitzer, and Weinert, 1987; Heckhausen and Gollwitzer, 1987) (see figure 2.1), goals play a central role. This model distinguishes four phases: In the first pre-decisional phase, goal candidates are compared in terms of positive and negative consequences, costs of goal pursuit, and the probability of goal achievement. In the second pre-actional phase, a goal has been chosen for pursuit, and concrete actions and strategies are derived. In the third, actional phase, those actions and strategies are applied. In the fourth and last phase, the post-actional phase, the outcome is evaluated regarding goal achievement and costs. This model, like any model, is an idealization; in reality, phases may overlap or iteratively repeat themselves. Conceptually, it shows similarities with the cyclic model of Self-Regulated Learning.

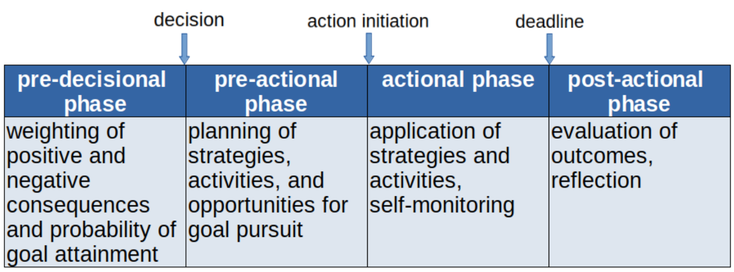

FIGURE 2.1: Action Phases as Proposed by Heckhausen.

Self-Regulated Learning is a conceptualization of learning that various theoretical frameworks can theoretically support, ranging from operant, social cognitive, to cognitive constructivist perspectives (Zimmerman, 1989). A core element of SRL is

[13]Heinz Heckhausen, 1926-1988, German Psychologist
[14]Peter Gollwitzer, born 1950, German Motivation Psychologist and Social Psychologist

that active learners play an essential role in regulating their behavior. Cyclic models of self-regulated learning assume iterative strategic loops (see figure 1.1) with phases of planning, acting, and reflecting learning processes (Zimmerman, 1989; Zimmerman, 1990). In such models, individual learning goals are an essential building block because they can constitute a foundation for planning and serve as benchmarks for evaluation.

The tri-phase cyclic model of self-regulated learning (Zimmerman, 1989; Zimmerman and Campillo, 2003), illustrated in figure 1.1. In this model, promoted by Zimmerman[15], learning goals serve as guidance for learning activities and benchmarks for progress evaluation. It resembles an iterative version of Heckhausen's action phases, in which phases of planning, acting, and reflecting are sequentially repeated.

2.1.2 Goals in Machines and Artificial Agents

As some of the definitions in the previous sections have already pointed out, goals exist in human and nonhuman living forms and artificial agents. With the increasing progress of technology and especially information-processing machines, the perspective on goal-directed systems is increasingly extended to non-biological systems. In the following sections, artificial goal-directed systems will be introduced in the order of their complexity.

Cybernetics and Regulatory Loops

The word cybernetics comes from Greek $\kappa\upsilon\beta\epsilon\rho\upsilon\eta\tau\iota\kappa\eta$ *kybernetike*, meaning "governance", and $\kappa\upsilon\beta\epsilon\rho\upsilon\eta\tau\zeta$ *kybernetes*, the governor, pilot, or helmsperson of a ship. In 1948, Norbert Wiener significantly coined the term *cybernetics* in his book "Cybernetics, or Control and Communication in the Animal and the Machine", in which he outlined how machines can work towards internal equilibria (Wiener, 1948).

In 1979, Frederick Adams*Frederick R. Adams, contemporary Cognitive Scientist, Linguist, and Philosopher* published a paper in the *Canadian Journal of Philosophy*, in which he outlined "A Goal-State Theory of Functional Attributions" (Adams, 1979). He defines goal-directed systems as follows: "I shall contend that a goal-directed system – whether mental or non-mental – is a cybernetic system. It is a cybernetic system in the sense that its behavior is not mere random behavior which accidentally terminates in an end state. Rather, its behavior is controlled or directed toward an end state or goal-state. The system must also be able to process information about its present state (both internal and external state variables), and it must be able to compare that information with its goal-state. The system then performs a set of operations which minimize the difference between the present state and the goal-state. " (Adams, 1979)

[15] Barry J. Zimmerman, contemporary Educational Researcher

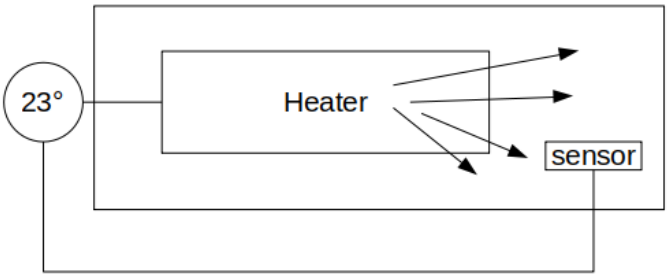

FIGURE 2.2: Cybernetic Heating System with a Feedback-Control Loop.

As a practical example of a non-mental goal-directed system, Adams (Adams, 1979) uses the control unit in heating systems, as shown in figure 2.2. Other authors have used similar examples for servo-mechanical goal-directed systems, such as, for instance, torpedoes (Houdé et al., 2004).

In his 1979 paper, Adams developed the following two increasingly abstract formal definitions of goal-directed systems: "An analysis of goal-directedness which is based on a cybernetic account maintains that a system must have:

(1) an internal representation of the goal-state;

(2) a feedback system by which information about the system's state variables and its output values are fed back into the system as input values;

(3) a causal dependence between the information which is fed back into the system and the system's performance of successive operations which minimize the difference between the present state of the system and its goal-state." (Adams, 1979)

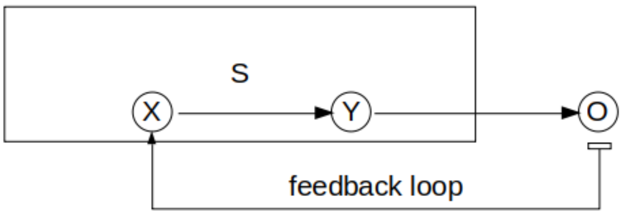

FIGURE 2.3: Abstract Feedback-Loop in Goal-Directed Systems.

"With this understanding of goal-directedness, let me now re-state the central tenet of the goal-state theory of function attributions. A structure x has a function y just in case:

(1) x does y in system S;

(2) y causally contributes towards S's outputting O (through the causal feedback mechanism);

(3) O is (or itself contributes toward) a goal-state of S."

(Adams, 1979) As well in the concrete example of the heating system in figure 2.2, as in the two abstract models, a feedback loop is a necessary functional element of goal-directed systems. This fact is interesting in the context of self-regulated learning, introduced in this chapter, because learners need some kind of perception or monitoring device to keep track of their progress and evaluate and refine their strategies. A digital study assistant for educational goals can serve this self-monitoring function and be part of a feedback loop.

Goal states in Search Spaces

In classical symbolic AI, a common strategy for problem-solving or game-playing is translating a problem into a search problem. According to Russel[16] and Norvig[17] (Russell and Norvig, 2021), search problems can be defined formally by

(1) A set of possible states, together constituting the state space.

(2) The initial state defining the start.

(3) A set of goal states ($1 \leq n \leq \infty$)

(4) A set of actions for each state.

(5) A transition model defining which state results from an action applied to a state.

(6) An action cost function that defines the costs for each action.

A sequence of actions leading to a goal state is a solution, the one with the lowest costs is the optimal solution (Russell and Norvig, 2021).

In logical agents, representatives of classic symbolic AI, goal-directed reasoning approaches, such as, for instance, backward chaining, search for solutions starting from the goal state. This procedure has the advantage that computation resources can be minimized due to a higher probability of only using relevant facts (Russell and Norvig, 2021).

In automated planning, agents have to dynamically adapt their behaviors to unexpectedly changing environments. One approach to optimizing its actions is *goal monitoring*, which means that before an action is executed, the agent checks if there is a better set of goals available to pursue (Russell and Norvig, 2021). The *goal monitoring* strategy in artificial agents demonstrates the practical value of the dynamic evaluation of goals and actions on a level of behavioral economics, which probably also exists in natural learning environments of university students.

Russel and Norvig (Russell and Norvig, 2021, p. 71) describe *Goal-based agents* as follows: "Knowing something about the current state of the environment is not always enough to decide what to do. For example, at a road junction, the taxi can turn left, turn right, or go straight on. The correct decision depends on where the taxi is trying to get to. In other words, as well as a current state description, the agent needs some sort of *goal* information that describes situations that are desirable – for example, being at a particular destination. The agent program can combine this with the model (the same information as was used in the model-based reflex agent) to choose actions that achieve the goal. {...} Sometimes goal-based action selection is straight-forward – for example, when goal satisfaction results immediately from a single action. Sometimes it will be more tricky –for example, when the agent has to consider long sequences of twists and turns in order to find a way to achieve a goal. Search and planning are the subfields of AI devoted to finding action sequences that

[16] Stuart Jonathan Russell, born 1962, is a British Computer Scientist known for his contributions to AI.

[17] Peter Norvig, born 1956, is an American Computer Scientist and Distinguished Education Fellow at the Stanford Institute for Human-Centered AI.

achieve the agent's goals. Notice, that decision making of this kind is fundamentally different from the condition-action rules described earlier, in that it involves consideration of the future – both "What will happen if I do such-and-such?" and "Will that make me happy?". In the reflex agent designs, this information is not explicitly represented, because the built-in rules map directly from percepts to actions. The reflex agent brakes when it sees brake lights, period. It has no idea why. A goal-based agent brakes when it sees brake lights because that's the only action that it predicts will achieve its goal of not hitting other cars. Although the goal-based agent appears less efficient, it is more flexible because the knowledge that supports its decisions is represented explicitly and can be modified. For example, a goal-based agent's behavior can easily be changed to go to a different destination simply by specifying that destination as the goal. The reflex agent's rules for when to turn and when to go straight will work only for a single destination; they must all be replaced to go somewhere new." (Russell and Norvig, 2021, p. 71)

This explanation about goal-based agents is interesting because it highlights an advantage of explicit goal representation compared to implicit goal representations: An explicit goal definition allows a correction of actions and strategies that are not efficient, possibly by backward chaining, starting from the goal state. Goal-directed systems without goal representations, for instance, those functioning with reward functions, cannot do this.

In the context of problem-solving agents, Russel and Norvig (Russell and Norvig, 2021, p. 81) define a *Goal formulation* as the first step in a general four-step problem-solving algorithm. They state, "Goals organize behavior by limiting the objectives and hence the actions to be considered."

In problem-solving by search, Russel and Norvig (Russell and Norvig, 2021, p. 83) state that one component in a formal definition of a search problem is "A set of one or more *goal states*. Sometimes there is one goal state (e.g., Bucharest), sometimes, there is a small set of alternative goal states, and sometimes the goal is defined by a property that applies to many states (potentially an infinite number). For example, in a vacuum-cleaner world, the goal might be to have no dirt in any location, regardless of any other facts about the state. We can account for all three possibilities by specifying an IS-GOAL method for a problem. In this chapter, we will sometimes say "the goal" for simplicity, but what we say also applies to "any one of the possible goal states".

Rewards and Error Functions

In the 1971 paper "Human problem solving: The state of the theory in 1970.", the authors Newell[18] and Simon[19] reason about human problem-solving, and find that for humans traversing through problem spaces, "Reaching a node that differs less from the goal state than nodes visited previously is progress; and selecting an operator that is relevant to a particular difference between current node and goal is a technique for (possibly) reducing that difference." (Simon and Newell, 1971, p.152) Although the domain of the cited statement is classical search, the focus is on discrepancy reduction from the current state to the goal state.

Reinforcement learning is a domain in machine learning in which agents receive take actions to maximize rewards. This mechanism is semantically related to goals

[18] Allen Newell, 1927 – 1992, American Computer Scientist, Cognitive Psychologist, and AI Pioneer

[19] Herbert Alexander Simon, 1916 – 2001, American Political Scientist, Computer Scientist, Economist, Cognitive Psychologist, and AI Pioneer

because future states are more or less desirable for an agent, depending on their reward.

Q-Learning, for instance, is a model-free learning algorithm with high efficiency that uses reward signals (Watkins and Dayan, 1992). It is an example of algorithms making use of rewards, which is semantically related to the concept of goal because the goal is to maximize the reward. Hence, technically, the expectancy of reward and desire have much in common.

In supervised learning, machine learning models learn input-output mappings based on labeled training examples. In many algorithms of this class, minima in error functions are searched for, for instance, with gradient descent. Searching for analogies to goal states, one could argue that minima in error functions are a kind of goal state for the algorithm.

Geospatial Navigation

Navigation software is a perfect illustration of how digital assistants can act in an algorithmic way to provide ideal paths through a reduced representation of the real world. In former times, when humans navigated with maps on paper, detours, stopovers, and discussions about the best route were common in way-finding. Modern navigation software allows users to enter the destination address, and within seconds, the shortest route to the destination is displayed in real-time and adapts to new situations, such as traffic jams and wrong turns.

2.1.3 Goals as Interface between Humans and Machines

Goals can play a central role in human-machine interaction to unfold synergistic and mutually beneficial effects. In contrast to humans, machines are not intrinsically "interested" in states of the world, but they possess optimization capacities that outperform human capacities, such as in route planning. Some Robotics and strong AI enthusiasts, for some reason, strive for artificial agents with their own intrinsic goals, intentions, and emotions. If they succeeded, this would cause ethical issues and unfold unwanted side effects based on mismatches between artificial and natural agents’ desires and goals. Of course, this argument is strictly hypothetical as long as there are no robots with desires, but as long as machines are understood as assistive technology, optimizing the pursuit of human goals, the mentioned risks can be reduced.

Another reason goals are very well-suitable as the interface between humans and machines is that complexity can be reduced and usability increased by neglecting unnecessary details of the algorithms used for goal-striving. Navigation apps are a good example: Humans define a goal, and the machine calculates the optimal path.

2.1.4 Disambiguation from Similar Terminology

There is a row of terms with partially overlapping semantics or relatedness with the concept of *goals*. The following sections (in alphabetical order) provide definitions and clarify differences.

Action

The "Dictionary of Cognitive Science" by Houdé defines action as follows: "Psychology: Motor action is understood to mean the occurrence of a movement made up of three stages: planning, programming, and motor execution. Only the last stage is directly observable and brings about a change in the environment. The first two stages, elaborated mentally before the onset of the action, determine the goal and the strategy to adopt (planning), and the sequence of movements to make (programming)." (Houdé et al., 2004) This definition entails goals as a directive component and shows a row of commonalities with planning in artificial systems, although the author assigns the term to the domain of psychology.

The "Encyclopedia of Cognitive Science" by Nadel[20] defines action as follows: "Action is the ability to move the body or body parts in a purposeful, coordinated manner in order to physically interact with the environment. It is based on the integration and cooperation of sensory and motor systems." (Nadel, 2006) Compared to the former definition by Houdé, this one emphasizes the embedding into sensory and motor systems, which situates the action in the domain of neurobiology. Goal-directedness is implied by the word *purposeful*. The wording emphasizes the importance of coordination and integration of sensation and the motor system.

Desire

The term *desire* is of interest because *goals* are often defined as desirable states. So if we want to understand goals, it might be interesting to know what desire is. The "Oxford Handbook of Philosophy and Neuroscience" (Bickle, 2009) defines it as follows: "Notably, the word *desire* has a certain kind of ambiguity. For example, sometimes the word refers to a mental state – an unsatisfied want held by the goal's bearer. Other times, the word refers to an object of desire. For clarity, let us call the psychological state underlying a goal for action *desire*. We can then let *goal* refer to a state that satisfies a desire. Thus, we can distinguish between intrinsic desires and instrumental desires (i.e., psychological states) and basic goals and subgoals (i.e., objects of desire). Like basic goals, intrinsic desires are held for their own sake. Instrumental desires, like subgoals, are held for the sake of satisfying intrinsic desires." Interestingly, the definition makes excessive use of the term *goal*, and makes a distinction between basic goals, which directly fulfill a desire, and instrumental subgoals. The word *desire* is defined as a mental state of being unsatisfied without having achieved a specific goal state, which is a rather deficit-oriented definition. Desires are closely related to intrinsic motivation as desire-related activities are perceived as innately rewarding.

Intention

In Animal Cognition and Neurobiology, the term *intentionality* is used to describe goal-directed behaviors or physiological processes related to those behaviors. The term *desire* is used in contexts where a physiological need is involved. This slightly different framing is explainable by the non-declaration of the desirable states. If a goal cannot be explicated due to a lack of linguistic abilities or no communication at all, but at the same time, an experimental setup is built to measure related variables, the term *intention* is an accurate description of a non-declared goal.

The American Psychological Association's Dictionary of Psychology (American Psychological Association, 2020) defines *intentions* as

(1) "a prior conscious decision to perform a behavior. In experiments, intention is often equated with the goals defined by the task instructions."

(2) "more generally, any directedness in one's thoughts or behaviors, whether or not this involves conscious decision making. —intentional adj."

[20] Lynn Nadel, born 1942, American Psychologist

This definition shows that intentions are often directed towards goals but are less conscious or known to their bearer, but are action-oriented.

Milestone

The term *milestone* is often used in project management contexts or software for collaboration. The term implies that it is a subgoal of a project, as it marks a certain distance towards a higher goal that has to be covered. Milestones are often clearly defined by tasks that have to be completed or measurable achievements.

Personal Project

The American Psychological Association's Dictionary of Psychology (American Psychological Association, 2020) defines *personal project* as "the aims of an individual that involve an organized set of activities of personal relevance over an extended period. [analyzed by Canadian personality Psychologist Brian R. Little]" Personal projects can be understood as high-level goals with high personal relevance, and originate from research on personality (Little, 1983).

Problem

The term *problem* describes a state of the world, which is suboptimal and usually not trivial to transform into a satisfying state. Changing this state into a desirable state requires (mental) effort and activity. A problem is the ugly twin of a goal insofar that a goal produces a discrepancy between the current state and the goal state that the unlucky bearer of the goal has to overcome somehow.

Purpose

The American Psychological Association's Dictionary of Psychology (American Psychological Association, 2020) defines *purpose* as

(1) "the reason for which something is done or for which something exists."

(2) "a mental goal or aim that directs a person's actions or behavior."

(3) "persistence or resolution in pursuing such a goal."

Especially the second and third definitions show the close relatedness to goals. In comparison to goals, purposes seem to be even more intrinsic and more intense in terms of persistence and resolution, according to these definitions. In Ethology, purposes serve as overarching explanations for behavior, and insofar can serve as explanations for intrinsic motivations.

Standard

In contexts of regulatory processes that are functionally directed towards homeostasis, often the goal or target range of a variable is called standard. Standards are used to evaluate behaviors or outcomes of behavior. Standards can be based on individual, social, or factual criteria.

Value

The American Psychological Association's Dictionary of Psychology (American Psychological Association, 2020) defines *value* as

(1) "the mathematical magnitude or quantity of a variable."

(2) "a moral, social, or aesthetic principle accepted by an individual or society as a guide to what is good, desirable, or important."

(3) "the worth, usefulness, or importance attached to something." (American Psychological Association, 2020) The second definition has in common with goals in that it aims at something desirable. A difference between goals is that values have a moral, social, or aesthetic connotation.

Wish

The American Psychological Association's Dictionary of Psychology (American Psychological Association, 2020) defines *wish* as

(1) "in classical psychoanalytic theory, the psychological manifestation of a biological instinct that operates on a conscious or unconscious level."

(2) "in general language, any desire or longing." In comparison to goals, wishes are less conscious and less explicit. A folk-psychological definition states that a wish is a goal without a plan.

2.2 Summary

Goals direct actions and behaviors in biological, artificial, and virtual agents and play a central role in planning and problem-solving. Explicit goal representations have functional benefits compared to implicit representations. In goal-directed systems, often feedback-loops play a central role. In this chapter, definitions from various cognitive sciences have been gathered, analyzed, and compared. This conceptual background is helpful for a deeper understanding of how learners can be supported in their pursuit of educational goals by Digital Study Assistants.

Chapter 3

Measuring Goal Characteristics

This chapter has partially been published in "Towards a Comprehensive Taxonomy of Study Goals of University Students." (Weber, Osada, and Thelen, 2019), "A Tagset for University Students' Educational Goals" (Weber and Le Foll, 2020), "Characterizing Personal Educational Goals: Inter-rater Agreement on a Tagset Reveals Domain-Specific Limitations of the External Perspective" (Weber and Thelen, 2022a) , and "Development and Validation of a Goal Characteristics Questionnaire" (Iwama et al., 2021).

3.1 Introduction to Goal Characteristics

The characteristics of goals are essential for the probability of goal achievement and the process of goal-pursuit, and they can even unfold side-effects on its' bearer. For instance, the characteristic of goal importance can moderate the amplitude of the emotional response after success or failure (Cooper, 2018), and goal characteristics can have effects on Subjective Well-Being (SWB) after goal-attainment (Ehrlich, 2012). It can be relevant whether a goal aligns with the person's needs, wishes and values (Gollwitzer and Oettingen, 2012). According to Ehrlich (Ehrlich, 2012) the reasons for goal-striving are a significant predictor of well-being. Intrinsic goals correlate with well-being, satisfaction, and goal achievement, while extrinsic goals correlate with lower well-being and vitality, more anxiety, depression, and physical symptoms. For well-being, the right balance between feasibility and challenge has to be given (Cooper, 2018).

3.1.1 Goal Setting Theory

Goal-setting theory (Locke and Latham, 1990; Latham and Locke, 1991a; Locke and Latham, 2002; Locke, 2013) postulates that by explicitly formulating personal goals, individuals are more likely to attain them. Goal-setting individuals are more capable of directing their effort and attention towards goal-relevant tasks and ignoring distractions. Indeed, setting goals can, in itself, bolster individuals' self-regulation capacity. Furthermore, goal setting boosts persistence, thus reducing the impact of negative influences such as anxiety, disappointment, or frustration. In addition, well-defined goals can encourage individuals to develop more efficient strategies to meet their aims. Over the past four decades, more than 400 experimental and correlational studies have provided evidence for the validity of goal-setting theory (Locke and Latham, 2002; Latham and Locke, 2007).

3.1.2 Change of Process-Outcome Focus Over Time

Research has shown that the kind of goals humans set themselves change over their life span. While infants approach goal states with high immediate rewards, choosing goals based on a balanced time perspective is essential for a good life in Positive Psychology (Boniwell and Zimbardo, 2012). At least two-goal characteristics change with increasing age: While younger people tend to be more outcome-focused, the elder tend to be more process-focused (Freund, Hennecke, and Mustafić, 2012), and while the younger tend to have achievement goals directed towards maximizing gains, older people tend to have maintenance goals, directed to the avoidance of losses (Freund, Hennecke, and Mustafić, 2012). These findings make sense when young age is considered an indicator for a life phase of growth and high age as an indicator for a life phase of decline. Thus, we assume that typical university students are in a life phase of growth, with a tendency towards outcome-focused goals. Furthermore, choosing and pursuing goals based on a long-term perspective may be challenging, especially for first-year students, because of limited experience with freedom of choice in preceding phases of education.

Behavior	Nonself-Determined					Self-Determined
Motivation	Amotivation	Extrinsic Motivation				Intrinsic Motivation
Regulatory Styles	Non-Regulation	External Regulation	Introjected Regulation	Identified Regulation	Integrated Regulation	Intrinsic Regulation
Perceived Locus of Causality	Impersonal	External	Somewhat External	Somewhat Internal	Internal	Internal
Relevant Regulatory Processes	Nonintentional, Nonvaluing, Incompetence, Lack of Control	Compliance, External Rewards and Punishments	Self-control, Ego-Involvement, Internal Rewards and Punishments	Personal Importance, Conscious Valuing	Congruence, Awareness, Synthesis With Self	Interest, Enjoyment, Inherent Satisfaction

FIGURE 3.1: The Self-Determination Continuum Shows Types of Motivation, their Regulatory Styles and Perceived Loci of Causality as Described by Ryan and Deci (Ryan and Deci, 2000).

3.1.3 Self-Determination Theory (SDT)

Self-Determination Theory (SDT) by Ryan and Deci (Deci and Ryan, 1985; Ryan, 2012) is a humanistic, organismic theory of human behavior and personality development. The semantically related self-determination continuum (SDC) (Ryan and Deci, 2000) outlines a taxonomy of motivation and self-regulation styles. It distinguishes between amotivation, which is related to non-regulation, extrinsic motivation, which is related to external, introjected, identified, or integrated regulation, to intrinsic motivation, causing intrinsic regulation (see figure 3.1). The internalization of goals in this model depends on personal importance, self-endorsement, self-congruence, and personal interest in goals. A higher education system aiming to produce independent, proactive individuals should aim to support students in developing internal motivation in the form of identified, integrated, and intrinsic motivation.

3.1.4 Motivation and Self-Regulated Learning

As outlined in chapter 2, self-regulated learning is a conceptualization of learning in which active learners play an essential role by regulating their behavior in iterative loops of planning, executing, and reflecting learning processes (Zimmerman, 1990). In cyclic models of self-regulated learning (see figure 1.1), individual learning goals are an essential building block because they form the foundation for planning and serve as benchmarks for evaluation (Zimmerman, 1989). Internal motivation predicts the use of strategies for self-regulation and learning strategies (Virtanen, Nevgi, and Niemi, 2013), which underlines the importance of internally regulated educational goals for personal development based on self-regulation.

3.1.5 Goal Clarification in Higher Education

There is a long tradition of applying goals to the academic arena (Morisano, 2013). Simply elaborating on personal goals and the ideal future can significantly increase academic performance (Schippers et al., 2020), especially for the extreme group of struggling students (Morisano, 2008; Morisano and Shore, 2010). These findings imply that students can benefit from interventions that let them think about, clarify and construct personal educational goals. This finding has significant implications for goal-setting research in higher education. Studies can be designed as goal-setting interventions with personal relevance for participants, potentially increasing intrinsic motivation and facilitating the success of recruitment procedures.

In the German context, the EU-wide Bologna reforms have introduced new challenges, particularly for Bachelor students, for whom the transition to work requires an increasingly high degree of professional goal orientation and self-control (Olos, Hoff, and Härtwig, 2014). However, many students are relatively poor at formulating intrinsic study goals. Studies suggest that they can significantly benefit from support to formulate and maintain a commitment to self-set goals (Schippers et al., 2020).

The three goals of the study outlined in this chapter were to collect a set of realistic educational goals in natural language, develop a tagset that is suitable to describe the characteristics of students' goals and, in the future, to train machine learning models to predict the characteristics of unseen goals.

3.2 History of Goal Characteristics Assessment

Describing and measuring the characteristics of goals has a long history, but a comprehensive system unifying the plethora of previous attempts is a blank spot in goal-setting research. In this section, we introduce some influential classification systems without claiming completeness.

Bloom's Taxonomy of Educational Goals (Bloom et al., 1956) is an early approach to structuring educational objectives. The original taxonomy entails the six graded levels of cognitive learning goals: Knowledge, comprehension, application, analysis, synthesis, and evaluation, and has been adapted and refined since its' development in the 1950ies. Since its' development, it has been broadly applied in higher education and is a topic of ongoing debate. In developmental psychology and educational psychology, there is a line of research about achievement goals (Murayama, Elliot, and Friedman, 2012) that led to a 2 x 2 model (Elliot and McGregor, 2001) and a 2 x 3 model (Elliot, Murayama, and Pekrun, 2011). The foundation for the 2 x 2 model is a distinction between two types of educational goals, termed learning goals and performance goals by Dweck (Dweck, 1986) or task-involvement goals and ego-involvement goals (Nicholls, 1984; Nicholls, 2017). With performance (or ego-involvement) goals, students focus on their abilities and sense of self-worth, achieving ability by surpassing normative-based standards or the performance of others. By contrast, learning, mastery, or task-involvement goals reflect the belief that effort and outcome co-vary. They thus highlight intrinsic motivational patterns. In contrast to performance goals, mastery goals are evaluated based on self-referenced standards (Ames, 1992). The mastery-performance distinction is related to implicit theories about the changeability of intelligence and competence. If an individual implicitly assumes that those two variables can be changed by effort and learning processes, it is worth investing in related self-improvement. If, in contrast, an individual assumes that those parameters are static, then it is rational to minimize task costs.

There are some issues with theoretical clarity in motivational constructs (Pintrich, 2000a). These conceptualizations have in common that one conceptual extreme is mastering a task to learn or simply solve the task for its own sake, while the other is solving a task to demonstrate personal competence or perform well. These early conceptualizations converged in the mastery goal-performance goal dichotomy, forming the first dimension of the 2 x 2 model. The second dimension of valence distinguishes between positive approach-goals and negative avoidance-goals, developed by Elliot and colleagues (Elliot and Harackiewicz, 1996; Elliot and Church, 1997; Elliot, 1999). The resulting 2 x 2 matrix contains mastery-approach goals, mastery-avoidance goals, performance-approach goals, and performance-avoidance goals. Both types of mastery goals correlate with intrinsic motivation, performance-avoidance goals correlate with dysfunctional learning strategies, and low grades and performance-approach goals predict high grades (Elliot and Church, 1997). In the 2 x 3 model, a trichotomy related to the reference frame of goal definition replaces the mastery-performance dichotomy in the definition dimension: A goal can be defined relative to one's past achievements (self) by the concrete task (task) and relative to other persons (others). This new distinction results in six goal types: self-approach, self-avoidance, task-approach, task-avoidance, other-approach, and other-avoidance goals.

There is empirical evidence for these discrete variables' interaction effects on outcome variables, such as intrinsic motivation, grades, and quality of learning strategies. Furthermore, there are conclusive theoretical explanations for these effects. A weak point of both models is a simplification of discrete variables, which assumes distinct sets of goals. Instead, we think it is more realistic to model the dimensions of the 2 x 2 model as continuous variables, where a goal can have components of mastery (*I want to understand the concept of factor analysis.*) and performance (*I want to pass the statistics test with a good grade.*) in the same goal. Furthermore, this goal characteristic may change over time; perhaps mastery is more substantial when starting learning for the exam, and the performance aspect reaches a peak shortly before the exam.

The 2 x 3 model is even more apart from reality because, at first, its reality is not discrete in the reference frame dimension, either, and second, the trichotomy does not fit into one continuous dimension. A prospective approach could be to develop a 2 x 2 x 2 model, perhaps with the dichotomies approach-avoidance, mastery-performance, and internal-external reference frame.

The goal-setting theory assumes that goals are cognitive representations of what individuals are trying to accomplish and their purposes or reasons for attempting a task. They are inherently cognitive and assumed to be accessible by the individual. This accessibility, however, is not necessarily a given, and, in real-world contexts, students spontaneously formulate much more varied goals. Furthermore, each achievement goal category potentially encompasses many different sub-levels of goals. By way of illustration, Elliot and Thrash (Elliot and Thrash, 2001) differentiate between high-level striving, e.g., *learn as much as I possibly can at school this* *year* and lower-level striving, e.g., *get at least 45 out of 50 problems correct on my math exam*. Hence the kind of goals that students freely formulate may be simple task-based target goals, overarching goal orientations, or goal complexes. In addition, goals are cognitive representations and, as such, are expected to be adapted based on contextual sensibility (Pintrich, 2000b).

Although these goal categories are traditionally theorized as dichotomous and in opposition to one another, empirical correlational studies based on survey data have reported conflicting results with positive, negative, and non-significant correlations between the supposedly opposing types of goals (Pintrich, 2000a). A further issue with such goal classification schemes concerns the consciousness or cognitive accessibility of motivational constructs and thus whether students can accurately report on their motivation (Murphy and Alexander, 2000).

For instance, Elliot and Church (Elliot and Church, 1997) devised a questionnaire to assess college students' adoption of mastery, performance-approach, and performance-avoidance achievement goals. Participants responded to six items, such as *It is important to me to do better than the other students* and *I want to learn as much as possible from this class*, on a 7-point Likert scale ranging from *not at all true of me* to *very true of me*. Important to note is that this questionnaire asks about the individual, not the goal, which reveals the influence of motivation research tradition.

Also, in the German higher education context, Ahn and colleagues (Ahn et al., 2012) applied both previously established goal categories and added new categories based on interviews and questionnaires with students and lecturers. These categories reflect goals related to choosing a particular course of study. The authors classified them into six supra-categories. Ahn et al. (Ahn et al., 2012) proposed a four-level hierarchical model of study goals based on the data collected. The highest level represents the overarching aim of living a good life. The second level differentiates between goals concerning students' university studies and those concerning life after graduation. The model's third level concerns the goal's contextual environment: at university vs. outside the university and private vs. professional lives. The fourth, most fine-grained level, distinguishes between self-focus vs. other-focus, high vs. low involvement in the learning process, professional vs. personal considerations, and fulfilling personal wishes vs. those of others.

Travers and colleagues (Travers, Morisano, and Locke, 2015) explored the types of academic performance-related growth goals students choose to set themselves as part of a personal growth goal-setting program. The authors subsumed these goals into three broad categories:
(1) personal organization and time management;
(2) emotional and psychological control; and
(3) interpersonal skills development,
stressing that these need not be discrete categories. Similarly, as part of an extensive quasi-experimental goal-setting intervention program, Schippers and colleagues (Schippers et al., 2020) categorized students' self-set goals with a set of seven categories based on life domains: academic, career, social relationships, material, physical health, mental well-being, and miscellaneous. Two independent raters classified the goals according to these seven categories, and Schippers et al. (Schippers et al., 2020) report high inter-rater agreement scores of k = 0.85–0.87.

In this chapter, two approaches to measuring goal characteristics are introduced: The first external approach was based on six raters, tagging a set of goals with tags from a tagset, and the second is an internal approach, based on self-assessment with Likert-scale items.

3.3 A Tagset for the External Assessment of Goal Characteristics

This chapter has partially been published in "Goal Trees as Structuring Element in a Digital Data-Driven Study Assistant" (Weber, 2019), "A Tagset for University Students' Educational Goals" (Weber and Le Foll, 2020), and "Characterizing Personal Educational Goals: Inter-rater Agreement on a Tagset Reveals Domain-Specific Limitations of the External Perspective" (Weber and Thelen, 2022a).

This section summarizes an approach to measuring goal characteristics from an external perspective.

3.3.1 Introduction

Previous studies on students' personal educational goals have tended to focus on one or two study disciplines (most frequently economics, management, and psychology), and attempts to classify freely formulated study goals have usually been restricted to a handful of inclusive goal categories, with only a few studies providing evidence for validity beyond the conceptual level, or reliability, such inter-rater agreement scores. By contrast, the present study seeks to create and validate a tagset that covers a broad range of characteristics of individual educational goals of university students. The tagset is inspired by and evaluated based on a data set of goals from three German universities from a broad range of disciplines. Ultimately, we hope that such a tagset, together with an extensive, reliably manually tagged training data set, may later be used by a digital study assistant to automatically analyze students' self-set goals to design personalized goal-directed recommendations.

3.3.2 Methods

In the first, the data processing subsection, we outline the data processing starting from the recruitment of participants and ending with the final data analysis. In the following second subsection about the technical setup, the software architecture allowed smooth integration into the local learning management system Stud.IP[1] (Stockmann and Berg, 2005) and was mostly "hand-coded", is described. The tagset is introduced and enriched with literature for further reading in the third subsection.

Data Processing

The procedure is summarized in figure 3.2 First, we invited students from the universities of Bremen, Hannover, and Osnabrück across all study programs to participate in the study using existing university- and faculty-specific email mailing lists and advertising on the universities' local learning management system (LMS). The sampling technique used was a combination of self-selection and convenience sampling (Oates, 2006).

The link provided in the emails and the LMS adds redirected students to a web-based interface embedded in the universities' local Stud.IP learning management system. The web page detailed the SIDDATA project's broader aims of creating a digital study assistant and encouraged students to participate by citing research

[1] Stud.IP is an open-source campus management system (CMS) and Learning management system (LMS) for universities, schools, companies, organizations, and government agencies. It provides interfaces that allow the integration of external systems and applications. More information is available on the project homepage at https://www.studip.de.

showing that the formulation of personal goals can positively contribute to attaining them (Locke and Latham, 2002).

A gamification element provided further motivation: The interface informed students that, on submitting their goals, they would be able to see the n most frequently submitted goals of all students after the data collection ended, where n is the number of goals they submitted themselves. So if a student submitted four goals after the data acquisition ended, the student would get to know the four most frequent goals. Due to the uniqueness of most of the goals collected, we showed participants the n most frequent goal tags instead of the concrete goals.

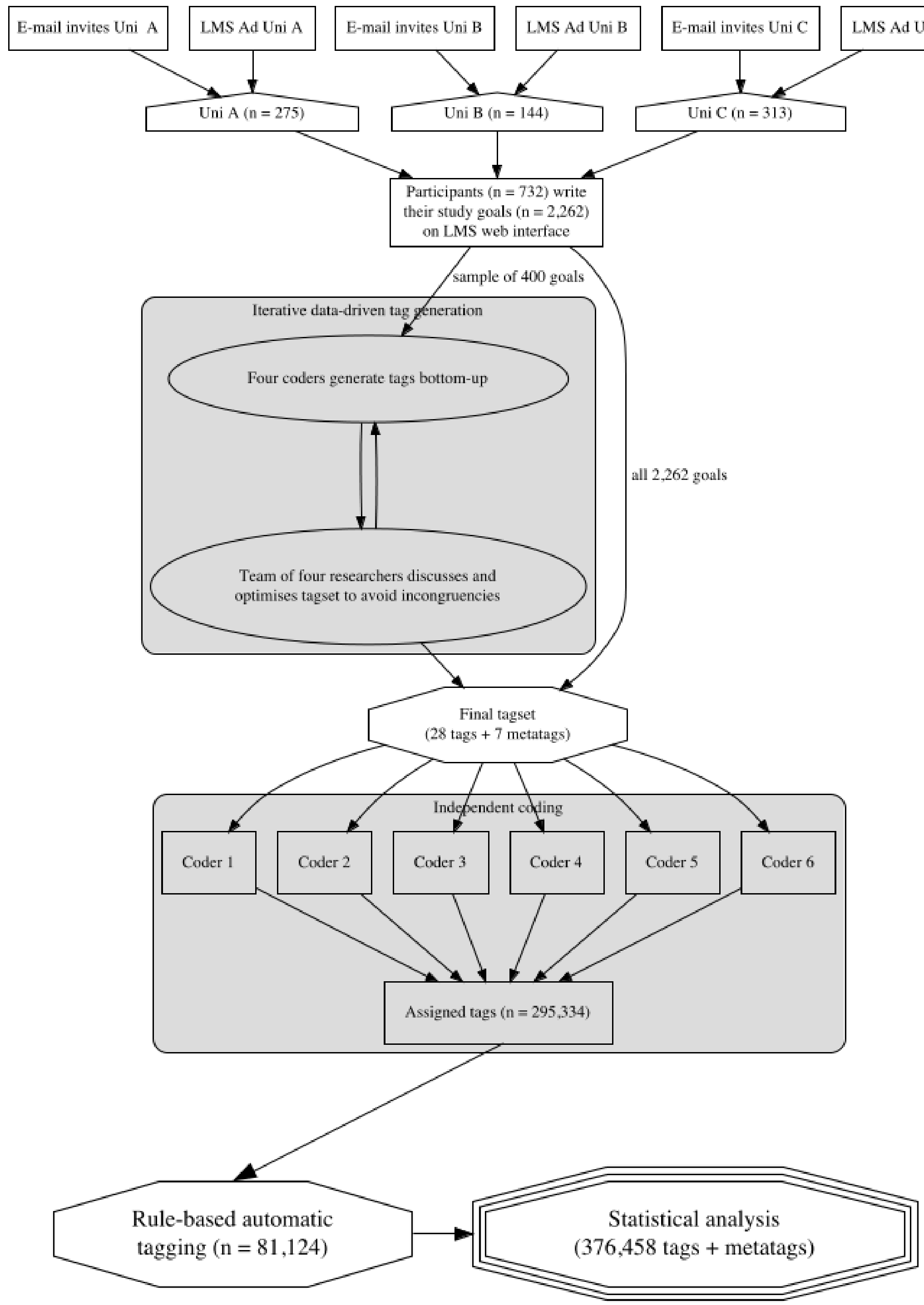

FIGURE 3.2: Data Acquisition Procedure as Described in Weber and Le Foll, 2020.

The university data protection officials checked and approved the data collection procedure to align with GDPR. In the first text box of the input interface, we informed participants about the pseudonymization procedure of their data. They could opt-in to have personal information about their course and current semester of study saved alongside their goals. The exact information saved was displayed next to the check box. The second text box required participants to input their goals one by one. They also had the option of deleting previously submitted goals.

Post-data collection, one of the researchers iteratively tagged a random sample of 400 goals, following a cyclical, data-driven process, and four project members discussed and improved the proposed tags. The resulting rater manual describing the tags and criteria for their assignment can be found in Appendix D (German) and Appendix E (English). Six independent raters then applied the final tagset to the complete set of goals collected. The raters took binary decisions for each goal/tag combination. Post-manual coding meta-tags were assigned rule-based and automated by a python script. For instance, if a rater assigned the tags *Orientation* to the goal *Promotionsstelle bekommen* (*get a Ph.D. position*), the meta-tag *Career goals* was automatically added because the assigned tag belongs to the group of tags, subsumed by this meta-tag. Additionally, following Bloom's (Bloom et al., 1956) taxonomy of educational objectives, the tags subsumed under the meta tag Education goals were hypothesized to be sequentially dependent: *Personal growth* > *Competences* > *Comprehension* > emphKnowledge. Consequently, if a goal was tagged as *Competences*, the tags *Knowledge* and *Comprehension* were automatically assigned to that goal, too. The dataset, including analysis scripts in Python, is available in the osnaData repository[2].

Sample

In total, 732 students participated in the study. Among the participants, 74.69% percent agreed to provide data about their subject, degree type, and semester. 2.262 goals were generated so that, on average, participants provided around three goals each. The length of goals varied from single words to several elaborate sentences with word counts from 1 to 39 and an average of 3 words. The number of characters per goal ranged from 3 to 276, with an average of 27. All in all, we tagged 2262 goals with 295.334 manual ratings. Due to time and resource constraints, the six raters did not tag the entire data set. A table listing the missing ratings can be found in Appendix C.

Krippendorff's α as a Metric for Inter-Rater Agreement

We used Krippendorff's α (Krippendorff, 2004) to quantify inter-rater agreement since it can handle missing data and is comparable to many other well-known metrics (Krippendorff, 2004).

Krippendorff's α in its most general form is defined as

$$\alpha = 1 - \frac{D_o}{D_e} \tag{3.1}$$

where D_o is the amount of observed disagreement and D_e is the amount of expected disagreement, based on chance.

Relative tag frequencies were calculated for each tag across all ratings by all raters. Data analyses were carried out in Python 3.7 using the Pandas (McKinney, 2010), NumPy (Oliphant, 2006), and Statsmodels (Seabold and Perktold, 2010) libraries.

[2]Weber, Felix; Thelen, Tobias, 2022, "Students' Educational Goals in Natural Language", https://doi.org/10.26249/FK2/UJWLJ2,osnaData,V1

Technical Setup

We implemented the software for data acquisition, storage, processing, and analysis as a web application. The user interface for data collection (also referred to as frontend) was integrated into the Stud.IP learning management system (Stockmann and Berg, 2005), and is a plugin coded in the PHP scripting language (Kunda and Siame, 2017). The plugin's job was to react to user input, send data to the backend, and visualize the stored data. The user interface offers a checkbox asking for user consent for study information data processing and a text input asking for goals in natural language. Inserted goals are displayed, and clicking on a trash icon leads to deletion. A screenshot of the graphical user interface can be found in figure 3.3.

FIGURE 3.3: Screenshot from the Web Interface Used for Data Acquisition.

The backend server runs on a virtual machine with the Ubuntu Linux operating system, as an application written in the python3 programming language and based on the Django web framework (Django Software Foundation, 2013; Holovaty and Kaplan-Moss, 2007) and using a PostgreSQL database (Stonebraker and Kemnitz, 1991).

Backend and frontend communicate via a RESTful interface, using textual representations with a stateless protocol. The backend can receive, transfer, update

private or professional	career goals	educational goals	social goals	concrete goals	temporal horizon	other tags
professional	grades	knowledge	communication and contact	work(-related) experieces	within this semester	fun, happiness and satisfaction
private	duration of studies	comprehension	volunteer work and idealism	going abroad	during studies	S.M.A.R.T.
	graduation	competences		foreign languages	post-graduation	too vague
	orientation	personal growth		academic and scientific skills		non-sensical or non-genuine
	career opportunities			programming skills		
	networking					
	status and wealth					
	safety					

FIGURE 3.4: The 28 Tags are Grouped into 7 Groups and Metatags.

or delete data through requests formatted, following the JSON-API standard. The transfer of data is implemented over SSL-encrypted channels to ensure data security. HTML views provided by the backend implemented the goal tagging. Each rater used personalized credentials to log in at any place and time via a web interface. Technically this setup was realized using in-built mechanisms of the Django framework, such as the Django template engine, the object-relational mapping, and Django's native authentication system.

Development of the Tagset

The iterative development process of the tag set started with a preliminary data set of 400 goals and background knowledge about previous research. The final tagset consists of 28 tags, organized in 7 groups, each resulting in a meta-tag, which applies for a goal if at least one of the subsumed tags is assigned (see Figure 3.4).

Private or Professional

The distinction between *private* and *professional* goals originates in our interest to know whether students pursue educational goals to find a job and earn money or for personal reasons, such as a thirst for *Knowledge* or *Personal growth*. Conceptually the distinction is related to the two sets of *career goals* (which can be considered *professional* because they are related to external rewards) and *educational goals* (which can be considered as *private* because they are related to personal development).

Career Goals

The set of *career goals* contains specific formal achievements in an educational career and more abstract goals related to professional success or earning a living in the future. They are semantically related to performance goals in terms of the achievement goal literature because they aim at benchmarks of the educational and societal surrounding[3].

[3] Except for the *Orientation* tag, which can be considered an *educational goal* directed towards *Knowledge*, *Comprehension*, *Competences*, and *Personal growth* in the domain of finding a path through a professional career.

Grades: This tag is applied to goals aiming at a specific grade and passing an exam or a course, as passing is usually equivalent to achieving at least a certain degree.

Duration of studies: This tag applies to goals that aim to complete a study program at a specific time, within a certain time frame, or generally as soon as possible.

Graduation: This tag applies to a certain degree or professional position, such as a teacher or lawyer.

Orientation: This tag applies to goals that aim to clarify one's aspired degree, occupation, or other professional goals.

Career opportunities: This tag applies to all goals that aim to improve job situations and perspectives.

Networking: This tag applies to goals that aim to establish and strengthen personal contacts for career building.

Status and wealth: This tag aims at degrees, income, prestige, titles, power, resources, or possession.

Security: This tag applies to goals directed to establishing material or professional security.

Educational Goals

Educational goals are conceptually related to mastery goals in the achievement goal literature, insofar that learning or acquiring a competence or growing as a person is the essence of the goal. The educational goal tags are inspired by Bloom's Taxonomy of Educational Goals (Bloom et al., 1956), which is an early approach to structuring educational objectives. The proposed taxonomy entails knowledge, comprehension, application, analysis, synthesis, and evaluation. We adapted *Knowledge* and *Comprehension* from this set and subsumed application, analysis, synthesis, and evaluation under the tag *Competences* because we understand all four as types of skills. As the highest-level tag for this group of tags, we added the *Personal growth* tag.

For the *educational goals*, we define a recursive subsumption relationship: *Personal growth* requires acquiring *competencies*, which require at least a certain degree of *comprehension* which requires a certain degree of *knowledge*. In practice, we instructed the raters to assign only the highest goal tag in the subsumption hierarchy to avoid redundant mouse clicks. A Python-script post-tagging automatically complemented the subsumed lower tags (see figure 3.2).

Knowledge: This tag applies to goals that are related to the acquisition of knowledge.

Comprehension: This tag applies to goals related to understanding, which goes beyond *Knowledge* and subsumes it.

Competences: This tag applies to goals related to acquiring an ability or a skill. It goes beyond *Comprehension* and subsumes it.

Personal growth: Personal growth goals are directed toward self-improvement. Self-improvement motivation is a relevant motivational tendency in meta-cognition (Jiang and Kleitman, 2015). Growth goals predict Subjective Well-Being (SWB) in the future (Bauer and McAdams, 2010).

Social Goals

Institutionalized learning in schools and the higher education system usually occurs in a group context of classes, courses, study programs, study groups, or homework groups. Perceived social support can positively affect motivation and achievement of educational goals (Song et al., 2015). Public commitment to a goal can improve goal commitment (Locke and Latham, 2002). Maslows' theory about basic human needs assumes a strong need for love and belongingness (Maslow, 1943) and psychologists assume that attachment and relatedness are central antecedents for eudaimonic well-being (Ryan and Deci, 2001). In the set of goals, we identified two types of goals related to these needs:

Communication and contact: This tag applies to goals that aim to meet and communicate with other students or lecturers.

Volunteer work and idealism: This tag applies to goals related to serving or working for a good cause. Examples are *working for an NGO* or *Getting engaged in the student's union*.

Concrete Goals

The reason for this group of tags is the development of a digital study assistant for higher education. For each of the *Concrete goals*, the digital study assistant will be able to derive recommendations and reminders. Therefore, with data from this study, we plan to train a machine learning model to detect those specific goals.

Work(-related) experiences: This tag applies to internships and student jobs.

Going abroad: This tag applies to students' interest in going abroad to study or do an internship. Universities provide a broad range of support services for such endeavors, which the digital assistant can recommend.

Foreign languages: This tag applies to language learning goals. The digital assistant can recommend language courses and exchange programs based on such a goal.

Academic and scientific skills: This tag applies to goals related to scientific methods, for which a broad range of extracurricular activities and learning opportunities exist, which are not evident to students. A digital assistant can potentially unlock such learning opportunities.

Programming skills: This tag applies to goals aimed at programming or other computer-related skills. Digital technologies are essential for all academic disciplines, but finding the right learning opportunities within the university may be non-trivial for students from non-technical fields.

Temporal Horizon

The temporal scope of goals is a characteristic that goal-setting researchers have investigated for a long time. In the classical goal-setting literature by Locke and Latham (Latham and Brown, 2006; Locke and Latham, 1990; Locke and Latham, 2019), a dichotomous distinction between proximal and distal goals has been made. Processes of self-regulation in education occur on the micro- meso- and macro-level. These terms refer to single learning sessions, organization and time management during a semester, and planning an education pathway through a study program or even life-long learning. In the context of an educational goal-setting intervention, it is unlikely that students will formulate goals on the micro-level in just a few hours. The reason is that humans tend to commit only to goals that they assume to be within their abilities (Locke and Latham, 1990). So if a goal on the micro-level is feasible, it can be selected to be executed. If it is not feasible, acquiring the required competencies exceeds the micro time level, and the temporal scope of the resulting learning goal is at least on a meso-level. Consequently, the time frames below one semester are not covered by the tagset. The following tags operationalize the temporal horizon of educational goals:

Within this semester: This tag reflects the educational environment which offers educational activities structured in semesters. In most cases, these activities have a performance measure or examination component, which results in a certificate as a building block for a degree. We expected individual goals without curricular connection to be rare. So the rationale behind this tag is to apply it to courses and exams.

During studies: This tag implies that a goal will be completed during academic education.

Post-graduation: This tag applies either to abstract distal learning goals, such as *understanding data science*, or *Career goals* with a scope beyond a study program, such as *becoming a data scientist*.

Other Tags

This set of goal tags contains tags that do not fit into the other meta-tags, which are semantically related.

Fun, happiness and satisfaction: This tag applies to goals with a hedonistic orientation. An example is *enjoying college life* .

S.M.A.R.T goals: Specific, measurable, assignable, realistic, and time-related goals were by Doran (Doran, 1981) in the context of management objectives to increase the clarity of goals and make them actionable and controllable. These aspects of goal setting are essential for estimating goal achievement duration, effort, and circumstances. Goal specificity increases the probability of goal achievement (Locke et al., 1989; Seijts et al., 2004).

Too vague: This tag applies to goals that are so unspecific that hardly any tag can be assigned. An example from the data set is *make experiences*. Although one can subjectively imagine what this formulation might mean, it is hard to be alive without making experiences. So this example is too vague to apply any tag than this one.

Non-sensical or non-genuine: This tag applies to goals that the raters expect not to be a serious goal but a joke. The goal *Gucci Socken* (*gucci socks*) pointed at the necessity for such a tag. In some cases, the decision from an external perspective is non-trivial. For example, the tag cannot be assigned without knowing the context of the goal *Massenvernichtungswaffen* (*weapons of mass*) destruction]. Nevertheless, all raters tagged it a *non-sensical*, following their subjective view.

3.3.3 Results

Post-coding, the data cleaning process involved excluding goals identified by the raters as non-sensical utterances and non-genuine goals ($\alpha = 0.712$), resulting in a total of 2.204 goals to be further analyzed. The results are summarized in Figures 3.5 and 3.6, which show relative frequencies in percent and Krippendorff's αas a measure for inter-rater agreement.

Inter-Rater Agreement

The overall meager inter-rater agreement rates reveal that, in practice, many of the tags proved rather difficult to distinguish. Thus, it was initially assumed, in line with Ahn et al.'s (Ahn et al., 2012) hierarchical goal model, that every goal would be assigned the meta-tag *Private or Professional*; in other words, that every goal would be classified as either related to *private*, or *professional* life plans. However, 57.19% of goals were not assigned this meta-tag in practice. By contrast, in a few cases, both the *private* AND the *professional* tags were assigned to the identical goal. Thus, it would appear that educational goals are often tied to both personal and professional interests and that, in many cases, the two cannot be disentangled easily.

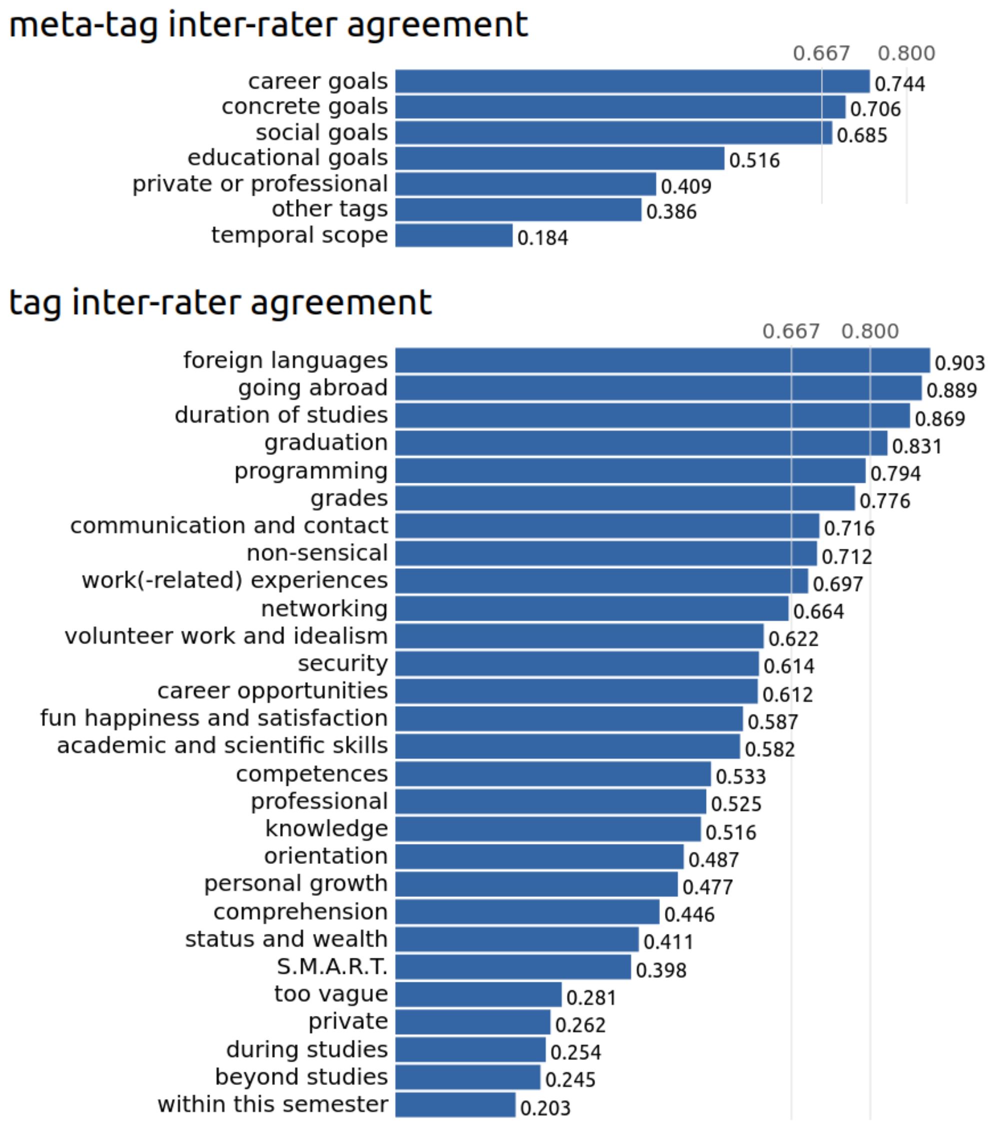

FIGURE 3.5: Krippendorff's α is a Measure for Inter-Rater Agreement of all Tags and Meta-Tags (Interpretation: $\alpha \geq 0.800$ Tentative Conclusive, $\alpha \geq 0.667$ Acceptable According to Krippendorff, 2004.)

Conceived as a pragmatic way to make the fuzzy concept of distal and proximal goals operational, the temporal scope of goals was also often hard to determine without additional background information. The αscores for the three temporal tags Within this Semester, During Studies, and Post-graduation are among the lowest. Theoretically, these three tags cover all the possible temporal scopes of study goals. Hence, in principle, at least one of the tags should apply to each goal formulated. However, as many as 67.14% goals were not assigned a temporal tag. On the one hand, this circumstance was due to participants not assigning explicit temporal scopes to their goals and, on the other, to implicit temporal scopes not being inferred by the raters.

Similarly, the inter-rater agreement rates reported for the *educational goals* tags are surprisingly low. This finding is due primarily to participants' often very sparse elaboration of goals. Thus, many participants formulated goals that read *Lernen* [learn/revise] or *Neue Inhalte erlernen* [learn new things], for which even the four broad *educational goals* tags of the present tagset (see figure 3.4) were already too detailed.

The *security* (job and financial security) tag was also frequently difficult to ascertain. Again, goals explicitly mention these factors are rare, e.g., *Ein eigenes Haus haben* (*be a homeowner*). Raters also reported that the tags *networking* (assigned to 46 goals) and *communication and contact* (assigned to 76 goals) were hard to distinguish. The tagset included this distinction in the hope of tapping into the motives behind the two-goal types. On a practical level, however, raters frequently lacked contextual information to disambiguate the two, so 22 goals were assigned both the *networking* and *communication and contact* tags. It is worth noting that, in German culture, admitting to building relationships purely for professional reasons is often not regarded as socially acceptable and may be perceived as selfish. On the other hand, *concrete goals* tags, such as those referring to *learning a foreign language*, *studying abroad*, graduating quickly: *duration of studies*, acquiring *programming skills*, obtaining good *grades*, and gathering *work experience*, have a high inter-rater agreement. This finding is probably due to their specificity, their non-ambiguity, and because they are widespread and, consequently, familiar to the raters, who were university students themselves.

Relative Frequencies

Due to the number of students (n = 732) and, in particular, the uncontrolled variables in the selection of the participants, the external validity of the relative frequencies presented in figure 3.6 towards a generalization of the goal characteristics of university students is inherently limited. Nevertheless, they reveal that the most frequent tags assigned to participants' self-set goals are *career goals*, *knowledge*, *during studies*, *competences*, and *graduation*. *Career goals* refers to goals related to either studies or work instead of private goals; hence, this finding was expected. Goals tagged as *during studies* suggest that the majority of students' goals do refer to their current student status, instead of more long-term goals referring to their professional lives beyond their studies.

Indeed, many of the participants' goals revolved around learning objectives and were thus assigned the tag *knowledge*. However, these goals were often highly unspecified: many simply stated *Wissen* (*knowledge*) or *Lernen* (*learning*), courses or broad disciplines, e.g., *Biologie* (*biology*), *Statistik bestehen* (*pass statistics*). Other students formulated longer but even more general goals such as *Mehr Wissen sammeln, allgemein und fachspezifisch* (*gather more general and subject-specific knowledge*).

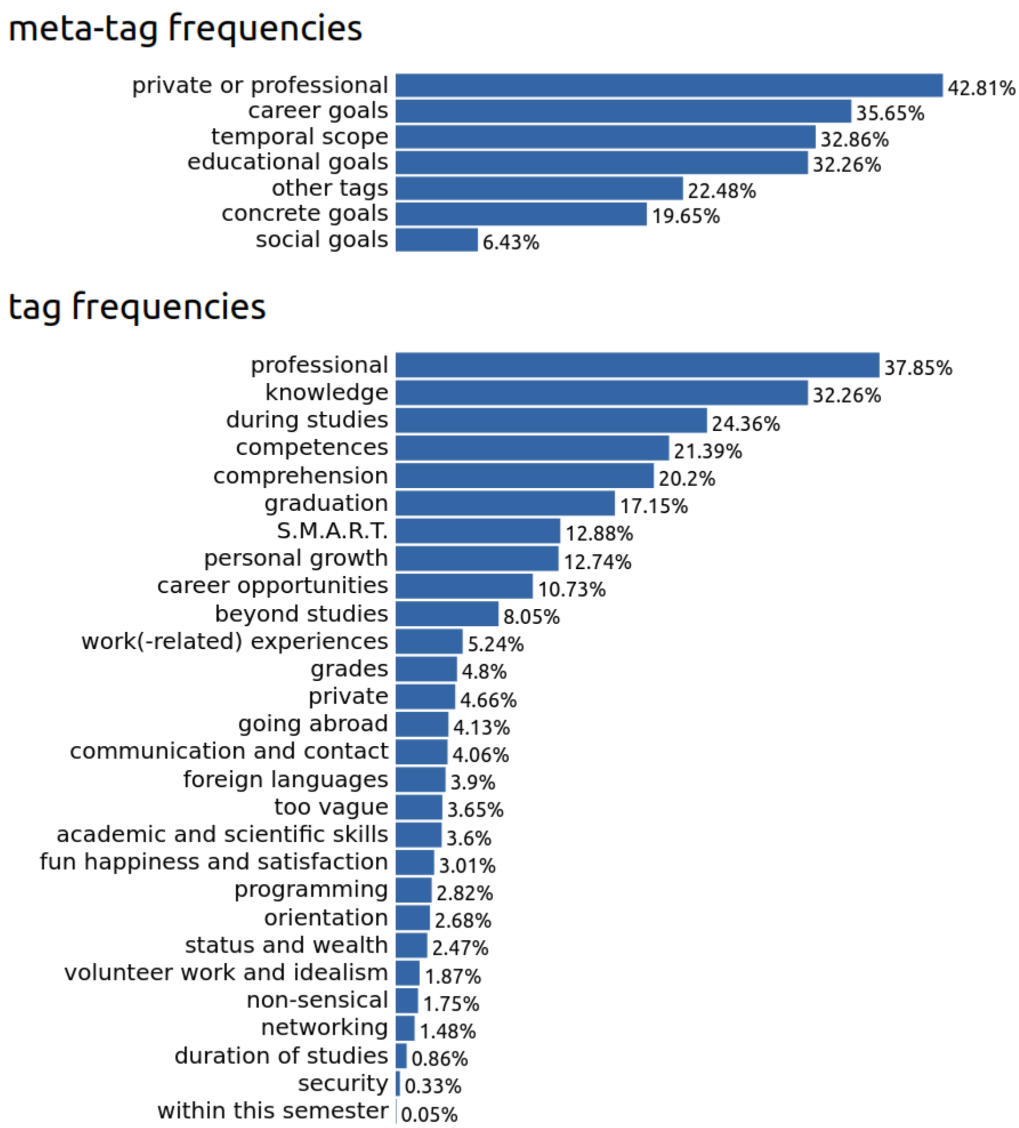

FIGURE 3.6: Relative Tag Frequencies.

Across all degree programs, many students articulated a wish to improve their foreign language skills. Nevertheless, a relatively high proportion of goals were also assigned the tag Competences, which refers to applying comprehended knowledge. Such goals were often more specific, so the tag *Competences* highly correlates with the tags corresponding to specific skills such as programming and foreign languages skills. However, it was also frequently assigned to goals referring to critical thinking and soft skills, for which no specific tags are included in the present tagset. It is striking that such goals are also frequently formulated in a very abstract manner, e.g., *eine weitere Sprache erlernen* (*to a learn another language*).

Given these examples, it will be no surprise that the relative frequency of SMART goals is low. The inter-rater agreement rate for SMART goals is also surprisingly low: this is due to a disagreement between the raters as to whether goals were referring to graduation, which was also among the most frequent, e.g., *Master abschließen* (*complete my Masters*), should be considered specific, measurable, achievable and time-bound (*S.M.A.R.T*).

Correlations and Co-occurences

To get an impression of possible co-occurrences of tags, a correlation matrix with correlation coefficients (see figure 3.7) and a matrix of the unexpectedness of co-occurrences (see figure 3.8) were generated using a Python script. *Expectedness* means the joint probability of two tags, given their single (measured) probabilities. *Unexpectedness* was defined as co-occurrences divided by expectedness. These plots are not discussed in detail due to the extent of the included data.

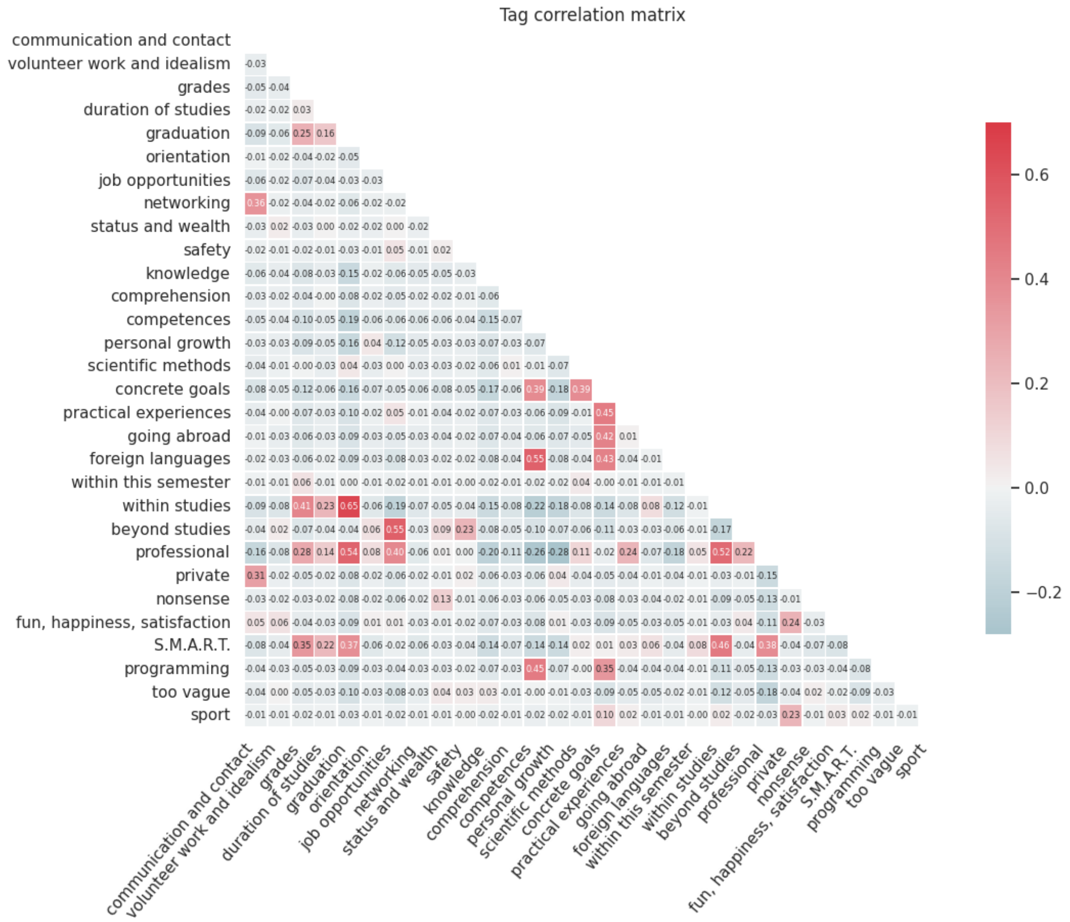

FIGURE 3.7: Correlation Matrix for Tags.

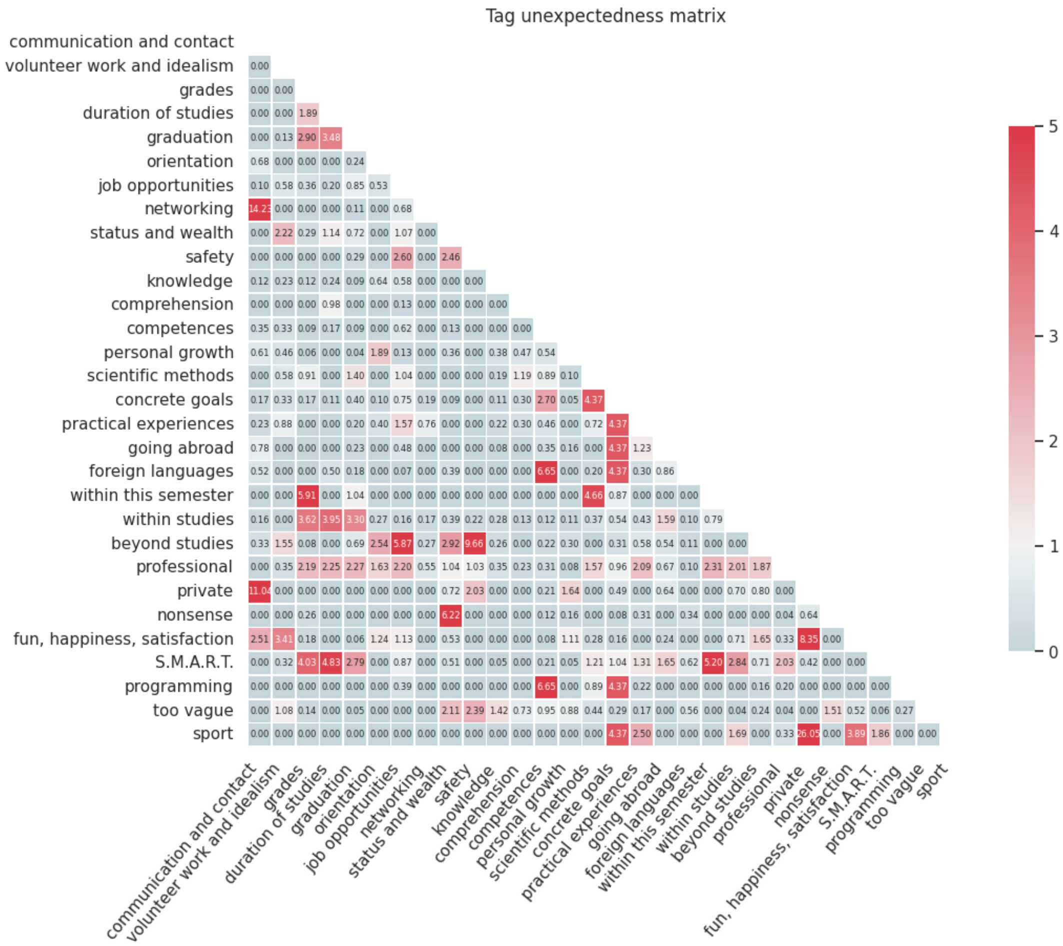

FIGURE 3.8: Co-occurrence Unexpectedness Matrix for Tags.

3.3.4 Discussion

This study encouraged students to submit their personal study goals via an online interface embedded in universities' local LMS. Previous research has shown that the very process of formulating such goals may induce learning and contribute to reaching these goals (Locke and Latham, 2002; Schippers et al., 2020). In particular, Morisano et al.'s (Morisano and Shore, 2010) study concluded that detailing personal goals and strategies can significantly improve educational performance. Thus, such personal goal-setting interventions can contribute to making the value of goals more salient and help develop strategies to attain them.

We suggest that a digital study assistant could provide this kind of support in a personalized manner on a large scale. Further, such a tool could support goal progress monitoring, which is also known to improve effective self-regulation and increase the likelihood of successful goal outcomes (Harkin et al., 2016). The present results suggest that A digital study assistant may most easily support concrete goals based on simple rule-based algorithms. The tagged data from our study can serve as labeled training data for machine learning algorithms capable of assigning tags to goals entered as user input.

Methodological Considerations

We implicitly assumed in the current study's design that external raters can objectively characterize goals. As can be recognized clearly from a retrospective perspective, this assumption contradicts the – by definition – subjective nature of goals. The same goal formulation may have different meanings because personal preferences and predispositions determine why a goal is worth striving for. Taking math classes may be a pleasurable experience for some persons and an unpleasant means towards a super-ordinate goal for others. So in this specific example, only the person having the goal can provide reliable information about the motivational background and properties of a goal. On the other hand, Raters lack essential information and may compensate for this by projecting their preferences and predispositions onto the goal. The method of externally assigning goal characteristics seems to work well for particular types of goals, such as *going abroad*, *graduation*, or *learning a foreign language*, but not so well for more abstract characteristics, such as the *temporal scope* of a goal or whether it is *private* or *professional*.

This study has made clear that, without any support, students tend to formulate rather unspecified goals. In contrast, meta-analyses have shown that specific and challenging yet attainable goals are most likely to be reached (Locke and Latham, 2002). Alternatively, Schippers et al. (Schippers et al., 2020) hypothesize that developing detailed strategies for goal attainment may compensate for the lack of specificity in the goal formulated. In either case, the results of our study suggest that university students could benefit from additional support to formulate their goals and develop specific strategies to attain them.

As mentioned above, the externally assigned tags' overall inter-rater agreement is relatively low. This finding raises methodological questions concerning the external characterization of goals, especially for highly subjective aspects. Goal characteristics that cannot be assessed from an external perspective merely from an articulated goal can better be captured by psychometric self-report measures used by the person with the goal in mind.

3.4 The Goal Characteristics Questionnaire (GCQ)

3.4.1 Introduction

The ongoing development of a goal characteristics questionnaire (Iwama, Wirzberger, and Lieder, 2019; Iwama et al., 2021), which constitutes a psychometric measure covering a wide variety of goal-related variables, bears a huge potential for future research on goals. This section has, in parts, been published in Iwama et al., 2021 and was (re-)written by the author based on an older version (Iwama, Wirzberger, and Lieder, 2019). The questionnaire items of the GCQ in German and English, as used in the studies in this thesis, can be found in Appendix A.

The GCQ covers a broad range of variables of relevance in goal research. As a self-assessment tool, it is well-suitable to measure the subjective qualities of goals. Goal-setting interventions can unfold effects on such subjective qualities of goals. Among the possible application scenarios for the GCQ are empirical studies with pre-post designs, in which the GCQ is suitable for measuring intervention effects. While the process of scale development, and the empirical methods and results of the evaluation and refinement, can be found in the paper "Development and Validation of a Goal Characteristics Questionnaire", the following sections, based on the paper, will introduce the dimensions of the GCQ and highlight their relevance for educational goal-setting and their application in a goal-related DSA.

3.4.2 Subscales and Dimensions

Based on dimension semantics, the dimensions are ordered into subscales of ideally equal sizes (see figure 3.9).

Structural	Framing	Attainability	Resources Availability	Interestingness	Usefulness
Content Specificity	Approach-Avoidance	Immediate Actionability	Social Support	Self-Congruence	Long-Term Utility
Time Specificity	(Maintenance-Attainment)	Estimated Effort	Informational Support	Value Congruence	Short-Term Utility
Hierarchy - High Level	Process-Outcome Focus*	Plannability	Instrumental Support	Importance	Relative Utility
Hierarchy - Low Level		Controllability	Financial Affordance	Awareness	Self-Improvement Utility
Goal Network Congruence		Challenge	Visibility	(Attentiveness)	Negative Utility*
Measurability		Defined Subgoals	Time Availability	Vitality*	
			Competence Adequacy		

FIGURE 3.9: The Subscales and Dimensions of the GCQ.

Structural Characteristics Subscale

On the one hand, the structural characteristics subscale is concerned with the precision of a goal's definition, including its content's specificity and intended time of achievement. On the other hand, it was designed to measure the relation of a goal to other goals in a goal system, such as their level in a hierarchy and congruence with each other. In sum, it covers six goal characteristics that are described as follows:

Content Specificity Content specificity describes the degree of precision of the goal description. It increases the probability of goal achievement (Locke et al., 1989). Goal specificity and its opposite, goal ambiguity, have been shown to predict public service motivation (PSM) in a study about motivation in the US Federal Agencies (Jung and Rainey, 2011).

Time Specificity Time specificity describes how far the time frame for goal achievement is precisely defined. It has been found that task deadlines increase the probability of task completion (Doran, 1981). In implementation intentions, a precise time for a task is defined, and a trigger event is specified (if-then plan), which increases the effectiveness of goals (Gollwitzer, 1999).

Measurability Measurability describes how easily goal progress can be tracked. Measurability of progress is of significant relevance for monitoring goal progress and, consequently, goal achievement (Harkin et al., 2016). Monitoring goal progress is considered part of self-regulation and metacognition (e.g., (Bjork, Dunlosky, and Kornell, 2013)). If an individual can measure the progress or distance towards a goal, effort, and strategies can be adjusted to ensure goal achievement in time.

Hierarchy- Low and High Level These characteristics describe how much the goal is considered a low-level goal contributing to a higher-order or a high-level goal requiring subgoals. Based on a hierarchical structural organization, goals can be organized in different levels of abstraction, from describing a very abstract concept (e.g., *be goals*) to precise motor sequences (e.g., *slice broccoli*; (Carver and Scheier, 1998). In the last decades, the study of goals as parts of goal systems with supportive or conflicting interrelations has become an emerging field of study (Kung and Scholer, 2018; Ballard et al., 2016; Kruglanski et al., 2002). The organization and control of behavior in hierarchical (goal-) structures have been debated, and there is substantial evidence to assume such representations (Cooper and Shallice, 2006).

Goal Network Congruence Network congruence quantifies the compatibility of a goal with other goals and goal systems. Goals have been investigated in isolation but contextualized to other goals (Louro, Pieters, and Zeelenberg, 2007) and goal systems (Kung and Scholer, 2018). According to (Kung and Scholer, 2020), beneficial relations between goals have been studied as *goal facilitation* (Kruglanski et al., 2002; Riediger, Freund, and Baltes, 2005), *goal coherence*, or *goal integrity* (McGregor and Little, 1998).

Framing Characteristics Subscale

The framing subscale subsumes characteristics related to the subjective perspective toward a goal, which may change over time. A *goal* can be defined as avoiding versus approaching a state, maintaining a state versus attaining a state, and focusing on the process of goal pursuit versus focusing on the final goal. These are different ways of perceiving a goal, which have been demonstrated to affect our way of dealing with it. Those characteristics are suitable to assess the effects of interventions in a pre/post-test design since the end state of the goal does not need change. In sum, it covers three goal characteristics that are described as follows:

Approach-Avoidance Framing Approach-avoidance framing describes whether the goal aims to avoid an aversive future state or approach the desired state. The distinction between approach and avoidance goals has emerged from the research on educational psychology (Elliot, 1999; Elliot and McGregor, 2001; Miller, 1944; Elliot and Thrash, 2001). Approach and avoidance orientation of goals moderate the effect of goal attainment on Subjective Well-Being (Ehrlich, 2012).

Maintenance-Attainment Framing Maintenance-attainment framing distinguishes goals that can be achieved and result in a stable achievement, such as completing a marathon, or goal states that must be maintained, such as being sportive. Conceptually, maintenance goals can be seen as reference values or a standard, as outlined in the conceptual work by Boldero and Francis (Boldero and Francis, 2002). The General Approach, attainMent, Maintenance, and Avoidance (GAMMA) Motivation Scale (Lappi and Wilkowski, 2020) measures this construct as stated in the name. This characteristic impacts perceived difficulty and goal choice (Stamatogiannakis, Chattopadhyay, and Chakravarti, 2018).

Process vs. Outcome Focus Outcome focus can be defined as the motivation for an activity because it is a means to a desirable end. In contrast, process focus is about the means (Sansone and Thoman, 2005; Freund, Hennecke, and Mustafić, 2012; Mustafić and Freund, 2012). In other words, the process vs. outcome focus characteristic describes whether the goal representation focuses on the means, such as climbing the mountain, or the goal outcome, such as reaching the summit. Studies found goal focus changes across adulthood, in which people shift from outcome- to process-focus with age (Freund, Hennecke, and Mustafić, 2012; Mustafić and Freund, 2012). It has been shown that goal focus changes during action phases because they require a different perspective regarding process and outcome (Freund, Hennecke, and Mustafić, 2012; Mustafić and Freund, 2012).

Attainability Characteristics Subscale

The attainability subscales subsume constructs that are related to successful goal achievement. Many of the following characteristics can be related to the concept of SMART goals by Doran (Doran, 1981), defined as specific, measurable, attainable, realistic, and time-related and originate from the management domain. In sum, it covers six goal characteristics that are described as follows:

Immediate Actionability Immediate actionability measures the perceived height of the internal or external hurdle to act upon. It is closely related to the specificity of Doran's (Doran, 1981) SMART goals. Planning strategies, such as implementation intentions (Gollwitzer, 1999), rely on this goal characteristic. Low scores in this characteristic may indicate a need for planning.

Estimated Effort Estimated effort is intended to measure the amount of mental or physical effort the process of goal striving costs, approximated from the current point in time. The perceived effort may depend on other goal characteristics. For example, an arduous task for a goal with high self-congruence may feel less demanding than an easy task for a goal with low self-congruence. Subjective ease has been shown to benefit goal progress (Werner et al., 2016).

Plannability Plannability measures to which extent the steps towards goal pursuit are foreseeable. This aspect of goal setting is essential for estimating goal achievement duration, effort, and circumstances. People tend to concentrate their time planning on the near future (Lynch et al., 2010). Therefore, plannability can be an elementary target for most inventions. Perceived low plannability does not necessarily indicate a factual low plannability, but low scores for this characteristic may indicate a lack of planning.

Controllability Controllability quantifies the degree to which a person perceives the locus of control for a specific goal within himself versus the environment. Indeed, some goals lie beyond one's control, such as winning the lottery or having good weather tomorrow. For most of the goals humans have, they also have control. Personality psychology has studied how people perceive causality for a long time (Russell, 1982; Crafts and Rotter, 1955), so trait factors may influence this goal characteristic. For example, locus of control is a trait variable that reflects how a person believes the control over events in their life lies within or outside himself. Locus of control strongly predicts attitudes, motivation, and behavior (Galvin et al., 2018). Intuitively, a necessary prerequisite for taking action toward a goal is a belief in control over the outcome; however, belief alone is insufficient.

Challenge The goal property of challenge has already been investigated early in the history of goal setting. Locke and Latham postulated in their goal-setting theory that the perceived challenge of a goal correlates positively to performance as long as the limit of perceived ability is not exceeded. Above this point, productivity drops due to hopelessness to reach the goal (Locke, 1968; Locke and Latham, 1990; Latham and Locke, 2007; Locke and Latham, 2002; Locke, 2013; Locke and Latham, 2019).

Defined Subgoals The number of defined subgoals is the operationalization of the degree to which a plan for goal achievement has been established and can be described with a set of subgoals, possibly in a logical order. It can measure the degree to which a plan for goal pursuit has already been explicitly determined or how far it needs to be done. The study of multiple goals instead of isolated goals is an emerging field (see, for instance, (Louro, Pieters, and Zeelenberg, 2007), which motivated the authors to introduce this subscale).

Resources Availability Characteristics Subscale

The resources availability subscale assesses the degree of presence of facilitators for goal pursuit. Semantically, the characteristics from this scale are related to the attainability characteristics. For example, goals with sparse or unavailable crucial resources probably result in high scores for the challenge characteristic and low scores for the immediate actionability characteristic. The separation into two subscales motivated distinguishing characteristics based on the resource-related nature. Diversifying resource availability has high practical relevance because lacking support for goal pursuit may result in compensation strategies or goal abandonment. The characteristics in this scale were also inspired by the job demands-resources model, which aims to explain job engagement, which the authors assume to be close to goal commitment, based on job demands and a set of resources (Demerouti and Bakker, 2011). In sum, this subscale covers seven goal characteristics that are described as follows:

Social Support The characteristic of social support quantifies the degree of perceived support in the social environment to attain a goal. In the educational context, it has been shown that perceived social support can positively affect motivation and achievement (Song et al., 2015).

Informational Support Informational support is the availability of information necessary for successful goal pursuit. Informational support has been investigated as a part of social support (Malecki and Demaray, 2003). It plays a central role in educational contexts where acquiring knowledge, skills, and competencies relies on the availability of information.

Instrumental Support Instrumental support is the availability of equipment and materials required for successful goal pursuit. It is reasonable to assume that the (perceived) availability of required materials is a necessary precondition for goal pursuit. Creating subgoals or withdrawals might compensate for the lack of instrumental support. Instrumental support has also been investigated as a part of social support (Malecki and Demaray, 2003).

Financial Affordance Financial affordance is the availability of monetary resources required for goal pursuit. It is a specific aspect of instrumental support that can affect goal-setting. For example, the financial affordance of health care services can impact treatment options (e.g., Ren et al., 2019) and, therefore, impact if and how people pursue their health-related goals.

Visibility Visibility is the characteristic of a goal being visible by the social environment. Visibility is considered a resource since public commitment to a goal improves goal commitment (Locke and Latham, 2002). On the other hand, public visibility of identity-related behavioral intentions can decrease the respective behavior caused by the premature sense of possessing the desired identity and decreasing effort to attain it (Gollwitzer et al., 2009). Therefore, visibility can unfold positive effects by increasing commitment to a goal. Still, visibility can be counterproductive, especially for identity-related goals, because it leads to rewarding experiences before reaching the goal. Furthermore, the social status of the audience knowing about a goal was found to be positively correlated to goal commitment (Klein et al., 2020).

Time Availability Time availability measures the degree to which the time required to pursue a goal is available. Limited temporal resources are a crucial limitation of goal pursuit and prioritization. Goal selection and goal disengagement are strategies suitable to deal with it. Time-relatedness is traditionally an essential aspect of practical goal-setting (Doran, 1981). In sum, time is a valuable finite resource whose allocation should be considered during goal selection and pursuit (e.g., (Wrosch et al., 2003).

Competence Adequacy Competence adequacy is a characteristic related to the required skills for the person having the goal. If a goal is perceived as far below one's capabilities, it may be easy to achieve but may be perceived as not challenging. On the other hand, goals being far above one's competencies may be perceived as overwhelming, leading to decreased activity and motivation (Latham and Locke, 1991a; Locke and Latham, 1990). The goal characteristic of competence adequacy is closely related to self-efficacy (Bandura, 1977), defined as the belief in competence to achieve one's goals. It positively affects health and effectiveness (Bandura, 1982; Bandura, Freeman, and Lightsey, 1999).

Interestingness Characteristics Subscale

The interestingness subscale subsumes variables related to the subjective relevance of goals. Most constructs of this subscale are studied in positive psychology and have been shown to affect well-being positively. Although the intrinsic-extrinsic motivational continuum is not directly covered in the GCQ, the characteristics of this subscale may be suitable for predicting it. In sum, it covers five goal characteristics that are described as follows:

Self-Congruence Self-congruence or self-concordance is the degree to which a goal aligns with the person's self-concept or identity. Self-congruence can also be related to the self-determination continuum (Deci and Ryan, 1985; Ryan and Deci, 2000; Deci and Ryan, 2000) to measure the degree to which a goal is internalized. Evaluating a goal's self-congruence can help people identify a more intrinsic selection (Sheldon, Prentice, and Osin, 2019). In addition, a meta-analysis has shown that self-concordance positively correlates with goal progress (Koestner et al., 2002).

Value Congruence Value congruence is the degree to which a goal aligns with one's beliefs, values, dreams, and ideal self. Value congruent goals are associated with the experience of meaning in life (McGregor and Little, 1998). They are a marker of approach motivation and resource for goal pursuit, especially under uncertainty, anxiety, and threat (Mcgregor, Prentice, and Nash, 2013).

Importance The importance characteristic measures the personal relevance of a goal. In situations of goal prioritization, this characteristic may help determine which goals to drop. Importance is a commonly used goal characteristic closely related to goal commitment. Vancouver and Austin (Vancouver and Austin, 1996) have identified importance-commitment as one of six factors across a broad range of empirical and theoretical goal dimensions.

Awareness Awareness is the degree to which a goal has been conscious prior to the measurement time. It has been demonstrated that goal pursuit can originate and work at the unconscious level, and even behavior control is possible without conscious awareness (Bargh et al., 2001; Aarts, Custers, and Veltkamp, 2008). Awareness can moderate the relationship between goal progress and well-being under certain conditions (Pomaki, Karoly, and Maes, 2009). In social contexts, goal contagion arises when humans adopt goals implied by the behavior of others (Aarts, Gollwitzer, and Hassin, 2004). For the investigation of this and related phenomena, awareness is of relevance. This characteristic should not be confused with attentiveness, which does not require awareness (Dijksterhuis and Aarts, 2010).

Vitality Closely related to the construct of absorption in the engagement literature (Wefald and Downey, 2010), vitality measures a positive affection in a person elicited by their goal representation. This variable is a desirable goal characteristic per se, especially from the perspective of positive psychology. Additionally, it predicts goal progress (Hope et al., 2016).

Usefulness Characteristics Subscale

The usefulness subscale includes variables of utility a goal may have. The variables of this subscale are intended to uncover positive and negative rewards on different temporal horizons due to pursuing the goal in question. These characteristics might be especially relevant for the selection of conscious goals. For example, moral utility theory suggests that (un-)ethical decisions are based on a trade-off between different aspects of utility (Hirsh, Lu, and Galinsky, 2018), which might directly affect the selection of altruistic goals. Moreover, subjective evaluations of direct and indirect outcomes affect goal selection and pursuit differently depending on other goal characteristics and the person's traits and abilities, such as cognitive control. In sum, it covers five forms of goal characteristics expressing usefulness that are described as follows:

Long-Term Utility Long-term utility is the property of goals leading to rewards in the far future. The long-term utility is relevant in goal-setting interventions because humans naturally prefer the short-term utility of actions or goals over long-term utility in the early stages of their development. This ability to choose actions with high long-term and low short-term utility is a skill investigated under the critical term of time-perspective in psychology (Boniwell and Zimbardo, 2012).

Short-Term Utility Short-term utility is the property of goals leading to rewards soon. Balancing time perspectives and overcoming the temptations of immediate benefits has been considered a key to a good life by positive psychologists (Boniwell and Zimbardo, 2012). For example, inter-individual differences in weighting immediate and distant outcomes of actions are highly relevant for various health problems (Strathman et al., 1994).

Relative Utility Relative utility is the degree to which pursuing a goal leads to rewards compared to other goals. Humans tend to have more goals than they can pursue with their limited resources (Neal, Ballard, and Vancouver, 2017; Kung and Scholer, 2020), so they have to decide on which goal to commit to. Multiple goal pursuit is an emerging field of research (Kung and Scholer, 2020) in which this goal characteristic may be applied.

Self-Improvement Utility Self-improvement utility quantifies the degree to which the process of goal pursuit is expected to lead to personal growth or the development of new abilities or insights. This characteristic is conceptually related to *learning goals*, which are opposed to *performance goals* in educational psychology (Bouffard et al., 1995). Growth goals have been shown to predict Subjective Well-Being (SWB) in the future (Bauer and McAdams, 2010), and goals about eudaimonic functioning have been shown to tend to succeed (Sheldon, Prentice, and Osin, 2019). Moreover, self-improvement motivation is a relevant motivational tendency in meta-cognition (Jiang and Kleitman, 2015).

Negative Utility Negative utility measures the degree to which achieving a goal leads to aversive consequences. The negative utility is a relevant feature of goals since most have positive and negative consequences. In addition, appetite and aversive motivation elicit distinct neural processes and behavioral responses (M.Yee and Leng, 2021).

3.5 Discussion

Compared to the tagset described in the first part of this chapter, the GCQ quantifies a row of goals properties from an internal perspective, namely the bearer of the respective goal. As indicated in the discussion in section 3.3.4 and the methodological considerations section 3.3.4, an internal approach of self-assessment is, in principle, more suitable to investigate the domain of personal goals because they are subjective by definition.

In chapter 4, the GCQ in its German version measures the characteristics of goals evoked after priming tasks and checks for correlations of goal positions in a goal system with GCQ dimensions. The high number of 32 dimensions and the broad range of covered semantics makes the GCQ an excellent tool for explorative studies concerned with goals. The GCQ was a valuable tool in this research because it was simple to apply and analyze.

Chapter 4

Hierarchical Goal Systems

This chapter has partially been published in "Goal Trees as Structuring Element in a Digital Data-Driven Study Assistant" (Weber, 2019), "Towards A Web-Based Hierarchical Goal Setting Intervention for Higher Education" (Weber et al., 2021), "Development of a Digital Goal Setting Companion for Higher Education" (Weber, Schrumpf, and Thelen, 2021), "Valence Comparison of Hierarchical Diagrams" (Weber, 2022c), "Structural Characteristics of Hierarchical Goal Systems from Online Field Studies" (Weber, 2022b), "A Digital Study Assistant for Hierarchical Goal-Setting Campanion Faces the First Real Users" (Weber, 2022a), "A Web-Based Hierarchical Goal-Setting Intervention for Higher Education" (Weber et al., 2023), and "Towards a User Focused Development of a digital Study Assistant Through a Mixed Methods Design" (Schurz et al., 2021).

4.1 Introduction to Hierarchical Goal Systems

This chapter centers around the concept of hierarchical goal systems, which have been present in the cognitive sciences for decades, for instance, explicitly under the term of *goal hierarchies* in the context of planning and problem solving, and implicitly in various attempts to model human behavior, such as, for instance, the control theory to human behavior by Carver and Scheier, 1981. This approach's central idea to solve complex problems is a recursive simplification by splitting a task into subtasks until a tractable level of task complexity is achieved.

The chapter starts with examples of HGS-like structures in the cognitive sciences and continues with formal and functional definitions of hierarchical goal systems. Subsequently, the idea of a digital study assistant for hierarchical goal-setting is outlined. A row of formative studies and analyses with the constantly developing DSA named *GoalTrees*[1], are reported on. The chapter concludes with results and implications about hierarchical goal systems derived from the data acquired with the GoalTrees goal-setting intervention.

4.2 Goal Hierarchies in the Cognitive Sciences

4.2.1 Hierarchical Organization of Behavior

Carver[2] and Scheier[3] hypothesized that human behavior is organized hierarchically and "..that the nervous system consists of a hierarchy of feedback loops.." and "..that feedback loops could be linked hierarchically.." (Carver and Scheier, 1981, p. 129)

[1]The GoalTrees software is publicly available under MIT license at https://github.com/fweber/GoalTrees.

[2]Charles S. Carver, contemporary American social psychologist

[3]Michael F. Scheier, contemporary American social psychologist

4.2.2 Hierarchical Planning in Robotics

In plan-based robotics, Hierarchical task Networks are used to plan, execute, and dynamically adapt complex tasks. "Hierarchical Task Networks (HTN) planning distinguishes non-primitive and primitive tasks [2]. Primitive tasks are like actions in classical planning that can be executed directly. Non-primitive tasks are decomposed by methods into subtasks. The planner gets a goal task and uses its methods to decompose it into subtasks until only primitive tasks are left that can directly be executed." (Stock, Günther, and Hertzberg, 2014, p. 1 /p. 605) This procedure is astonishingly similar to the functional definition of HGS, given in pseudo-code in listing 4.1.

4.2.3 Problem-Subproblem Hierarchies in Early AI

A very early AI program, the Logic Theorist (LT), which Newell and Simon invented in 1956, even before the term *artificial intelligence* was coined at the Dartmouth Conference[4], was able to prove 38 of the first 52 theorems in Whitehead and Russell's *Principia Mathematica* (Whitehead and Russell, 1997). The corresponding paper "The logic theory machine–A complex information processing system" states that "..one of LT's main features [is], the use of a problem-subproblem hierarchy..." (Newell and Simon, 1956, p. 78-79). The success of an early AI program using it underlines the efficiency and practical value of breaking goals or problems down into subgoals or subproblems. In their 1958 paper "The logic theory machine–A complex information processing system", Newell, Shaw, and Simon describe that LT uses hierarchical structures, similar to what human problem-solvers do: "The problem-subproblem hierarchy in LT's program is quite comparable with the hierarchies that have been discovered by students of human problem-solving processes..." (Newell, Shaw, and Simon, 1958, p. 162)

4.2.4 Tree-Shaped Goal Structures

In the disciplinary borderlands between Complexity Theory and Experimental Psychology, it has been hypothesized that ".. people's capacity to achieve their goals can be predicted from combinatorial parameters of the structure of the network connecting their goals to the means available to pursue them." (Bourgin et al., 2017). By expressing means and goals as bipartite graphs with edges expressing which goal is attainable by which means, the authors could show that tree-shaped goal systems lead to more optimal goal achievement. This finding indicates that humans benefit from goal structures that they can easily understand if this holds in the limited space of this experimental setup, then one may assume that in the much more vast space of our daily reality with noise and temptations, clear goal systems may be even more valuable for choosing the means connected to goal states.

4.2.5 Goal Hierarchy

In the "Wörterbuch der Kognitionswissenschaft" (*Dictionary of Cognitive Science*) by Strube (Strube and Becker, 1996), Klaus Opwis defines the term *goal hierarchy* as follows[5]: "Many problems can only be solved by breaking down the original problem into individual sub-goals (principle of problem reduction based on the formation

[4]The Dartmouth Summer Research Project on Artificial Intelligence was a 1956 summer workshop which is retrospectively often seen as initialization of artificial intelligence as a field.

[5]Translated from German to English with GoogleTranslate

of sub-goals; (↑problem solving; ↑planning). The resulting goals can usually be described by an and/or graph. The root node represents the original problem (top goal). The nodes stand for partial or sub-goals to be solved. "Or" nodes stand for alternative sub-goals, each of which is sufficient to achieve the overarching goal; "And" nodes represent sub-goals necessary to achieve the overall goal. And/or graphs enable the definition of flexible control strategies for the simultaneous management of multiple goals, for the non-deterministic order of goal processing, for the consideration of dependencies between goals, and for parallel processing of multiple goals." (Strube and Becker, 1996)

"The basic goal of a motivational state can serve as a foundation for the subgoals that are instrumental in the satisfaction of the basic goal. Thus, having the basic goal of being fed, one might be led to form the subgoal of opening a refrigerator door. That subgoal, in turn, might lead to a subgoal for reaching out to grasp the refrigerator door handle." (Bickle, 2009)

4.2.6 Goal Systems in Recent Motivational Research

There is a growing body of literature about goals and their relations (Kung and Scholer, 2018; Ballard et al., 2016; Kruglanski et al., 2002; Louro, Pieters, and Zeelenberg, 2007). In recent years, research on goals has extended its perspective from single goals to goal systems and relationships between goals (Weber, 2019; Kruglanski et al., 2002; Bourgin et al., 2017). This development has broadened the researchers' perspective from isolated goals to a plethora of goals with various interrelations, for instance, synergistic or conflicting. Goals with synergistic relationships can be modeled as coherent goal systems. It has been shown that the structure of goal systems predicts people's ability to choose the suitable means for goal pursuit and that a tree-shaped structure of goal systems increases human tractability (Bourgin et al., 2017).

4.3 Theoretical Approach: Hierarchical Goal Setting

There are good arguments to assume that hierarchical structures underlie the control of sequential human behavior (Cooper and Shallice, 2006). We think hierarchical goal systems might work well in the context of a digital study assistant for higher education: Originating from a personally relevant, distal educational goal, sub-goals are derived until the action level is reached. The procedure is similar to the Personal Projects Analysis (PPA) laddering procedure, where participants are repeatedly asked for sub-goals of superordinate goals (Little, 1983).

4.3.1 Hierarchical Goal Systems

Simple actions, such as pressing a key, are part of fast action sequences, such as typing a word, which is part of longer action sequences, such as writing a sentence, and so on. Action sequences are performed in the service of goals, such as explaining a specific concept, and those goals are often pursued in the service of larger and more abstract goals, such as writing a good background section, which is a sub-goal of the goal to write a good paper, which in turn is a sub-goal of an even larger and more abstract goal. A well-structured goal hierarchy makes it much easier for people to plan and decide what to do. Previous research suggests that practical living requires a goal hierarchy where the goals and sub-goals are consistent with each other (Sheldon and Elliot, 1999). Hierarchical goal systems can change people's perspective on daily necessities, such as working on statistics homework, by connecting them to higher-order goals more closely connected to their values, such as improving the world as a data scientist. Establishing clear relations between goals, sub-goals, and actions makes it easier for people to resolve conflicts and focus their limited time on the high-level goals they want to prioritize (Kung and Scholer, 2020).

4.3.2 Formal Definition of HGS

In the following sections, Hierarchical Goal Systems are defined on a structural level (see definition 4) and on a functional level, on which the construction (see listing 4.1) and the solution (see listing 4.2) are covered.

Definition 4 ***: Hierarchical Goal Systems (HGS)*** *are synergistic goal systems originating from one root goal and a set of sub-goals, each contributing to exactly one superordinate goal.*

4.3.3 Functional Definition of HGS

Recursion is an algorithmic pattern used to solve tasks in which a function calls itself again with refined parameters, called *recursion step*. This procedure repeats until a solution is found and returned, called *base case*. Recursive algorithms need to reach a *base case* to terminate. Otherwise, they end up in an *infinite loop*. Two entertaining examples of such infinite loops are the fictional dictionary entry "Recursion, see: Recursion.", and the recursive acronym of the GNU operating system, standing for "GNU's Not Unix!" [6].

The process of hierarchical goal system construction can be formally modeled by the following recursive function, described in Python-like pseudo-code. Note that the function *split_into_subgoals()* is not formally specified but stands for some reasonable procedure to break a goal down into a set of subgoals.

LISTING 4.1: Recursive function to define a HGS.

```
def simplify(goal={"goal":"root-goal", "subgoals"=[]}):
    if tractable(goal) == True:
        return goal
    else:
        subgoals = split_into_subgoals(goal)
        for subgoal in subgoals:
            subsubgoal = simplify(subgoal)
            goal["subgoals"].append(subsubgoal)
        return goal
```

The function takes a data structure of type *goal* as input, which consists of a goal description and a possibly empty list of subgoals. If the goal is tractable, the function returns the goal. This is the *base case*, which leads to the termination of the process. If the goal is not tractable, it is split into subgoals, on which the simplify() function is recursively evoked again (*recursion step*).

Assuming that an HGS is complete, hence contains all actions required to reach the goal state, AND only the leaf nodes are actionable goals, any leaf node traversal, combined with taking the necessary action, leads to a state in which the root goal

[6] https://www.gnu.org/gnu/gnu.html

state is part of reality. Although the traversal order is irrelevant to goal achievement, the costs may vary depending on the order. One aspect to consider is task-switching costs. If tasks are similar, the mental effort is lower than for tasks that require different mental resources. For the tasks at the leaf-node layer of an HGS, the similarity of tasks belonging to the same superordinate goal will probably be higher than for others, which is an argument to process tasks in an order determined by superordinate goals. A second aspect is a human need for variety: To avoid boredom, which decreases motivation and efficiency, tasks with varying cognitive demands should be chosen. These two aspects with conflicting implications for task order show that there is no general rule of thumb for optimal traversal, but task selection always is a challenging task by itself.

LISTING 4.2: How to complete an HGS with any leaf node traversal.

```
def solve(hgs):
    for leaf_node in hgs:
        take_action(leaf_node)
```

4.3.4 Goal Pursuit as a Navigation through Goal State Space

Theoretically, we can model the process of human goal pursuit as navigation through a state space towards a goal state or a set of goal states. In material reality, state transitions are fluent, and the state space is continuous and infinite. In digital higher education, where students strive towards their educational goals within a learning management system, the state space is finite, states are separable, and transitions are discrete. Consequently, for goal-setting researchers interested in digital assistant technologies, the domain of higher education learning management systems is an excellent environment for research because it is simpler and more tractable than the real world.

4.3.5 Assumed Beneficial Effects of HGS

Processes leading to goal clarification, such as elaboration and planning, can lead to progress in terms of goal achievement from a long-term perspective. Elaboration on goals and intensive writing about goals and ideal future can significantly increase academic performance (Morisano, 2008; Schippers et al., 2020). From these findings, it can be concluded that students can benefit from intensive thinking, writing, or digitally working on their personal educational goals. Hence, a digital assistant for guiding students through processes of goal setting, goal striving and reflecting on goal progress and goal achievement in higher education has the potential to be used by students and to accelerate individual academic progress. Beyond these general effects of goal-setting interventions, a digital assistant for hierarchical goal-setting can be expected to have the specific effects outlined in the following subsections.

Meaningful Distal Goals and Actionable Goals

The literature on goal setting distinguishes proximal and distal goals (Latham and Brown, 2006), which differ in their effects on performance, motivation, activity, and self-efficacy. Latham and Brown (Latham and Brown, 2006) have shown that challenging distal outcome goals may discourage and decrease perceived self-efficacy if not combined with proximal learning goals. They also showed that distal outcome goals in combination with proximal goals lead to a higher GPA than distal goals alone (Latham and Brown, 2006). There is a broad range of empirical evidence for the beneficial effects of low-level goals that are precisely defined and actionable. "We found that specific, difficult goals consistently led to higher performance than urging people to do their best." (Locke and Latham, 2002) The concept of S.M.A.R.T goals (Doran, 1981) means defining goals in a specific, measurable, achievable, realistic, and time-bound fashion. It has been shown that goal-directed behavior can be facilitated by implementation intentions that plan when, where, and how such behavior is supposed to occur (Gollwitzer and Sheeran, 2006). A central idea of the GoalTrees software is to bring together the beneficial effects of both actionable proximal goals and meaningful and inspiring distal goals (see figure 4.1.

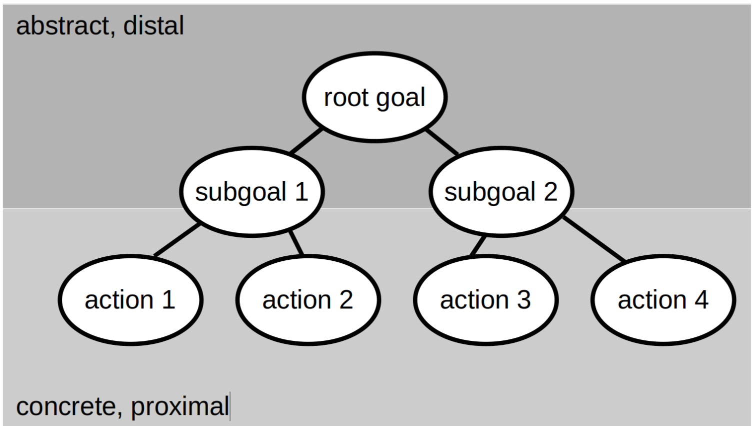

FIGURE 4.1: Prototypical HGS Connecting Root-Goals, Sub-Goals, and Actions.

Goal Mechanisms on Three Levels

Hierarchical Goal Systems can interconnect goals on various levels of abstraction and unfold emergent synergistic effects. Goals can occur on many levels of abstraction, temporal scope, and personal relevance. While high-level goals of great personal relevance are often abstract and not easily tractable, concrete proximal goals often suffer from low attractivity. Table 4.1 shows characteristics on micro- meso-, and macro-time scales. Values can be understood as personally meaningful, abstract goals with hard tractability. They define the *why?* aspect of goals. On a meso-level, goals are precise definitions of states realizing the demands of those values. On the micro-level, concrete actions, which can also be understood as goals, define the *how?*, *when?*, and *where?* aspects of implementation. Hierarchical goal systems are suitable to guide behavior towards concordance with personal values and high-level goals as structures that connect goals of all three time scales and abstraction levels.

level	question	time-scale
values	why?	macro
goals	what?	meso
actions strategies	how? when? where?	micro

TABLE 4.1: Values, Goals, and Actions: Abstraction Levels, Content, and Time Scale.

HGS for Uncovering Goal-Directedness of Behaviors

Self-monitoring behaviors with HGS as formalism can uncover previously unknown or unconscious behaviors. Everything that humans do has a goal or motivation. In most cases, these causes remain unconscious. While many goal-setting interventions focus on setting functional goals in the future to make behavior adjust to these goals, a complementary approach could be a bottom-up approach. Such an approach would access current behavior and actions and ask why these actions should lead to desired states. Going even further, the reasons why these states could be desirable are asked for. As a result, formerly unconscious hierarchical goal systems may be uncovered and questioned. As a result, dysfunctional goal systems can be deleted or their resource consumption reduced to free capacities for functional actions and behavior.

4.4 Practical Approach: The GoalTrees DSA

FIGURE 4.2: The GoalTrees Software Logo.

4.4.1 Conceptual Motivation

Implementation of Locke's and Lathams' Goal Mechanisms

Goal Setting Theory by Locke and Latham has been developed since 1975. It led to knowledge about the relationship between goal setting and performance (Locke and Latham, 1990; Latham and Locke, 1991a; Latham and Locke, 1991b). The underlying mechanisms of successful goal-setting, according to Locke and Latham (Locke and Latham, 2002) are: 1. the direction of attention and effort toward goal-relevant actions 2. the mobilization of resources and effort for goal-relevant actions 3. the maintenance of goals over time support enduring goal striving 4. goal-directed actions as a consequence of task-relevant knowledge and strategies The regular usage of a DSA for goal-setting is theoretically suitable to support all of these mechanisms, especially the third. An external representation of goals supports maintenance over time, and regular usage directs attention, mobilizes resources, and fosters goal-directed actions because relevant knowledge and strategies emerge from the process.

Self-Regulated Learning

We assume that self-regulated learning processes are based on iterative cycles of pre-actional planning, actional, and post-actional reflection phases (see figure 1.1). The purpose of the digital goal-setting assistant is to support all three phases by externally representing fine-grained goal systems. The scope of this thesis focuses on the first phase of pre-actional goal-setting, while the other two phases remain to be covered by future research.

Self-Monitoring and Meta-cognitive Learning

To assist in self-regulation, the study assistant may regularly remind the student with push notifications by email or text message to review their goal systems. Such a nudging function can raise the probability of software usage, goal pursuit, and reflection on goal progress. In a sense, this is a technical implementation of self-monitoring. During the review of Goal Trees, students may actively - evaluate the success or failure of applied actions/strategies - monitor whether they invested time and resources according to the Goal Tree or not - derive new sub-goals and actions (methods, strategies, and behaviors in terms of self-regulated learning) An essential aspect of self-monitoring is a critical review of strategies that failed. For this purpose, simply deleting goals in the review process will not be possible. Instead, the software will encourage students to reflect on why a goal could not be reached or why it does not make sense anymore. This persistence of goals may lead to meta-cognitive learning processes.

4.4.2 Functional Requirements Definition

University students learn on a concrete curricular level and a meta-level of self-organization in their everyday life. They must organize and prioritize tasks and plan and individualize their study paths. The current research prototype of a digital tool for hierarchical goal setting supports students by the following mechanisms:

- Students are encouraged or nudged to think about abstract personal goals and define them. This functionality can lead to more motivation caused by meaningful educational goals.
- The Visualization of HGS shows that every actionable goal contributes to a superordinate goal, highlighting its purpose and increasing motivation.
- Personal goals as roots of goal hierarchies allow maintenance over time and the dynamic adaptation of sub-goals, actions, and strategies. This externalized memory supports goal stability and can increase attentional and volitional focus.
- The connections between personally meaningful long-term goals to concrete tasks in everyday academic life are highlighted. Having essential life goals and understanding higher education as a means to their achievement can increase academic achievement.
- Students are regularly nudged to think about new sub-goals, actions, and strategies suitable to achieve personal root goals. This habit can lead to the refinement of suitable meta-cognitive strategies.

- Task selection and prioritization can be organized by picking tasks from the bottom layer. If the priorities of root goals are known, the task prioritization problem can be solved quickly, and mental planning and decision costs are reduced.
- In reflection phases, goal progress, can be evaluated based on the number of achieved sub-goals, and alternative actions and strategies can be dynamically changed.
- Reflecting and evaluating goal progress applied actions and strategies based on the goal system representation in the assistant leads to self-realization and learning on a meta-cognitive level.

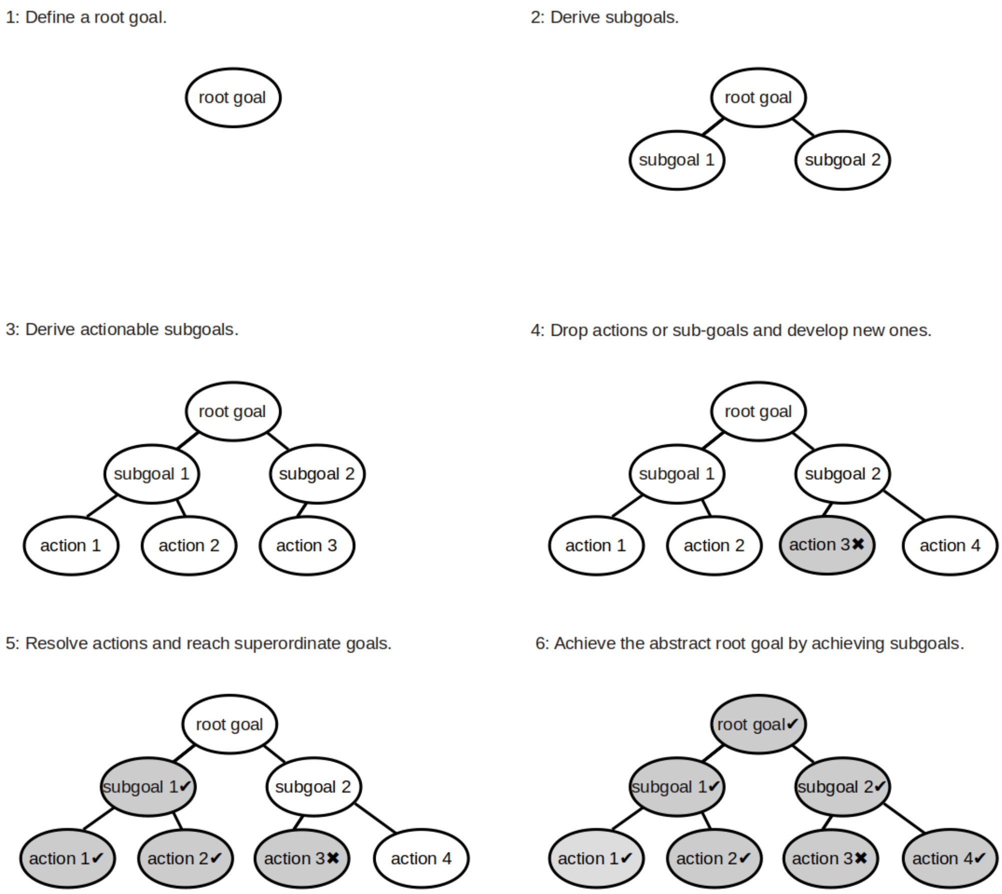

FIGURE 4.3: HGS Life-Cycle and User Interactions.

4.4.3 Paper and Pencil Prestudy

Leandra Draksler has carried out the research described in this subsection as a BA Thesis "Effekte der hierarchischen Strukturierung individueller Studienziele auf das Selbstwirksamkeitserleben Studierender" (Draksler, 2020), under the supervision of the author.

The analog pre-study was conducted as an interview to identify difficulties and user requirements for constructing hierarchical goal systems. Participants (n=8) were recruited by emails distributed over a mailing list and incentivized by test subject hours mandatory in specific study programs to achieve a degree. In a second email, participants were instructed to think about their educational goals and fill out an online questionnaire inspired by the future authoring program by Morisano (Morisano, 2008). As a result of the online questionnaire, participants wrote down a list of personal goals as potential root nodes. Then appointments for an interview in person were made. In the interview, students were instructed on how to pick goals from their list of personal goals and extend them to hierarchical goal systems. This task was done on a pin board with paper cards, as the example in figure 4.4 shows. Participants were encouraged to talk about difficulties during the construction process. The interviewer gave supportive advice as required by participants and recorded observations about difficulties and user behavior. The participants constructed 12 hierarchical goal systems.

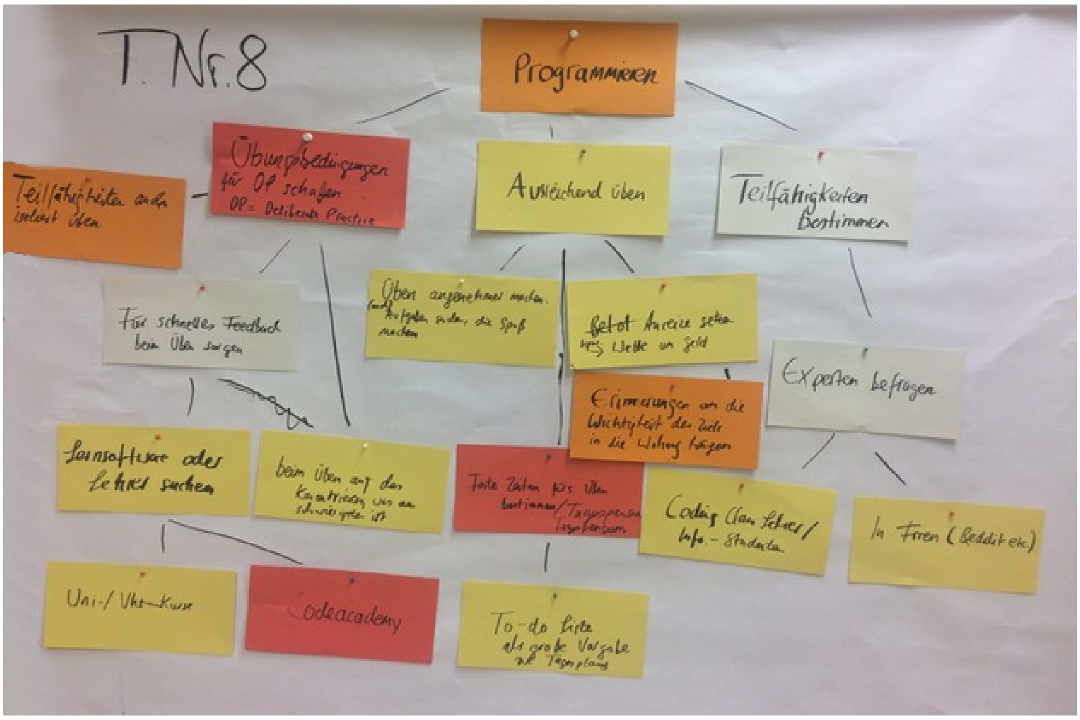

FIGURE 4.4: Paper Pencil Example HGS with Forbidden Cross-Link.

Participants often reported difficulties with the "rule" that a goal could have only one parent (except it is the root goal). They stated that some goals have synergistic effects or, in other words, serve more than one superordinate goal, so participants had the wish to form cross-links. Figure 4.4 shows an example of a cross-link from one multi-final sub-goal to two superordinate goals, where the participant had to keep only one link. Consequently, the picture shows one scratched link. This question of how to deal with such goals beneficial to more than one higher goal remains an open problem. The solution cross-links would make the resulting structure harder to understand for humans. The solution to having multiple representations of multi-final goals indeed leads to redundancy but solves the issue. Under the prioritization perspective, such goals are interesting because reaching them pays off for multiple reasons or superordinate goals.

In some cases of personal goals, the interviewer's presence may have been perceived as disturbing by participants; at least, that is what the interviewer reported. This point constitutes an advantage of a digital assistant, which allows participants to be alone in the goal clarification process.

4.4.4 Software Architecture

Based on the analog pre-study, a web-based software prototype was implemented using the Django web framework (Django Software Foundation, 2013) and the d3.js JavaScript library (Bostock, Ogievetsky, and Heer, 2011) to visualize hierarchical goal systems as a Dendrogram (see figure 4.9 for a system architecture overview.) In the background, the Django Object-Relational-Mapping (ORM) connects to a PostgreSQL database. The integrity of the connection between users' browsers and the GoalTrees server is ensured by Secure Sockets Layer encryption with certificates authorized by the "Rechenzentrum/RZ" of the University of Osnabrück and the DFN[7] certification authority. A test server ("Locke") and a productive server ("Sirdata") were realized as virtual machines, hosted by the RZ, with the Ubuntu 20.04 operating system (`https://ubuntu.com/`) and an Apache Webserver (`https://httpd.apache.org/`). The agile software development processes were organized with the Git(`https://git-scm.com/`) free and open-source software for distributed version control on a self-hosted Gitea (`https://docs.gitea.io/en-us/`) server from 2019 to May 2022, and since then on GitHub (`https://github.com/`).

The structure of the GoalTrees software was designed to optimize effort and freedom for the design of varying studies with different procedures. Therefore, a Python base class *Study* defines attributes, such as the name and the sequence of events for a study. A set of Html views, such as, for instance, a consent form view or a questionnaire view, provides an extensive set of components that an experimenter and/or programmer can choose from. This elegant design allows running a row of studies in parallel, each starting from a different URL on the same server.

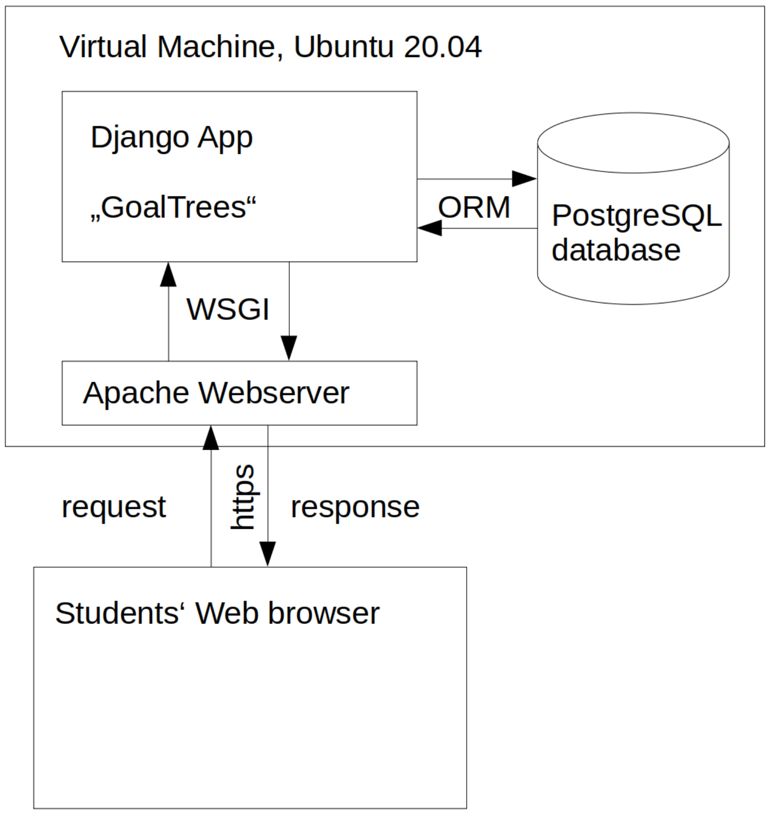

FIGURE 4.5: Web-based Architecture of the GoalTrees Server.

[7]Deutsches Forschungsnetz

4.4.5 Pilot Study

Participants were invited by email with the URL of the web application.

FIGURE 4.6: Pilot study example HGS.

In the web app, users are guided through a sequence of a consent form, a pre-questionnaire, instructions, an example goal hierarchy, personal goal hierarchy construction, and a post-questionnaire. In total, 17 participants generated 25 goal hierarchies with 281 nodes, from which an average goal system size of 11.24 can be derived. The branching for each node ranged from 1 to 5, the number of nodes per goal system varied from 4 to 20, and the depth of the goal hierarchies ranged from 1 to 6. These measured formal characteristics are a valuable foundation for the app's further development because they constitute a first hint of which structural characteristics to expect. In the open questions, participants reported that the task was demanding but that the intervention helped them to gain clarity and get a better overview. One participant reported difficulties in developing subgoals in domains that are yet unknown. That is an aspect from which we expect beneficial effects because clarification may occur when thinking hard about means for goal achievement.

4.4.6 UX and Usability Studies

The research described in this subsection has been carried out by Jana Kernos and published in "Comparison of Usability and User Experience of four Hierarchical Goal System Visualizations for a Digital Data-Driven Study Assistant" (Kernos, 2022). It has also been published collaboratively in "A Web-Based Hierarchical Goal-Setting Intervention for Higher Education" (Weber et al., 2023), and "Towards A Web-Based Hierarchical Goal Setting Intervention for Higher Education" (Weber et al., 2021).

Background and Aims

Usability and User Experience play a constantly increasing role in software development. According to Vlachogianni and Tselios (Vlachogianni and Tselios, 2021), "Usability is one of the key factors for successful technology adoption ". The International Organization for Standardization points out three dimensions: effectiveness, efficiency, and satisfaction, to evaluate Usability (ISO 9241-210, 2019). Also, Lewis (2018) also emphasizes the importance of perceived Usability as it does not necessarily correlate with efficiency and effectiveness. We want to determine which visual representation, among the candidates Sunburst, Treemap, Dendrogram, and Circlepacking is most suitable for the digital study assistant.

Hierarchical Data Visualizations

The visual sense allows humans to grasp high amounts of data, formulated by a proverb: "a picture says more than a thousand words". A visual metaphor can bridge the cognitive gap between humans and computers in a graphical user interface with different data processing and representation characteristics. Therefore, we aim to identify the most intuitive diagram type for hierarchical data from a set of known candidates. For hierarchical data, a set of suitable diagrams have been proposed and investigated (Chimera and Shneiderman, 1994; Vehkalahti, 2008; Shneiderman, 1992). The four visualization types chosen for this comparative study will be introduced in the following paragraphs.

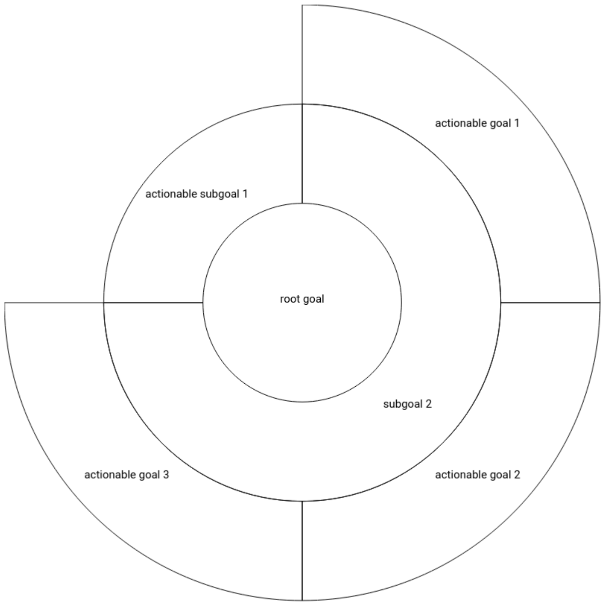

FIGURE 4.7: Sunburst

Sunburst The Sunburst diagram (see figure 4.7) consists of concentric circles, each representing a depth level segmented into the goals of the layer. Sub-goals occur at the same angles on the next outer circle.

Treemap The Treemap diagram (see figure 4.8) consists of nested rectangles, each within its superordinate goal and subgoals arranged within its borders.

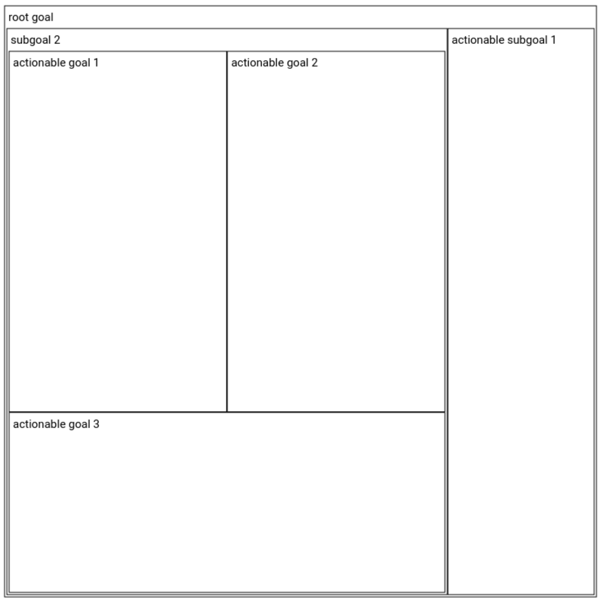

FIGURE 4.8: Treemap

Dendrogram The Dendrogram diagram (see figure 4.9) visualizes goals as circles and subsumption relationships as lines connecting them. With its simplicity, it has been historically used to visualize, for instance, biological taxonomies.

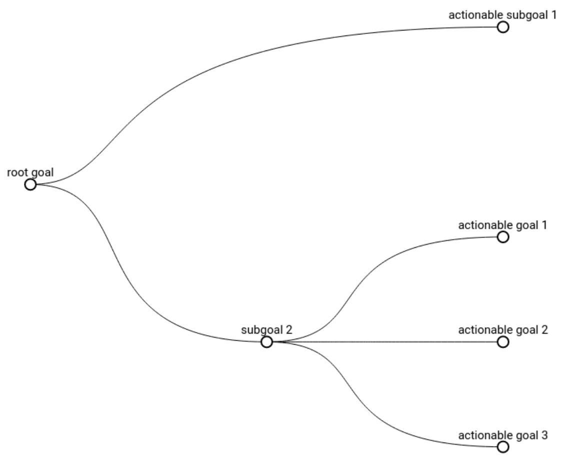

FIGURE 4.9: Dendrogram

Circlepacking The Circlepacking diagram (see figure 4.10) uses nested circles to represent hierarchies. The outermost circle is the root node, and the circles from the lowest layer visually pop out as empty circles.

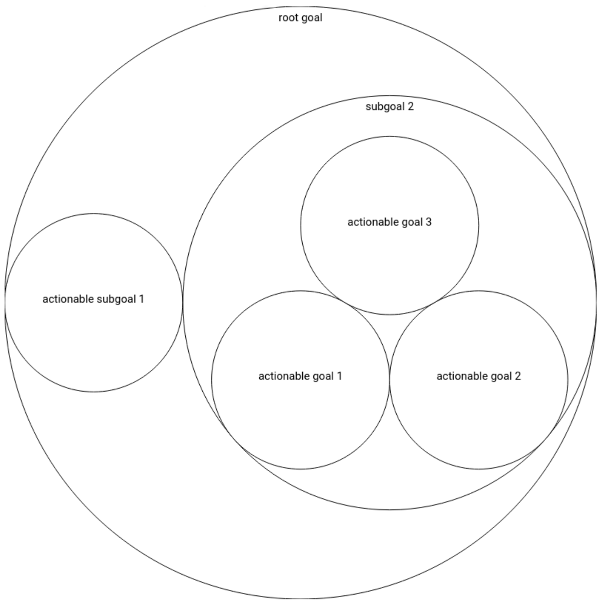

FIGURE 4.10: Circlepacking

Methods

Sample Fifty-four students (70% female, 30% male) with a mean age of 22.5 years ($SD = 3.45$) participated in the online study conducted in the English language.

Procedure Using a between-group design, we pseudo-randomly assigned participants to one of four given visual conditions displayed when they solved a predefined task (fixed scenario). We recorded the number of interactions (clicks) and measured time-on-task (William, 2008) for the efficiency evaluation. After successful task completion (participants with incomplete participation were excluded from the data set), we used a System Usability Scale (Brooke, 1996) to evaluate user satisfaction and compare it between groups. In the next step, we asked subjects to define their four study goals. Then for each goal, they created an HGS using a different visual software representation in a pseudo-randomized order. We excluded participants who created less than two goals from the data set as they did not test each visual representation properly. Finally, having used all four visualizations, participants were asked to rank them regarding their intuitiveness.

Dynamic Adaptations Despite careful testing, a bug in a study running in parallel on the same server led to inaccurate data collection regarding interaction count calculation. Thus, node deletions in an HGS were not recorded, and the system deleted the corresponding create-actions. In order to estimate the amount of deleted nodes retrospectively, we created a table with unused (hence probably deleted) node ids in the system. Additionally, a Boolean variable indicated if an HGS belonged to a fixed scenario task (from the between-subject part of our experiment), participant id, who had created that last found node, and timestamps about the first and last interaction of that participant. We could reconstruct 154 nodes probably deleted during fixed scenario task completion with that inferred information. As each deleted node necessarily belongs to the creation of that node, we added twice the amount of deleted goals to the interaction count. Seventeen nodes (11%) belonged to the Sunburst, 89 (58%) to the Treemap, 12 (8%) to the Dendrogram, and 36 (23%) to the Circlepacking visualization (see figure 4.11).

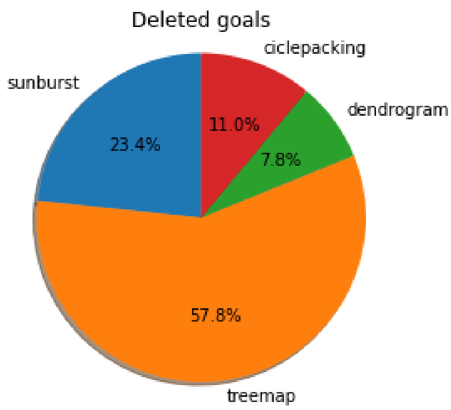

FIGURE 4.11: Deleted Goals Estimation, Indicator of Error-Proneness.

Results

The results across dependent variables show a certain coherence concerning the most advantageous (Dendrogram) and the most disadvantageous visualization type (Treemap). In the following, interactions and time-on-task, SUS, and ranking data are reported separately.

Amount of interactions and time-on-task: As normality (Shapiro-Wilk-Test p=4.57 $* e - 11$) (Shapiro and Wilk, 1965) and homogeneity (Levene-Test (Levene, 1960) p=0.06) assumptions did not hold, we used the non-parametric Kruskal-Wallis H test (Kruskal and Wallis, 1952). A global statistical effect (p=0.04) was detected between groups. Comparing the average durations showed that subjects - on average - completed the task with more interactions when using the Treemap visualization (see Figure 4.12). Similarly, a global effect ($p = 0.03$) could be observed in evaluating time-on-task with the Kruskal-Wallis H Test, while average scores show that usage of the Treemap took more time than the usage of the other three visualizations (see figure 4.12).

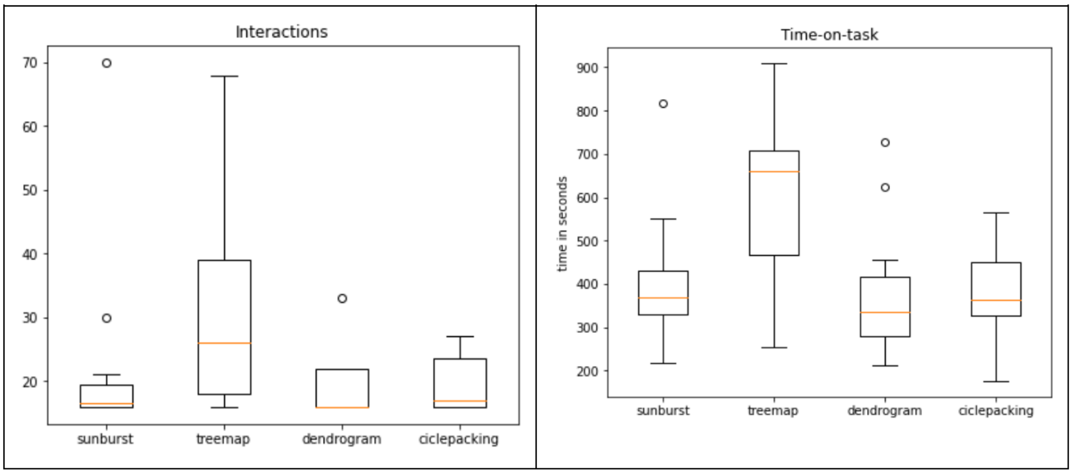

FIGURE 4.12: Box-Whiskers of Interactions and Time-on-task Groups.

System Usability Scale: The System Usability Scale is a standardized questionnaire to evaluate perceived user satisfaction. We compared SUS scores between groups with the help of the non-parametric Kruskal-Wallis H Test, as the normality assumption for ANOVA did not yield. Even though no global effect could be detected ($p = 0.0501 < 0.05$) with a post hoc t-test, we could observe significant differences between Dendrogram and Sunburst ($p = 0.024$) and Dendrogram and Treemap visualization ($p = 0.022$). Pairwise user satisfaction difference between other groups was not significant (see figure 4.13).

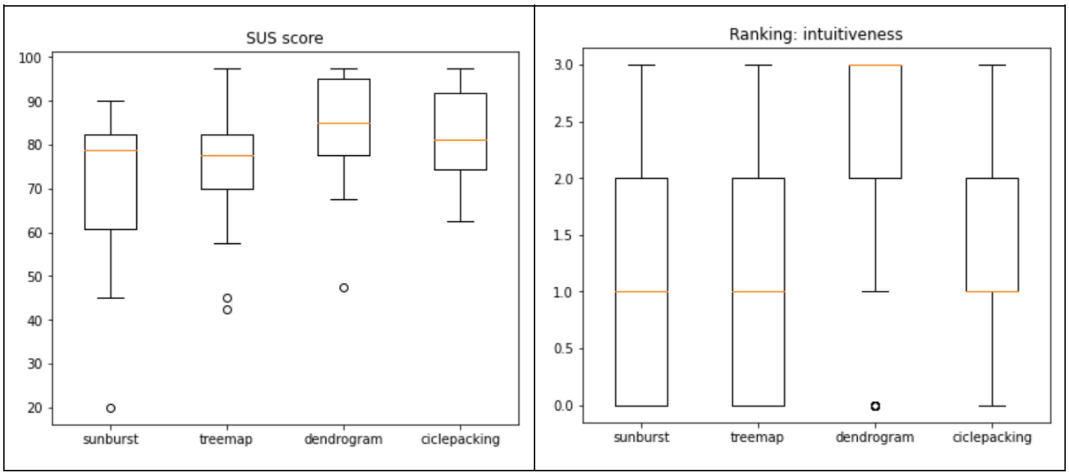

FIGURE 4.13: Box-Whiskers Diagram of SUS and Ranking Groups.

Ranking: At the end of the experiment, after participants had used all four visual representations of HGS, we asked them to rank visualizations regarding their intuitiveness. Kruskal-Wallis H Test showed a strong effect ($p = 7.03 * e - 6$) between groups demonstrating that the Dendrogram led to significantly higher user satisfaction levels than other visualizations.

Discussion

Examining performance differences when measuring time-on-task and number of interactions within a fixed scenario with the Kruskal-Wallis test, we could observe that subjects using the Treemap visualization invested significantly more time and initiated significantly more interactions than subjects exposed to other visualizations. Thus, we conclude that the Treemap is the least efficient HGS visualization. User satisfaction analysis with the help of SUS showed in a Kruskal-Wallis test and corresponding post-hoc t-test that usage of the Dendrogram led to a significantly higher satisfaction level than the Sunburst and the Treemap visualization. In contrast, there was no significant difference between Dendrogram and Circlepacking. By comparing rankings with the Kruskal-Wallis test regarding the intuitiveness of HGS representations, we could observe a strong effect showing that participants perceive the Dendrogram as more intuitive than other visualizations. Therefore, according to the collected data and its evaluation, we the Dendrogram was chosen as default visualztation for the GoalTrees DSA.

Limitations: We observed a remarkable drop-out rate during this study: only 54 participants out of 133 completed the experiment. As it was an online study during a lockdown, and we placed a link to the experiment directly in the invitation emails, we assume that many students have clicked on the link just out of curiosity. Retrospectively, we think that a pre-registration via email could have minimized the probability of "unreliable" students starting the experiment without an intention to participate. Furthermore, as described in the methods part, the recording of interactions did not work as intended, so we had to estimate the number of deleted nodes. However, the number of editing interactions on deleted nodes could not be estimated and is not included in our statistics. Finally, comparing efficiency (time on task and amount of interactions) and user satisfaction of a fixed scenario task, we only considered participants who completed the task successfully. Further qualitative research might compare the effectiveness of different visualization enlightening reasons for failures.

4.4.7 Visualization Preferences and OCEAN Personality Traits

Mae Grenz has carried out the research described in this subsection as a BA Thesis "Hierarchical Goal System Visualizations and Personality Traits in a Digital Goal Setting Intervention: A Correlational Study" (Grenz, 2022) under supervision of the author. It has also been published collaboratively in "A Web-Based Hierarchical Goal-Setting Intervention for Higher Education" (Weber et al., 2023), and "Towards A Web-Based Hierarchical Goal Setting Intervention for Higher Education" (Weber et al., 2021).

Background and Aims

An individual goal-setting intervention faces one major issue: the user- dependent success probability. The intervention can only be as effective if the student is willing to use it. Using an HGS visualization that fits the individual preferences allows for a more pleasant experience and should increase the motivation to use the intervention continuously. The study investigated correlations between preferences for four

HGS visualizations and the Big Five personality traits (Goldberg, 1990; McCrae and Costa, 1987). If a significant effect of personality traits on visualization preferences were found, then a user-controlled visualization selection in the graphical user interface would be a straightforward solution. Otherwise, a one-fits-all approach seems reasonable.

Methods

Sample Forty-six students (59% female, 41% male) with a mean age of 24.4 years (SD = 7) participated in the online study conducted in German.

Procedure Evaluating the personality was done by employing the Big Five questionnaire by Satow (Satow, 2012). A 7-point Likert scale with four items was used to measure the perceived complexity of the four HGS visualizations. The Usability of the intervention was assessed by the System Usability Scale (Brooke, 1996) after constructing a personal HGS using a randomly assigned visualization type. Finally, the participants were asked to rate all four visualizations according to their preferences. We used the median split technique to assign the participants to groups based on their personality trait score, accounting for weakly and strongly pronounced personality trait expressions. Participants with the median value as trait score were randomly allocated to one of the two groups. The median split allowed us to test for differences between groups with high and low trait expressions. The significance test of differences in preference ratings between the trait expressions was done utilizing the Mann-Whitney-U-test as the dependent variable of preference rating was ordinal scaled. Since the group allocation was partly randomized, the Mann-Whitney-U-test was repeated ten times to eliminate significant results that happened by chance. Spearman's rank correlation coefficient was calculated to investigate correlations between the usability rating and the openness trait scores and test for a potential bias in the preference ratings caused by using one visualization for building the personal HGS. For all statistical tests, we set the alpha level to .05.

Results

Examining differences in visualization preferences between the different trait expressions through the Mann-Whitney-U-test revealed group differences between groups with the high and low pronunciation of the agreeableness trait and the preference for the Circlepacking visualization ($U = 480$, $p \approx .59e - 07$). Furthermore, 50% of the repeated Mann-Whitney-U-test trials indicated a slight negative correlation between the neuroticism trait and the Circlepacking visualization ($U = 173.5$, $p \approx 0.043$). In light of the existing bias for the Circlepacking visualization (Spearman's rank correlation coefficient, with $\rho \approx 0.467$, $p \approx 0.001$) caused by using this visualization to construct the personal HGS, these findings must be interpreted with caution. Investigating the relationship between the Openness to Experience trait and the usability rating of the intervention, the calculated Spearman's rank correlation coefficient of $\rho \approx 0.0049$ ($\rho \approx 0.0049$; $p \approx 0.974$) is smaller than the critical value of .291 ($n = 46$, non-directional α-level=.05) (Ramsey, 1989), indicating no significant correlation. A slight negative correlation (Spearman's rank correlation coefficient, with $\rho \approx 0.411$, $p \approx 6.51 \times 10^{-9}$) was found while exploring the relationship between the visualizations' perceived complexity and the preference ratings. Visualizations perceived as simpler seem more preferred by the participants (see figure 4.14).

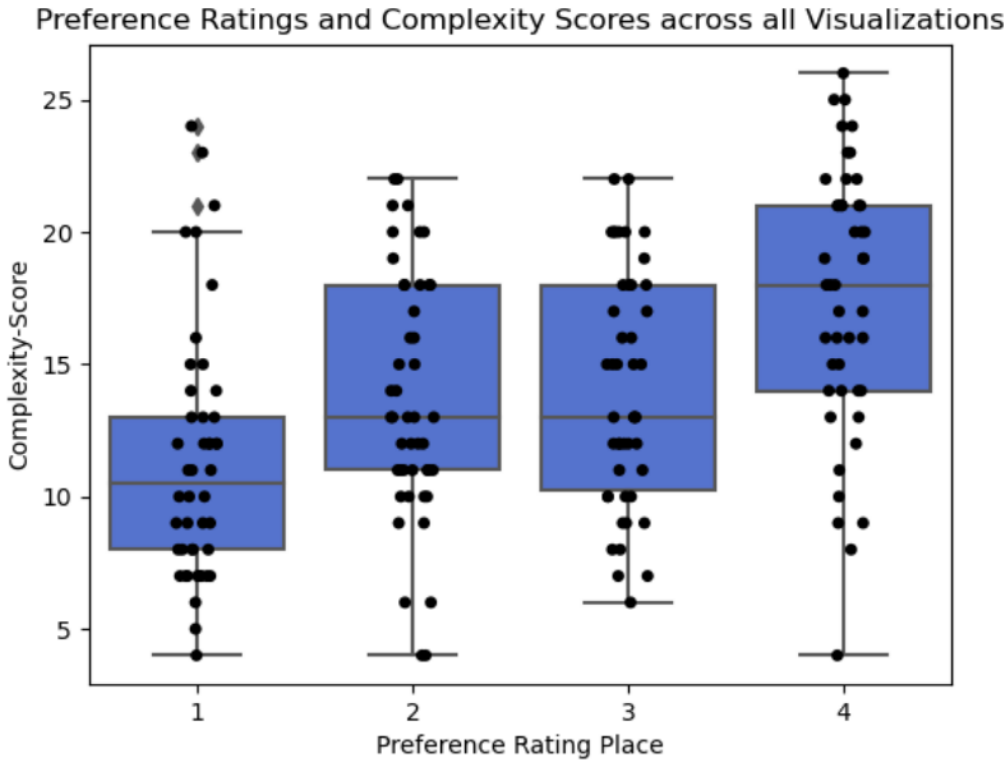

FIGURE 4.14: Preference Ratings and Complexity Scores Across all visualizations.

Discussion

This study investigated correlations between preferences for HGS visualizations and Big Five personality traits. Overall, personality traits are not the determining factor in preference ratings of HGS visualizations. However, the finding from the previous study that more straightforward perceived visualizations seem to be more preferred could be replicated. Due to the small sample size, these findings must be interpreted cautiously. Nevertheless, the tendency in the collected data implies that trait factors do not determine visualization preferences, and the findings from study 1 are stable across OCEAN traits.

4.4.8 Meta-Analyses of Visualization Preferences

This subsection describes cross-sectional data analyses based on data collected during the previously summarized two studies. Consequently, there is some redundancy here, which is justifiable by the higher power based on the aggregated data.

Background and Aims

University Students, especially in the early stages of the student life cycle, face the challenge of freedom and a need for self-organization and self-regulation of learning behaviors (Weber, 2022c). Parallel to the technical progress of digital hardware and software, the use of digital tools for various purposes constantly increases in general and higher education. As the diversity of students and the plethora of curricular and extracurricular learning resources increase, there is a growing need for individual educational goals which can guide navigation in educational environments. Learners must direct their limited material, temporal and psychological resources towards educational activities, serving those individual educational goals. In this chapter, I introduce a digital study assistant with hierarchical goal setting as the core element and summarize the comparison of four diagram types for hierarchical data in an online experiment.

The research in this chapter has implications on two levels; on a practical level, it supports design decisions regarding the software's graphical user interface, while on a scientific level, conclusions about mental representations of goals, or at least about the compatibility of graphical and mental representations of goals and goal systems, may be derived. The following research questions are of interest:

1. Which visualization type is most suitable to represent HGS and to function as a visual metaphor in a graphical user interface?
2. Is there a graphical representation of goal systems that ideally resembles mental representations?
3. Are there differences between representations of goal systems between individuals?
4. If there are inter-individual differences, do they correlate with person-related variables, such as OCEAN personality traits?
5. Do representations in humans and computers fundamentally differ regarding completeness, extent, and ambiguity?
6. How can priming be used to lead students to personally meaningful educational goals?

Research Question The central research question in this study is: Which hierarchical diagram type do students prefer to represent goal systems? A secondary question from qualitative data is: What kind of qualitative feedback do students give?

Methods

The visualization ranking data used to answer the research question stems from two studies[8], which investigated visualization preferences and correlations with OCEAN personality traits.

Sample We recruited participants by emails to mailing lists. Students of Cognitive Science and Psychology got compensation in hourly credit as a trial subject. Of 120 participants, 43 (36%) were male, and 77 (64%) were female. The average age was 23.4 years, with a standard deviation of 5.95. The average semester enrollment at University was 5.03, with a standard deviation of 3.36. Sixty-seven participants (56.83%) studied Cognitive Science, 33 participants 27.5% studied Psychology, and 20 (16.66%) studied other subjects.

[8]For the conceptual background of the studies, see Weber et al., 2021

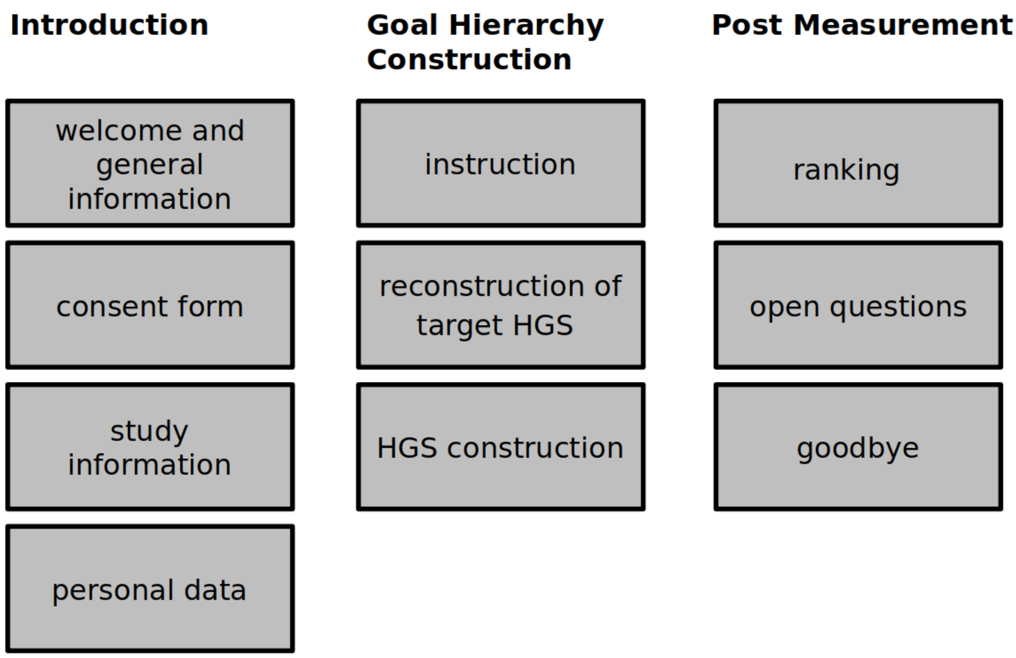

FIGURE 4.15: Study Flow of the two Usability Studies.

Experimental Setup The technical setup for the online study builds on the Django Web Framework (Django Software Foundation, 2013) and the D3.js JavaScript library (Bostock, Ogievetsky, and Heer, 2011) for visualizations. The web application was deployed on a virtual machine and made available for participants by opening a URL in their web browser.

To eliminate confounding variables, visualizations are monochrome and equal in size. The implementation of the Visualization with HTML5 and the d3.js JavaScript library was structured such that only the parameter visualization type varied. Participants could create, modify and delete goals by an identical input form for all conditions. In a post-questionnaire, participants were asked to rank the diagram types according to their preference and to give qualitative feedback about the diagram types in the form of written text.

Data Analyses For further analyses, data sets from test subjects and participants who did not complete the study were identified by inspection and excluded. The filtered data was exported from the PostgreSQL database to comma-separated-value (csv) files. The analysis script is written in the Python programming language, version 3.7, using NumPy, Pandas, SciPy, Matplotlib, and Scikit-posthocs (Terpilowski, 2019). A Friedman test (Friedman, 1937; Friedman, 1939; Friedman, 1940) was used to determine significant differences in the rank with hypotheses H0: There is no difference in the respondents' ranks and H1: There is a difference in the respondents' ranks. H0 had to be rejected, so a post-hoc test (Nemenyi test) was conducted for each visualization combination to determine the relatively preferred one.

Results

This section separately summarizes the quantitative results from the rankings and qualitative results from open questions.

Quantitative Results The descriptive statistics of the ranking data, shown in table 4.2 showed (in order of average preference) an average mean rank of 1.75 and rank-sum 210 for Dendrogram, an average mean rank of 1.69 and rank-sum 323 for Circlepacking, an average mean rank of 2.77 and rank-sum 332 for Sunburst, and an average mean rank of 2.79 and rank-sum 335 for Treemap.

The statistical analysis was conducted for four conditions with 120 paired samples. The family-wise significance level of the tests is alpha=.050. We rejected the null hypothesis that the distribution is normal for the conditions Dendrogram ($p <$ .001), Circlepacking ($p < .001$), Sunburst ($p < .001$), and Treemap ($p < .001$). Therefore, we assume that not all conditions are normally distributed. Because we have more than two conditions, and at least some are not normally distributed, we use the non-parametric Friedman test as an omnibus test to determine if there are any significant differences between the median values. We use the post-hoc Nemenyi test (Nemenyi, 1963) to infer which differences are significant. We report the median (MD), the median absolute deviation (MAD), and the mean rank (MR) among all conditions over the samples. Differences between conditions are significant if the difference in the mean rank is greater than the critical distance CD=.428 of the Nemenyi test.

TABLE 4.2: Descriptive Statistics of the Ranking Data (Rank 1 to Rank 4).

	R 1	R 2	R 3	R 4	rank sum	mean	SD
Sunburst	13%	27%	30%	30%	332	2.77	1.03
Treemap	19%	18%	27%	36%	335	2.79	1.13
Dendrogram	54%	26%	11%	9%	210	1.75	0.98
Circlepacking	13%	29%	32%	25%	323	2.69	0.99

We reject the null hypothesis (p<.001) of the Friedman test that there is no difference in the central tendency of the conditions Dendrogram (MD=1.000+-0.500, MAD=0.000, MR=3.250), Circlepacking (MD=3.000+-0.500, MAD=1.000, MR=2.308), Sunburst (MD=3.000+-0.500, MAD=1.000, MR=2.233), and Treemap (MD=3.000+-1.000, MAD=1.000, MR=2.208). Therefore, we assume that there is a statistically significant difference between the median values of the conditions. Based on the post-hoc Nemenyi test, we assume that there are no significant differences within the following groups: Circlepacking, Sunburst, and Treemap. The differences between the Dendrogram and all other groups are significant. The effect size is large with $\gamma = 1.908$.

TABLE 4.3: Nemenyi Post-Hoc Test.

	Sunburst	**Treemap**	**Dendrogram**	**Circlepacking**
Sunburst	1.000	0.900	0.001	0.900
Treemap	0.900	1.00	0.001	0.900
Dendrogram	0.001	0.001	1.000	0.001
Circlepacking	0.900	0.900	0.001	1.00

Qualitative Results Participants frequently described Circlepacking and Sunburst as aesthetic and appealing. A widespread comment was the wish for colors. The Treemap was described as cumbersome and not very intuitive, which is in line with findings from related studies, which found a higher time demand for the Treemap condition.

Discussion and Outlook

On a practical level, the results indicate that users significantly prefer the Dendrogram visualization and should be used as the default visualization in the hierarchical goal-setting intervention. Although not significant, the Treemap visualization is preferred least, and quantitative and qualitative shows that users do not like it and have difficulties using it. Therefore, it will be dropped from the list of prospective visualization candidates and not be further investigated within this line of research.

It is important to note that only the phase of goal-setting and the specific requirements have been investigated at the current state of the research project. During phases of goal-pursuit and evaluation of goal progress, other aspects of Visualization may be predominant and shift preferences for visualizations. For instance, in a situation of goal selection, the Circlepacking Visualization, presenting actionable leaf nodes as salient circles, may be advantageous. Therefore, further studies will be conducted to investigate visualization characteristics in phases of self-regulated learning.

Limitations The normative question of which visual representation or metaphor is closest to mental representations of goal systems cannot be answered by the data obtained in the presented studies. On the one hand, the set of visualizations covered does not cover all possible visualizations for goal systems. On the other hand, a clear preference for a specific visualization would not prove equality with mental representations.

Conclusion This study shows that university students prefer the Dendrogram visualization among four pre-selected candidates to represent hierarchical goal systems. The findings indicate that the mental representation of goal systems is most compatible with Dendrograms and least with Treemaps. However, the findings cannot be concluded on how exactly goal systems are represented mentally. The research questions about how hierarchical goal systems are represented and if goal systems are mentally represented remain to be answered. One aspect of the diagrams that have not been covered yet is that they can all represent goal size, namely by size. This diagram feature could represent the estimated effort or required time, which may help plan activities.

4.4.9 Cross-Study Data Analyses of Structural Characteristics

This section has partially been published as "Valence Comparison of Hierarchical Diagrams" (Weber, 2022c).

Background and Aims

Structural characteristics of HGS, such as depth, branching factors, and size, are relevant for the following three reasons. Firstly, for the development of the user interface of our HGS DSA, size matters, Second, these characteristics have not been empirically investigated, so there is a need to elucidate this object of scientific research.

Third, the inter-individual differences in structural goal system characteristics have not been investigated.

This section aims to answer the following research questions:

1. Which structural characteristics, such as goal system size, branching factor, and depth, do the initial goal systems show?

2. Which degree of variance do we find in these parameters?

On a practical level, the answers to those questions are essential for designing a software artifact, serving as technical augmentation for goal-setting, maintenance, and pursuit. On a normative level, the answers to those questions are a starting point to draw inferences on mental representations of goal systems.

Methods

Here, we present aggregated data from five studies conducted between 2019 and 2022, holding data from 223 participants, 486 goal systems, and 4208 goals.

Results

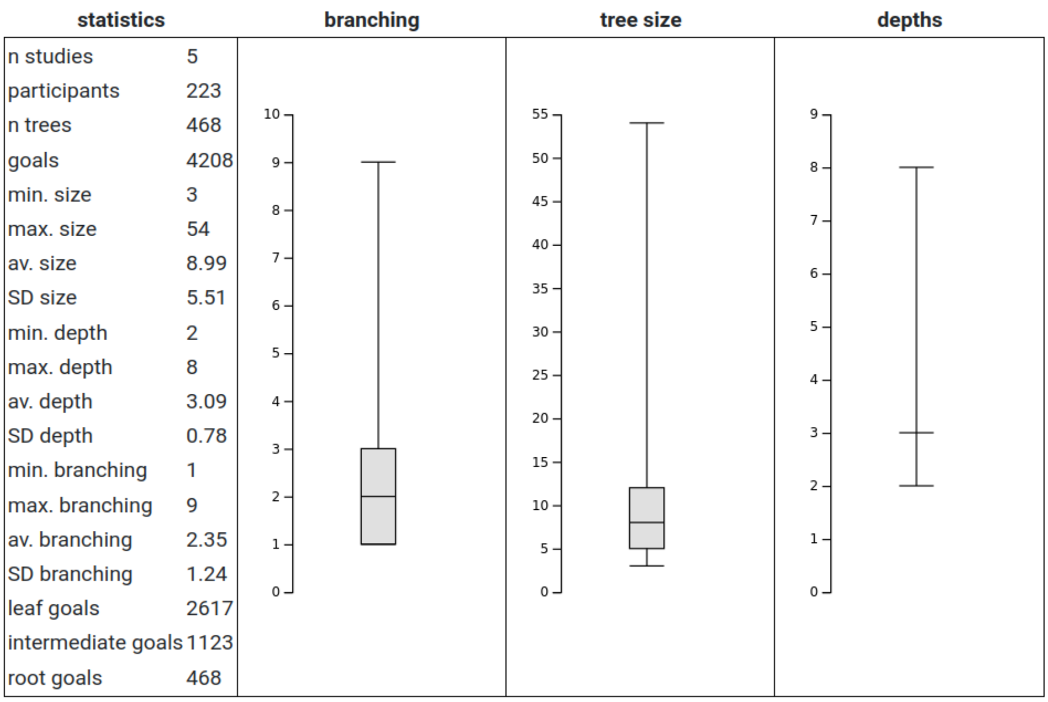

FIGURE 4.16: Descriptive Statistics Aggregated Over Studies.

The results (see figure 4.16) show an average tree size of 8.99 ($SD = 5.51$), a minimum of 3, and a maximum of 54, an average depth of 3.09 ($SD = 0.78$) with a minimum of 2 and a maximum of 8, and an average branching factor per node of 2.35 ($SD = 1.24$), a minimum of 1, and a maximum of 9.

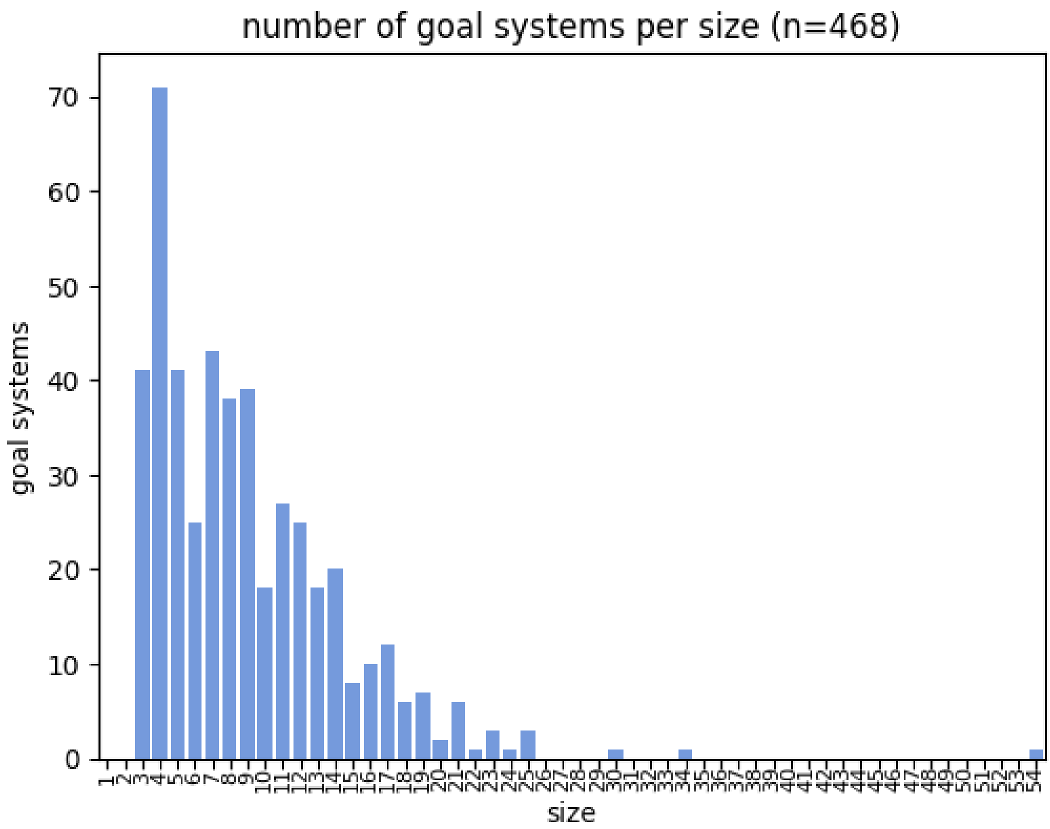

FIGURE 4.17: HGS (n=468) Sizes Aggregated Over Studies.

HGS Size Frequencies Figure 4.17 shows the distribution of goal system sizes. Each bar represents the number of goal systems for a specific size. There is no data for sizes one and two because the interface defined three as the minimum goal system size. The highest number of goal systems is 70 for the size of four. The number of goal systems is relatively high, with approximately 40 or higher from sizes three to nine, and continuously decreases from a size of ten up to a size of 25. There are only three goal systems of larger sizes, namely one for sizes 30, 34, and 54. These extraordinary large goal systems can be found in figures 4.20, 4.21, and 4.22.

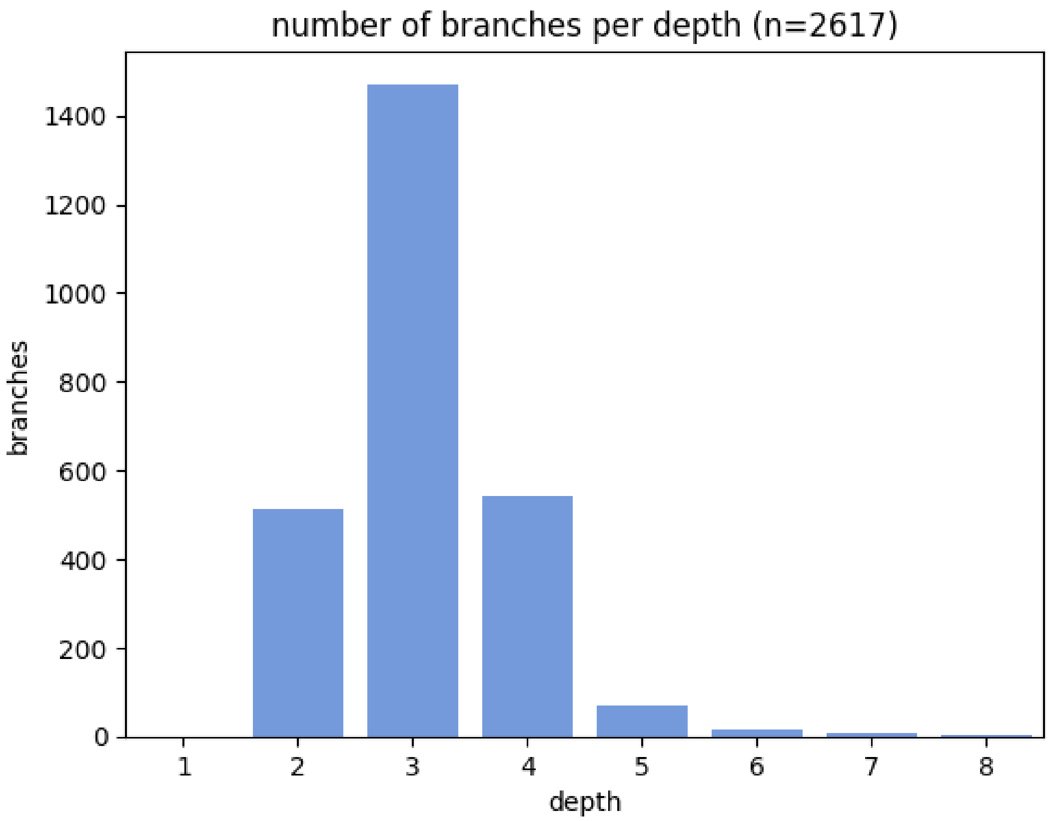

FIGURE 4.18: Depths of 2617 Branches from 468 HGS.

HGS Depth Frequencies Figure 4.18 shows the distribution of goal system branch depths. The depth was computed for each leaf node goal by following the superordinate goals until the root goal was reached. There are no values for depth one because the interface did not allow goal systems of size one, which are, by definition, the only HGS structure resulting in a depth of one. There is a peak at depth three with more than 1400 occurrences. For depths two and four, there are approximately 500 occurrences. Only a small number of branches show size of more than four, whereas the depths seven and eight show negligibly low numbers.

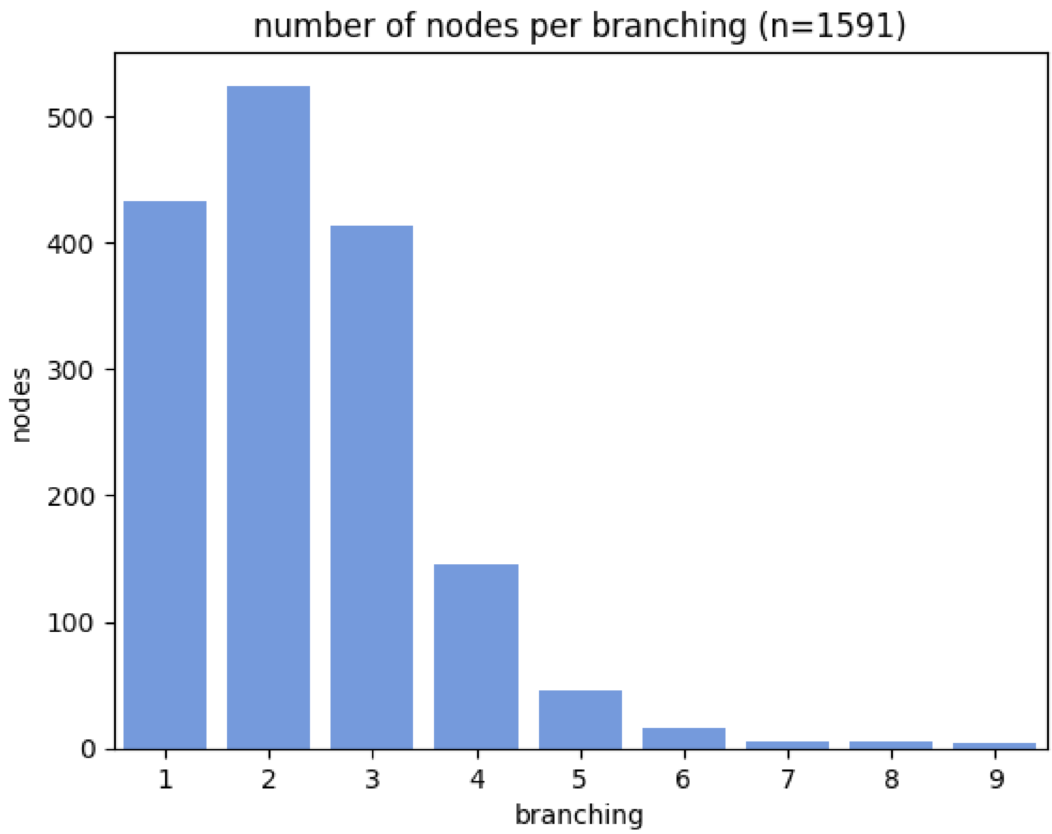

FIGURE 4.19: Branching from 468 HGS and 1591 Nodes.

HGS Branching Frequencies Figure 4.19 shows the branching distribution per non-leaf node. The values were computed by iterating over all non-leaf nodes and counting the number of subgoals. By definition, zero values exist because all non-leaf nodes have at least one subgoal. There is a peak for the value two with more than 500 occurrences and high numbers for branching values one and three. The function rapidly decays from the value for on. For the branching values seven, eight, and nine, the values are negligibly low.

Large Examples Three goal systems are shown in this section to give the reader an impression of goal systems and also goal formulations. The three largest ones were chosen to maximize the detail and the number of goals per figure. The figures 4.20, 4.21, and 4.22 show the three largest goal systems, which can be considered as extreme cases or outliers, as figure 4.17 indicates. The figures are screenshots taken from the GoalTrees software. The rendering shows overlaps of goal description texts, especially on the leaf-node layer, which shows the limitations of the graphical user interface. Aside from these aesthetic shortcomings, reading the goal description texts with some effort is possible.

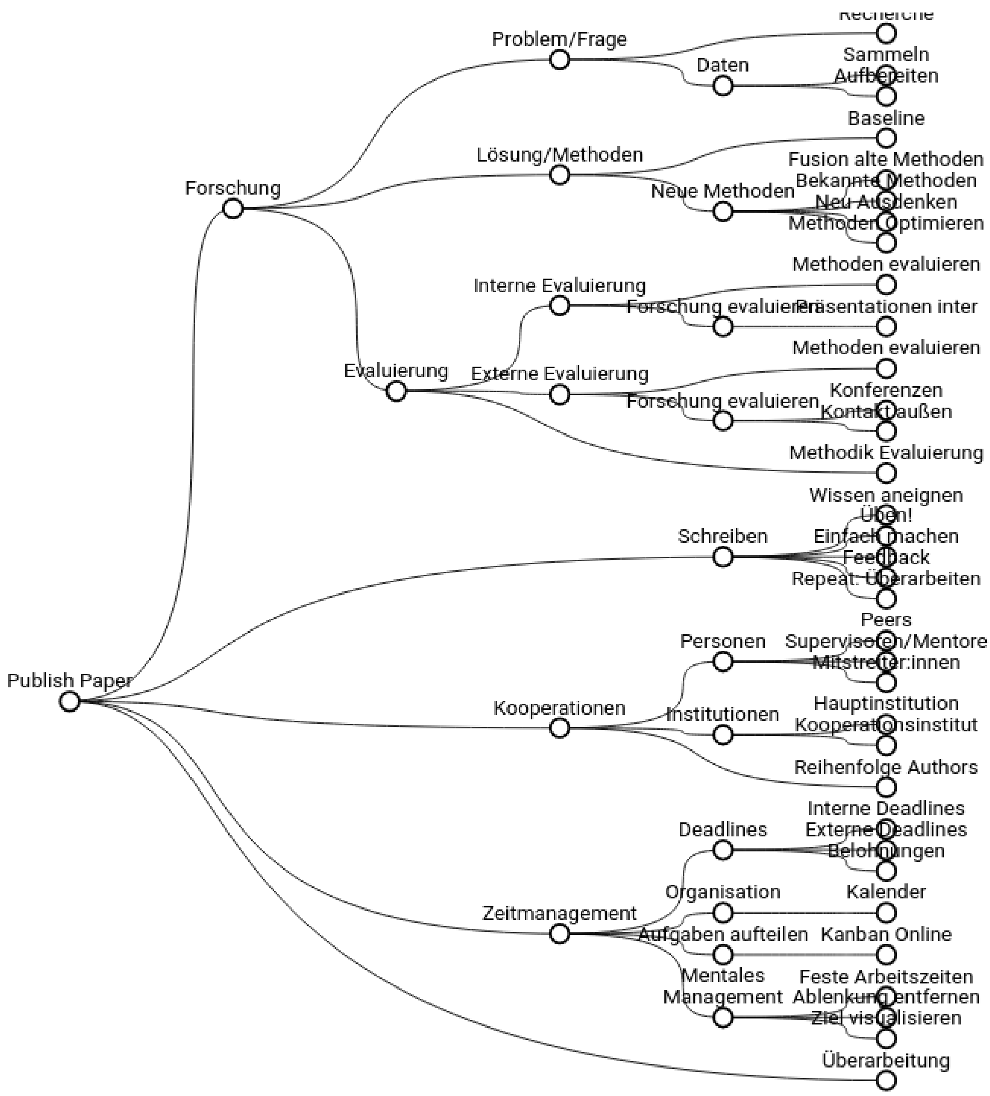

FIGURE 4.20: The Largest HGS Includes 54 Goals, with 34 Goals on the Leaf Layer, which Challenges the Interface's Limits and Affects Readability. (The Cut-Off Text at the Upper Right is "Recherche".)

The largest HGS in figure 4.20 models the root goal of *publishing a paper* (*Publish Paper*, which is split into the subgoals *research* (*Forschung*), *Cooperations* (*Kooperationen*), and *time management* (*Zeitmanagement*). These cryptic formulations may not sound like goals at first sight, but they can easily be reformulated into the following goal-like representations:

- **research** →"Carry out the *research* for the paper to be published."
- **cooperations** →"Build research *cooperations* for the paper to be published."
- **time management** →"Develop and maintain a good *time management*" for the process of working on the paper to be published.

As the engaged reader may test, the goals following deeper in the HGS can be transformed into formulations that satisfy the goal definition.

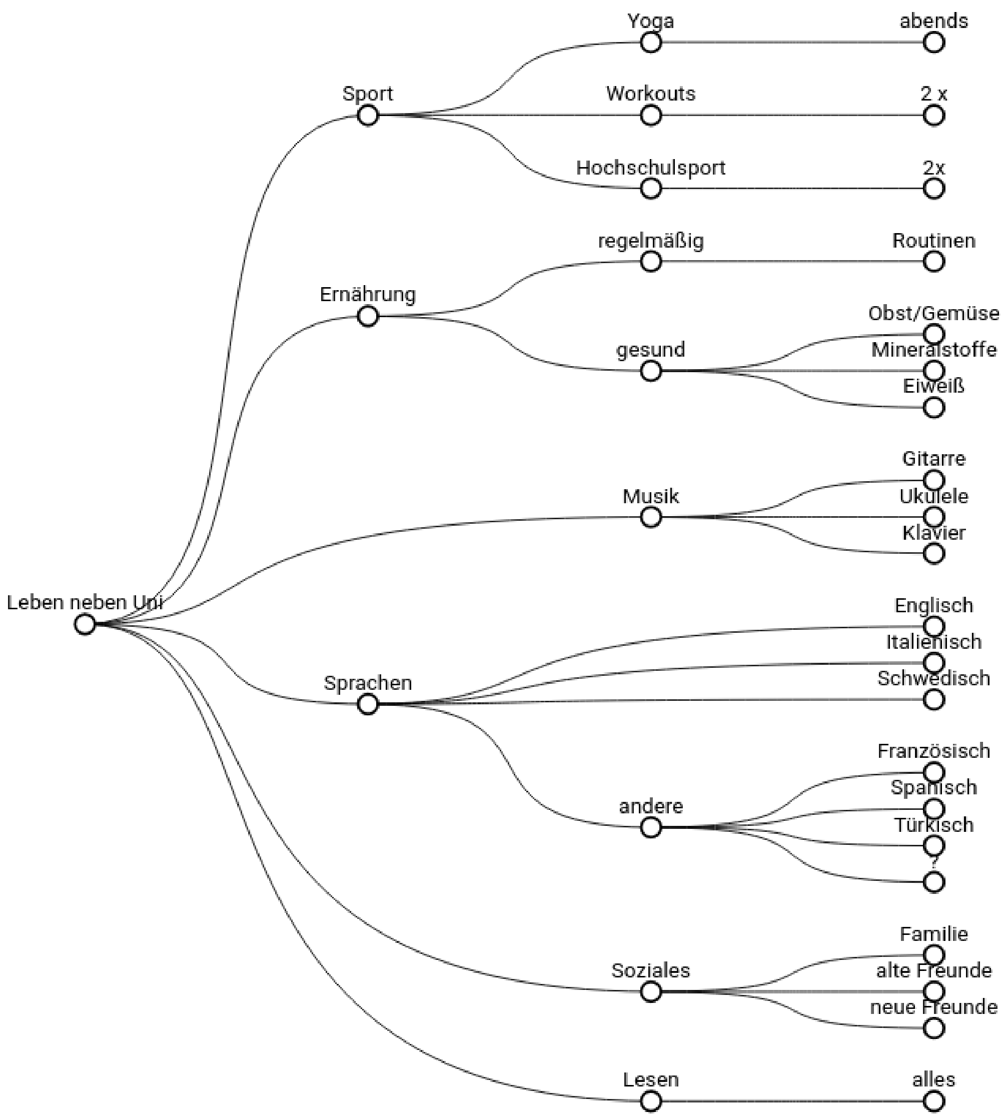

FIGURE 4.21: The Second Largest HGS includes 34 Goals.

The second largest HGS in figure 4.21 models the goal domain of *life outside university* (*Leben neben Uni*), hence personal ambitions of a student apart from curricular activities. Subgoals are *sports* (*Sport*), *nutrition* (*Ernährung*), *music* (*Musik*), *languages* (*Sprachen*), *socializing* (*Soziales*), and *reading* (*Lesen*). Although the formulations are short, they can easily be understood, given the context. The list of candidates for language learning, in addition to English, Spanish, and Swedish, is ambitious as the overall goal system spans a broad range of life domains from health, family, and friends, to education. The lowest branch [life outside the university - reading - anything], is redundant at the leaf node because it does not yield additional information. A possible explanation is that the participant added the goal to equalize the branch depth for aesthetic reasons.

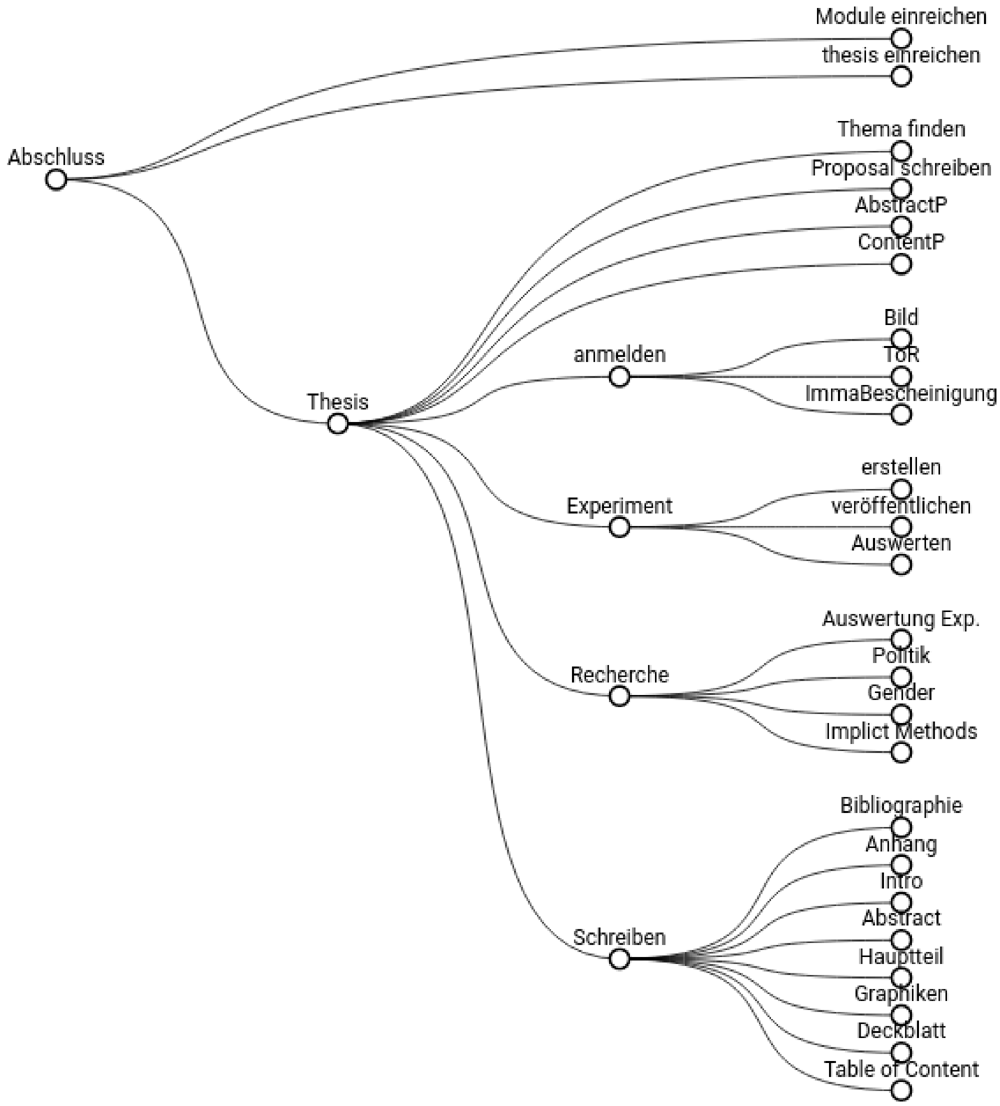

FIGURE 4.22: The Third Largest HGS Includes 30 Goals.

The third largest HGS in figure 4.22 models the endeavour of *graduating* (*Abschluss*, which we have identified to be one of the most common concrete goals among students, with a frequency of 17.15% among educational goals (see figure 3.6. The goal system entails administrative aspects, such as *handing in modules* (*Module einreichen*), as well as thesis-related aspects, such as *writing* (*Schreiben*), which is differentiated into a set of eight sections, modeled as subgoals.

Goal or not a Goal? Understanding goals as desirable future states, almost any cryptic text can be interpreted as a goal for good reasons. Many goals are described by only one word, which may evoke subjective interpretation by the viewer. The question arises whether all nodes are goals, whether the software has been used as a mind map to represent a problem or knowledge domain, or if the software was used as a planning tool. In both cases, the nodes are equal to a goal or can easily be transformed into a goal. For some knowledge domain x, the resulting goal is *learning x*, and for a plan including a step or milestone y, the resulting goal is *doing or achieving y*.

Conclusions

Suppose, according to Millers' law (Miller, 1956), the human working memory can store 7 ± 2 items or, according to more recent work by Cowan, only 4 ± 1 (Cowan, 2001), and the average HGS size in our data is 10. In that case, the external representation in the graphical user interface, on average, supersedes human goal system cognition in terms of capacity. Consequently, a hierarchical goal system of the demonstrated type is suitable to augment goal-setting and meta-cognitive processes in education. It could be argued that the representation on screens limits size, branching, and depth, but there are examples of large HGS with up to 54 goals (see figure 4.20)and a depth of up to 8. These examples illustrate that the technical environment is not a limiting factor.

4.4.10 Priming as Root Goal Elicitation Procedure Candidate

The research described in this subsection has been carried out by Jueun Lee and published in "Effects of Motivational Priming on Goal Characteristics" (Lee, 2022). It has also be published collaboratively in "A Web-Based Hierarchical Goal-Setting Intervention for Higher Education" (Weber et al., 2023), and "Towards A Web-Based Hierarchical Goal Setting Intervention for Higher Education" (Weber et al., 2021).In her master' Thesis, Jueun Lee investigated if priming tasks with wordings from the Relative Autonomy Index (RAI) lead to related goal characteristics in a subsequent goal formulation target task under the author's supervision.

Background and Aims

Finding personally relevant high-level educational goals is essential for Hierarchical Goal-Setting, but it is a non-trivial task for university students. Priming is the effect that the exposure of a first stimulus subconsciously influences a response to a second stimulus (Weingarten et al., 2016). This study uses priming to elicit goals with specific characteristics to develop a root-goal elicitation in the future. Goals' self-concordance is a positive predictor of persistent effort in goal pursuit and is associated with increased happiness and goal attainment in the longer term (Sheldon, 2014; Werner et al., 2016). This study investigates whether priming different motivations based on the self-determination continuum (intrinsic, identified, introjected, external motivation, and amotivation) can influence the self-concordance of subsequently elicited goals. In addition, we examine how the priming effect influences other goal characteristics, such as goal structure and framing. This study hypothesizes that intrinsically regulated motivation is positively associated with higher goal concordance; thus, students primed with intrinsic motivation select more self-concordant goals than those primed with stimuli related to external motivation or amotivation. An initial hurdle for students using hierarchical goal-setting is finding personally relevant educational goals, which can be explained by a low degree of choice and self-determination in institutionalized education. This study aims to test if priming is suitable as a root goal elicitation procedure for the hierarchical goal-setting intervention by testing if priming tasks can impact goal characteristics.

Methods

Participants were 37 students of the University Osnabrück majoring in Cognitive Science or Psychology. They completed an online study on academic goal-setting in English in a PC setting. We excluded two participants from data analysis due to technical errors during data collection and a misunderstanding of task instructions. Therefore, 35 students, 11 males and 24 females, (age $M = 21.31$, $SD = 2.47$) were included in statistical analyses. Participants answered open-ended questions about five motivational priming conditions in a within-subject design. The order was randomized using the Latin square method. Each condition, followed by an academic goal-setting task, consisted of four questions with corresponding keywords of five motivations as priming stimuli. We modified a goal-setting question from Burton's study on goal self-concordance (Burton, 2008) and combined it with priming text based on items of the Relative Autonomy Index (Sheldon et al., 2017). The RAI is a revised version of the original Relative Autonomy Continuum (RAC) of self-determination theory elaborating on the "perceived locus of causality" (PLOC). For example, the RAI item "because I enjoy X" describes the intrinsic motivation of behavior X to the question "why do you do X?" (Sheldon et al., 2017). In this study, RAI items were modified into a question for writing tasks, e.g., the priming question based on the same RAI item was formulated as "Think about a task that you enjoyed. Describe why it was an enjoyable experience for you". The full set of priming stimuli being used can be found in Appendix B. In addition, participants were asked to enter at least a certain minimum number of words as an answer so that they could think about the questions for our aimed duration of priming, i.e., 5 minutes in each condition, in a remote online experiment. After completing the priming and goal-setting tasks, participants assessed their five previously elicited goals in the goal characteristics (GC) questionnaire (Iwama, Wirzberger, and Lieder, 2019; Iwama et al., 2021). In order to prevent the conscious connection between primed motivation and the next goal-setting task, priming questions were designed to not directly address the study topic but instead ask about personal experience, which was irrelevant to the study's actual research interest. The study's true purpose was debriefed at the end of the experiment.

Results

To test our hypothesis on the effects of motivational priming on goal characteristics, we conducted the Friedman test on participants' GC questionnaire responses based on the non-normal distribution of sampled data. We followed up with the pairwise Wilcoxon signed-rank test as post hoc analyses, using the Python Pinguoin and scikit-posthocs package. Collected data were first preprocessed by averaging GC ratings on each subscale and removing outlier values using the interquartile range (IQR).

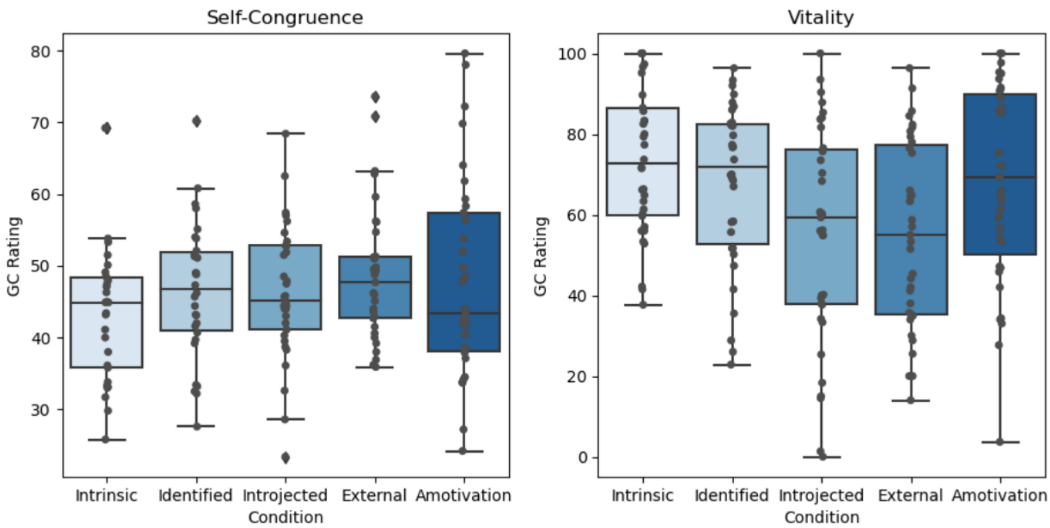

FIGURE 4.23: Self-congruence and Vitality Ratings.

The test results did not reveal a significant main effect of motivational priming on goal self-congruence ($p = .07$). Post hoc tests, however, showed that the self-congruence ratings of goals elicited in intrinsic priming condition were significantly lower than identification condition ($p = .007$). In comparison, the external condition was related to higher ratings of self-congruence than intrinsic ($p = .001$) and identification condition ($p = .02$), as well as amotivation condition ($p = .04$).

To investigate various goal characteristics relevant to self-congruence, we also analyzed CGQ subscales measuring goal value-congruence, importance, awareness, vitality, hierarchy, approach-avoidance framing, and process-outcome focus. A Friedman test showed that the vitality of elicited goals was positively influenced by motivational priming (p=.01). In post hoc tests, goal vitality in the intrinsic condition was higher than in the introjection, and the external condition ($p = .03; p = .03$), and so was that in identification condition ($p = .009$; $p = .008$). The amotivation condition was also related to higher vitality ratings than introjection ($p = .02$) and external condition ($p = .01$). No other significant main effects were found on the rest of the GCQ subscales. However, post hoc Wilcoxon tests pointed out that the amotivation condition was associated with higher ratings of goal awareness than external condition ($p = .03$), as well as a stronger focus on the goal process than the goal outcome than identification ($p = .01$) and introjection condition ($p = .01$).

Discussion

This study investigated the effects of motivational priming on various goal characteristics related to intrinsic motivation. The core aim was to check whether priming is suitable as an elicitation procedure for educational goals with high self-congruence, value-congruence, and vitality, which could then serve as root goals for HGS. The priming task was a writing task with wordings taken from the RAI. Only a few significant effects were observed, implying that priming is not sufficiently effective to be used as a root goal elicitation procedure. An interesting finding is that amotivation and intrinsic motivation seem to have led to low scores for Self-Congruence. Theoretically, amotivation priming should not lead to any goal because goals are motivated by definition. Intrinsically motivated goals, on the other hand, are intrinsically rewarding. An explanation for our results could be that participants chose goals randomly in those two conditions, which was unrelated to the priming.

4.4.11 Field Study in the LMS of three Universities with Real Users

In this section, we summarize the implementation and results of a field study with a DSA for hierarchical goal-setting (HGS) at the Bremen, Hannover, and Osnabrück universities from November 2021 to April 2022. The results show that 70% of the students in the sample chose to get digital assistance for educational goal-setting, the highest interest rate among the nine assistance functions available. Of the 290 students who chose to use the assistant, only 10 completed the full assistive intervention, which equals only 3.4%. We conclude that we should improve the Usability and user experience and reduce the interaction costs of the intervention.

Background and Aims

As described in Chapter 1, parallel to this line of research, another DSA for educational goal-setting was developed in the SIDDATA project, called the 'SIDDATA' Study Assistant. A central feature of the digital study assistant prototype is the modular structure, which allows for the development of particular features with different functionalities that appear to the users alongside each other in a navigation bar. This section summarizes the first attempt to integrate the two DSA systems and investigate real student users' interactions with the resulting software.

Methods

The SIDDATA study assistant has been integrated into the learning management system (LMS) Stud.IP, is frequently used by students at the universities of Bremen, Hannover, and Osnabrück. By default, the plugin is not visible, so students had to activate it by calling a URL, which has been made publicly available by invitation emails, the project website, flyers, online university news, and other advertising channels.

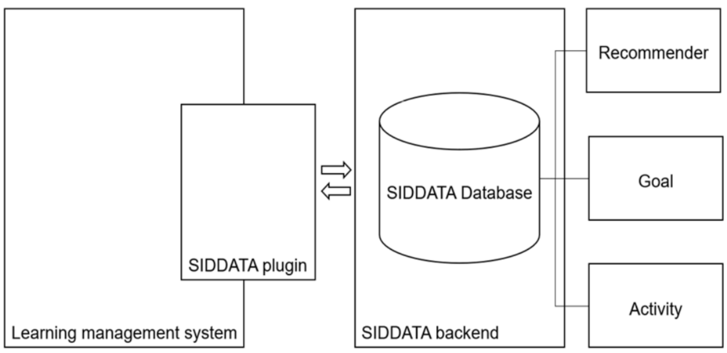

FIGURE 4.24: The Architecture of the SIDDATA DSA in the Field Study as Described in "A Free and Open Dataset from a Prototypical Data-Driven Study Assistant in Higher Education"

Once students open the SIDDATA study assistant (see figure 4.25), all functionalities, which we call "recommender modules", are shortly introduced as elements of a newsfeed, and students can choose to activate or deactivate the recommender module. The "Meine Studienziele" (my study goals) recommender module used an iframe Html element to embed the GoalTrees software from a different URL. On a practical level, this allows users to personalize their DSA, and from an empirical perspective, it yields valuable data about user preferences. Students could actively agree to donate their data in the data settings. We use the resulting statistics to infer how many students activated the *my study goals* recommender.

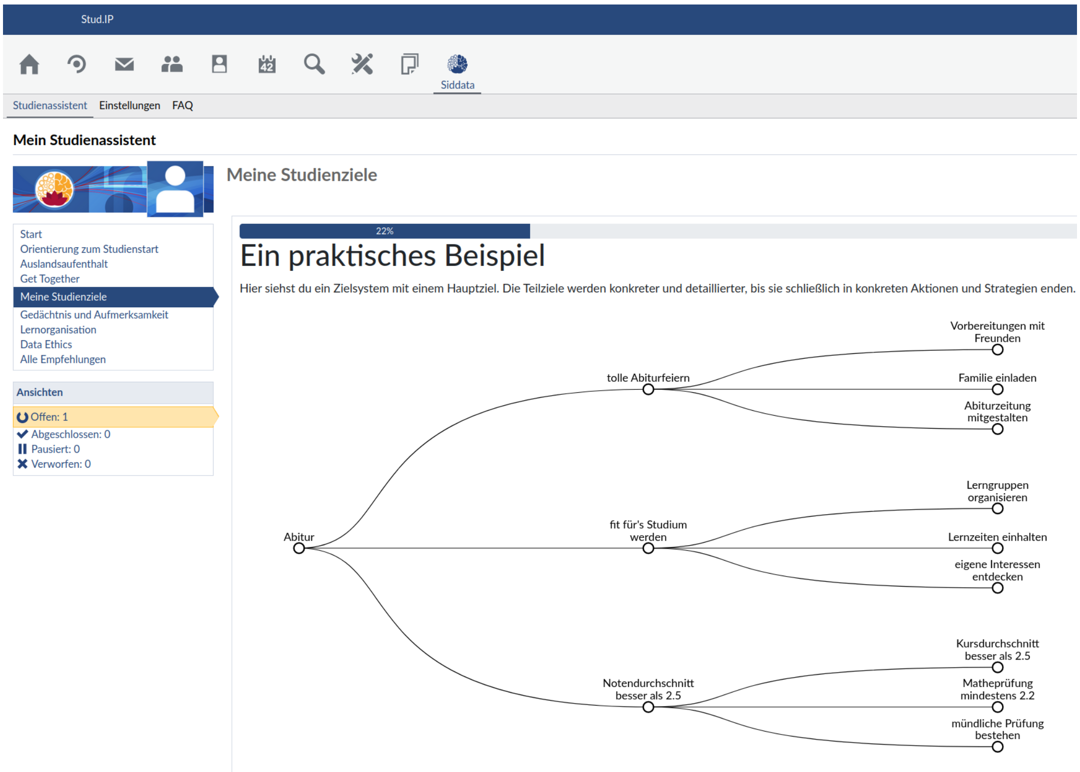

FIGURE 4.25: Screenshot of the SIDDATA DSA and GoalTrees in an Iframe.

The procedure of the *my study goals* intervention consists of three phases as illustrated in figure 4.26. In the first phase of goal elicitation, the user is welcomed and receives general information about the intervention. Writing about an ideal future and ideal university studies is intended to stimulate participants towards personally meaningful high-level goals, a list of which users type as the final part of the goal elicitation procedure. In the second phase, students get instructions and an example for HGS, reconstruct a given HGS, and finally choose one of their previously inserted root goals and build an HGS from it. In the third phase, participants answer the 32 items of the short GCQ version for all goals of the GCQ, and afterward, participants can explore the resulting scores for all goal characteristics and texts explaining their relevance. The whole procedure, starting from setting root goals, can optionally be repeated to create additional HGS.

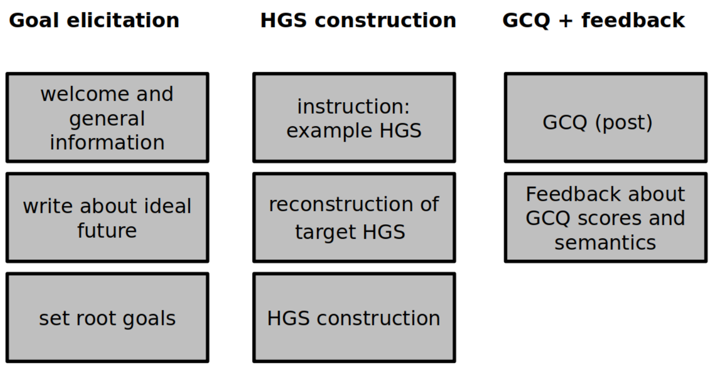

FIGURE 4.26: Procedure Flow of the Goal-Setting Intervention.

Results

In total, 1314 students used the SIDDATA DSA. From those, 22% (n=290) users donated their data for scientific purposes, and 78% (n=1024) did not. Of the 290 users who donated their data, 70% (n=203) activated *the my study goals* recommender, which is the highest activation rate among the available recommender modules (see figure 4.27). Assuming that the activation rate of 70% in the population of data-donating students was representative of the total population, the total number of users for the *my study goals* recommender was 920.

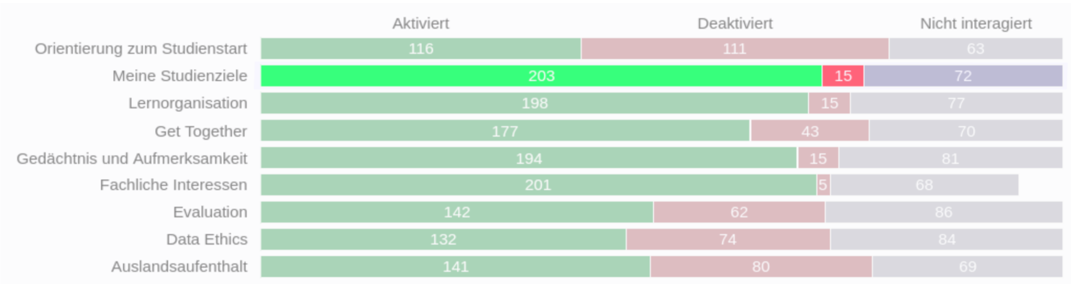

FIGURE 4.27: Statistics of Recommender Module Activations in SIDDATA DSA P3.

The statistics of the GoalTrees software server show that only ten students completed the entire procedure. Table 4.4 lists the numbers of high-level goals and derived sub-goals for those participants. In total, they created 38 goals and 258 sub-goals.

participants	root goals	sub-goals
1	2	5
2	6	37
3	3	19
4	4	8
5	4	15
6	6	6
7	4	48
8	5	23
9	1	59
10	3	9
total: 10	**38**	**258**

TABLE 4.4: Ten Participants Completed the Intervention and Created at Least one HGS.

Discussion

The high percentage of 70% of activations of the *my study goals* recommender, which ranks the module first among nine in total, shows a high interest in goal-oriented digital assistance. We interpret this as an encouraging signal for the future development and improvement of our DSA. Only ten students completed the intervention, indicating that the interaction costs and the benefits seem to be mismatched. Improvements in terms of Usability and user experience seem to be necessary. Possible improvements could be adding color to the interface, which is currently still monochrome due to experimental requirements, and providing more gamification to reward interactions. A progress bar is present already to give participants an estimation of the duration.

A part of the intervention that can be aversive is answering the GCQ for all goals, which requires 32*n clicks for answering, where n is the number of goals in the HGS, and 32 clicks to submit the answers. Assuming an average goal system size of nine goals equals 297 clicks to complete the GCQ. These interaction costs could be reduced by using only a subset of the GCQ dimension, picking only a subset of the goals, or predicting goal characteristics with machine-learning methods from the goal wordings instead.

4.4.12 Field Study on HGS and Goal Characteristics

This chapter summarizes a row of formative studies that optimize the web-based GoalTrees intervention for hierarchical goal-setting. In Chapter 3, the development of the Goal Characteristics Questionnaire, as a self-assessment tool suitable to quantify subjective qualities of goals by their bearer, has been summarized. In the following ongoing field study, the effects of hierarchical goal-setting on root goals, correlations between goal characteristics and goal system structure, and general characteristics of goals of German University students are investigated.

Background and Aims

Putting together the theoretical foundation, empirical methods, and the software development achievements from the previous chapters, the following research questions can be answered:

1. Which of the Goal Characteristics of root goals change through hierarchical goal-setting?
2. Are goal properties propagated into the deeper nodes of hierarchical goal systems?
3. Are there characteristics that predict which goal is chosen as the root goal?
4. Which goal characteristics correlate with the depth of a goal in a hierarchical goal system?

The GoalTrees DSA, used as a platform for a larger data set, is suitable to answer these questions on a solid empirical foundation. The following sections will present average goal characteristics and their correlations in the preliminary data set.

Methods

We implemented this study as a Python class in the GoalTrees software, as described in section 4.4.4. The procedure is illustrated in figure 4.28. It consists of an *introduction phase* with general information, consent form, and participant data assessment, a *root goal elicitation phase* where participants write about their ideal future to stimulate them to formulate a list of personally meaningful root goals subsequently, and answering a one-item version of the GCQ for those, the *goal hierarchy construction phase*, and the *post measurement phase*, where a three-item version of the GCQ is answered for all goals. The pre-post design results in two scores for each of the 32 GCQ dimensions for the root-goals

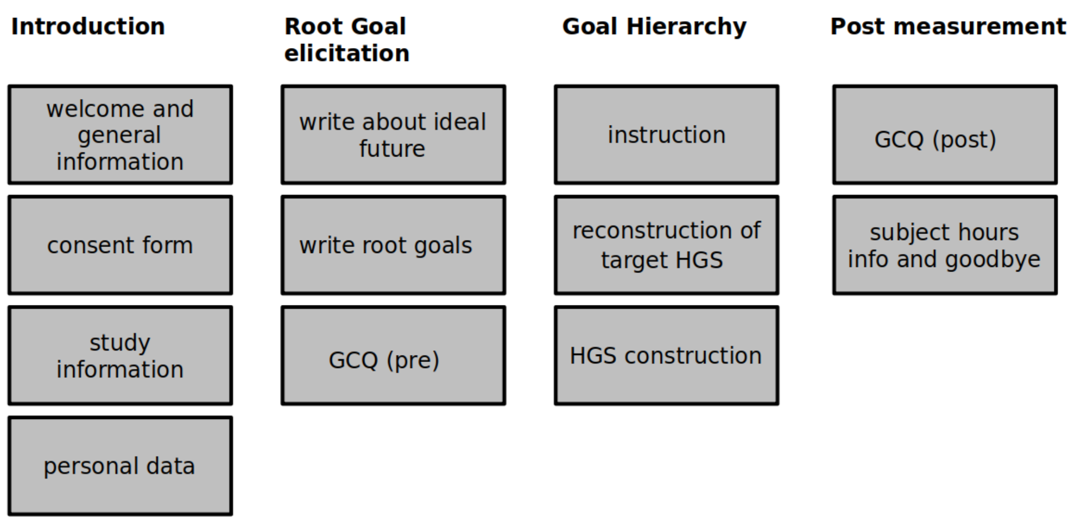

FIGURE 4.28: Program Flow of the Online Study

Data Collection We invited participants via mailing lists of the Institute of Cognitive Science and the Institute of Psychology, University of Osnabrück, and compensated with test-person hours and participation in a tombola for three Amazon vouchers of 10, 20, and 50 Euros.

Procedure The online study started with a consent form. Subsequently, participants had to write about their ideal future, why they chose their field of study, and what would have to happen until the end of their studies to consider it as successful. Then, they were asked to formulate at least three educational goals. They chose one goal from the list and derived sub-goals in the next step. Finally, the participants answered the Goal Characteristics Questionnaire for all goals. The study terminated with a final view giving thanks.

Sample The preliminary data presented here includes 637 goals from 38 students.

Preliminary Results

When interpreting those scores, one should keep in mind the circumstances of their assessment, namely in the context where the goals bearer iteratively broke down a high-level goal into subgoals. Consequently, the number of low-level goals is much larger than that of high-level goals. Also, the antecedent choice of one of the root goal candidates constitutes a bias towards the personally most meaningful root goal, which may affect the characteristics of the subgoals.

Goal Characteristics Scores The scores for all 32 GC, as well as the variable *Depth*, which refers to the normalized relative position in the HGS, can be found in the whisker plots of figure 4.29. The depth characteristic refers to the position in the HGS and is relatively high (=deep) because the goal count increases from layer to layer. Most other scores are relatively high, as the 75% percentile is above 0.4 for most dimensions. Exceptions are *Outcome-Focus*, *Estimated Effort*, *Challenge*, *Defined Subgoals*, *Social Support*, and *Negative Utility*. The scores of *Approach-Avoidance-Framing*[9] and *Competence Adequacy* are very high, with the 75% percentile above 0.7. The lowest score can be found for *Negative Utility*, where the 75% percentile is below 0.3.

[9] High values indicate Approach-Framing, low values indicate Avoidance-Framing.

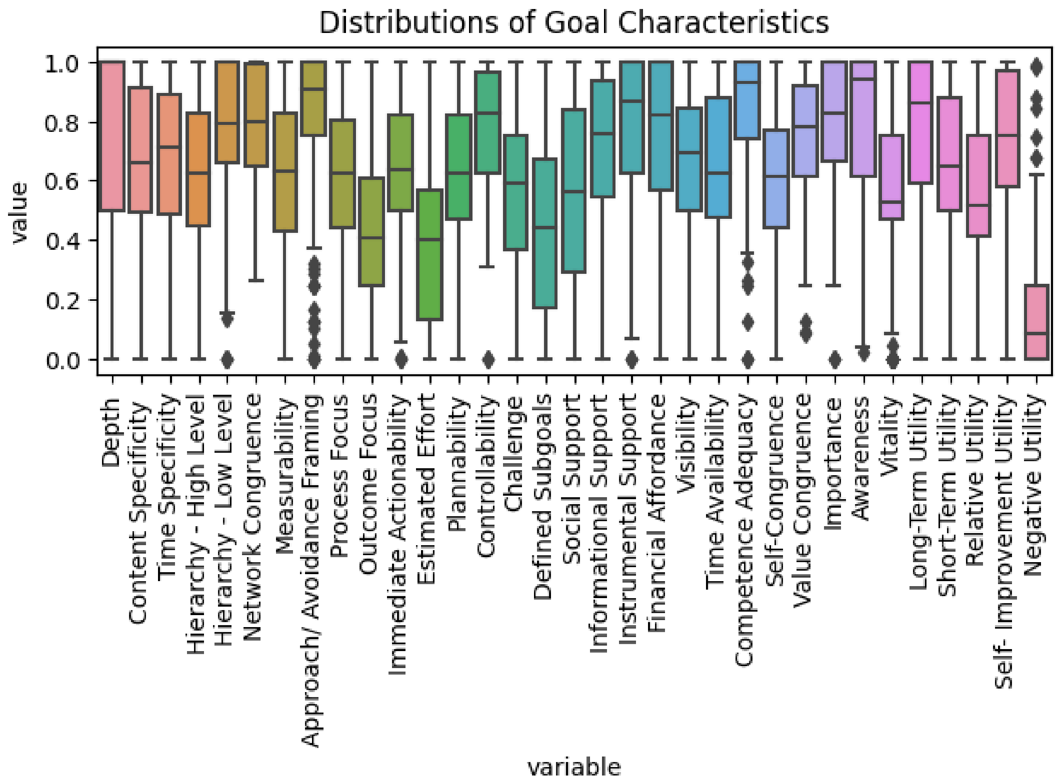

FIGURE 4.29: GCQ Score Distributions.

Goal Characteristics Correlation Heatmap The scores for all permutations of the 32 GC can be found in figure 4.30. The highest positive correlations are between *Value Congruence* and *Self-Congruence* with 0.76, *Instrumental Support* and *Informational Support* with 0.74, *Long-Term-Utility* and *Importance* with 0.71, *Long-Term Utility* and *Hierarchy-High-Level* with 0.70, and *Importance* and *Value-Congruence* with 0.69. The highest negative correlations are between *Challenge* and *Estimated Effort* with -0.69, *Estimated Effort* and *Hierarchy-High-Level* with -0.55, and *Process-Focus* and *Outcome-Focus* with -0.49.

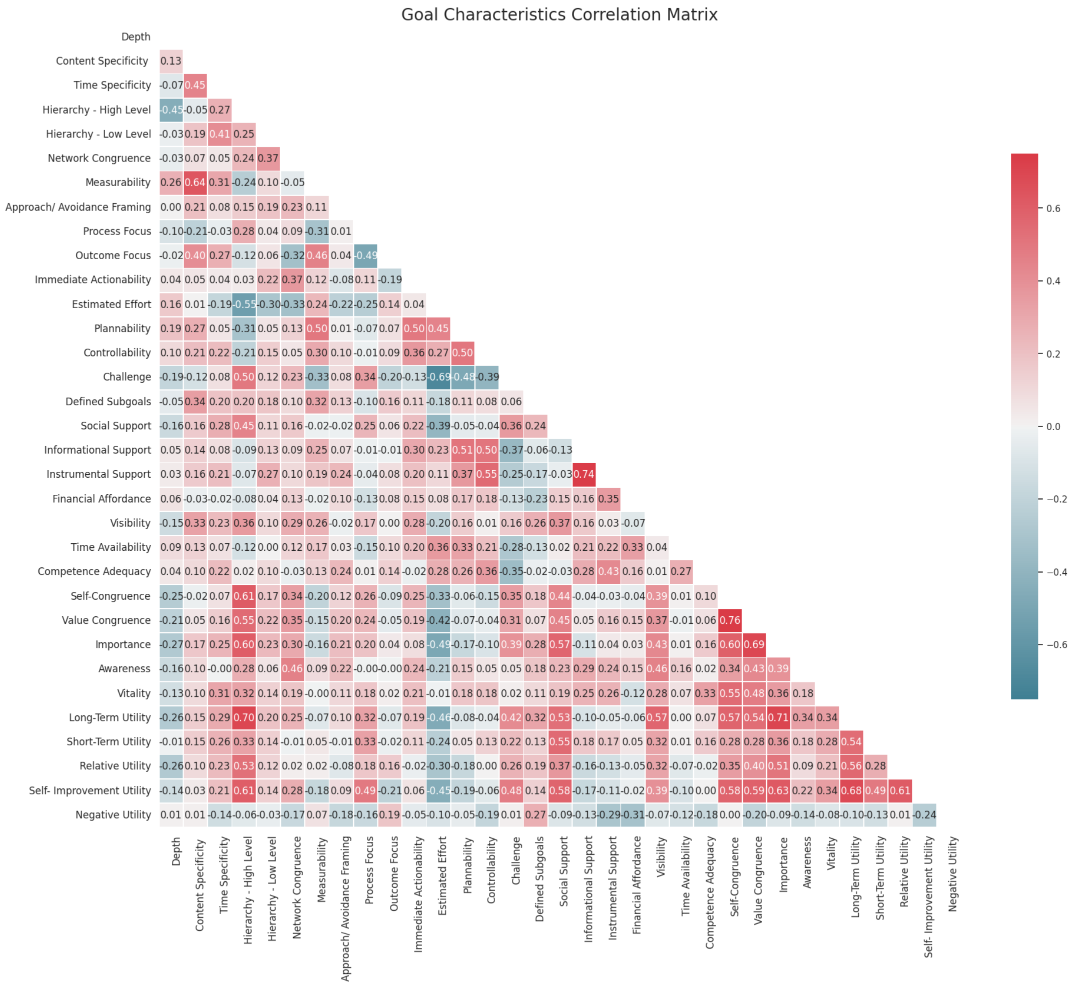

FIGURE 4.30: Goal Characteristics Correlation Heatmap.

Discussion

The most outstanding GCQ scores and correlations will be discussed and interpreted in the following paragraphs.

Goal Characteristics Scores The results from the Goal Characteristics Scores in figure 4.29 show that most of the goals are framed with a *Process-Focus*, which is beneficial for the formation of habits and can support learning processes. The *Estimated Effort* is relatively low, indicating that the participating students underestimate the effort. The same is true for the *Challenge* characteristic. Although these estimations may not align with reality, they do not hinder learning processes, as overcharging goal representations could be according to Goal-Setting Theory. The overall low scores for the *Defined Subgoals* characteristic can be explained by the HGS structure, where the majority of goals are on lower levels, resulting in high numbers of goals with low numbers of subgoals. The low scores for the *Social Support* characteristic is a bit of a surprise because learning processes in higher education should be designed such that learning in groups plays a central role. The low scores indicate that curriculum designers and teachers at Osnabrück University should ask themselves whether enough has been done to use group dynamics in educational settings. The extremely low scores for the *Negative Utility* characteristic show minimal negative side-effects for the educational goals of participants.

Goal Characteristics Correlation Heatmap Among the positive and negative correlations between goal characteristics, there are no big surprises, and most of the correlations can be understood as evidence for the functionality of the GCQ scale. *Value-Congruence* and *Self-Congruence* are semantically closely related constructs, as *Instrumental* and *Informational Support* are. *Long-Term Utility* and *Importance* are positively correlated, which shows that the participants are rational and value goals with *Long-Term-Utility* as very *Important*. The finding that *Long-Term-Utility* and *Hierarchy-High Level* are positively correlated supports our theoretical assumptions about goal characteristics in HGS. The positive correlation between *Importance* and *Value-Congruence* shows that students in higher education prioritize value-congruent goals. The negative correlations between the pair *Challenge* and *Estimated Effort* and the pair *Process-Focus* and *Outcome-Focus* show that the GCQ scale works as intended because the constructs are semantically related in the way of our findings. A surprise is a negative correlation between *Estimated Effort* and *Hierarchy-High Level*, which indicates that participants think that the effort for goals that are higher in the hierarchy is less effortful. Theoretically, this should not be the case because the high-level goals subsume their subgoals, clearly resulting in an accumulation of effort for the high-level goals. A possible explanation is that high-level goals are more abstract, and participants tend to mentally locate the effort at concrete low-level goals. If this is the case, then the hypothesis that HGS can help to increase the subjective feasibility of high-level goals can be supported by this result.

4.5 General Discussion and Outlook

The two most critical intermediate goals of the outlined research are a) to build a hierarchical goal-setting intervention that improves students' academic life, and b) implement a field study that allows the collection of hierarchical goal systems in a natural environment. To make it easier for students to use the hierarchical goal-setting intervention, we have worked on an attractive interface with low interaction costs and high availability embedded into the local learning management system. In the intervention, goal characteristics are measured with the GCQ, and the scores, enriched with background information, are displayed to students. In this way, students can benefit from scientific insights into human goal setting and goal pursuit, and at the same time, valuable data arises, promoting scientific progress.

As a wide variety of software is available to university students, it will be a significant challenge to convince students to use additional software regularly. The software can only be effective if its users are motivated and invest time and effort. One significant limitation is the usage of the study assistant. Using the GoalTrees study assistant may convey essential meta-cognitive skills because personal goals are explicitly set and proactively pursued, and the process is reflected by tracking progress and strategy refinement. Goal attainment may be perceived as rewarding, and our study assistant can increase this effect through gamification and (self-set) rewards. The potential of a goal-setting tool for higher education is to empower students to think about individual inspiring education goals, develop self-regulation abilities, and increase self-efficacy. In a constructivist sense, such a study assistant may help to implement a shift from curricular-driven learning for exams to interest-driven learning for life.

4.5.1 Limitations

The full potential of the *GoalTrees* intervention for Hierarchical Goal-Setting is not fully explored yet, and there are limitations worth mentioning.

- In the current stage of development, the goal-setting and planning phase of cyclic self-regulated learning (see figure 1.1 is already covered, while the dynamics of learning processes and goal pursuit remain to be covered by the GoalTrees intervention, in the future.
- Once a student has modeled a higher-order goal and the problem domain as HGS, the former mechanisms promote goal pursuit. The cost for these functional advantages is the effort of transforming the goal-related problem domain into a strict hierarchical schema. Participants in our studies have reported that translation is especially challenging for sub-goals contributing to more than one superordinate goal. This difficulty is innate to the approach of Hierarchical Goal-Setting.
- The GoalTrees intervention allows for the conduction of longitudinal studies, which assess goal achievement over time. The correlations between goal characteristics and goal achievement and the process of Hierarchical Goal System pursuit remain to be investigated in future studies.

4.5.2 Outlook

From a scientific perspective, the potential advantages for students to use a digital companion to guide them toward their goals seem significant. Nevertheless, we know that competing digital tools and apps have an overall high availability. So a challenge is and will be to convince students to use our tool. We want to overcome the natural limitation of actual usage by designing an attractive interface with low interaction costs and high availability, realized by a web-based architecture. The current state of development is still in the research phase, but we plan to develop the tool further until it is perceived as a valuable digital helper for students. In the latter field study summarized, the effects of Hierarchical Goal-Setting on goal characteristics will be examined in detail. The pre-post measurement of root goal characteristics allows for measuring those changes.

Chapter 5

Clustering in a Conceptual Space of GCQ Dimensions

This chapter has partially been published in "Searching for types of goals in a Conceptual Space of goal characteristics" (Weber, Abdelfattah, and Kühnberger, 2022).

5.1 Introduction

This chapter introduces an approach to combine ideas from G "ardenfors' Conceptual Spaces Framework (CSF) (Gärdenfors, 2000) and Clustering Techniques to the domain of Psychometrics in general and Motivational Psychology in particular. In the goal-setting literature of the last 50 years, scientists have postulated and empirically confirmed various goal types with specific characteristics. In line with CSF, we aim to reproduce such goal types as convex regions in quality dimensions. The data we use originates from an ongoing field study with a digital study assistant (DSA) for goal-setting in higher education and holds goals in natural language ($n = 637$), formulated by university students ($n = 38$), each related to scores for 32 goal characteristics, assessed with the Goal Characteristics Questionnaire (GCQ) (Iwama et al., 2021). The method we apply in this chapter is searching for multi-peaked distributions by visually inspecting violin plots, scatter plots, and kernel density estimation plots (KDE) of single characteristics and two-dimensional permutations. If there are differences in data density in dimensions, applying clustering algorithms in these dimensions is worth the computation time. The results show multi-peaked distributions, while no non-overlapping convex clusters are evident by visual inspection. In the KDE plots, summits of high density exist, which are prospective candidates for convex regions, aka types. The findings encourage us to proceed in the endeavor and apply clustering algorithms in future studies, which may allow us to reproduce previous findings of goals and their characteristics with a novel method, apply and test the CSF on real-world data, and possibly derive new insights into the nature of educational goals.

The interdisciplinary research outlined in this chapter brings together Conceptual Spaces, an approach from cognitively inspired Artificial Intelligence that promises to solve the symbol grounding problem with data points from our digital goal-setting intervention in a high-dimensional psychometric space of goal characteristics, accessed with the Goal Characteristics Questionnaire (GCQ) (Iwama et al., 2021) in a web-based field study of a digital goal-setting tool for higher education (Weber, 2019; Weber, Schrumpf, and Thelen, 2021; Weber et al., 2021).

In this chapter, we outline the backgrounds of Conceptual Spaces and show commonalities with the psychometric method of factor analysis. We then outline the application of these concepts in an ongoing field study collecting student goals in natural language, structured as hierarchical goals systems (HGS). The latter are tree-shaped sets of synergistic goals, in which every goal except the root goal serves a superordinate goal. The results section shows a subset of a large set of violin-, scatter-, and kernel-density estimation plots that will be used for dimension selection. Scores for 32 goal characteristics describe each goal, representing the subjective qualities of the goal for its bearer, who generated the scores by answering the items of the GCQ self-assessment tool. The dimensions are equivalent to a multidimensional goal characteristics space with goals as points. This perspective allows the application of clustering algorithms to identify distinct types of goals that German university students typically have.

5.1.1 The Symbol Grounding Problem

The Symbol Grounding Problem (SGP) is related to symbols in cognitive systems and their relation to meaning or correlates in the world. The problem, as stated by Harnad, 1990, is "How can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads? How can the meanings of the meaningless symbol tokens, manipulated solely on the basis of their (arbitrary) shapes, be grounded in anything but other meaningless symbols?"(Harnad, 1990) In the application of symbolic AI, based on symbols and logic, the symbols need to be grounded onto correlates in the real world, which is not trivial. In research about educational goals, concepts, such as, for instance, *approach-goals* or *SMART goals* have to be mapped to goal instances.

5.1.2 Conceptual Spaces

Peter Gärdenfors mainly developed the idea of Conceptual Spaces as a solution for the symbol grounding problem and introduced it in his multifaceted book "Conceptual Spaces - The Geometry of Thought" (Gärdenfors, 2000).

Definition 5 ***Conceptual Spaces*** *were introduced as a concept, potentially solving the symbol grounding problem, by Peter Gärdenfors in his Book "Conceptual Spaces - The Geometry of Thought," in 2000(Gärdenfors, 2000). The core idea is that perceptual quality dimensions span a multidimensional space in which* concepts *are defined as (convex) regions entailing all instances of a type.*

The central idea of the CSF is the representation of concepts as convex regions in spaces defined by similarity dimensions. Classic examples of similarity dimensions are hue, saturation, and brightness for colors, pitch, and amplitude for sounds, and width, height, and depth for geometrical size. In a sense, these dimensions are orthogonal to each other, so one dimension cannot even partially be expressed by another.

Gärdenfors claims "..that conceptual spaces will solve the symbol grounding problem, at least when symbols referring to perceptual domains are considered." (Gärdenfors, 2000, p. 43) For instance, in the context of a robot, grounding the concept *apple* can be implemented as a conceptual space with dimensions related to shape and color.

Theorists produced proposals on how to deploy Conceptual Spaces and ground concepts. However, to evaluate the actual merit, there is a need to implement proofs-of-concept in real-world applications (Bechberger, 2021).

Goal Types in Conceptual Spaces

Suppose types are represented as convex regions in a quality space. In that case, there are, in principle, ways how to identify such regions: Either, in a top-down approach, a region or centroid of a region is defined based on the semantics of the space, or, in a bottom-up approach, data about entities in the feature space is collected, and clustering algorithms yielded convex regions. Labeling the new type is straightforward in the former case because the semantics are known. In the latter, the labeling of the new type is non-trivial. In this chapter, we chose a bottom-up approach where we aim to identify clusters from data.

5.1.3 Psychometrics in General and Factor Analyses in Particular

Psychometrics is a sub-discipline of psychology that aims to measure latent constructs, such as intelligence or conscientiousness. According to the APA, *psychometrics* can be defined as "the branch of psychology concerned with the quantification and measurement of mental attributes, behavior, performance, and the like, as well as with the design, analysis, and improvement of the tests, questionnaires, and other instruments used in such measurement." (American Psychological Association, 2020). The psychometric method of factor analysis is used to identify a set of ideally uncorrelated unobserved factors that can explain the variance in observed variables. It is used, amongst others, to develop questionnaires with items as observed variables that measure latent variables. Ideally, those latent variables are not correlated and can be interpreted geometrically as orthogonal vectors spanning a feature space. So, psychometric questionnaires and Conceptual Spaces have in common that they are multidimensional, and the dimensions are intended to be non-redundant and orthogonal.

5.1.4 Educational Goals' Characteristics

Goals have been described as internal representations of desired states (Vancouver and Austin, 1996), and Cognitive Scientists from various sub-disciplines have investigated them for decades. The result is a rich toolbox of empirical methods for assessing goal characteristics relevant to goal pursuit and achievement. The goal characteristics Questionnaire (GCQ) (Iwama et al., 2021) is a relatively young instrument that measures 32 dimensions of goal characteristics by self-assessment with Likert scale items. With its' 32 dimensions, the GCQ allows researchers to get a global view of the characteristics of goals. Among these dimensions are, for instance, *social support*, which describes how far others support the striving for a specific goal, or *self-congruence*, which describes how far a goal is in line with the identity and the lifestyle of its bearer.

5.1.5 Clustering in 32-Dimensional Goal Characteristics Space

Goals and their GCQ scores can be interpreted as points in a high-dimensional (32d) space, which allows us to combine such data with concepts and methods from the Conceptual Spaces Framework. Suppose types of goals exist not only in scientific papers, hypothetical and invoked by empirical tricks, such as median splits. In that case, it should be possible to identify their –possibly fuzzy– borders in the goal characteristics space. Examples of such goal types from previous research are, for instance, *SMART goals*, which are specific, measurable, achievable, realistic, and time-bound (Doran, 1981), or *performance goals*, which are pursued to fulfill measurable, and visible external benchmarks. If clustering algorithms could identify clusters of goals that are semantically congruent with goal types from goal-setting research in a Conceptual Space, that would harden previous findings by novel methods.

5.1.6 Research Questions

Can previously found concepts, such as goal types, be reproduced as clusters in relevant GCQ dimensions? If so, this empirical evidence would confirm their concordance with reality. If not, their practical value would be at least partially in question. Suppose borders between types are fuzzy, and the empirical methods applied so far rely on median splits. In that case, the concepts were relative to the data sets in question, and their semantics were not as absolute as they were in the case of reproduction by clustering methods.

In this chapter, we take the first step by searching for high-density areas in one-dimensional violin plots, two-dimensional scatter plots, and kernel density estimation (KDE) plots of GCQ data. *Kernel density estimation* is a smoothing technique that makes it easier for observers to find patterns in a plot. The KDE algorithm is also used for smoothing the violin plots. The results can serve as the foundation for a dimension selection of the conceptual GCQ space before clustering algorithms, such as the distance-based k-Means algorithm and the density-based DBSCAN algorithm, will be applied to the data. The core benefit of selecting a subset of dimensions is decreasing required computational resources and more optimal conditions for identifying clusters.

The central questions we address in this study are: Which dimensions of the GCQ are most suitable for clustering methods because they show more than one peak (visible in violin plots)? Which dimensions are redundant and hence can be excluded from clustering methods because they highly correlate with another dimension (visible in scatter plots)? Which dimension combinations are most promising for successful clustering because there is more than one peak in their bi-variate distribution (visible in kernel density estimation plots)?

5.2 Methods

The data was collected in the online field studies described in section 4.4.12 and analyzed with Python scripts. It consists of goals in natural language, for which participants answered the GCQ, which results in scores for 32 dimensions.

So far, the method applied to the data is the visual inspection of univariate and bivariate distributions of goal characteristics, focusing on multi-peaked distributions. We interpret multi-peaked distributions as indicators for distinct clusters in the respective dimensions. We will include those dimensions in future clustering computations and exclude dimensions with single-peaked distributions. Additionally, strong correlations between dimensions, showing up in two-dimensional plots as high data density along the main diagonal, indicate that one of the dimensions can be excluded from clustering computations to decrease the resource requirements.

5.2.1 Analysis Methods

We implemented data analysis scripts with Python scripts embedded into the Django application as management commands. We used the NumPy and Pandas libraries for data processing and the Matplotlib and Seaborn libraries for data visualization.

5.3 Results

The resulting plots are 32 violin plots (one per GCQ dimension), 496 two-dimensional scatter, and KDE plots [1], for each two-dimensional goal characteristic combination. The resulting plots are attached in Appendix G.

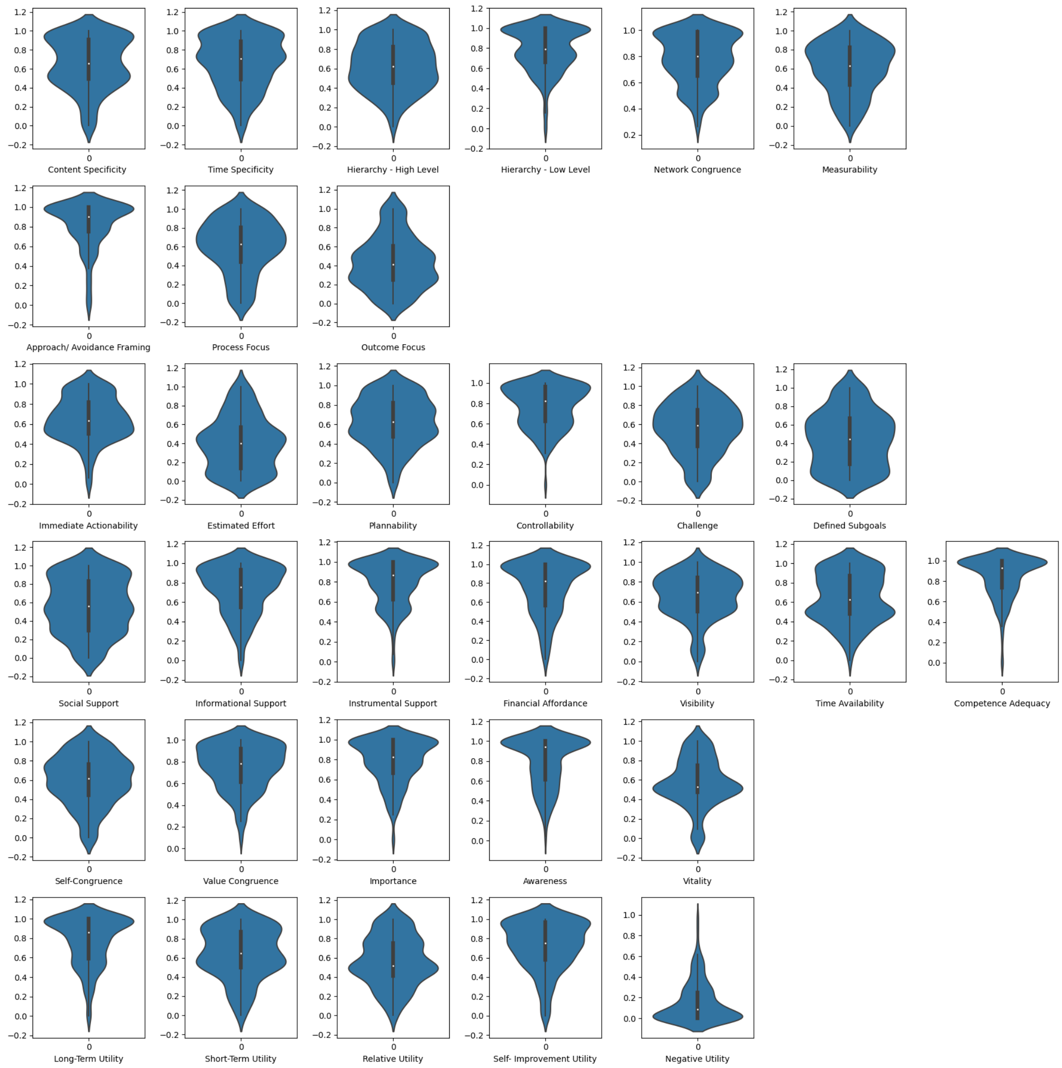

FIGURE 5.1: Violin-plots for all GCQ dimensions, ordered by rows according to the semantically ordered subscales of the GCQ. Violin plots are rotated and mirrored kernel density estimation plots. Multi-peaked plots indicate that distinct types of goals can be separated within the dimension.

5.3.1 Violin Plots for Single Dimensions

Violin plots are rotated kernel density estimation plots mirrored such that the shapes are amplified. Figure 5.1 shows violin plots for all 32 GCQ dimensions, ordered by subscales in each row. The *Content Specificity* plot (row 1, plot 1) is an example of

[1] $496 = \sum_{n=1}^{n=32} n - 1 = 496$, as each of the 32 characteristics was plotted against each of the others and not itself.

a prospective candidate for clustering because it shows peaks at one and approximately 0.5. Conversely, the *Measurability* plot (row 1, plot 6) shows only one prominent peak, lowering the probability of successful clustering in this dimension.

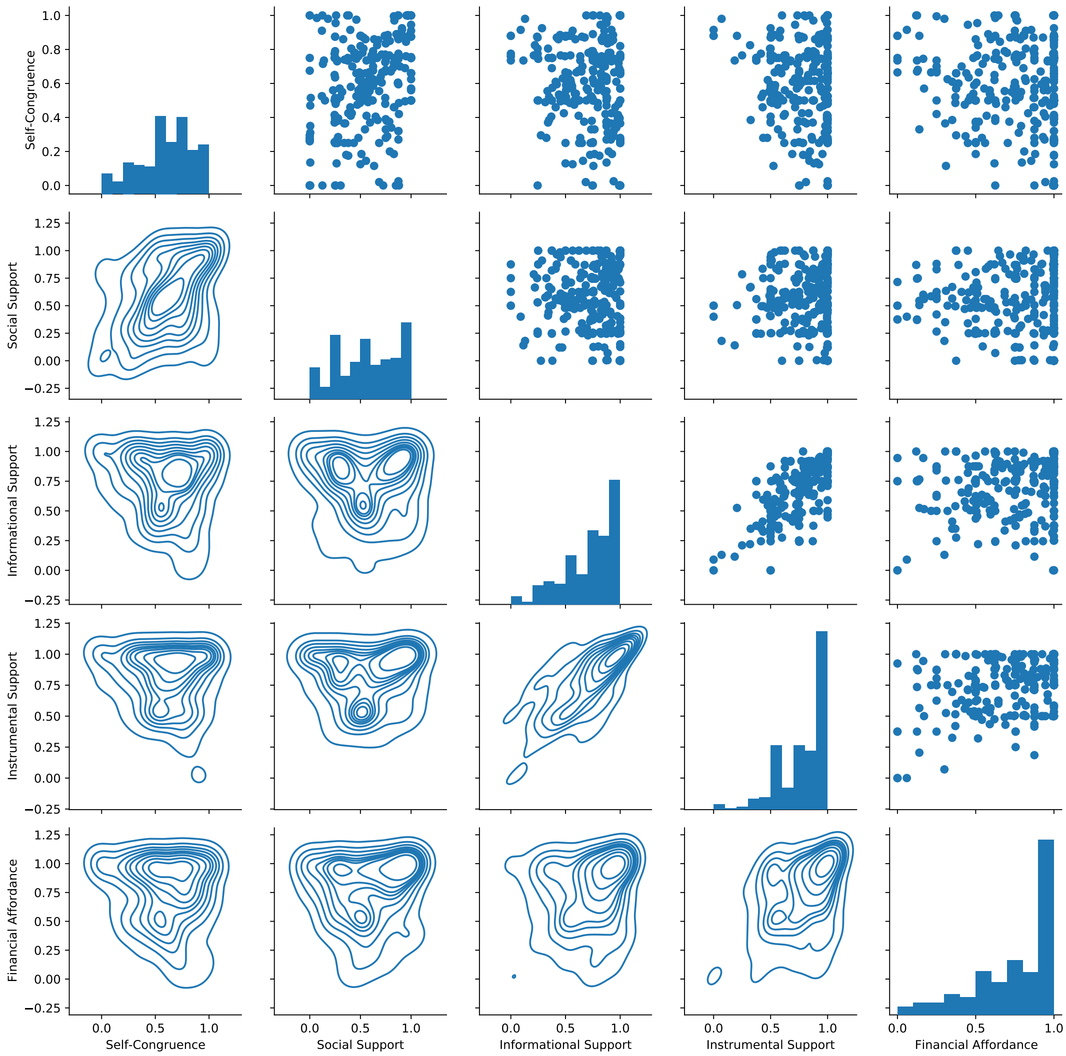

FIGURE 5.2: Pairwise scatter-plots and kernel density estimation (KDE) plots for five exemplary goal characteristics. *Informational Support* and *Instrumental Support* appear to have a linear relationship, as the KDE plot in row 4, plot 3, shows. Characteristic combinations with kernel density estimation plots showing more than one area with the highest density are prospective candidates for clustering algorithms.

5.3.2 Scatter Plots and Kernel Density Estimation Plots for all GCQ Dimension Combinations

Because of the high number of 496 scatter plots and 496 KDE plots, we include a representative exemplary subset of 10 scatter plots and 10 KDE plots illustrating the kind of derivable insights (see figure 5.2). The KDE plots at the lower left are partially multi-peaked; for instance, the three plots of the *Social Support* Characteristic (row 3, plot 2; row 4, plot 2; row 5, plot 2). So this dimension should be kept because the probability of cluster detection is high. On the other hand, the dimensions *Informational Support* and *Instrumental Support* in row 4, plot 3 seem to be highly correlated, indicating that we should eliminate those. Figure 5.2 represents the complete set of KDE plots and scatter plots insofar that there are not visually separable clusters in the entire data set but multi-peaked distributions in a subset.

These exemplary results show that there are, in fact, multi-peaked distributions in single characteristics and characteristic combinations. Therefore, we will pursue the outlined approach and take consecutive steps toward dimension selection and goal type identification in the condensed goal characteristics space.

These exemplary results show that there are, in fact, multi-peaked distributions in single characteristics and characteristic combinations. Therefore, we will pursue the outlined approach and take the following steps toward dimensionality reduction and goal type identification in the condensed goal characteristics space.

5.4 Discussion

In this chapter, we have outlined the application of the Conceptual Spaces Framework to a real-world application, namely a high-dimensional data set of educational goals. We have outlined how to use clustering in a bottom-up approach to identify convex regions defining goal concepts in the goal characteristics space. Paradigmatic plots illustrated how the upcoming dimension selection procedure could be implemented and gave evidence of clusters in the data. A more robust statistical method for dimension selection will be established and applied in the consequent steps. Multidimensional Scaling (MDS), also called Principle Coordinates Analysis (PCoA) (Mead, 1992; O'Connell, Borg, and Groenen, 1999) and Principle Component Analysis (PCA) (Jolliffe, 2002) are suitable methods for the challenges ahead.

Chapter 6

Summary of Results and Conclusions

This dissertation thesis has reported on a line of research aiming to support university students in their educational goal-striving through a Digital Study Assistant (DSA). On an empirical-methodological level, ways of measuring goal characteristics from an internal and external perspective have been developed, as described in chapter 3. On a conceptual level, Hierarchical Goal Systems (HGS) have been introduced as a promising approach for self-regulated goal pursuit. Based on this conceptualization, a DSA named *GoalTrees* has been developed and tested in a series of formative studies. As a side-effect of those studies, a body of labeled educational goals has been gathered, which allows us to shed light on the characteristics of educational goals. Chapter 5 combines this data with central ideas of the Conceptual Spaces Framework (CSF), and methods for the data-driven detection of goal types have been outlined.

In this chapter, the central findings of the doctoral research will be summarized in a section about epistemological results, a section about ontological results, and a section structured along the central research questions. Subsequently, a methodological reflection will balance the research process and reason about possible improvements and lessons learned. Finally, an outlook will throw a glance at the future of this line of research.

6.1 Epistemological Results

Epistemological questions concern the methods suitable to generate knowledge about research objects. Building on previous research, the research project has extended the cognitive scientists' toolbox for the inspection of goals and processes of self-regulated learning.

6.1.1 How to Measure and Predict Goal Characteristics

How can insights about the nature of goals be derived? Chapter 3 has outlined an approach from the external perspective suitable to detect particular and common types of goals, such as, for instance, *Graduation* or *Learning a specific language*. Subsequently, it introduced the GCQ as a self-assessment tool suitable for quantifying 32 relevant goal characteristics. These characteristics are highly subjective and may vary over time. For instance, the perceived characteristics of a personal educational goal may differ in measurements pre- and post-intervention.

6.1.2 How to Measure Goal Pursuit in Self-Regulated Learning

The GoalTrees intervention is a tool that allows researchers to accumulate data about the dynamics of goal systems during goal pursuit. The *GoalTrees* DSA for HGS is a tool that students can use in natural learning environments to organize their goal-directed learning activities and, as a side-effect, generate data about the evolution of Hierarchical Goal Systems and goal characteristics over time. By marking goals as resolved and creating new sub-goals, valuable data for empirical analyses is generated. Future studies with the *GoalTrees* software can uncover previously unknown mechanisms of self-regulated learning behaviors.

6.1.3 Epistemology of Artificial Agents and Digital Study Assistants

If one is willing to consider a software system or a DSA as an artificial agent, the question arises if and how such an agent can derive knowledge about the world. I want to sketch some thoughts about this issue in this paragraph briefly. In a sense, an artificial agent can be understood as an agent that uses automated scientific methods to process incoming data, derives insight from it, and responds to it in some way. For instance, the *GoalTrees* agent receives goal data as goal descriptions, information about the position of goals within a goal system, and users' answers to the GCQ items, resulting in 32 labels, one for each goal characteristic. Additionally, in longitudinal studies, data about the time of goal achievement can be accumulated. Given an extensive body of data, inferences about goal characteristics as predictors of goal achievement can be derived, and related predictions and recommendations can be fed back to the human user. Suitable techniques can be clustering algorithms that allow deriving concepts and classes defined by spatial domains in high-dimensional feature spaces and data mining algorithms that allow deriving rules from feature-rich databases. Describing such a scenario, it is not necessary to bother with the overused term of *Artificial Intelligence*, but instead, one could speak of the automated application of empirical methods.

6.2 Ontological Results: Characteristics of University Students' Goals

As a side-effect of the methodological achievements summarized above, knowledge about the characteristics of educational goals has been accumulated and can be explored in the following extensive visualizations:

- relative frequencies of Goal Tags (see section 3.3, figure 3.6)
- remarkable correlations between goal tag combinations (see section 3.3, figures 3.7 and 3.8)
- GCQ dimension distributions (see figures 4.29 and 5.1)
- remarkable correlations between GCQ dimensions (see figure 4.30)
- structural characteristics of Hierarchical Goal Systems (see figure 4.16)

Due to the high number of measured variables, and the explorative nature of the analyses, in some studies, no inferential statistics were applied. Indeed the application of Bonferroni corrections, or other methods to counteract the multiple comparison problem, would have changed p-values to insignificant ranges. Therefore, future studies should be conducted to harden the findings. As a first step, an alpha-error correction was omitted to ensure that no effects were overlooked.

6.3 Research Questions and Answers

In Chapter 1, a list of research questions has been stated. In the concluding section, they will be repeated and briefly answered based on the work summarized in this dissertation thesis.

1. Which methods can be applied to measure goal characteristics?
   As devised in Chapter 3, in principle, there are external and internal approaches to measuring goal characteristics. Both approaches have been explored, and the results clearly show that the agreement of external raters, six in the specific case, on most measured goal characteristics was rather low, except for concrete goal types, such as, for instance, *learning a foreign language*. Due to the highly subjective nature of goals, this is not a big surprise. It can be concluded that an internal approach, such as using the GCQ self-assessment tool, measuring 32 relevant characteristics, is best suitable to measure goal characteristics.

2. Which characteristics of goals are relevant in educational contexts?
   From the extensive literature review, which can be found in Chapters 2 and 3, it can be inferred that for internal motivation, the goal characteristics of Self-Congruence, Value-Congruence, and Importance are essential. For the process of goal-pursuit, practical goal characteristics, such as *Content and Time Specificity*, *Plannability*, and *Resources Availability* are essential.

3. How are goals and goal systems represented mentally, and how can they be represented in human-machine interfaces?
   In the *GoalTrees* DSA, hierarchical goal systems were chosen as goal representation forms. Conceptually, this allows splitting abstract meaningful goals into more actionable subgoals, which offers a row of functional advantages. Hierarchical Goal-Systems seem to conflict with the wish of system users to form cross-links from multifinal goals to more than one superordinate goal. This observation is a reason to assume that mental representations differ from HGS. Four types of visualizations (Circlepacking, Dendrogram, Sunburst, and Treemap) were compared in a row of usability studies with clear subjective and functional advantages of the Dendrogram. So, if there were pictorial mental representations of HGS, the findings from the visualization comparison studies can be seen as evidence for similar mental representations.

4. How can findings from former research on constructivism, goal-setting, self-regulation, and self-monitoring be applied in a digital data-driven study assistance software?
   The *GoalTrees* study assistant prototype has iteratively been tested and refined in a row of field studies, summarized in Chapter 4. Based on a theoretical foundation and step-wise improved with empirical methods, it constitutes an approach to assist students in their personal, educational goal-striving processes. The *GoalTrees* DSA can currently be used in planning phases to extend abstract high-level goals into Hierarchical Goal Systems. In addition, the questions of the GCQ can be answered in a visually appealing Likert-Scale, and the resulting scores with additional information about their relevance are displayed to

the user. Based on this personal feedback, University Students can reflect on their goals and may benefit on cognitive and meta-cognitive levels.

5. Which characteristics do the goals of students show, and which conclusions can be derived?
Measurements with the 32-dimensional GCQ show a comprehensive picture of educational goal characteristics. Figures 4.29 and 4.30 show a bar plot with single dimension distributions, and a heatmap with correlations of GC pairs. The most prominent findings are that students tend to have goals with an Approach-Framing, with little negative side-effects (low scores for *Negative Utility*), that they believe in their ability to achieve those goals (high scores for *Competence Adequacy*), but may underestimate the effort (low scores for *Estimated Effort*).

6. How can insights on the nature of educational goals be derived from high-dimensional goal data?
Chapter 5 has outlined how the understanding of GCQ results can be interpreted as high-dimensional conceptual space. Clusters of goals in GC space may either reproduce known goal types or reveal novel insights onto the nature of educational goals. Combining psychometric measures with algorithms from unsupervised learning, especially clustering algorithms, is a promising approach to identifying goal types in the data.

7. How can Machine Learning models be trained to predict goal characteristics from goals formulated in natural language?
The answer to this question is relatively short: The BERT language model (Devlin et al., 2019) seems to be a suitable Machine Learning Model to predict goals formulated in natural language, because of it's performance, and because it is pre-trained and can be fine-tuned for specific purposes. The results from an ongoing study will show whether the available data suffices in quantity and quality to train a BERT model.

8. How can methods from Artificial Intelligence be applied in Digital Study Assistants for goal-setting and pursuit?
There are countless possible applications to apply algorithms of AI to education-related data in ways that support learning processes. For the *GoalTrees* DSA, the most nearby approaches, as mentioned above, are the prediction of goal characteristics based on goal formulations. If the performance can be positively evaluated, a BERT model (Devlin et al., 2019) could predict goal characteristics to substitute the procedure of answering a questionnaire with more than a hundred items for, on average more than ten goals in an HGS. This improvement would decrease effort and increase usability and UX. If the unsupervised learning approach of clustering goals in GC space succeeds, this would be a solid foundation to implement recommendation mechanisms based on those clusters.

6.4 Methodological Reflection

One of the core purposes of a Dissertation Thesis is undertaking a research project to contribute to scientific progress while following a good scientific practice. The following sections critically reflect good scientific practice during this line of research.

6.4.1 FAIR Principles

Among the achievements of the outlined research are the publication of data sets in the OsnaData[1] repository, and the transparency of methods, given by the publicly available data analysis scripts included in the data sets. The publication of these data sets aligns with the FAIR principles as outlined by Wilkinson et al., 2016.

6.4.2 Generalizability of Results

Concerning the pre-registration of methods and hypotheses, there is room for improvement in the future, as none were made. Pre-registration is not crucial for the studies in this dissertation thesis because no directed hypotheses were stated. The effects found in the study about goal characteristics in Chapter four are exploratory insofar that the broad measurement with the complete 32 goal characteristics and the related alpha error inflation demands a Bonferroni correction, with devastating effects on the p-values. Consequently, confirmatory studies focusing on the subset of the most effective dimensions are required to harden the findings of my studies. Therefore, no claims about the findings' generalizability are made; only claims about the sample population were made. There were challenges regarding data handling during an ongoing field study with an iteratively evolving experimental, hand-made digital assistant. The real-world data was often dirty and dynamically evolving. Therefore participants had to be excluded and filtered to ensure the comparability of participants. Software testing also resulted in data sets being excluded. I did my best to ensure high data quality, and I hope to have achieved an acceptable standard. For future research on comparable projects, I will establish structured processes for data processing pipelines and data management.

6.5 Outlook

Based on the foundation summarized in this doctoral thesis, the following steps can be taken in the near future:

Prediction of Goal Characteristics with BERT The first steps towards implementing the long-term goal of tagging students' educational goals automatically in a digital data-driven study assistant software have been taken. We used the labeled goal data from the study summarized in this chapter to train and evaluate a pretrained Bidirectional Encoder Representations from Transformers (BERT) (Devlin et al., 2019) machine learning model. Preliminary results show that the performance of the artificial intelligence agent equals the performance of the six raters with natural intelligence insofar that the accuracy highly differs between tags. This finding aligns with methodological considerations concerning the external characterization of goal characteristics: Some goal characteristics are goal-inherent and suitable for detection from an external perspective. Some have subjective qualities that can only be measured by self-assessment and even maybe unstable over time.

Clustering in Goal Characteristics Space As outlined in chapter 5, goal types can be identified in a bottom-up approach of clustering in a Conceptual Space of Goal Characteristics.

[1] Research Data of Osnabrück University: `https://www.ub.uni-osnabrueck.de/forschen_publizieren/forschungsdaten_der_uos_osnadata.html`

Study about the Effects of Hierarchical Goal-Setting As outlined in section 4.4.12, in an ongoing field study, the amount of data is constantly growing and will form the foundation to study the specific effects of HGS on high-level goals.

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Appendix A

Goal Characteristics Questionnaire Items

id	Item	reverse coded
	Structural Subscale / Subskala Strukturelle Eigenschaften	
	Content Specificity / Spezifizität des Inhalts	
1	Dieses Ziel hat ein klar definiertes Ergebnis oder einen klar definierten Endzustand. This goal has a clearly defined outcome or final state.	0
2	Ich bin mir nicht sicher, wohin mich dieses Ziel führen wird. I am not sure where this goal will lead me.	1
3	Dieses Ziel hängt mit konkreten Aktionen zusammen. This goal is related to concrete actions.	0
4	Das Ergebnis oder der Endzustand dieses Ziels ist nur vage definiert. The outcome or final state of this goal is only vaguely defined.	1
5	Ich kann dieses Ziel nicht exakt beschreiben. I cannot describe this goal precisely.	1
	Time Specificity / Zeitliche Spezifizität	
6	Ich habe kein Zieldatum, an dem ich dieses Ziel erreichen möchte. I don't have a target date for when I want to attain this goal.	1
7	Ich habe eine klare Frist, bis zu der ich dieses Ziel erreichen möchte. I have a clear deadline by which I want to attain this goal.	0
8	Ich beabsichtige dieses Ziel innerhalb einer bestimmten Zeitspanne zu erreichen. I intend to achieve this goal within a specific amount of time.	0
9	Dieses Ziel sollte zu einem bestimmten Zeitpunkt erreicht sein. This goal should be achieved by a specific time.	0
	Hierarchy - High Level / Hierarchie - Hoch	

10	Bei diesem Ziel geht es um eine allgemeine Ambition in meinem Leben. This goal is an overall ambition in my life.	0
11	Dieses Ziel gibt Leitlinien für meine Entscheidungen und Verhaltensweisen. This goal provides guidance for my decisions and behaviors.	0
12	Um dieses Ziel zu erreichen muss ich an Teilzielen arbeiten. To achieve this goal, I need to work on subgoals.	0
13	Dieses Ziel ist ein grundlegender Antrieb in meinem Leben. This goal is an aspiration in my life.	0
	Hierarchy - Low Level / Hierarchie - Niedrig	
14	Dieses Ziel ist ein Mittel zu einem höheren Ziel. This goal is a means to a higher goal.	0
15	Dieses Ziel ist nur ein Teil eines Plans, um etwas Größeres in meinem Leben zu erreichen. This goal is just a part of a plan to achieve something bigger in my life.	0
16	Dieses Ziel ist ein Schritt in Richtung eines größeren Ziels. This goal is a step toward a greater goal.	0
17	Um ein größeres Ziel in meinem Leben zu erreichen, muss ich dieses zuerst erreichen. To achieve a larger goal in my life, I need to achieve this one first.	0
	Network Congruence / Kongruenz mit Zielnetzwerk	
18	Dieses Ziel hat keinen Zusammenhang mit meinen anderen Zielen. This goal has no relation to my other goals.	1
19	Dieses Ziel hängt mit anderen Zielen zusammen, an denen ich derzeit in meinem Leben arbeite. This goal is related to other goals I am currently working on in my life.	0
20	Dies ist ein zentrales Ziel im Zusammenhang mit vielen anderen Zielen, die ich verfolge. This is a central goal related to many other goals that I am pursuing.	0
	Measurability / Messbarkeit	
21	Es ist einfach zu verfolgen wie weit ich von diesem Ziel entfernt bin. It's easy to keep track of how far I am from achieving this goal.	0
22	Es ist möglich aufzuzeichnen wie nahe ich dem Erreichen dieses Ziels bin. It's possible to maintain a record of how close I am to achieving this goal.	0

23	Mein Fortschritt in Richtung dieses Ziels kann regelmäßig gemessen werden. My progress toward this goal can be regularly measured.	0
24	Mein Fortschritt in diesem Ziel kann mit objektiven Messungen verfolgt werden. My progress toward this goal can be tracked with objective measurements.	0
25	Es ist möglich, meinen Fortschritt zu diesem Ziel über die Zeit zu vergleichen. It's possible to compare my progress toward this goal over time.	0
	Framing Subscale / Subskala Rahmung	
	Approach/ Avoidance Framing / Annähern/ Vermeiden Rahmung	
26	Dieses Ziel hat damit zu tun ein Verhalten, eine Situation oder ein Ergebnis zu vermeiden. This goal is about avoiding a behavior, situation, or outcome.	1
27	Bei diesem Ziel geht es um etwas, bei dem ich mich schlecht fühle. This goal is about something that makes me feel bad.	1
28	Bei diesem Ziel geht es darum zu verhindern, dass etwas Schlimmes passiert. This goal is all about preventing something bad from happening.	1
29	Bei diesem Ziel geht es um etwas, das ich tun möchte, und nicht um etwas, das ich vermeiden möchte. This goal is about something I want to do, rather than something I want to avoid.	0
30	Bei diesem Ziel geht es eher um etwas Positives als um etwas, das ich verhindern möchte. This goal is about something positive, rather than something I want to prevent from happening.	0
31	Bei diesem Ziel geht es darum, sich von etwas Ärgerlichem fernzuhalten. This goal is about staying away from something upsetting.	1
	Process Focus / Prozessorientierung	
32	Für dieses Ziel ist der Weg das Ziel. For this goal, the journey is the destination.	0
33	Bei diesem Ziel geht es eher um einen Prozess als um ein Ergebnis. This goal is more about a process rather than a outcome.	0
34	Für dieses Ziel konzentriere ich mich mehr auf den Prozess als auf sein Ergebnis. For this goal, I am focusing more on the process than its outcome.	0
	Outcome Focus / Ergebnisorientierung	

35	Um dieses Ziel zu erreichen, rechtfertigt der Zweck die Mittel. For this goal, the end justifies the means.	0
36	Um dieses Ziel zu erreichen, muss ich nur ein bestimmtes Ergebnis erzielen, und es spielt keine Rolle, wie ich es bekomme. To achieve this goal, I just have to get a certain result and it doesn't matter how I get it.	0
37	Für dieses Ziel ist der Ende wichtiger als der Weg. For this goal, the end is more important than its means.	0
	Attainability Subscale / Subskala Erreichbarkeit	
	Immediate Actionability / Unmittelbare Umsetzbarkeit	
38	Ich könnte nahezu sofort den ersten Schritt in Richtung dieses Ziels machen. I could take the first step toward this goal almost immediately.	0
39	Ich muss warten, um an diesem Ziel arbeiten zu können. I have to wait to start working on this goal.	1
40	Ich weiß genau, was der erste Schritt sein wird, um an diesem Ziel zu arbeiten. I know exactly what the first step - to start working on this goal - will be.	0
41	Ich weiß, wie ich an diesem Ziel arbeiten kann. I know how to start working on this goal.	0
42	Etwas anderes muss getan werden, bevor ich an diesem Ziel arbeiten kann. Something else needs to be done before I can start working on this goal.	1
	Estimated Effort / Geschätzter Aufwand	
43	Ich glaube, ich kann an diesem Ziel arbeiten, ohne mich ermüdet zu fühlen, auch wenn es eine komplexe Aufgabe ist. I believe I can work on this goal without feeling tired, even if it's a complex task.	0
44	Ich könnte mich überwältigt fühlen wenn ich dieses Ziel verfolge, egal wie einfach es ist. I may be overwhelmed following this goal, no matter how easy it is.	1
45	Ich denke es ist anstrengend auf dieses Ziel hinzuarbeiten. I think it's exhausting to work toward this goal.	1
	Plannability / Planbarkeit	
46	Es ist schwer, einen Plan zu erstellen, um dieses Ziel zu erreichen. It's hard to make a plan to achieve this goal.	1
47	Es ist schwer vorherzusehen, was meine nächsten Schritte auf dieses Ziel zu sein werden.	1

	It's hard to foresee what my next steps toward this goal will be.	
48	Es ist leicht zu erkennen, was getan werden muss, um dieses Ziel zu erreichen. It's easy to know what needs to be done to achieve this goal.	0
49	Die Schritte zur Erreichung dieses Ziels sind naheliegend. The steps to achieve this goal are straightforward.	0
50	Die Schritte zur Erreichung dieses Ziels sind unklar. The steps to achieve this goal are uncertain.	1
	Controllability / Kontrollierbarkeit	
51	Solange ich tue, was nötig ist, werde ich dieses Ziel erreichen. As long as I do what it takes, I will achieve this goal.	0
52	Ich habe die Kontrolle über das Ergebnis dieses Ziels. I have control over the outcome of this goal.	0
53	Das Erreichen dieses Ziels hängt von den Handlungen anderer Personen ab. Achieving this goal depends on other people's actions.	1
54	Ich bin auf Glück angewiesen, um dieses Ziel zu erreichen. I must depend on luck to achieve this goal.	1
55	Ich kann nichts tun, um dieses Ziel zu erreichen. There is nothing I can do to achieve this goal.	1
56	Ob ich dieses Ziel erreichen kann oder nicht, hängt von Dingen außerhalb meiner Kontrolle ab. Whether or not I can achieve this goal depends on things beyond my control.	1
57	Egal wie viel Energie ich in dieses Ziel stecke, habe ich das Gefühl, keine Kontrolle über das Ergebnis zu haben. No matter how much energy I put into this goal, I feel I have no control over the outcome.	1
	Challenge / Herausforderung	
58	Da ich es schon viele male zuvor getan habe habe, ist dieses Ziel nicht besonders herausfordernd. Because I have done it many times before, this goal it is not that challenging.	1
59	Dieses Ziel ist eine Herausforderung für mich. This goal is challenging for me.	0
60	Dieses Ziel bringt mich aus meiner Komfortzone. This goal gets me outside my comfort zone.	0
61	Ich werde viel besser als sonst funktionieren müssen, um dieses Ziel zu erreichen. I will have to perform much better than usual to achieve this goal.	0
	Defined Subgoals / Definierte Teilziele	
62	Ich habe keinen Plan gemacht, um dieses Ziel zu erreichen. I didn't make a plan on how to achieve this goal.	1

63	Ich verfolge keinen systematischen Plan, um dieses Ziel zu erreichen. I am not following any systematic plan to achieve this goal.	1
64	Ich habe einen detaillierten Aktionsplan erstellt, um auf dieses Ziel hinzuarbeiten. I have made a detailed plan of action to work toward this goal.	0
	Resource Availability Subscale / Subskala Resourcenverfügbarkeit	
	Social Support / Soziale Unterstützung	
65	Ich habe Leute, auf die ich mich verlassen kann, um mir bei diesem Ziel zu helfen. I have people I can rely on to help me with this goal.	0
66	Anderen Personen ist es egal, ob ich an diesem Ziel arbeite oder nicht. Other people don't care if I am working on this goal or not.	1
67	Andere Leute ermutigen mich, dieses Ziel weiter zu verfolgen. Other people encourage me to keep going on this goal.	0
68	Die Menschen um mich herum zeigen Interesse und Anteilnahme daran, was ich für dieses Ziel tue. People around me show interest and concern regarding what I am doing in this goal.	0
	Informational Support / Informationelle Voraussetzungen	
69	Es ist schwierig, Informationen zu finden, um dieses Ziel zu erreichen. It's hard to find information to achieve this goal.	1
70	Ich habe genug Leitlinien, um dieses Ziel zu erreichen. I have enough guidelines to achieve this goal.	0
71	Ich habe keine Ahnung, wo ich Informationen darüber finden kann, wie ich an diesem Ziel arbeiten kann. I have no idea where to find information about how to work on this goal.	1
72	Wenn nötig, weiß ich, wo ich Informationen zur überwindung von Hindernissen finden kann, um dieses Ziel zu erreichen. I know where to find information about overcoming obstacles to achieve this goal if I need it.	0
73	Ich habe die notwendigen Informationen um an diesem Ziel zu arbeiten. I have the necessary information to work on this goal.	0
	Instrumental Support / Instrumentelle Voraussetzungen	
74	Ich habe die notwendigen Materialien und Ausrüstung, um dieses Ziel zu erreichen.	0

	I have the materials and equipment necessary to achieve this goal.	
75	Es ist schwierig, Zugang zu Ressourcen zur Erreichung dieses Ziels zu bekommen. It’s hard to get access to the resources needed to achieve this goal.	1
76	Um dieses Ziel zu erreichen bin ich auf Ausrüstung angewiesen, die ich nicht bekommen kann. To achieve this goal, I depend on equipment that I can’t get.	1
77	Um dieses Ziel zu erreichen, brauche ich bestimmte Materialien oder Ausrüstungen, von denen ich nicht weiß, wie ich sie bekommen kann. To achieve this goal, I need specific materials or equipment that I don’t know how to get.	1
	Financial Affordance Finanzierbarkeit	
78	Ich kann dieses Ziel erreichen ohne Auswirkungen auf meine Finanzen. I can achieve this goal without any affect on my finances.	0
79	Ich bin auf Geld angewiesen, das ich nicht habe, um dieses Ziel zu erreichen. I depend on money I don’t have to achieve this goal.	1
80	Ich muss viel Geld ausgeben, um dieses Ziel zu erreichen. I have to spend a lot of money to achieve this goal.	1
81	Ich kann mir die Kosten für die Erreichung dieses Ziels finanziell leisten. I can financially afford the costs of working toward this goal.	0
	Visibility / Sichtbarkeit	
82	Die Leute können erkennen, ob ich dieses Ziel erreiche oder nicht. People can know if I achieve this goal or not.	0
83	Ich bin die oder der einzige, der über dieses Ziel bescheid weiß. I am the only one who knows about this goal.	1
84	Niemand würde sagen können, dass ich an diesem Ziel arbeite. Nobody would be able to tell I am working on this goal.	1
85	Mein Fortschritt in Richtung dieses Ziels ist für andere beobachtbar. My progress toward this goal is observable to others.	0
	Time Availability / Zeitliche Resourcen	
86	Ich bin mir nicht sicher, ob ich genug Zeit habe, um an diesem Ziel zu arbeiten. I am not sure if I have enough time to work on this goal.	1
87	Ich kann meine Zeit so einteilen, dass ich dieses Ziel erreichen kann. I can manage my time to achieve this goal.	0
88	Ich habe genug Zeit, um alles zu tun was nötig ist, um dieses Ziel zu erreichen.	0

	I have enough time to do whatever it takes to achieve this goal.	
89	Ich habe verfügbare Zeit, um an diesem Ziel zu arbeiten. I have time available to work on this goal.	0
	Competence Adequacy / Kompetenz- Angemessenheit	
90	Ich bin fähig dieses Ziel zu erreichen. I am competent to achieve this goal.	0
91	Ich habe alle notwendigen Fertigkeiten, um dieses Ziel zu erreichen. I have all the necessary skills to achieve this goal.	0
92	Meine Fähigkeiten könnten nicht ausreichend, um dieses Ziel zu erreichen. My skills may be insufficient to achieve this goal.	1
93	Dieses Ziel liegt außerhalb meiner Fähigkeiten. This goal is beyond my competencies.	1
	Interestingness Subscale / Subskala Interessantheit	
	Self-Congruence / Sellbstkongruenz	
94	Dieses Ziel ist nicht gerade das, woran ich gerne arbeiten würde. This goal is not exactly what I wanted to be working on.	1
95	Dieses Ziel ist wesentlich dafür, wer ich bin. This goal is essential to who I am.	0
96	Dieses Ziel stimmt mit meinem Lebensgefühl überein. This goal is congruent with my lifestyle.	0
97	Dieses Ziel ist Teil meiner Identität. This goal is part of my identity.	0
98	Dieses Ziel beinhaltet Dinge, die ich nicht gerne tue. This goal involves doing things I dislike.	1
	Value Congruence / Wertekongruenz	
99	Dieses Ziel stimmt mit meinen Überzeugungen überein. This goal is coherent with my beliefs.	0
100	Dieses Ziel stimmt mit meinen Träumen überein. This goal is congruent with my dreams.	0
101	Dieses Ziel zu erreichen, ist in Übereinstimmung mit meinem idealen Selbst. Achieving this goal is in accordance with my ideal self.	0
102	Dieses Ziel spiegelt meine persönlichen Werte wider. This goal reflects my personal values.	0
	Importance / Wichtigkeit	
103	Ich denke selten über dieses Ziel nach. I seldom think about this goal.	1
104	Dieses Ziel zieht nicht viel von meiner Aufmerksamkeit auf sich.	1

	This goal doesn't catch much of my attention.	
105	Das Erreichen dieses Ziels ist mir wichtig. Achieving this goal is important to me.	0
106	Ich habe wichtigere Ziele, um daran zu arbeiten als dieses. I have more important goals to work on than this one.	1
107	Ob ich dieses Ziel erreiche oder nicht, spielt eigentlich keine Rolle. Whether I achieve this goal or not, doesn't really matter.	1
	Awareness / Bewusstheit	
108	Anscheinend möchte ein Teil von mir dieses Ziel aus einem Grund erreichen, den ich nicht vollständig verstehe. Apparently, part of me wants to achieve this goal for some reason I don't fully understand.	1
109	Ich wusste nicht einmal, dass ich dieses Ziel hatte, bevor ich gefragt wurde. I didn't even know I had this goal until I was asked about my goals.	1
110	Ich war mir nicht einmal bewusst, dass ich dieses Ziel verfolge, bis ich gebeten wurde, über meine Ziele nachzudenken. I wasn't even aware that I am pursuing this goal until I was asked to think about my goals.	1
111	Dieses Ziel wurde mir kürzlich erst bewusst. I recently became aware of this goal.	1
	Vitality / Vitalität	
112	Wenn ich über dieses Ziel nachdenke, fühle ich mich lebendig und vital. Thinking about this goal makes me feel alive and vital.	0
113	Wenn ich über dieses Ziel nachdenke, fühle ich mich nicht energiegeladen. Thinking about this goal doesn't make me feel energetic.	1
114	Ich fühle mich voller Energie und Temperament, wenn ich über dieses Ziel nachdenke. I feel full of energy and spirit when I think about this goal.	0
	Usefulness Subscale / Subskala Utilität	
	Long-Term Utility / Langfristige Utilität	
115	Das Erreichen dieses Ziels wird in Zukunft von Bedeutung sein. Achieving this goal now will be significant in the future.	0
116	Dieses Ziel ist wichtig für meine Zukunft. This goal is important for my future.	0
117	Dieses Ziel wird in Zukunft keine großen Auswirkungen haben. This goal won't make a huge impact in the future.	1

118	Die Verwirklichung dieses Ziels wird mir langfristige Vorteile bringen. Achieving this goal will give me long lasting benefits.	0
	Short-Term Utility / Kurzfristige Utilität	
119	Wenn ich dieses Ziel erreiche, habe ich keinen unmittelbaren Nutzen. If and when I achieve this goal, I won't have any immediate benefit.	1
120	Ich werde die Früchte dieses Ziels sofort bekommen, wenn ich es erreicht habe. I will reap the benefits of this goal right after achieving it.	0
121	Das Erreichen dieses Ziels wird für mich in naher Zukunft nicht nützlich sein. Achieving this goal won't be useful for me in the near future.	1
122	Wenn ich dieses Ziel erreiche, wird es sich sofort auszahlen. When I reach this goal, it will pay off immediately.	0
	Relative Utility / Relative Utilität	
123	Im Vergleich zu anderen Zielen wird es für mich besser sein, dieses Ziel zu erreichen. Compared to other goals, achieving this goal will be better for me.	0
124	Ich bevorzuge dieses Ziel unter den anderen, die ich habe. I prefer this goal among the others I have.	0
125	Dieses Ziel ist wertvoller als die anderen Ziele, über die ich nachgedacht habe. This goal is more valuable than the other goals I thought about pursuing.	0
126	Dieses Ziel hat mehr Nutzen als meine anderen Zielen. This goal has more benefits than my other goals.	0
	Self- Improvement Utility / Utilität für Persönliches Wachstum	
127	Während ich auf dieses Ziel hinarbeite, werde ich viele nützliche Dinge lernen. In the process of working toward this goal I will learn many useful things.	0
128	Dieses Ziel wird an meinen Schwächen wahrscheinlich nicht viel ändern. This goal probably won't improve my weaknesses much.	1
129	Dieses Ziel wird mir helfen, als Person zu wachsen. This goal will help me grow as a person.	0
130	Während ich an diesem Ziel arbeite, kann ich wertvolle Lektionen lernen. While working on this goal I can learn valuable lessons.	0
	Negative Utility / Negative Utilität	

131	Das Erreichen dieses Ziels könnte für meine Zukunft schädlich sein. Achieving this goal might be harmful for my future.	0
132	Das Erreichen dieses Ziels hat langfristig auch negative Folgen. Achieving this goal also has negative consequences in the long-term.	0
133	Wenn ich dieses Ziel erreiche, wird es für mich kurzfristig nachteilig sein. When I achieve this goal, it will be detrimental for a short time.	0
134	Das Erreichen dieses Ziels hat unmittelbare negative Folgen. Achieving this goal has immediate negative consequences.	0
135	In dem Moment, in dem ich dieses Ziel erreiche, werde ich mit einigen unerwünschten Ergebnissen konfrontiert sein. At the moment I achieve this goal, I will face some unwanted results.	0

Appendix B

Priming Task Stimuli

B.1 Priming Questions

B.1.1 Intrinsic condition

1. Think about a task that you **enjoyed**.
   Describe why it was an **enjoyable** experience for you.

2. Think about a task you found **fun**.
   Describe why it was **fun** to do.

3. Think about a task that was a **pleasure** to do.
   Describe why it was a **pleasant** experience for you.

4. Think about a task that was **interesting** for you.
   Describe why it was an **interesting** task.

B.1.2 Identification condition

1. Think about a task that you **strongly valued**.
   Describe why you **valued** that task.

2. Think about a task that was **personally important** to you.
   Describe why it was an **important** task for you.

3. Think about a task that was your **personal choice** to do.
   Describe why you think it was your **personal choice**.

4. Think about a task that was **meaningful** to you.
   Describe why it was a **meaningful experience** for you.

B.1.3 Introjection condition

1. Think about a task you did because you would have **felt ashamed** if you hadn't done it.
   Describe why you would have **felt ashamed** of it.

2. Think about a task you did because you didn't want to **feel bad about yourself**.
   Describe why you didn't want to **feel bad about yourself** by doing that task.

3. Think about a task in which you wanted to **feel proud of yourself**.
   Describe why you wanted to **feel proud of yourself** by doing that task.

4. Think about a task in which you wanted to **prove to yourself that you were capable**.
   Describe why you wanted to **prove to yourself that you were capable** by doing that task

B.1.4 External condition

1. Think about a task you did because it would **make important people (i.e., parents, professors) like you better**.
   Describe why it was **important to you that those people liked you**.

2. Think about a task that **others could have become angry about** if you hadn't done it.
   Describe why **others could have become angry on you**.

3. Think about a task that could have **got you in trouble** if you hadn't done it.
   Describe why it could have **got you in trouble**.

4. Think about a task that **you had no choice** but to do.
   Describe why you **didn't have any choice** about it.

B.1.5 Amotivation condition

1. Think about a task that you'd **once had good reasons for doing, but later you didn't anymore**.
   Describe why you think you **lost those reasons**.

2. Think about a task that you **honestly didn't know why** you did.
   Describe why you think you **didn't know the reason you did that task**.

3. Think about a task that you **wondered whether you should continue** doing.
   Describe why you think you were **not sure about continuing** that task.

4. Think about a task you did, but you **did not understand what exactly** you were doing.
   Describe why you **think you couldn't understand** what you were doing.

Appendix C

Missing Ratings

id	Tag name	r1	r2	r3	r4	r5	r6	sum
4	social goals	991	933	933	0	872	0	3649
5	communication and contact	991	933	933	0	872	0	3649
7	volunteer work and idealism	991	933	933	0	872	0	3649
8	career goals	991	933	933	0	872	0	3649
9	grades	991	933	933	0	872	0	3649
10	duration of studies	991	933	933	0	872	0	3649
11	graduation	264	933	933	0	872	0	3002
12	orientation	264	933	933	0	872	0	3002
13	career opportunities	264	933	933	0	872	0	3002
15	networking	264	933	933	0	872	0	3002
16	status and wealth	264	933	933	0	872	0	3002
17	security	264	933	933	0	872	0	3002
18	educational goals	0	933	933	0	872	0	2738
19	knowledge	0	933	933	0	872	0	2738
20	comprehension	0	933	933	0	872	0	2738
21	competencies	0	1964	1928	0	872	0	4764
22	personal growth	0	1964	1928	0	872	0	4764
23	scientific methods	0	1964	1928	0	872	0	4764
24	concrete goals	0	1138	1490	0	872	0	3500
25	practical experiences	0	1964	1928	0	872	0	4764
26	going abroad	0	1151	1928	0	872	0	3951
27	foreign languages	0	1151	1928	0	872	0	3951
28	temporal scope	0	1138	1583	0	872	0	3593
29	within this semester	0	1138	1583	0	872	0	3593
30	during studies	0	1138	1583	0	872	0	3593
31	post-graduation	0	1138	1583	0	872	0	3593
32	private or professional	0	0	0	0	850	0	850
33	professional	0	0	0	0	850	0	850
34	private	0	0	0	0	850	0	850
35	other tags	0	0	0	0	850	0	850
36	nonsense	0	0	0	0	850	0	850
37	fun, happiness, satisfaction	0	0	0	0	850	0	850
38	S.M.A.R.T.	0	0	0	0	850	0	850

Appendix D

Tagset Rater Instructions (German)

D.1 Grundregeln

1. Ziele sind nicht exklusiv, Mehrfachnennungen sind möglich.
2. Aufweichung durch lange Zusätze, die im Widerspruch zur Kategorie stehen: Nicht zuordnen.
3. Offensichliche Nonsense-Ziele können ignoriert werden.
4. Vage Formulierungen im Zweifelsfalle nicht zuordnen.
5. Wenn für eine Zuordnung Interpretation nötig ist, wird sie nicht getroffen
6. Vorsicht bei "um zu"-Sätzen.
7. Beinhaltet ein langes Ziel eigentlich mehrere Einzelziele, wird es zugeordnet auch wenn nur eins zutrifft.

D.2 Oberkategorie "Soziale Ziele"

Soziale Ziele beziehen sich auf den Kontakt mit Menschen oder Einsatz für Andere bzw. die Menschheit.

Kommunikation/Kontakt Bei diesem Ziel stehen menschliche Begegnungen, Gespräche und Diskussionen im Vordergrund.

- Fähigkeiten zählen nicht dazu. Zielt ein Ziel also auf biespielsweise auf soziale Kompetenzen rhethorische Fähigkeiten oder soft Skills ab, fällt es nicht in diese Kategorie.
- Achtung!: Networking ist professionell und zählt nicht. Ziele wie "Kontakte knüpfen" oder "Netzwerken" zählen also auch nicht in diese Kategorie, da dabei der eigene Nutzen im Vordergrund steht.
- Kulturen zählen nicht als Menschen. Kontakt mit Kulturen ist auch ohne menschlichen Kontakt möglich.

Engagement/ Idealismus Bei diesem Ziel geht es um die Verbesserung der Welt oder der Einsatz für eine gute Sache.

- Auch die Ausrichtung von Leben und Lernen an Wertmaßstäben fällt hierunter.
- Wörter wie "sinnvoll", "sinnstiftend" sind ein Indikator.

D.3 Oberkategorie "Karriereziele"

Karriereziele zielen auf die Verbesserung des eigenen Status in beruflicher und materieller Hinsicht ab.

Noten Es werden explizit Notenziele genannt. Auch der Abschluss von Kursen oder Scheinerwerb fallen in diese Kategorie.

- "Bestehen", "nicht durchfallen" werden ebenfalls als Notenziel interpretiert, das sie gleichbedeutend sind mit einer Mindestnote von 4.0..
- Ein Abschluss als solcher zählt nicht als Notenziel.
- Die Wörter "gut" und "erfolgreich" deuten auf ein (subjektives) Notenziel hin.

Studienzeit Es werden explizit Zeitziele genannt, also so etwas wie "in Regelstudienzeit" oder "Studium schnell beenden".

- Diese beziehen sich auf die Dauer des Studiums, nicht auf Termine oder Fristen, das Ziel bis zu einem bestimmten Zeitpunkt zu erreichen.

Abschluss

- Es werden Abschlüsse, ein Anstellungsverhältnis oder ein Beruf angestrebt.
- Abschlüsse können auch Zertifikate sein (Pilotenschein oder Staatsexamen).
- Wird ein Abschluss mit genannt, ist aber nicht direkt selbst das Ziel, trifft diese Kategorie zu.
- Abschlussarbeiten zählen auch in diese Kategorie.

Berufschancen

- Die Voraussetzungen für ein Karriereziel sollen verbessert werden.
- "Negativziele" wie "Nicht x oder y machen müssen" zählen zu dieser Kategorie.
- Beschreibungen eines "idealen" Berufslebens fallen ebenfalls in diese Kategorie.
- Qualifikation für Karriereschritte wie Master oder Promotion zählen ebenfalls.

Orientierung Eine Entscheidung in Richtung eines Abschlusses, Berufes oder anderen beruflichen Zieles soll vorbereitet werden.

- Wenn eine Zielformulierung Orientierungslosigkeit des Studierenden offenbart, reicht das alleine nicht aus, das Ziel hier zuzuordnen.
- Wörter wie "Überblick", "orientieren" oder "mögliche Berufe" sind Indikatoren.
- "Finden" alleine reicht nicht, Arbeitsplatzsuche beispielsweise fällt nicht in diese Kategorie.
- Auch inhaltliche Orientierung im Fach zählt in diese Kategorie.

Networking Es sollen persönliche Kontakte hergestellt werden, die von beruflichem Nutzen sein können.

- "Kontakte" oder "Net(z)..." sind Indikatoren.

Status/Wohlstand Ein Abschluss, Einkommen, Prestige, Rang, Amt, Titel oder Verfügung über Ressourcen oder Besitz soll erreicht werden.

- "besser als andere sein", "aus der Masse herausstechen", also Formulierungen die auf Überlegenheit abzielen, fallen ebenfalls in diese Kategorie.

Sicherheit Materielle oder berufliche Sicherheit soll etabliert werden. Nicht zu viel interpretieren!

D.4 Oberkategorie "Bildungsziele"

Bildungsziele zielen auf persönliches Wachstum hinsichtliche Wissen, Fähigkeiten und Eigenschaften ab. In der Regel subsummieren die "höheren" Kategorien die "unteren", eine Zuordnung reicht also. Ziele der Kategorie "Konkrete Ziele" wie "Programmieren" und "Fremdsprache" werden nicht manuell durch Rater zugeordnet, sondern automatisiert zu "Fähigkeiten".

Wissen Wissen soll abgespeichert werden.

- "Lernen", "kennenlernen", "reingucken", "erfahren", "entdecken", "entdeken", "kennen" sind Indikatoren
- Werden konkrete Inhalte, Themengebiete oder Fragen genannt, trifft diese Kategorie zu.
- z.B. bei Wissensgebiet (z.B.Statistik) -> Wissen

Verstehen Ein tieferes Verständnis soll hergestellt werden. Dies geht über das reine Wissen hinaus.

- Indikatoren sind "verstehen", "beherrschen", "nachvollziehen"

Fähigkeiten Es soll etwas gekonnt werden. Dies geht über Verständnis hinaus. Verben sind typisch für diese Kategorie.

Persönliche Entwicklung Es soll eine Eigenschaft erworben oder verbessert werden. Auch Orientierung auf Interessenebene fällt hierunter.

- "Bildung","Denken" und "Weiterbildung" Indikator
- "Interessen" zielen oft auf persönliche Entwicklung ab.
- "..ich will.."" oder "..möchte.." "..für mich interessant.." sind Indikatoren
- Fähigkeiten und Kompetenzen, die Teil der Persönlichkeit sind (soziale Kompetenzen, kritisches Denken..)
- Bei Grenzfällen eher "Fähigkeiten" zuordnen.

D.5 Oberkategorie "Konkrete Ziele"

Konkrete Ziele sind spezifische Ziele, die für den Assistenten relevant sein können.

Praxiserfahrung Diese Kategorie bezieht sich auf Praktika und interessante Nebenjobs. Auch praktische Tätigkeiten, die nicht explizit als qualifizierend formuliert sind, zählen als Praxiserfahrung.

Auslandserfahrung Zum Beispiel Auslandssemester oder Auslandspraktika. "andere Kulturen kennenlernen" -> Frage: Muss man dafür ins Ausland? Nein

Fremdsprache Es soll eine definierte oder undefinierte Fremdsprache erlernt werden.

- Fremdsprachen müssen keinem Bildungsziel zugeordnet werden.

Wissenschaftliches Arbeiten Es geht um wissenschaftliche Methoden.

- Indikatoren: "Forschen", "Wissenschaft", "Publizieren", "Promovieren" und "veröffentlichen".

Programmieren Eine definierte oder undefinierte Programmiersprache soll erlernt werden.

D.6 Oberkategorie "Beruflich/Privat"

Gibt den Lebensbereich an, auf den sich ein Ziel bezieht. Hier werden Ziele nur entweder "beruflich" oder "privat" zugeordnet, und auch nur dann, wenn diese Zuordnung eindeutig und auschließlich.

beruflich Ein Ziel ist eindeutig nur auf den Beruf bzw. die Uni bezogen.

- Was auf das Studium abzielt, ist in der Regel beruflich.
- Ausnahme: Das Ziel richtet sich auf Spaß oder Zufriedenheit im Studium. ("Studentenleben geniessen")
- Testfrage: Kann ich ein Ziel so interpretieren, dass es privat ist?
- Hinweis: Man darf auch im Job Spaß haben oder glücklich sein. ("Glücklich im Beruf sein")

privat Ein Ziel ist eindeutig nur auf das Privatleben bezogen.

- Testfrage: Kann ich mir ein Setting vorstellen, in dem das Ziel beruflich ist? (Beispiel: "Persönliche Entwicklung", Berufliches Setting: Fortbildungsmaßnahme im Job, die auf persönliche Entwicklung abzielt -> kein privates Ziel)
- Zufriedenheit und Glück sind Indikatoren für private Ziele.
- Freizeitgestaltung ist privat
- Work-Life-Balance beinhaltet auch Arbeit, ist also *nicht* privat.

- Ziele, die mit Studium zusammenhängen sind nicht privat (Berufsvorbereitung)
- Bei Kontakt: Unterscheidung zwischen Networking (=beruflich) und menschliche Begegnung (=privat)
- privat *und* beruflich ist nicht möglich.
- Aufweichung durch lange Zusätze, die im Widerspruch zur Kategorie privat stehen: Nicht zuordnen.

D.7 Oberkategorie "Sonstige Ziele"

Nonsense Ein Ziel scheint nicht ernst gemeint zu sein.

Spaß / Glück / Zufriedenheit / Freiheit / Autonomie Ziele, die auf Wohlbefinden abzielen.

- Formulierungen wie "anregend", "Spaß", "spannend", "Schokolade", "schön", "gutes Leben", "Leidenschaft", "Erfüllung" oder Smileys
- Glück meint Wohlgefühl, nicht günstige Zufälle.
- Das Ziel selbst muss mit Spaß / Glück / Zufriedenheit / Freiheit / Autonomie zu tun haben, nicht dessen Definition.
- Vermeiden von Aversivem, Unangenehmem gilt auch.

spezifisch/konkret, messbar/erreichbar Ein Ziel ist so konkret definiert, dass seine Erreichung klar erkennbar ist.

- Zeit muss nicht eingeschlossen sein (...anders als bei SMART)
- Handelt es sich um eine Teilleistung im Studium, dann trifft die Kategorie auf jeden Fall zu.
- Gibt es eine "Ziellinie"?
- Auf eine Größe bezogen, objektive Messgröße (Note)
- Ein Ziel kann unspezifisch werden durch unpräzise, nicht-messbare oder subjektive Zusatzangaben.
- Wenn nicht verständliche Dinge wie "MAKE Vortrag" oder "Leselisten abarbeiten" vorkommen, gehen wir davon aus, dass es sich um etwas Spezifisches handelt.
- Lässt sich eine lange Formulierung in einen logischen Ausdruck mit "und" und "oder" übersetzen und ist dadurch messbar, trifft diese Kategorie zu.
- Im Zweifel bei vagen Formulierungen wie "alles" gehen wir davon aus, dass die Person auf Nachfrage hin eine spezifische Definition liefern kann.

Zu allgemein Ein Ziel ist so allgemein formuliert, dass es nicht sinnvoll zuzuordnen ist.

- Indiz: Formulierung ist nur ein Wort lang.
- Es ist keine anderen Kategorien zuweisbar.
- Mehrdeutigkeit, zu großer Interpretationsspielraum.

Appendix E

Tagset Rater Instructions (English)

E.1 Basic Rules

1. Goals are not exclusive; multiple answers are possible.
2. Softening by long additions that contradict the category: Do not assign.
3. Obvious nonsense targets can be ignored.
4. Do not assign vague phrases when in doubt.
5. If interpretation is needed for an assignment, do not make it.
6. Be careful with "in order to" sentences.
7. If a long goal contains several single goals, it is assigned even if only one applies.

E.2 Category "Social Goals"

Social goals refer to contact with people or commitment to others or humanity.

Communication/Contact This goal focuses on human encounters, conversations, and discussions.

- skills do not count towards this. So if a goal focuses on, for example, social skills, rhetorical skills, or soft skills, it does not fall into this category.
- Note: Networking is professional and does not count. Therefore, goals such as "making contacts" or "networking" do not count in this category since the focus is on one's benefit.
- Cultures do not count as people. Contact with cultures is possible without human contact.

engagement/ idealism This goal is about improving the world or working for a good cause.

- Aligning life and learning with value standards also falls under this.
- Words like "meaningful" are an indicator.

E.3 Category "Career Goals"

Career goals aim to improve one's status professionally and materially.

grades Grade goals are explicitly stated. Completing courses or earning certificates also fall into this category.

- "Passing", and "not failing" are also interpreted as grade objectives equivalent to a minimum grade of 4.0.
- A degree as such does not count as a grade objective.
- The words "good" and "successful" indicate a (subjective) grade target.

study time Time goals are explicitly stated, i.e., "in standard study time" or "finish studies quickly."

- These refer to the duration of studies, not dates or deadlines, to achieve the goal by a certain date.

final

- Degrees, employment, or a profession are pursued.
- Degrees may also be certificates (pilot's license or state examination).
- If a degree is included but is not the immediate goal, this category applies.
- Theses also count in this category.

job opportunities

- To improve the conditions for a career goal.
- "Negative goals" such as "not having to do x or y" fall into this category.
- Descriptions of an "ideal" career life also fall into this category.
- Qualifications for career steps such as master's or doctorate also count.

orientation To prepare a decision toward a degree, profession, or other career goals.

- If a goal statement reveals disorientation on the part of the student, that alone is not sufficient to assign the goal here.
- Words like "overview," "orient," or "possible careers" are indicators.
- "finding" alone is insufficient; job search, for example, does not fall into this category.
- Content orientation in the subject also counts in this category.

Networking Personal contacts should be made that may be of professional benefit.

- "Contacts" or "Net(z)..." are indicators.

status/wealth A degree, income, prestige, rank, office, title, or disposition of resources or property is to be attained.

- "to be better than others," "to stand out from the crowd," and phrases aimed at superiority also fall into this category.

security Material or professional security should be established. Do not interpret too much!

E.4 Category "Educational Goals"

Educational goals aim at personal growth in knowledge, skills, and attributes. As a rule, the "higher" categories subsume the "lower" ones, so one assignment is enough. Goals in the "Concrete Goals" category, such as "Programming" and "Foreign Language", are not manually assigned by raters but are automatically assigned to "Skills".

knowledge Knowledge is to be stored.

- "learning", "getting to know", "looking in", "experiencing", "discovering", "discovering", "knowing" are indicators.
- If concrete contents, subject areas, or questions are mentioned, this category applies.
- e.g. for knowledge area (e.g. statistics) -> knowledge

understanding A deeper understanding should be established. This goes beyond pure knowledge.

- indicators are "to understand," "to master," and "to comprehend."

skills Something is to be proficient. This goes beyond understanding. Verbs are typical of this category.

personal development A characteristic is to be acquired or improved. Orientation at the interest level also falls under this.

- "education", "thinking", and "further education" indicator.
- "Interests" are often aimed at personal development.
- "..I want..." or "..would like..." "..interesting for me..." are indicators
- Skills and competencies that are part of the personality (social skills, critical thinking..).
- Rather assign "skills" in borderline cases.

E.5 Category "Concrete Goals"

Concrete goals are specific goals that may be relevant to the assistant.

practical experience This category refers to internships and interesting part-time jobs. Practical jobs are not explicitly stated as qualifying but also count as practical experience.

foreign experience For example, semesters abroad or internships abroad. "Getting to know other cultures" -> Question: Do you have to go abroad for this? No

foreign language A defined or undefined foreign language is to be learned.

- Foreign languages need not be assigned to an educational objective.

scientific work It is about scientific methods.

- indicators: "research," "science," "publish," "doctorate," and "publish."

programming A defined or undefined programming language is to be learned.

E.6 Category "Professional/Private"

Specifies the area of life to which a goal relates. Here, goals are only assigned to either "professional" or "private" and only if this assignment is unique and exclusive.

professional A goal is related only to the profession or university.

- What is aimed at studying is usually vocational.
- Exception: the goal is to have fun or be satisfied in one's studies. ("Enjoying student life")
- Test question: Can I interpret a goal as being private?
- Note: You can also have fun or be happy at work. ("Be happy at work")

private A goal is related only to one's personal life.

- Test question: can I imagine a setting in which the goal is professional? (Example: "Personal development", Professional setting: further training on the job aimed at personal development -> no private goal).
- Satisfaction and happiness are indicators of private goals.
- leisure time activities are private
- Work-life balance includes work, so it is *not* private.
- Goals related to study are not private (career preparation).
- For contact: Distinguish between networking (=professional) and human encounter (=private).
- private *and* professional is not possible.
- Softening by long additions that contradict the private category: Do not assign.

E.7 Category "Other Goals"

nonsense A goal does not appear to be serious.

fun/happiness/satisfaction/freedom/autonomy Goals that aim at well-being.

- phrases such as "stimulating," "fun," "exciting," "chocolate," "beautiful," "good life," "passion," "fulfillment," or smileys.
- Happiness means feeling good, not favorable coincidences.
- The goal itself must have to do with fun / happiness / satisfaction / freedom / autonomy, not its definition.
- Avoiding the aversive, unpleasant also applies.

specific/concrete/measurable/achievable A goal is defined in such concrete terms that its achievement is clearly identifiable.

- Time need not be included (...unlike SMART).
- If it is a partial achievement in the study, then the category applies.
- Is there a "finish line"?
- Related to a quantity, objective measure (grade).
- A goal can become unspecific due to imprecise, non-measurable, or subjective additional information.
- If non-understandable things like "MAKE lecture" or "work through reading lists" occur, we assume it is something specific.
- If a long phrase can be translated into a logical expression with "and" and "or" and is thus measurable, this category applies.
- When in doubt about vague phrases such as "anything", we assume that the person can provide a specific definition when asked.

too vague A goal is stated in such general terms that it cannot be meaningfully assigned.

- Indicator: the wording is only one word long.
- It is not assignable to other categories.
- Ambiguity, too much room for interpretation.

Appendix F

Correlation and KDE plots

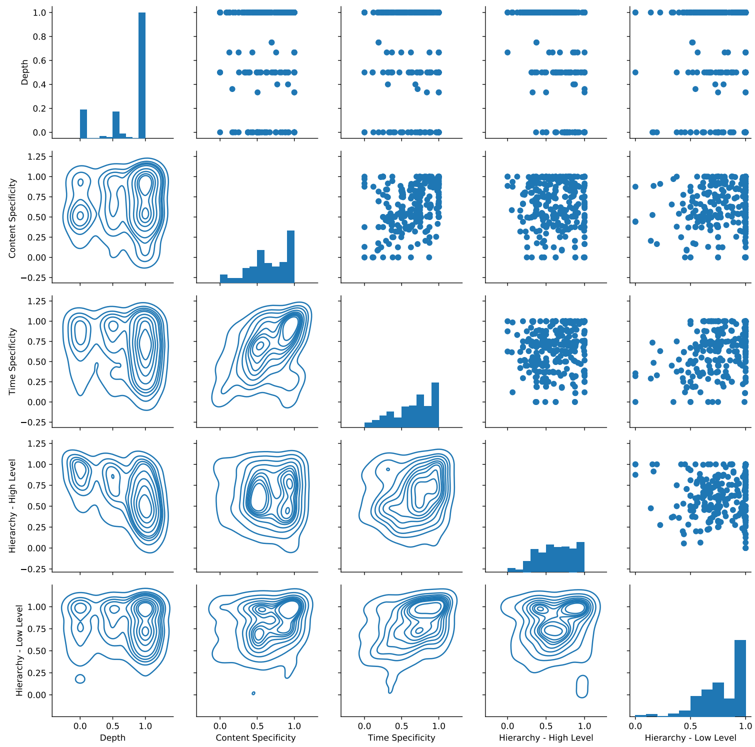

FIGURE F.1: Correlations and KDE for variable Depth matrix 1.

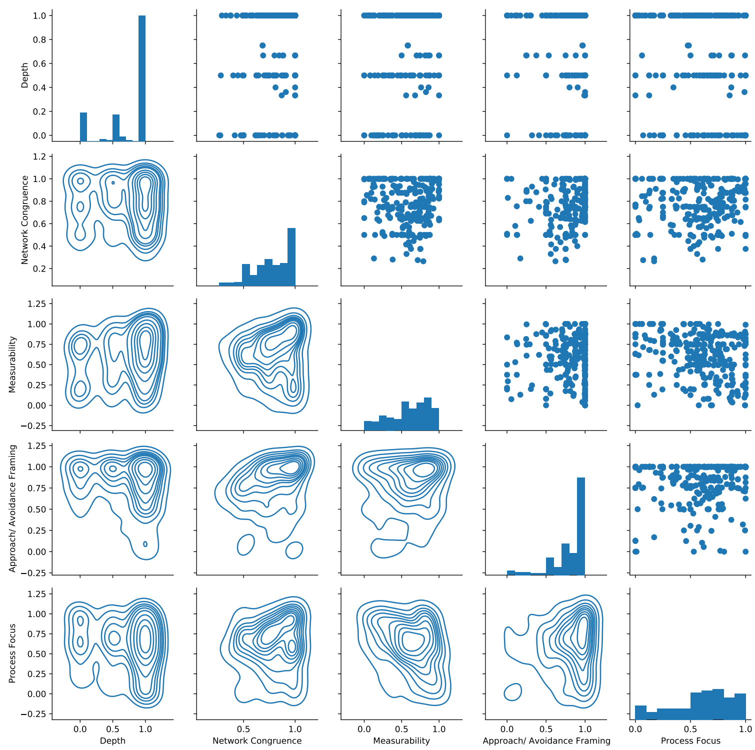

FIGURE F.2: Correlations and KDE for variable Depth matrix 2.

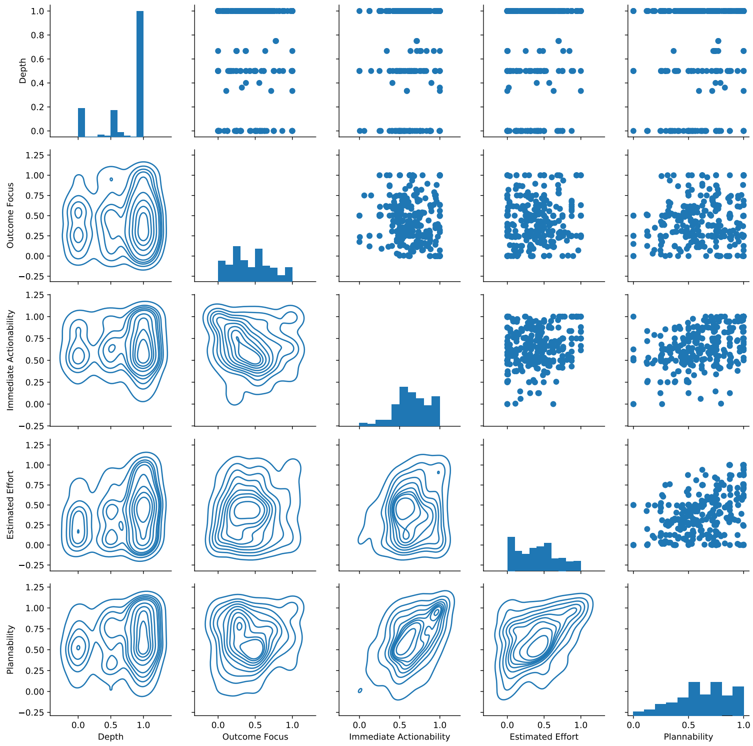

FIGURE F.3: Correlations and KDE for variable Depth matrix 3.

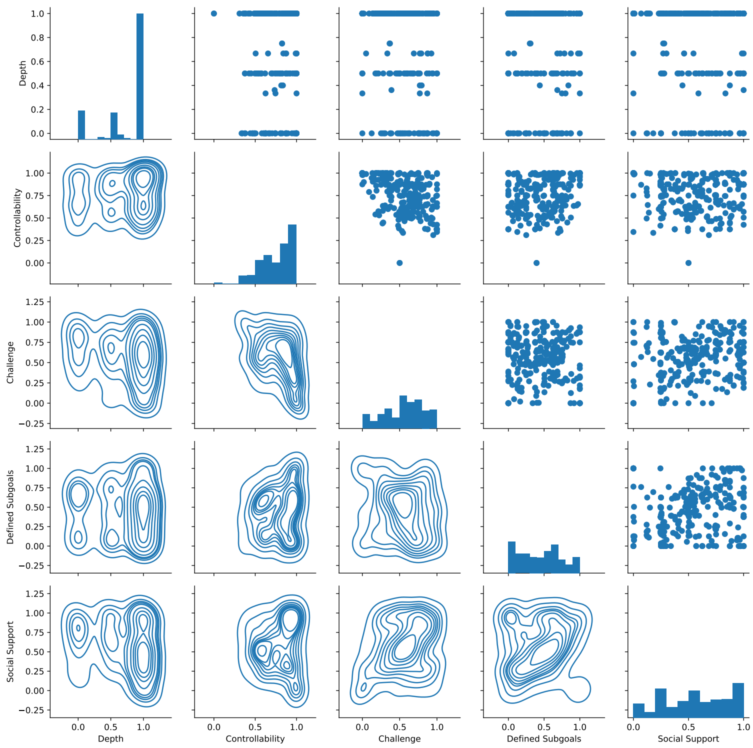

FIGURE F.4: Correlations and KDE for variable Depth matrix 4.

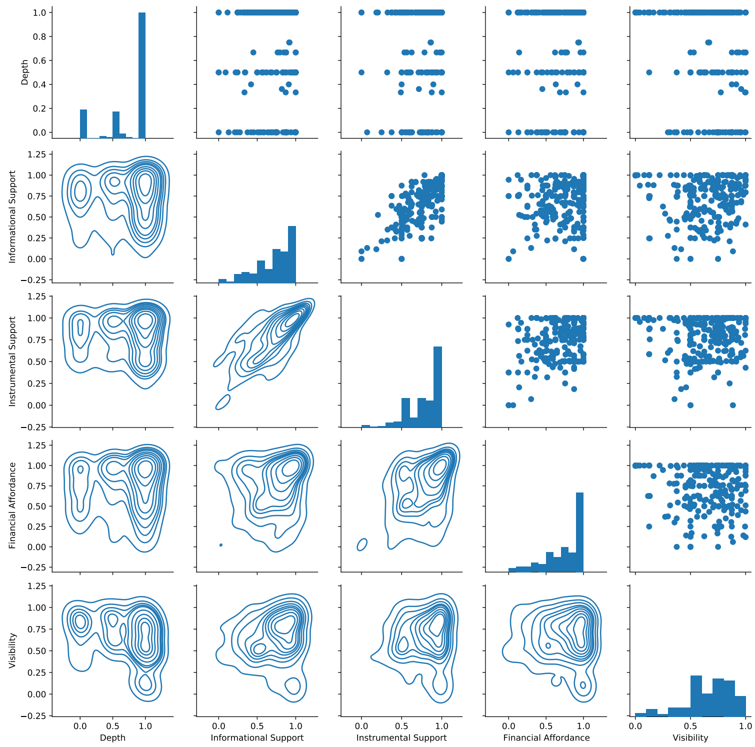

FIGURE F.5: Correlations and KDE for variable Depth matrix 5.

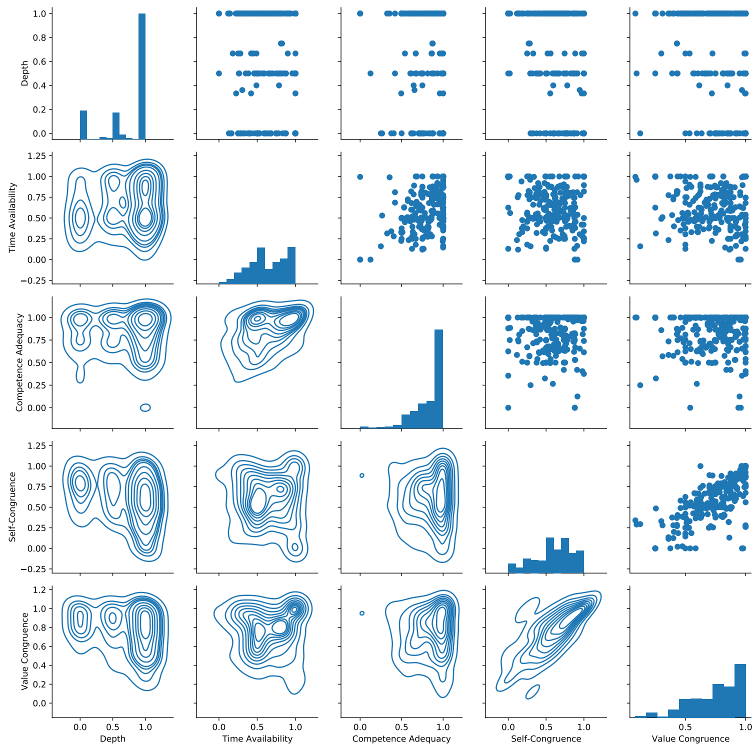

FIGURE F.6: Correlations and KDE for variable Depth matrix 6.

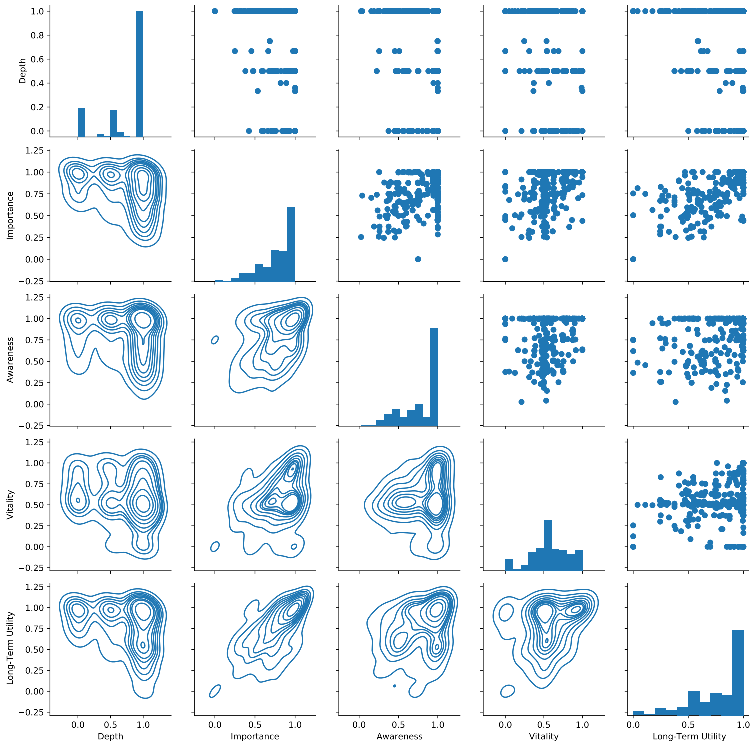

FIGURE F.7: Correlations and KDE for variable Depth matrix 7.

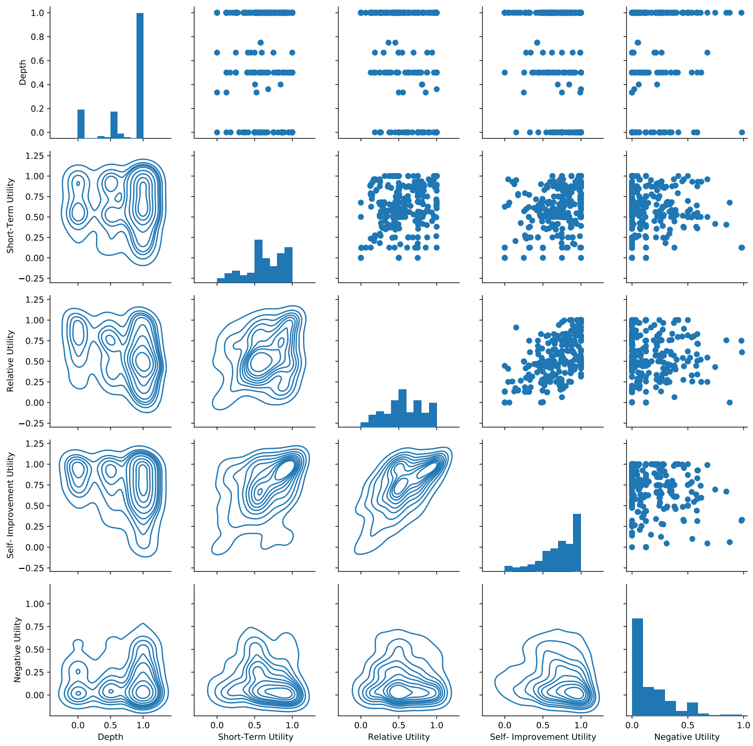

FIGURE F.8: Correlations and KDE for variable Depth matrix 8.

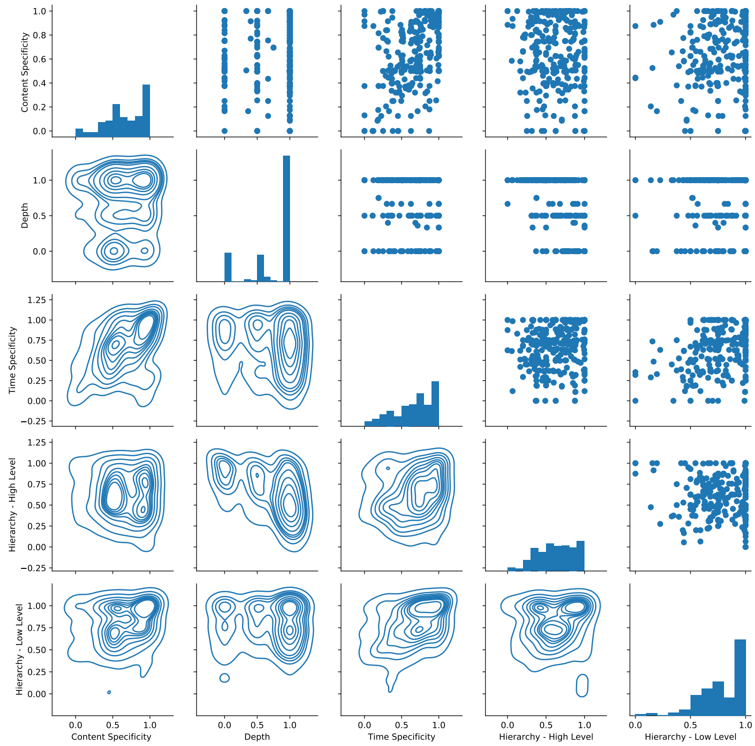

FIGURE F.9: Correlations and KDE for variable Content Specificity matrix 1.

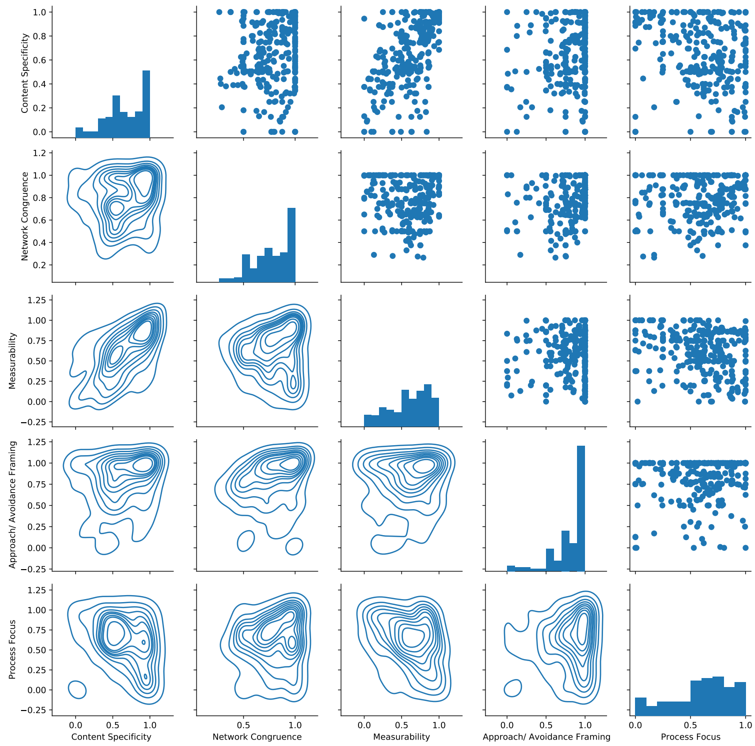

FIGURE F.10: Correlations and KDE for variable Content Specificity matrix 2.

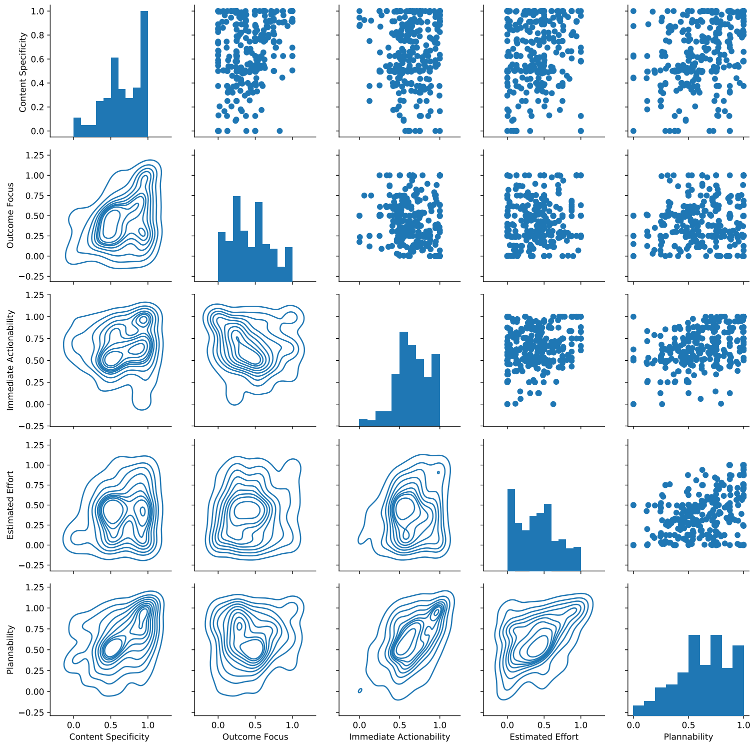

FIGURE F.11: Correlations and KDE for variable Content Specificity matrix 3.

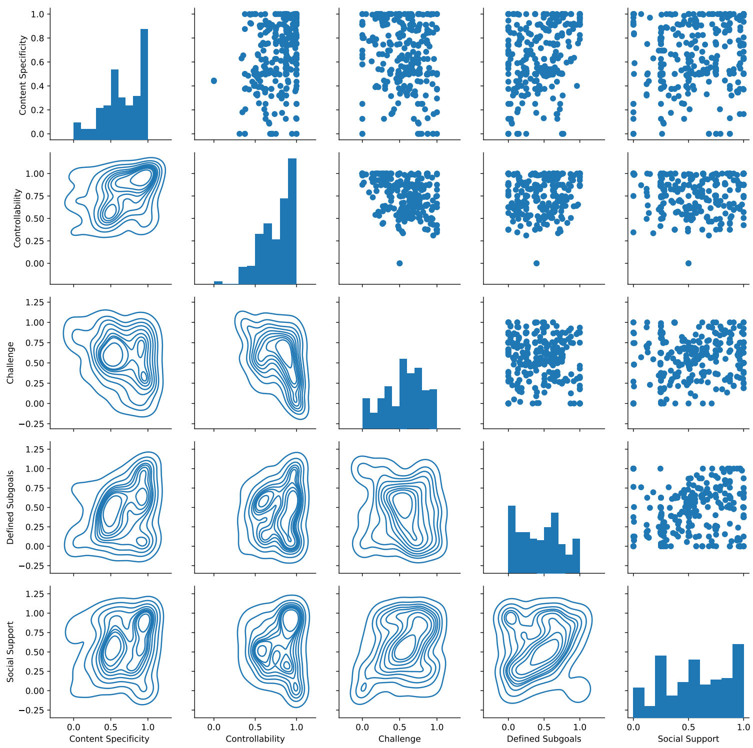

FIGURE F.12: Correlations and KDE for variable Content Specificity matrix 4.

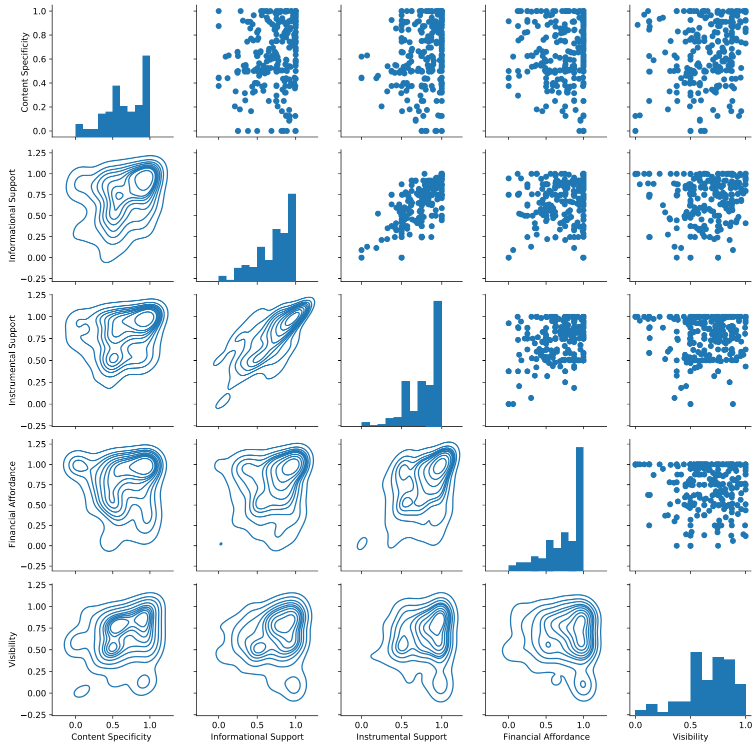

FIGURE F.13: Correlations and KDE for variable Content Specificity matrix 5.

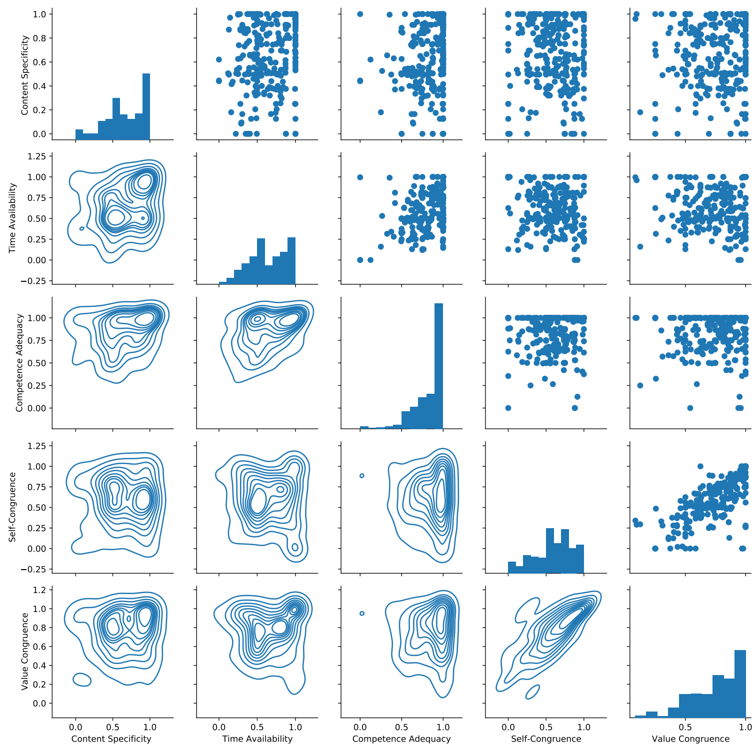

FIGURE F.14: Correlations and KDE for variable Content Specificity matrix 6.

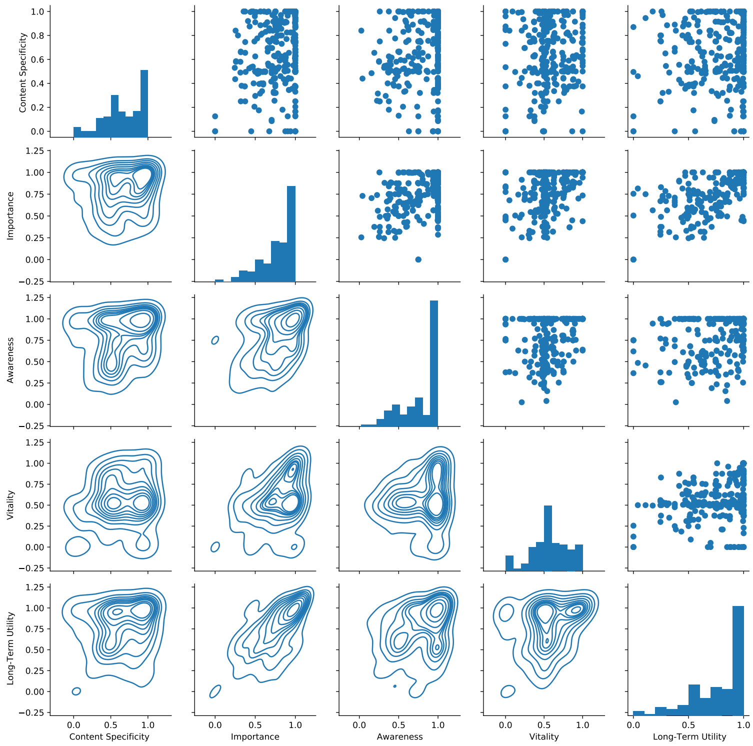

FIGURE F.15: Correlations and KDE for variable Content Specificity matrix 7.

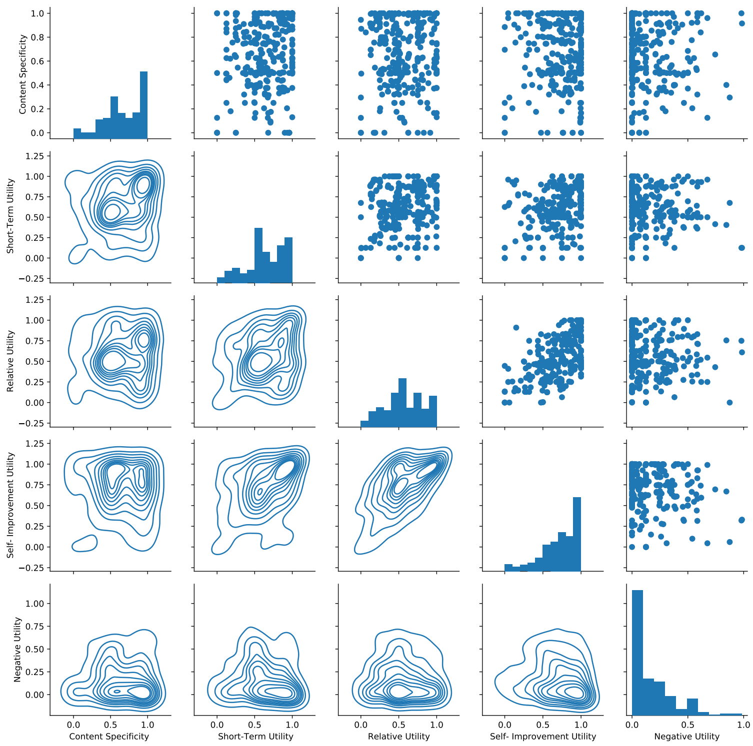

FIGURE F.16: Correlations and KDE for variable Content Specificity matrix 8.

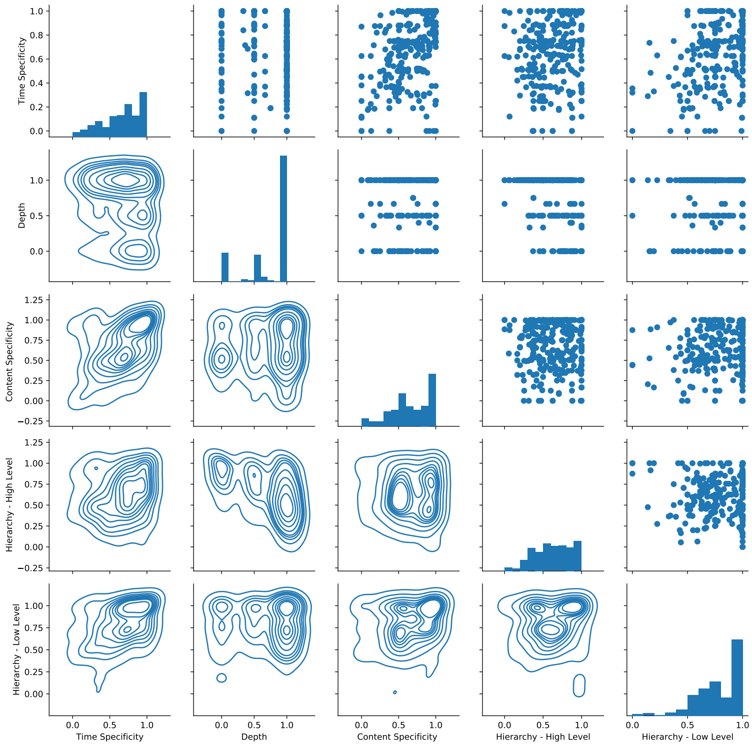

FIGURE F.17: Correlations and KDE for variable Time Specificity matrix 1.

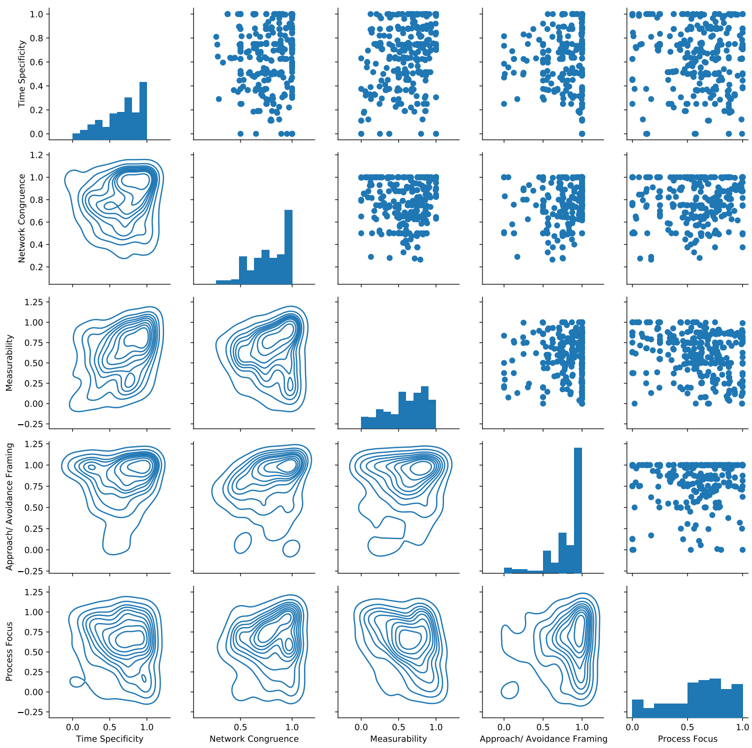

FIGURE F.18: Correlations and KDE for variable Time Specificity matrix 2.

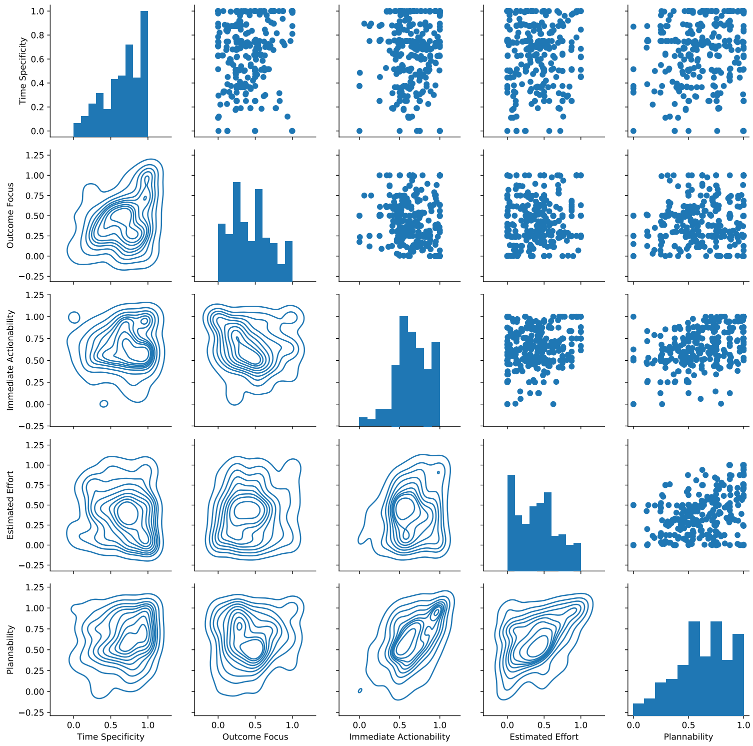

FIGURE F.19: Correlations and KDE for variable Time Specificity matrix 3.

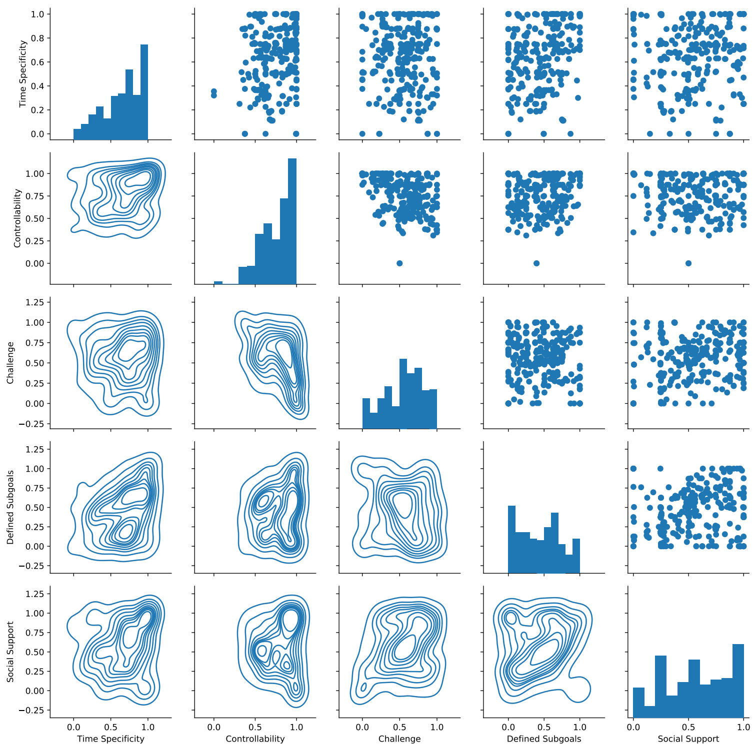

FIGURE F.20: Correlations and KDE for variable Time Specificity matrix 4.

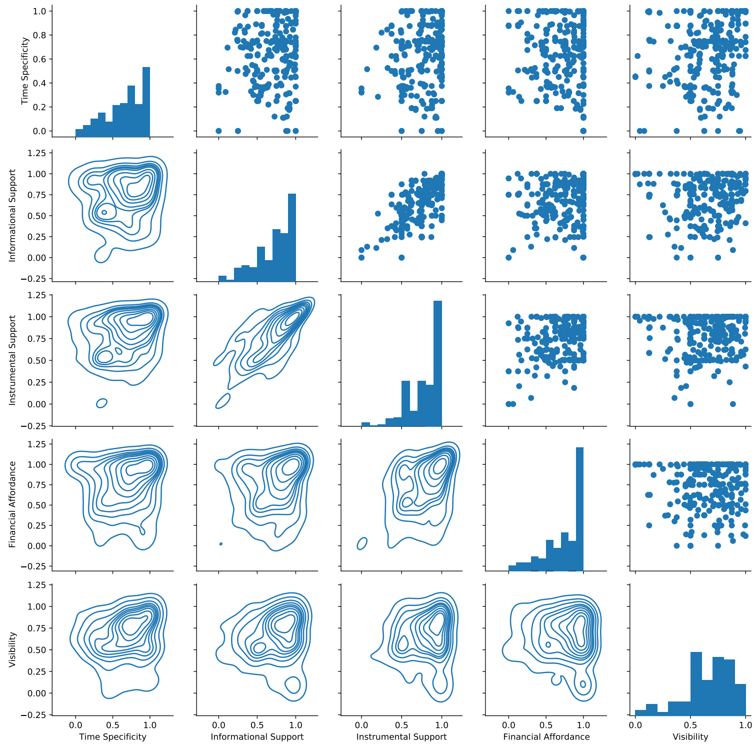

FIGURE F.21: Correlations and KDE for variable Time Specificity matrix 5.

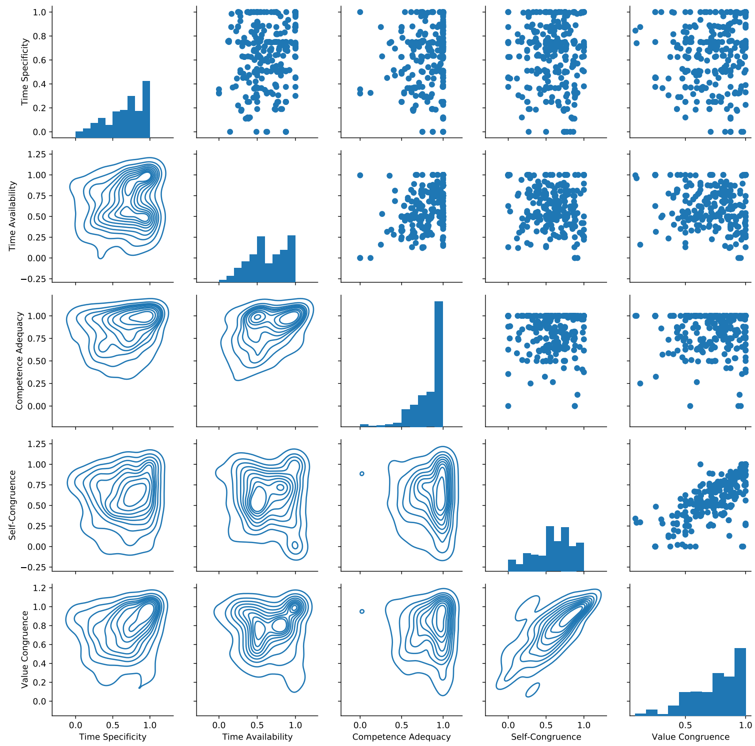

FIGURE F.22: Correlations and KDE for variable Time Specificity matrix 6.

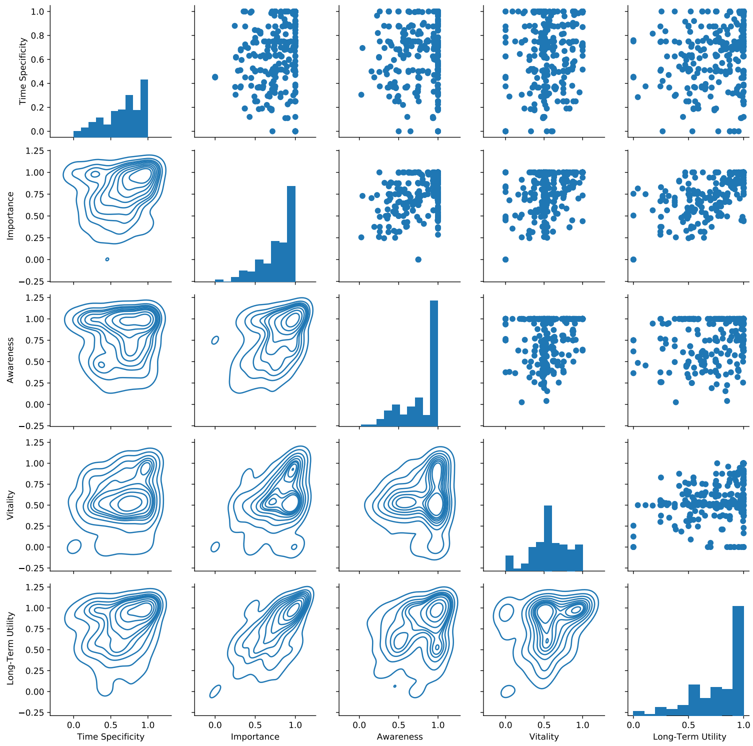

FIGURE F.23: Correlations and KDE for variable Time Specificity matrix 7.

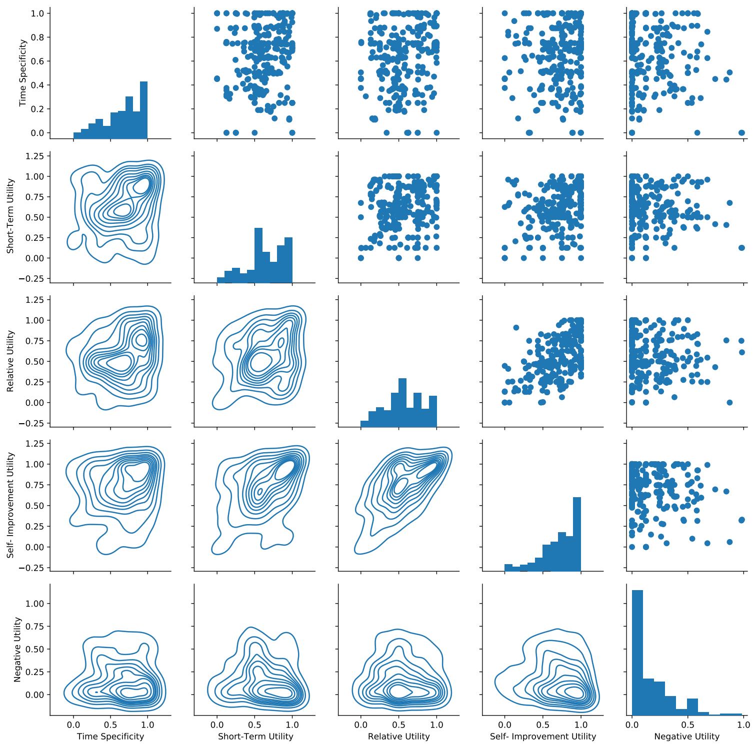

FIGURE F.24: Correlations and KDE for variable Time Specificity matrix 8.

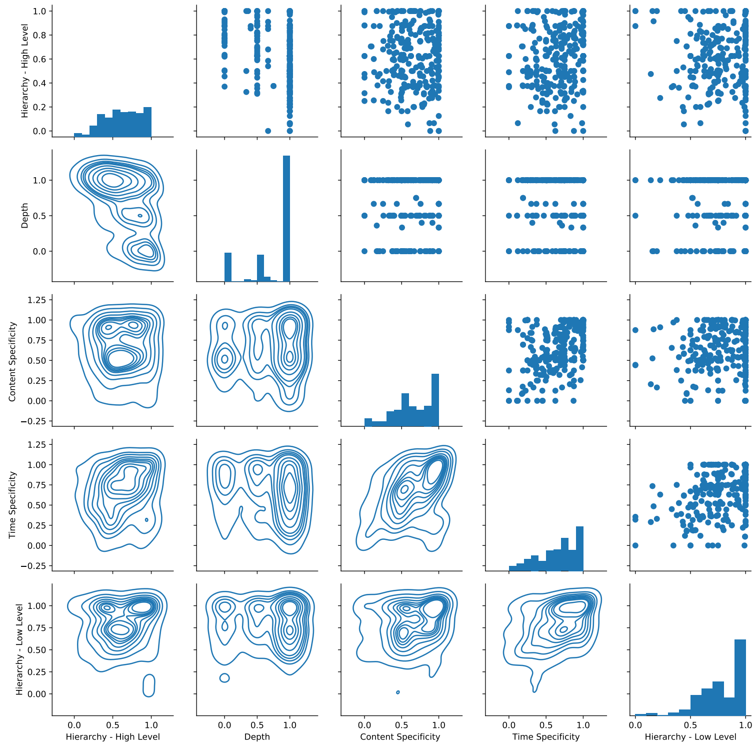

FIGURE F.25: Correlations and KDE for variable Hierarchy - High Level matrix 1.

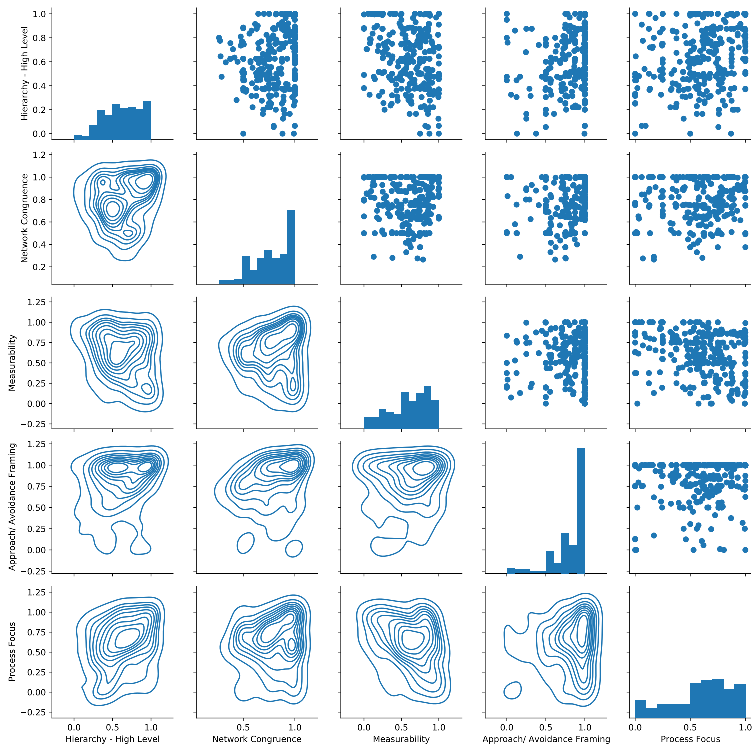

FIGURE F.26: Correlations and KDE for variable Hierarchy - High Level matrix 2.

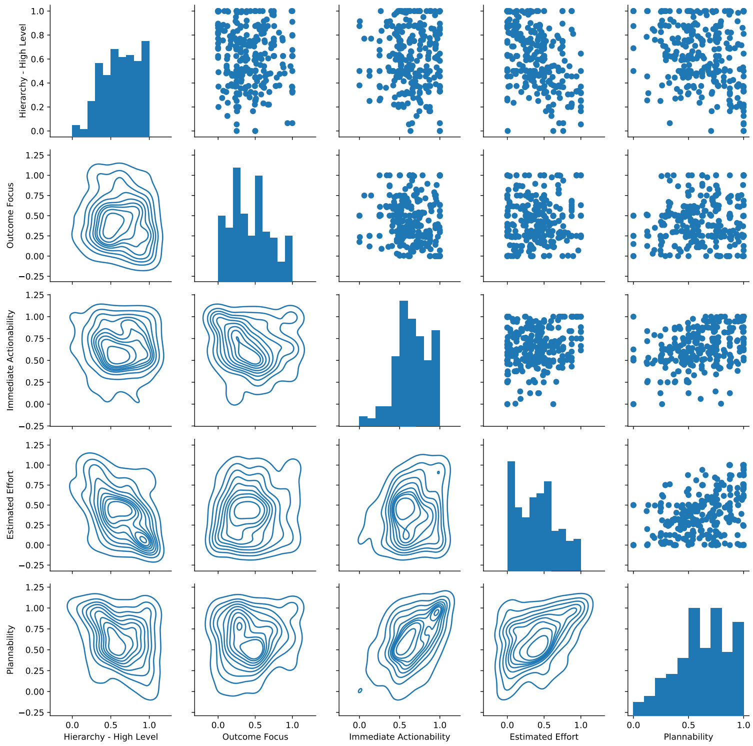

FIGURE F.27: Correlations and KDE for variable Hierarchy - High Level matrix 3.

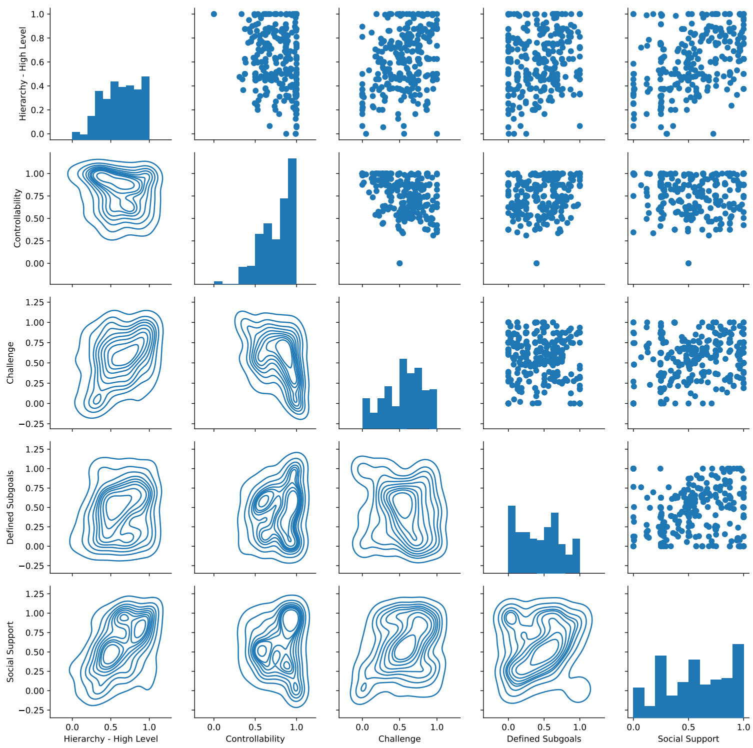

FIGURE F.28: Correlations and KDE for variable Hierarchy - High Level matrix 4.

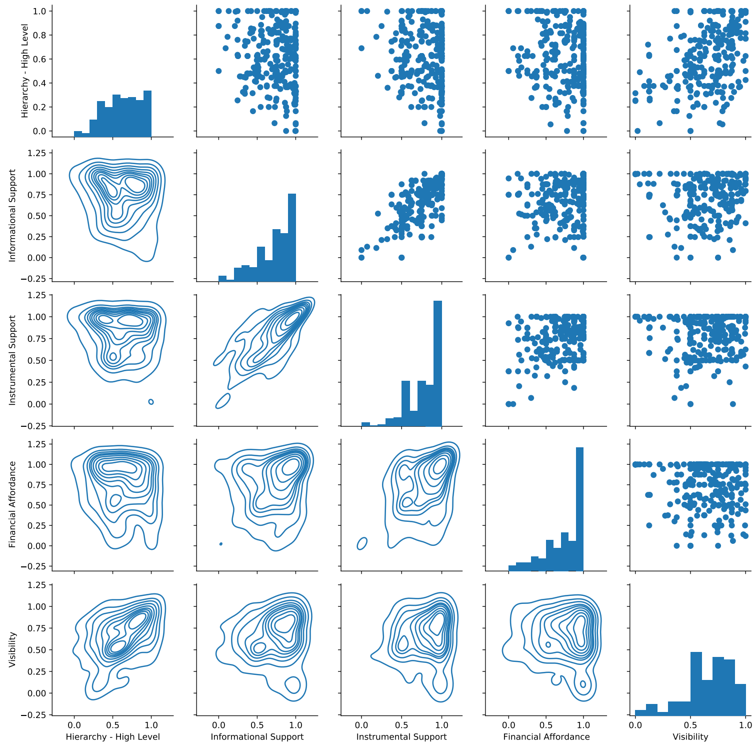

FIGURE F.29: Correlations and KDE for variable Hierarchy - High Level matrix 5.

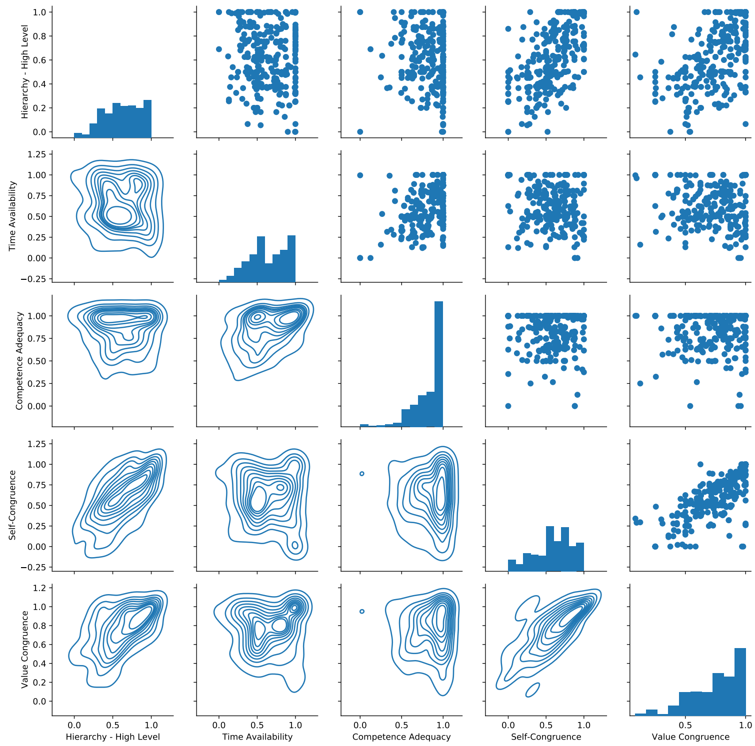

FIGURE F.30: Correlations and KDE for variable Hierarchy - High Level matrix 6.

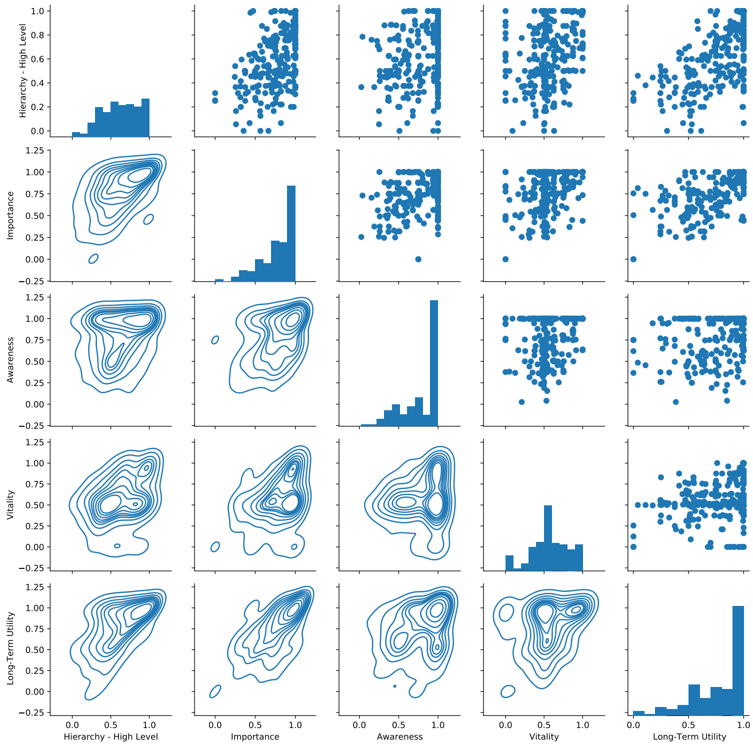

FIGURE F.31: Correlations and KDE for variable Hierarchy - High Level matrix 7.

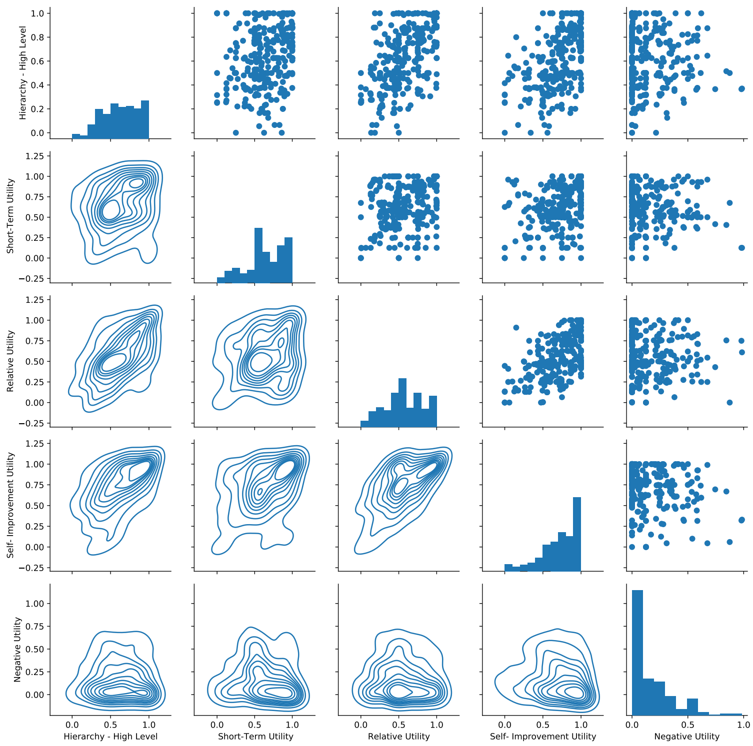

FIGURE F.32: Correlations and KDE for variable Hierarchy - High Level matrix 8.

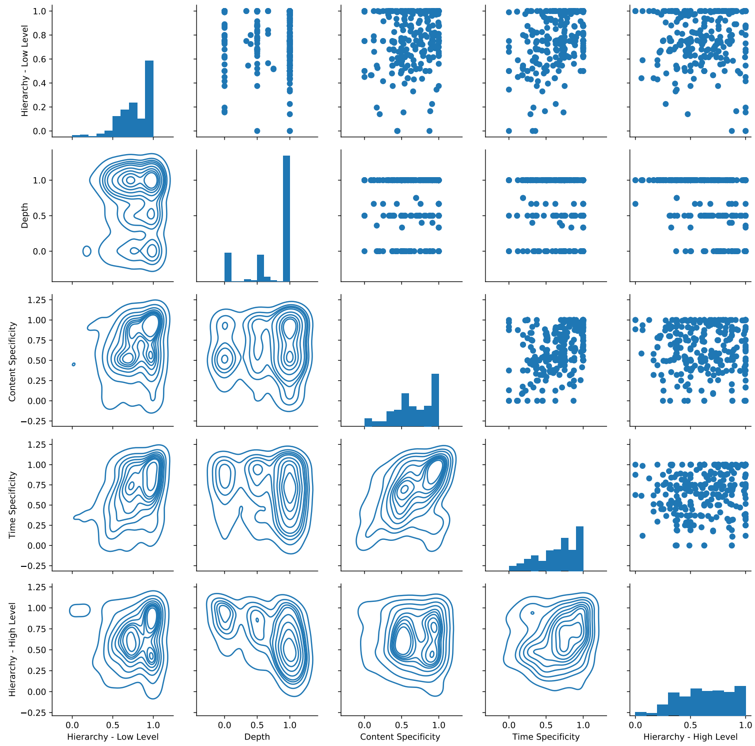

FIGURE F.33: Correlations and KDE for variable Hierarchy - Low Level matrix 1.

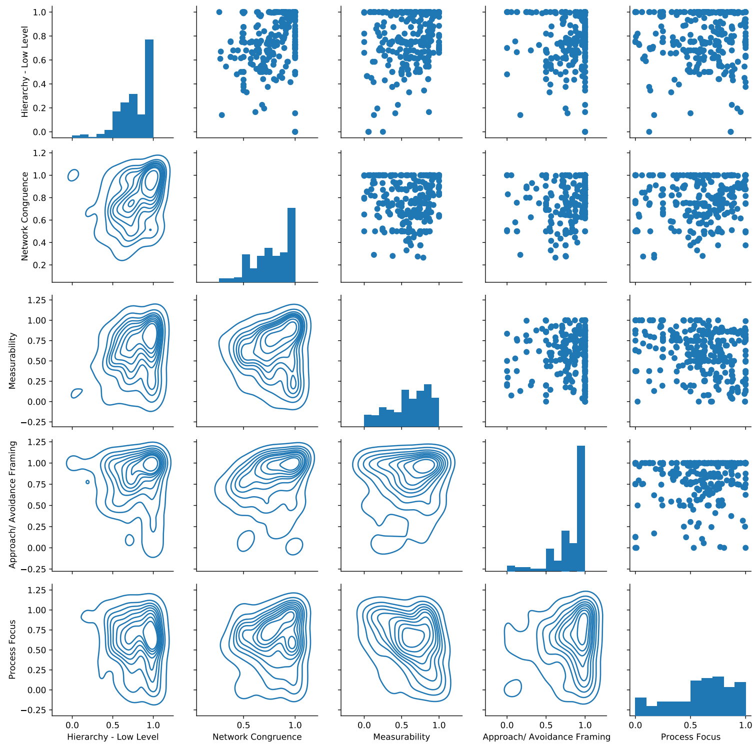

FIGURE F.34: Correlations and KDE for variable Hierarchy - Low Level matrix 2.

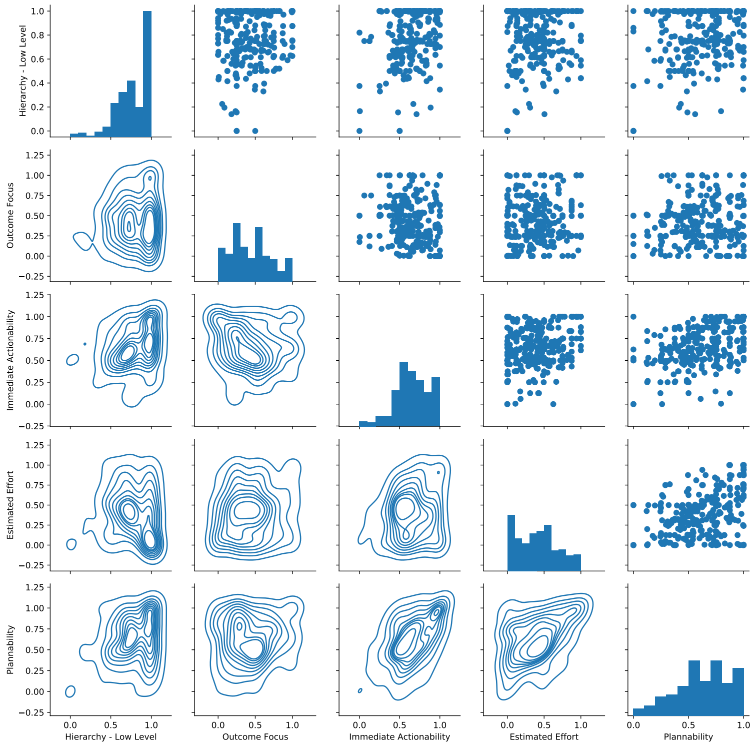

FIGURE F.35: Correlations and KDE for variable Hierarchy - Low Level matrix 3.

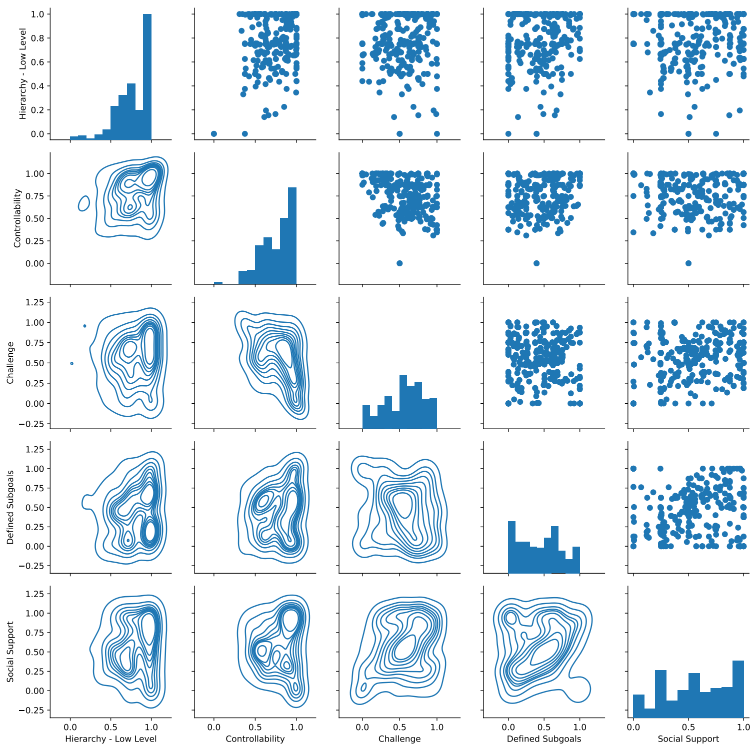

FIGURE F.36: Correlations and KDE for variable Hierarchy - Low Level matrix 4.

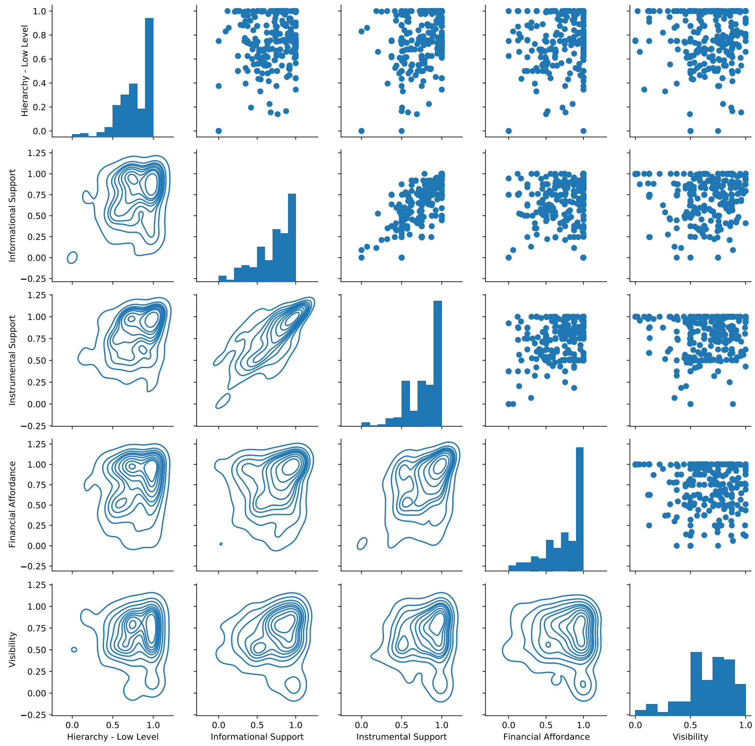

FIGURE F.37: Correlations and KDE for variable Hierarchy - Low Level matrix 5.

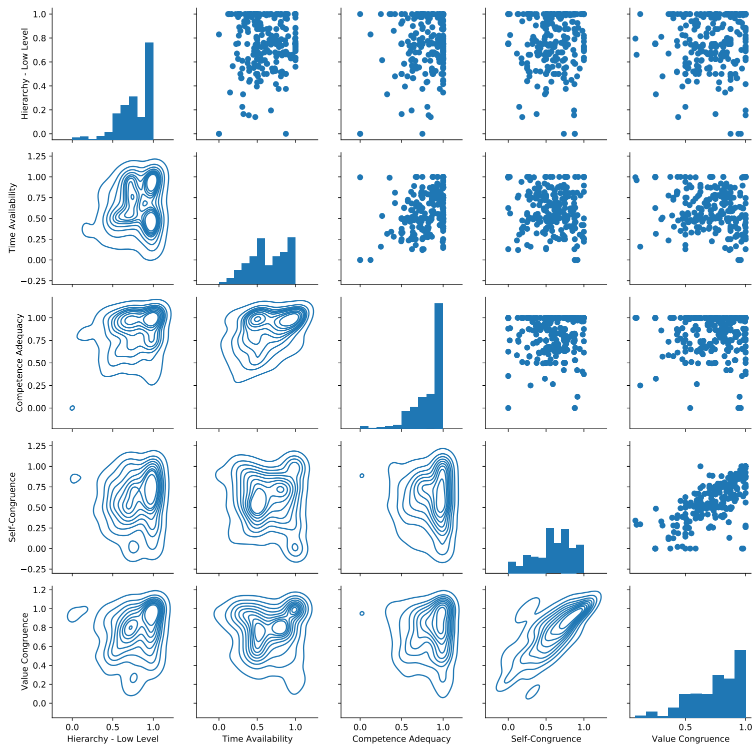

FIGURE F.38: Correlations and KDE for variable Hierarchy - Low Level matrix 6.

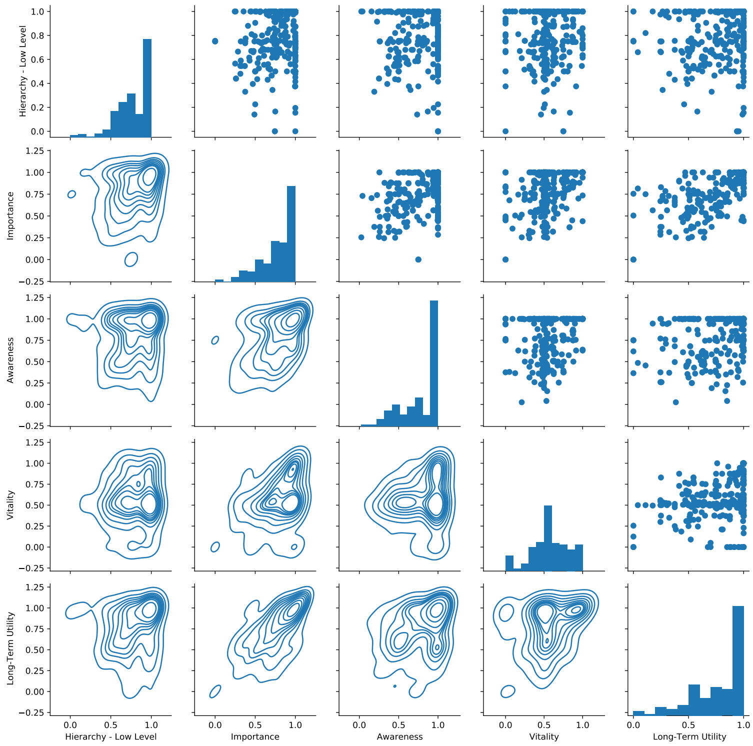

FIGURE F.39: Correlations and KDE for variable Hierarchy - Low Level matrix 7.

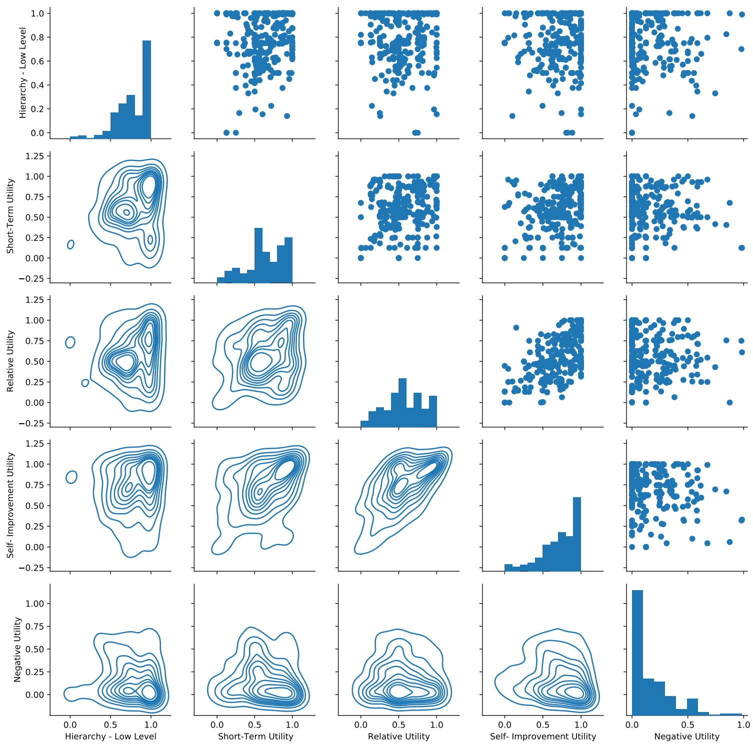

FIGURE F.40: Correlations and KDE for variable Hierarchy - Low Level matrix 8.

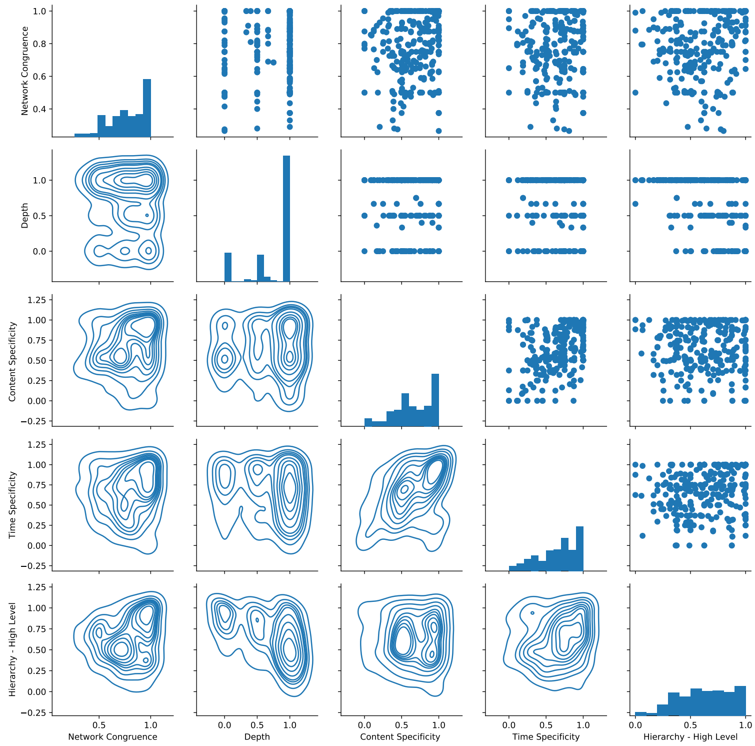

FIGURE F.41: Correlations and KDE for variable Network Congruence matrix 1.

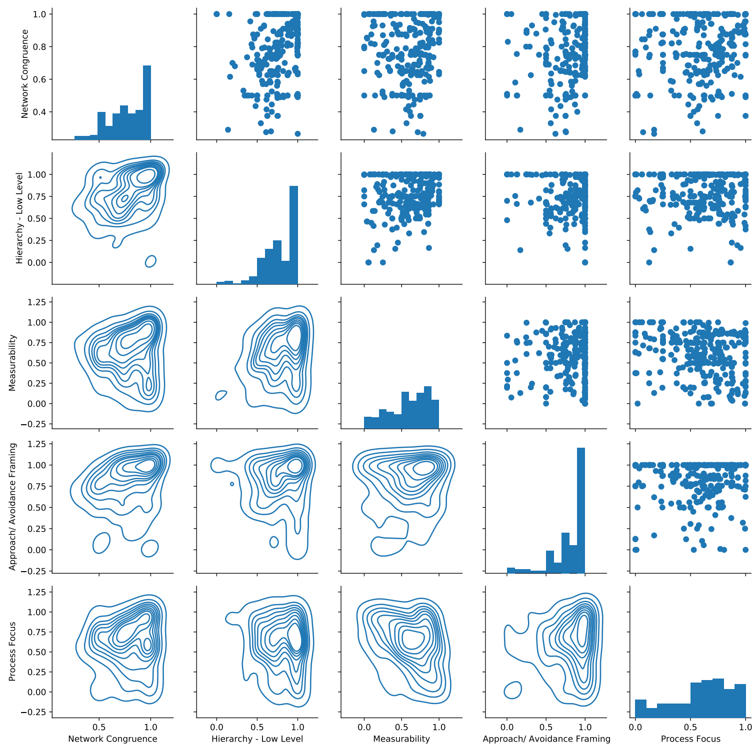

FIGURE F.42: Correlations and KDE for variable Network Congruence matrix 2.

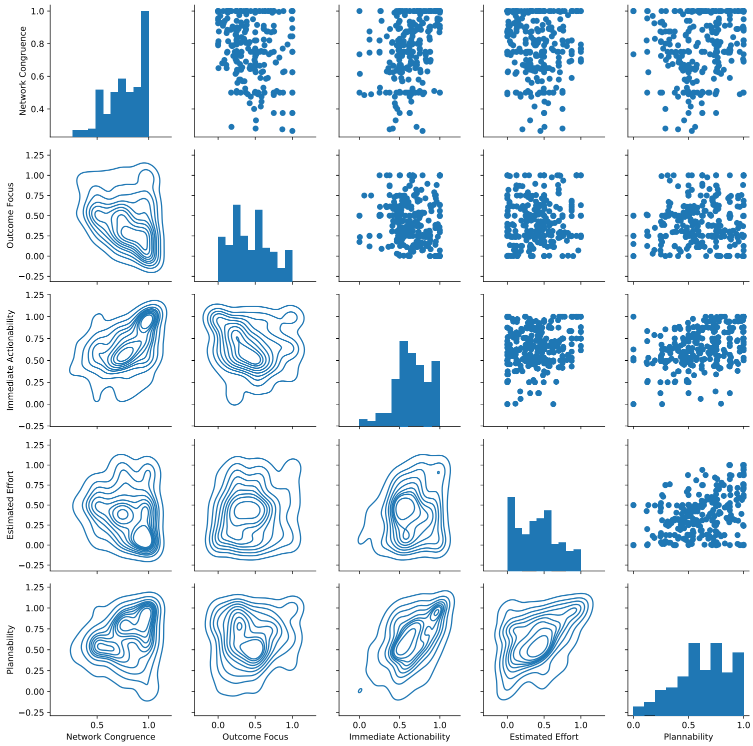

FIGURE F.43: Correlations and KDE for variable Network Congruence matrix 3.

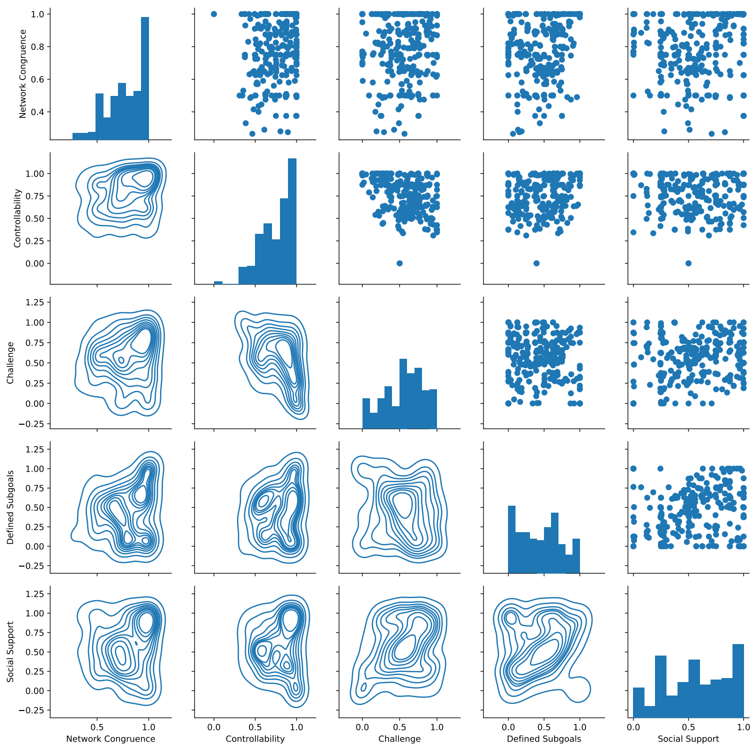

FIGURE F.44: Correlations and KDE for variable Network Congruence matrix 4.

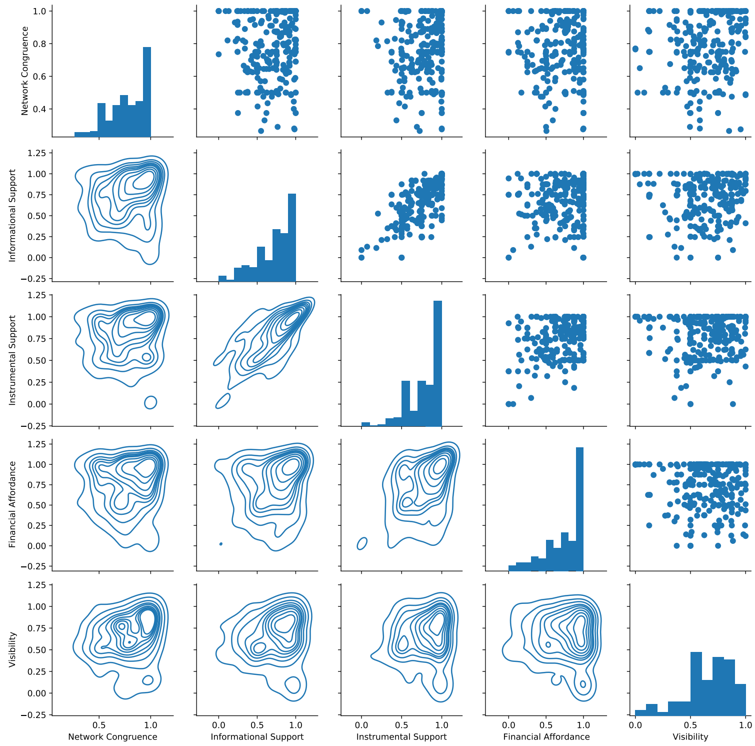

FIGURE F.45: Correlations and KDE for variable Network Congruence matrix 5.

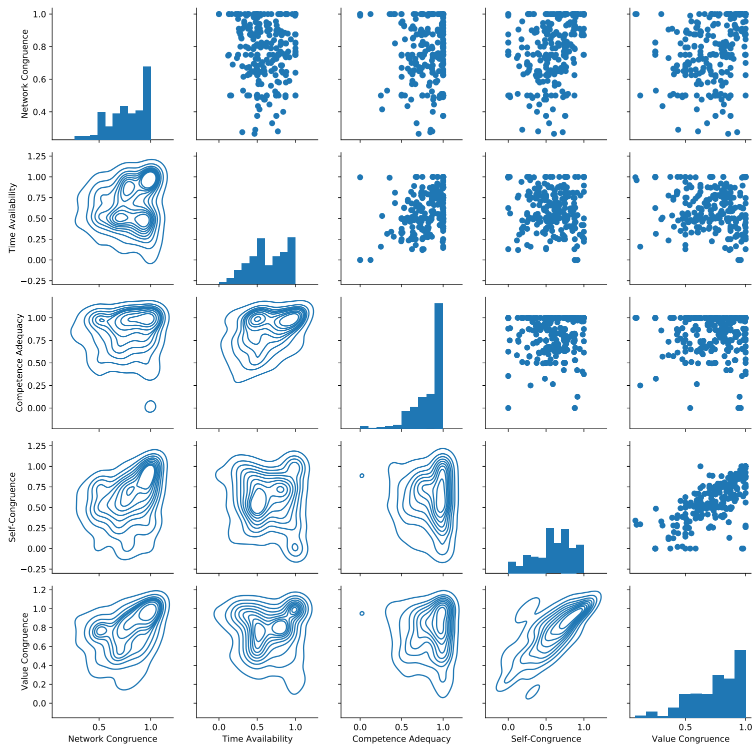

FIGURE F.46: Correlations and KDE for variable Network Congruence matrix 6.

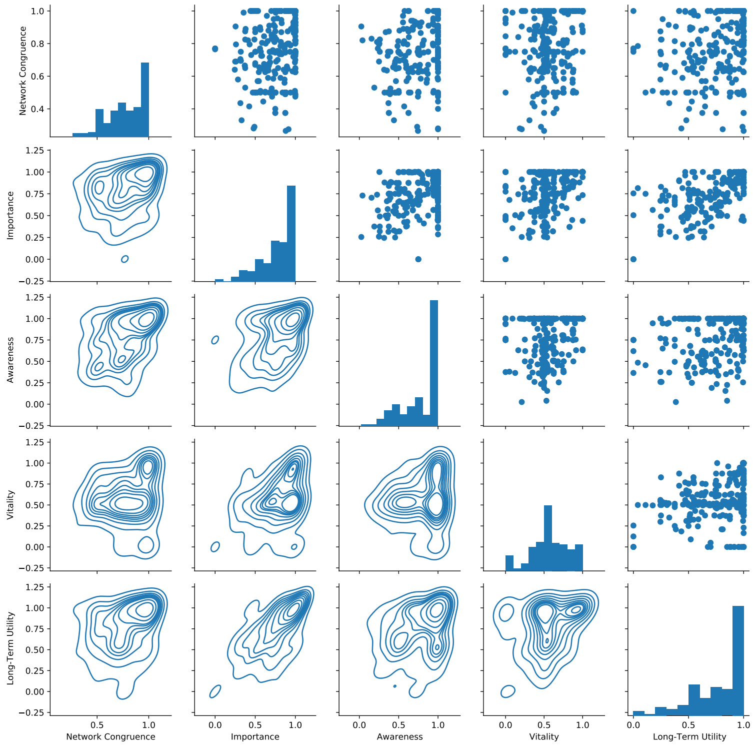

FIGURE F.47: Correlations and KDE for variable Network Congruence matrix 7.

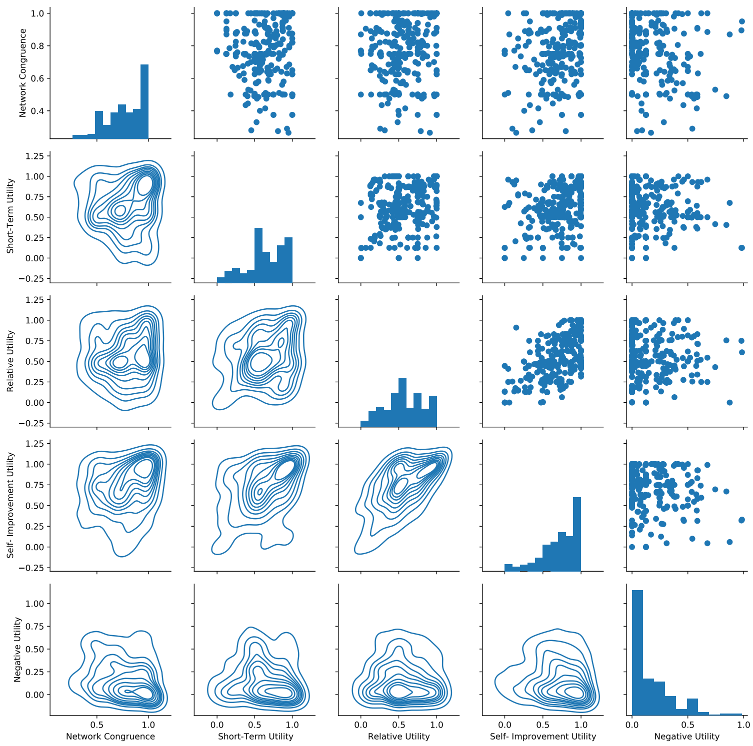

FIGURE F.48: Correlations and KDE for variable Network Congruence matrix 8.

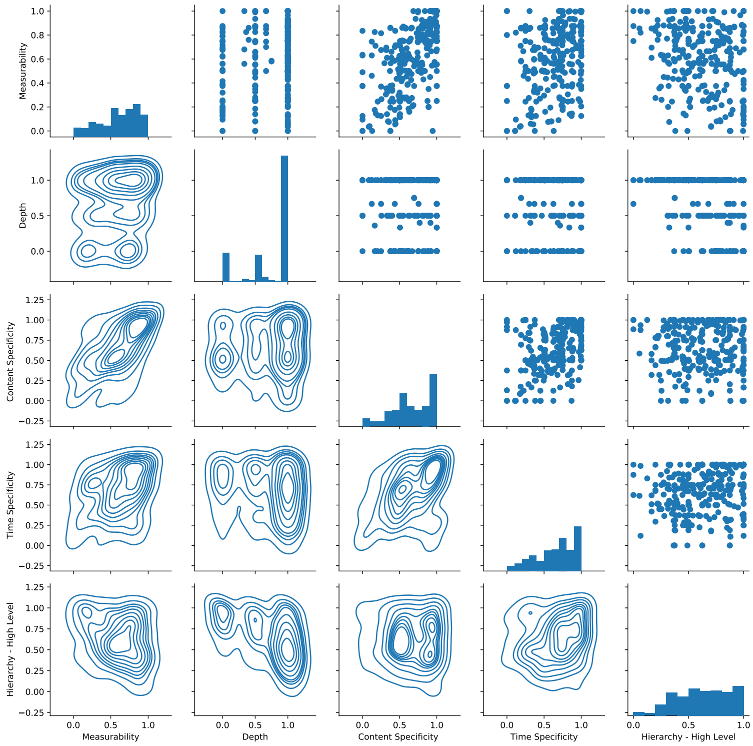

FIGURE F.49: Correlations and KDE for variable Measurability matrix 1.

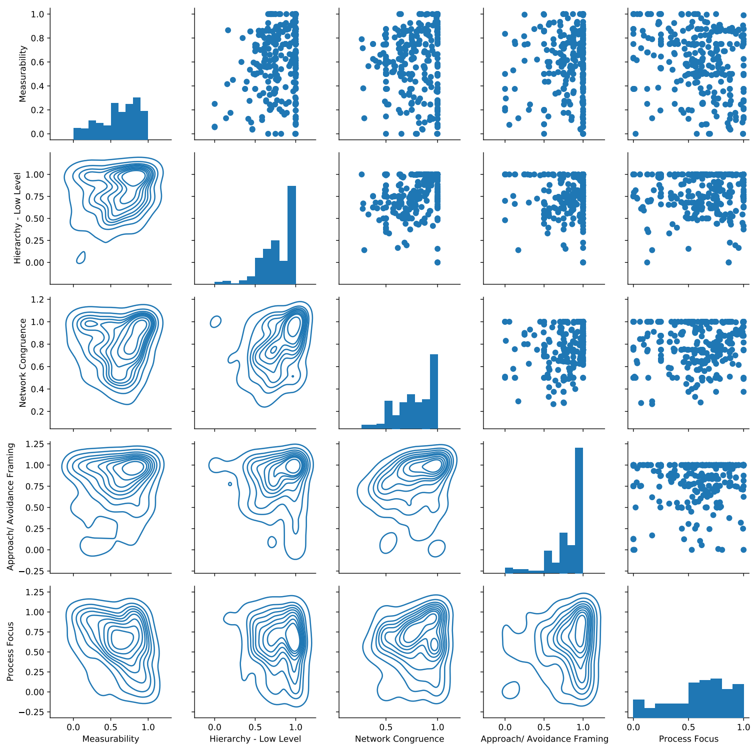

FIGURE F.50: Correlations and KDE for variable Measurability matrix 2.

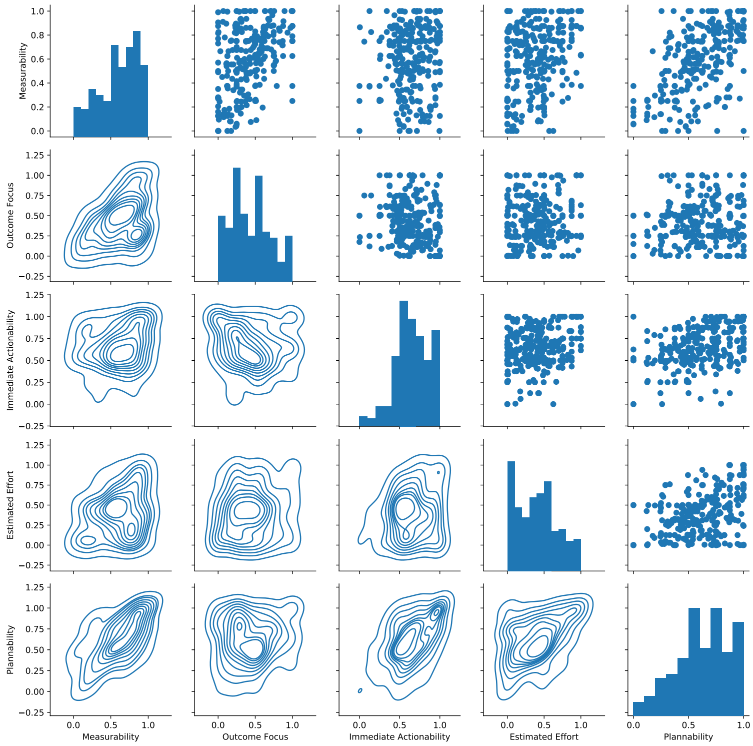

FIGURE F.51: Correlations and KDE for variable Measurability matrix 3.

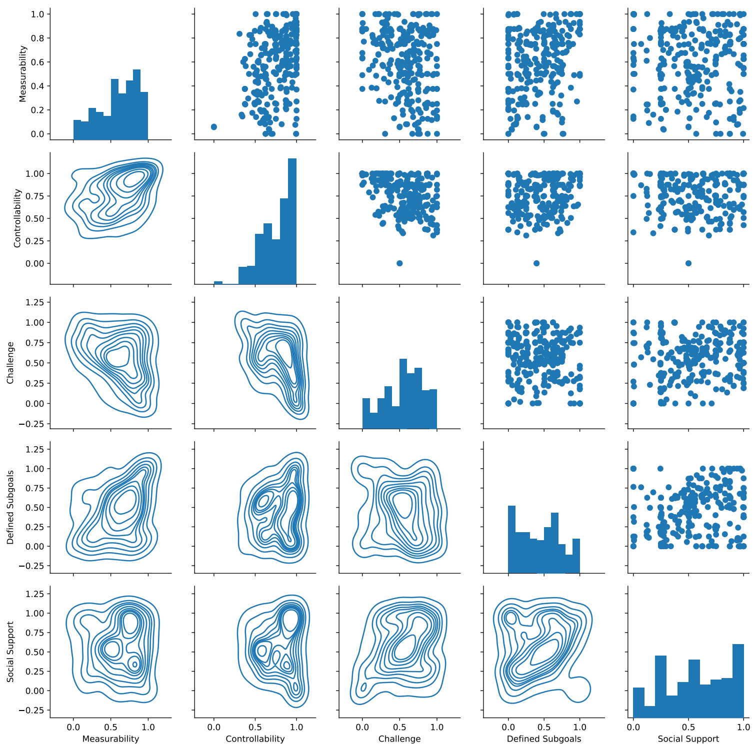

FIGURE F.52: Correlations and KDE for variable Measurability matrix 4.

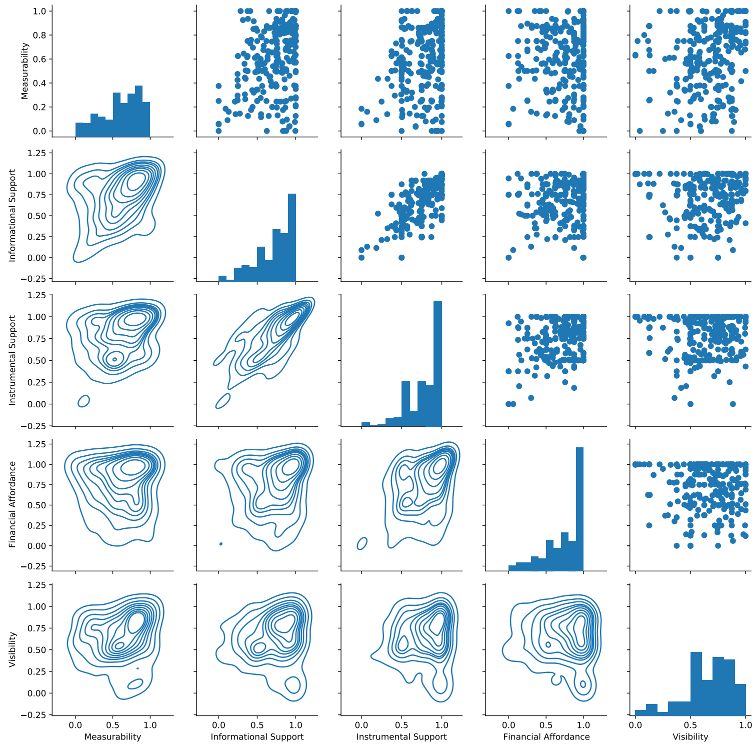

FIGURE F.53: Correlations and KDE for variable Measurability matrix 5.

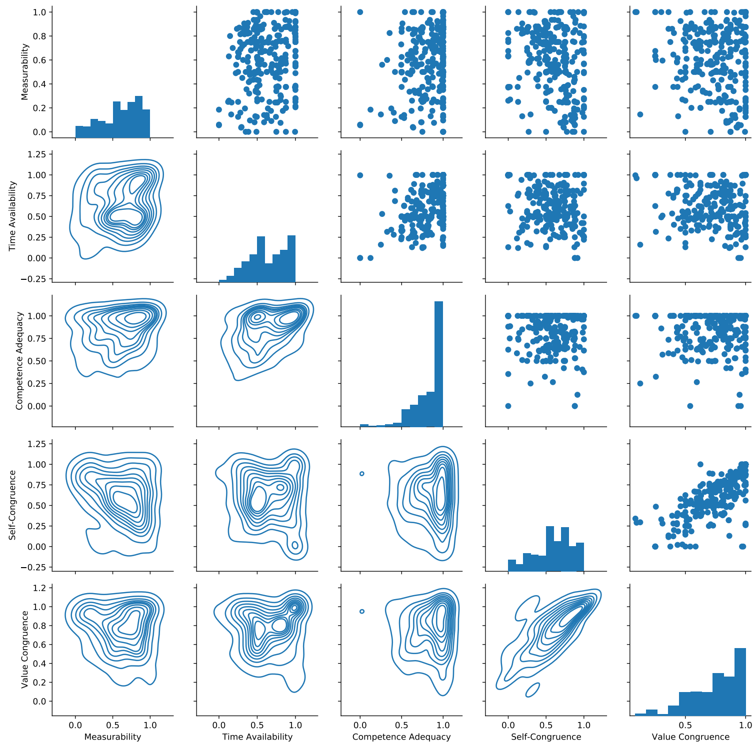

FIGURE F.54: Correlations and KDE for variable Measurability matrix 6.

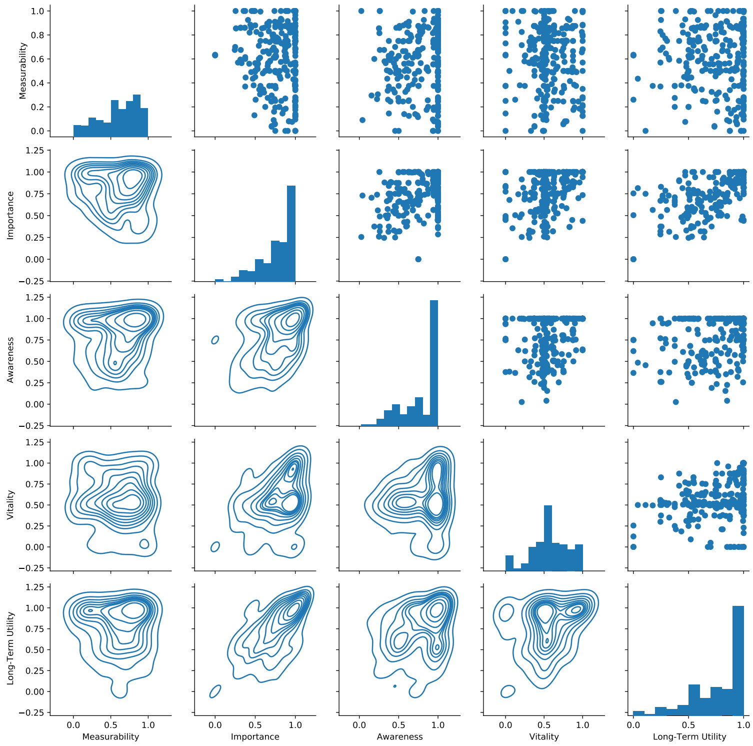

FIGURE F.55: Correlations and KDE for variable Measurability matrix 7.

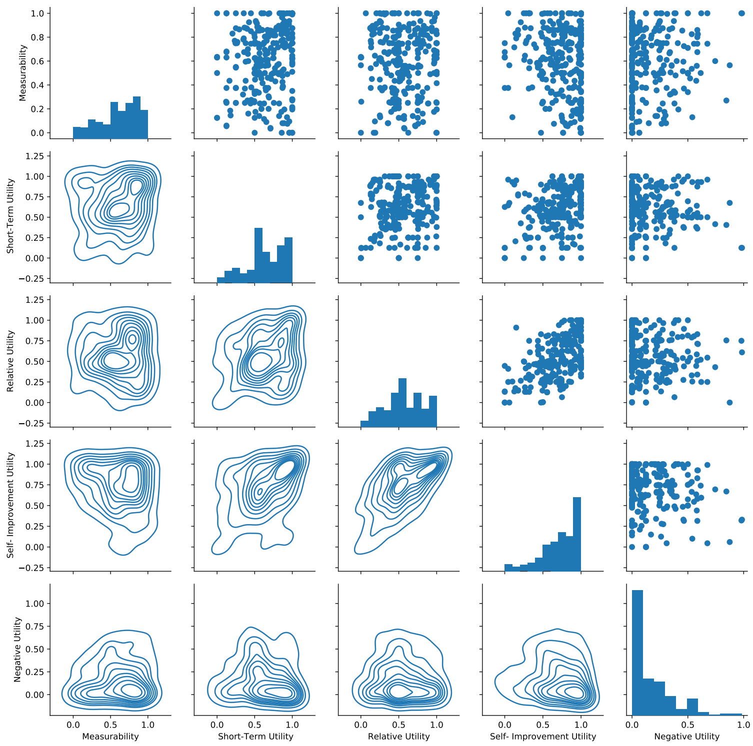

FIGURE F.56: Correlations and KDE for variable Measurability matrix 8.

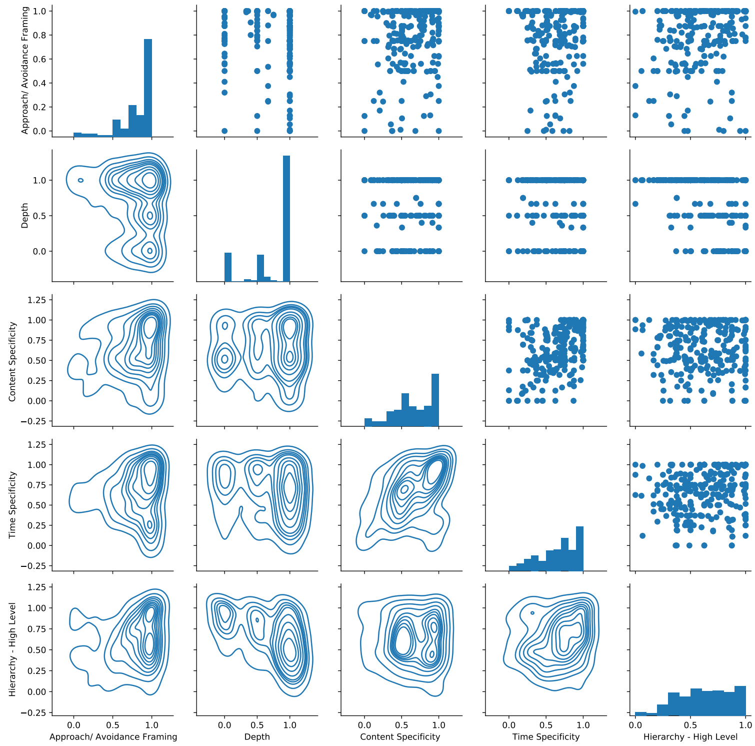

FIGURE F.57: Correlations and KDE for variable Approach Avoidance Framing matrix 1.

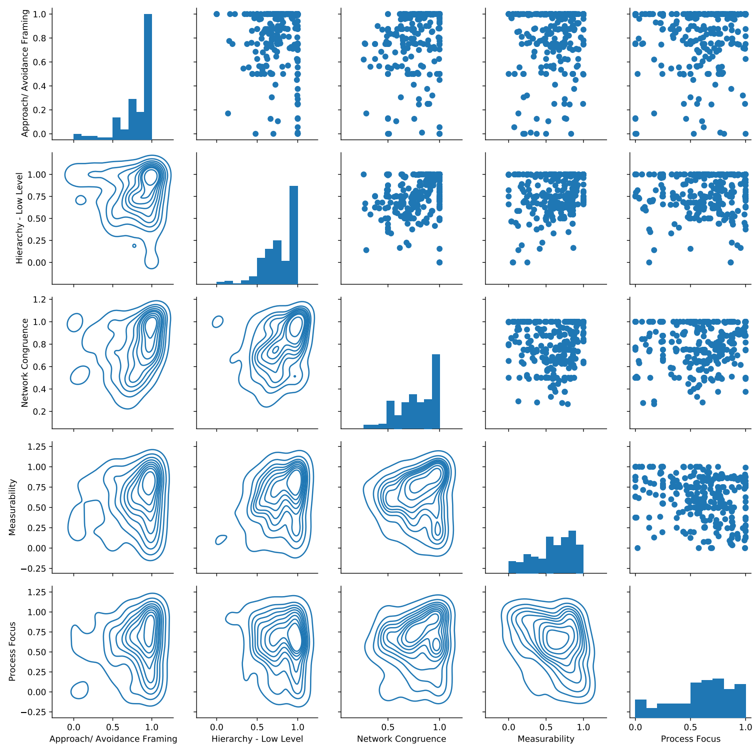

FIGURE F.58: Correlations and KDE for variable Approach Avoidance Framing matrix 2.

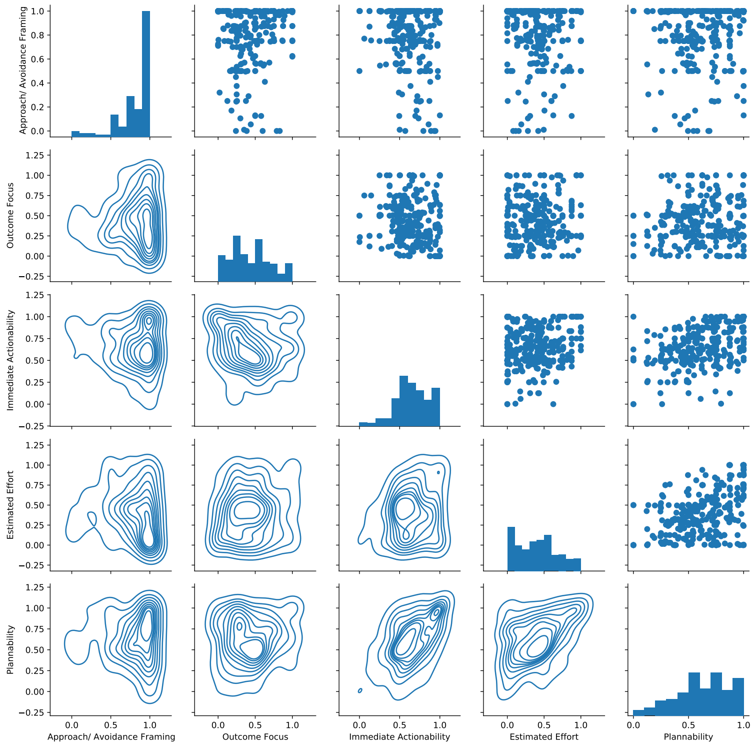

FIGURE F.59: Correlations and KDE for variable Approach Avoidance Framing matrix 3.

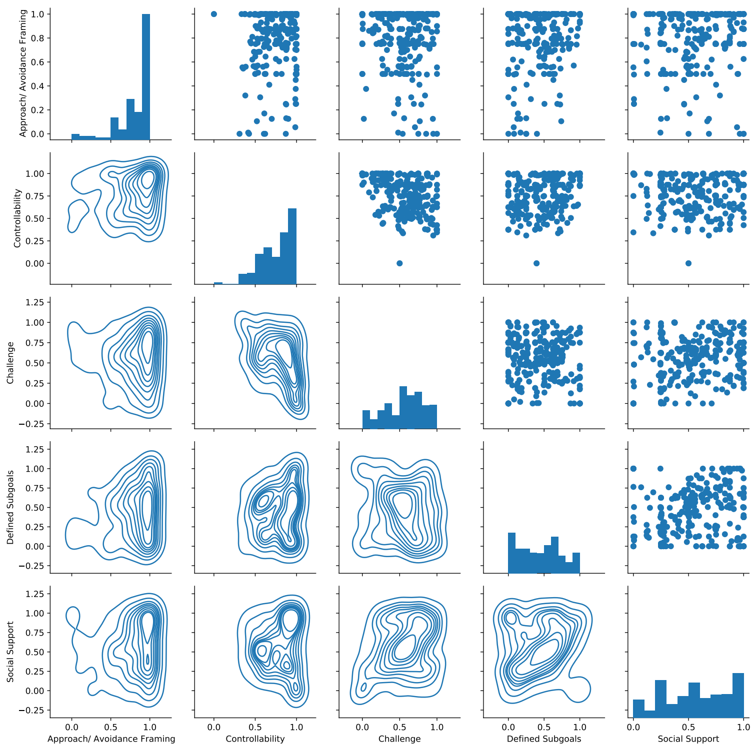

FIGURE F.60: Correlations and KDE for variable Approach Avoidance Framing matrix 4.

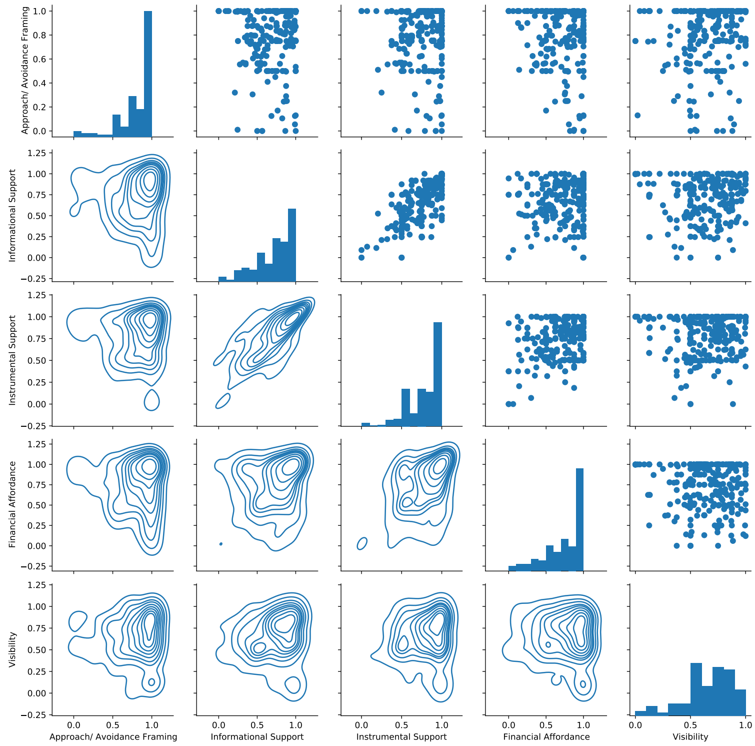

FIGURE F.61: Correlations and KDE for variable Approach Avoidance Framing matrix 5.

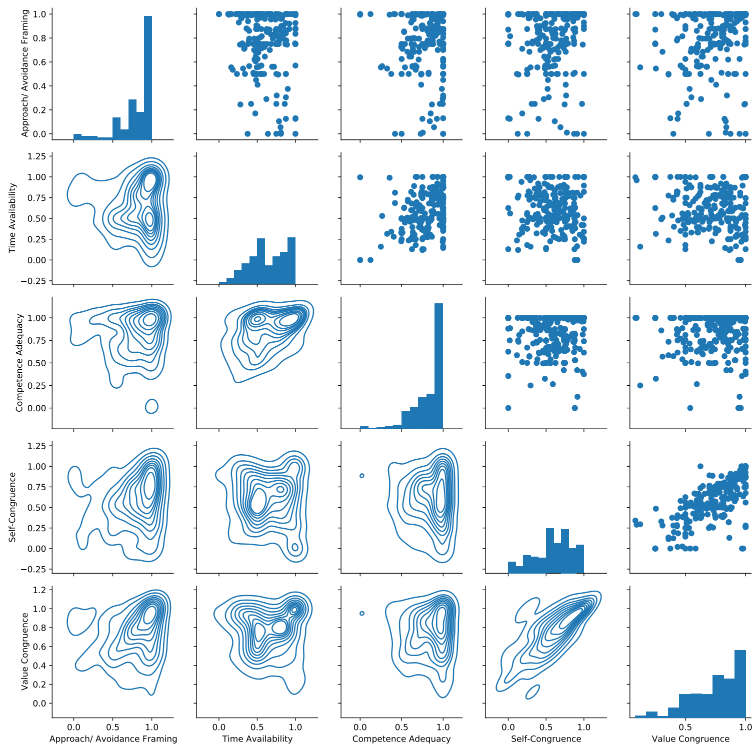

FIGURE F.62: Correlations and KDE for variable Approach Avoidance Framing matrix 6.

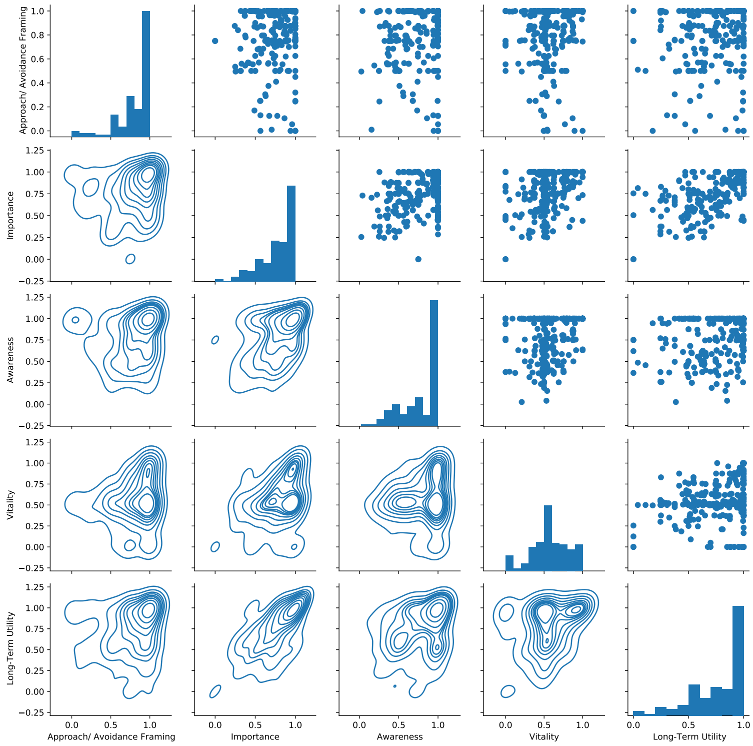

FIGURE F.63: Correlations and KDE for variable Approach Avoidance Framing matrix 7.

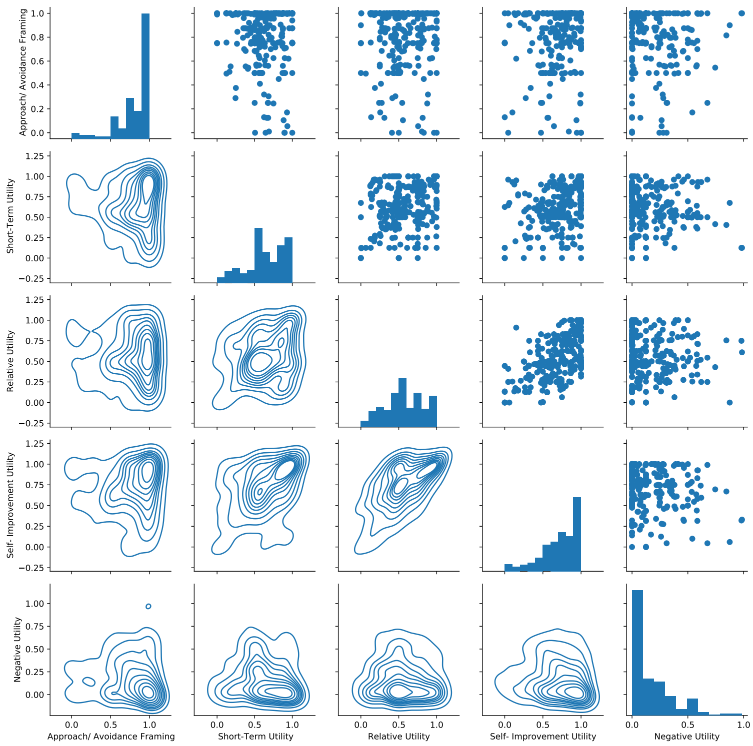

FIGURE F.64: Correlations and KDE for variable Approach Avoidance Framing matrix 8.

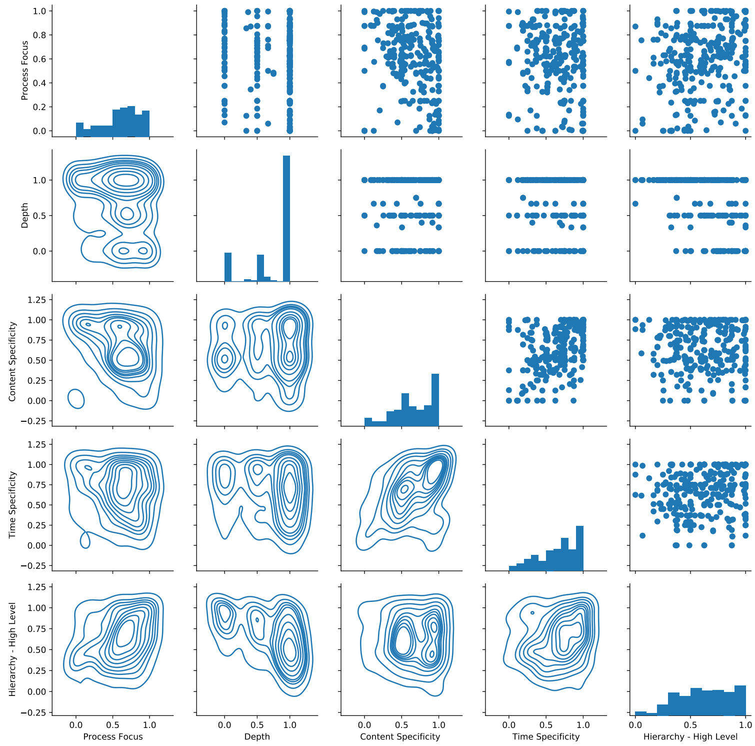

FIGURE F.65: Correlations and KDE for variable Process Focus matrix 1.

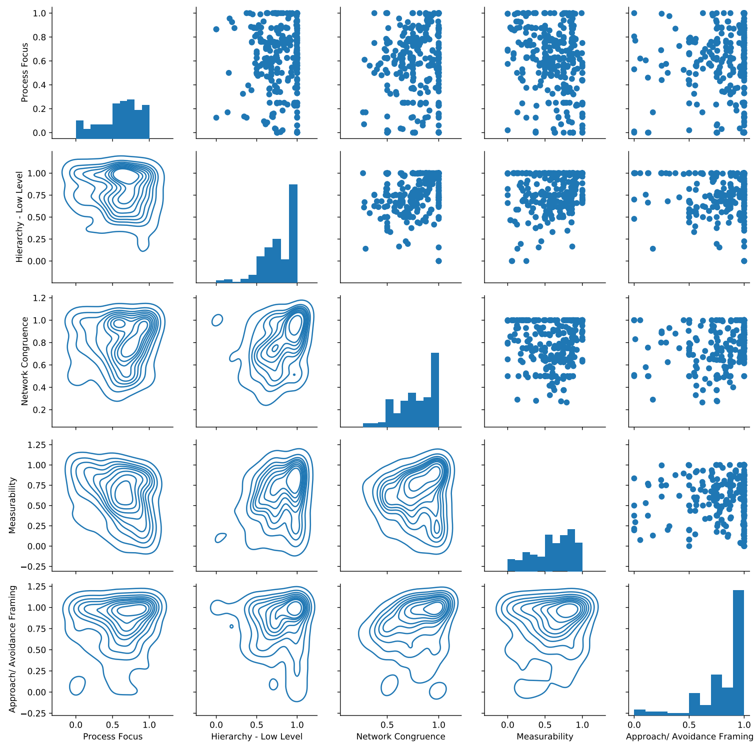

FIGURE F.66: Correlations and KDE for variable Process Focus matrix 2.

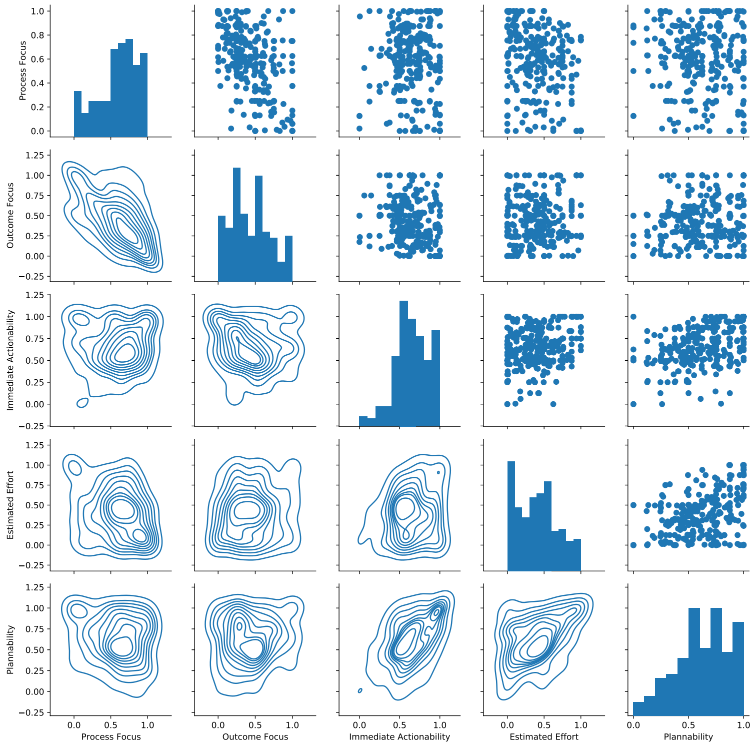

FIGURE F.67: Correlations and KDE for variable Process Focus matrix 3.

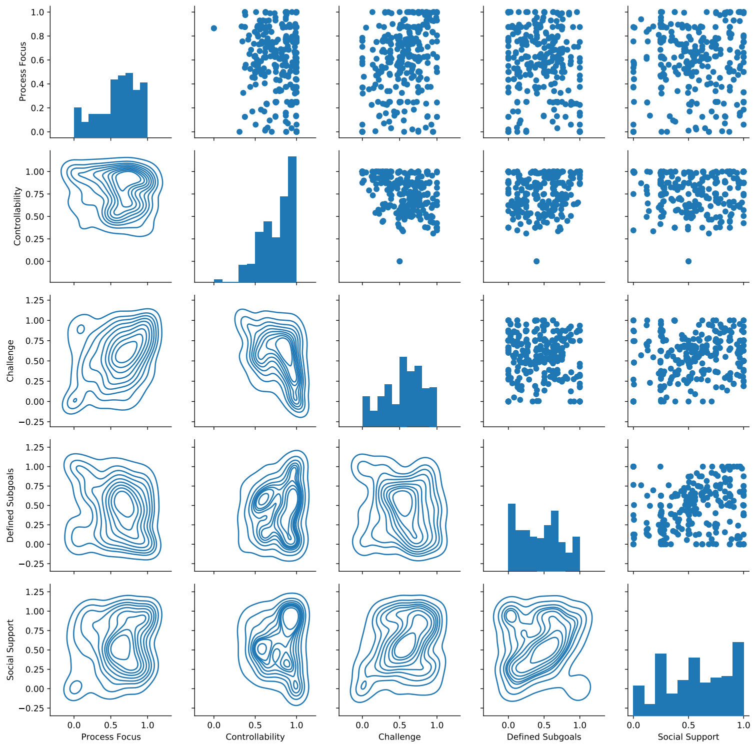

FIGURE F.68: Correlations and KDE for variable Process Focus matrix 4.

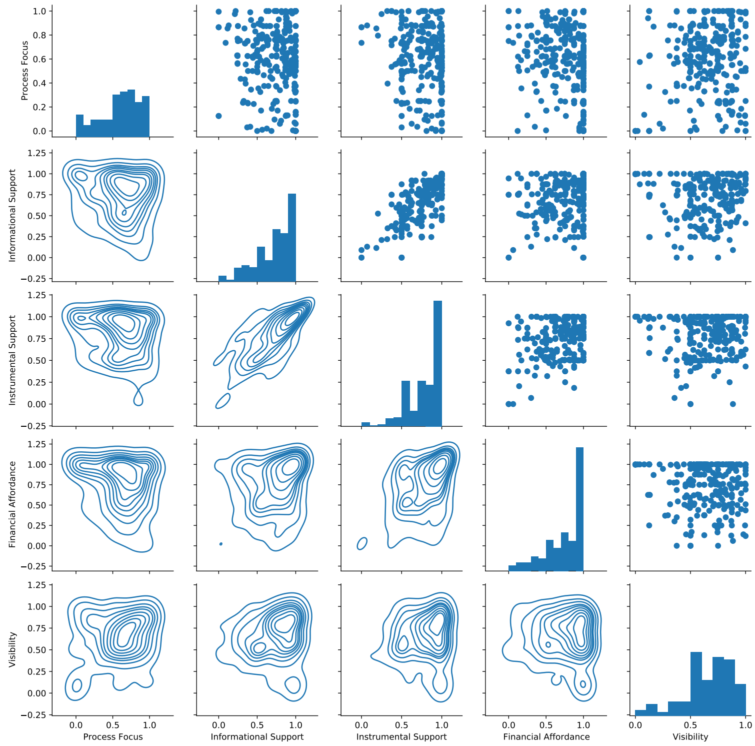

FIGURE F.69: Correlations and KDE for variable Process Focus matrix 5.

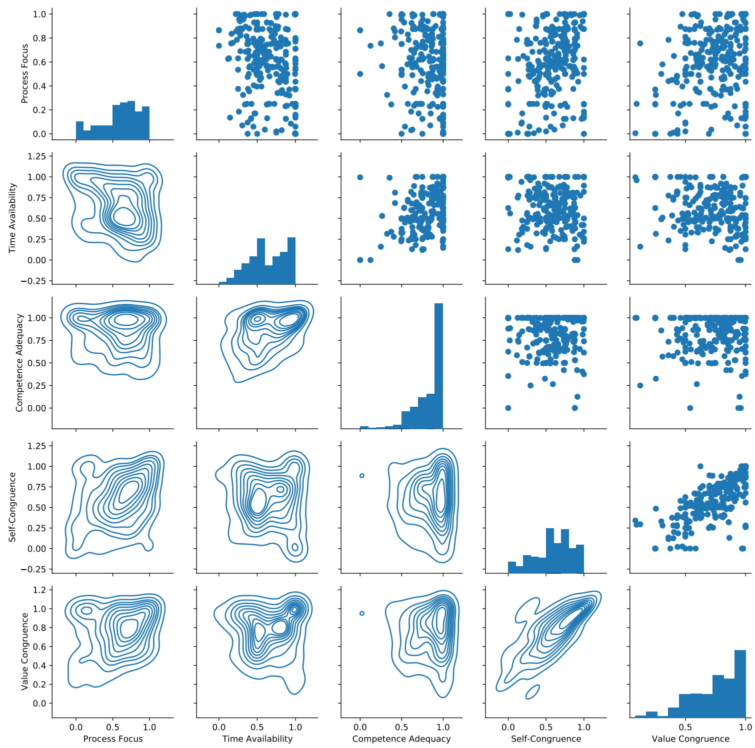

FIGURE F.70: Correlations and KDE for variable Process Focus matrix 6.

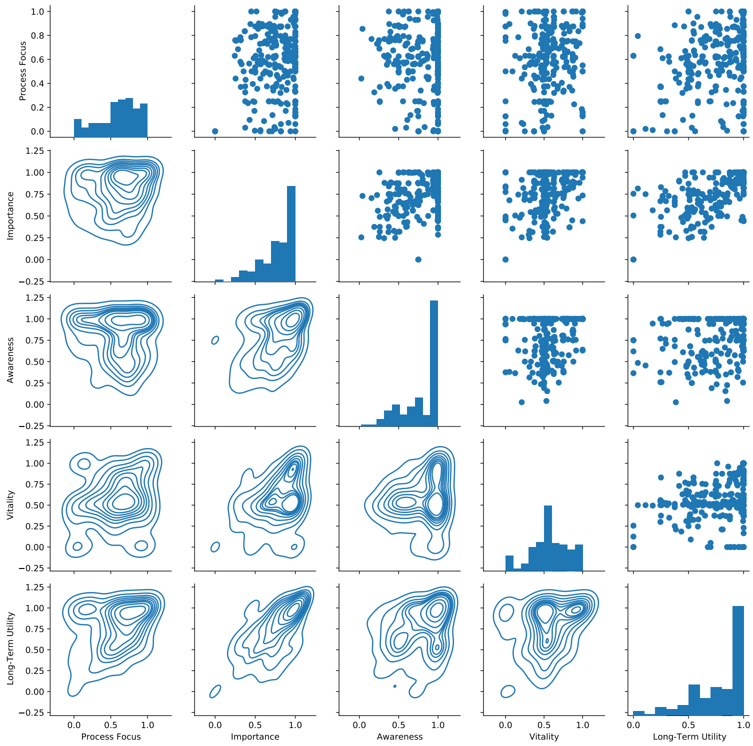

FIGURE F.71: Correlations and KDE for variable Process Focus matrix 7.

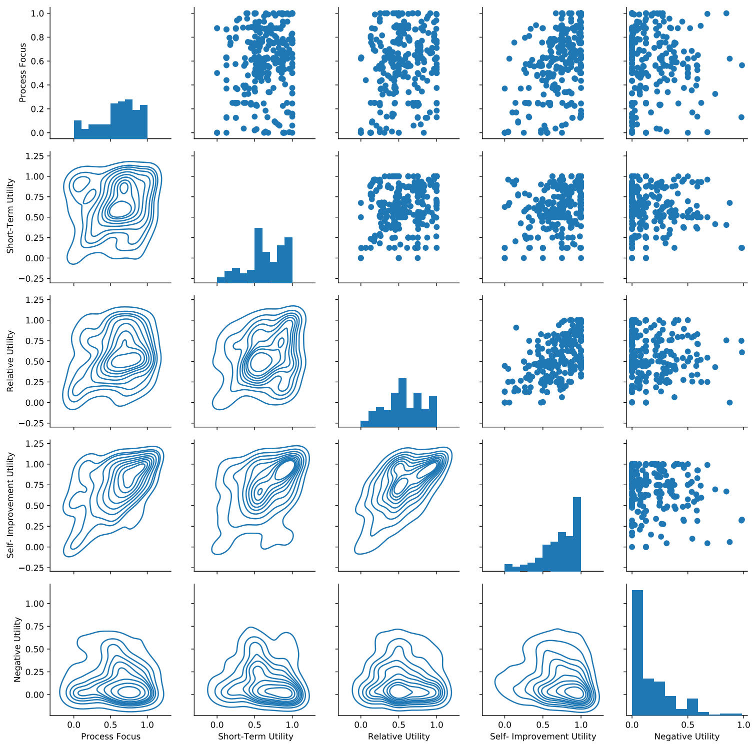

FIGURE F.72: Correlations and KDE for variable Process Focus matrix 8.

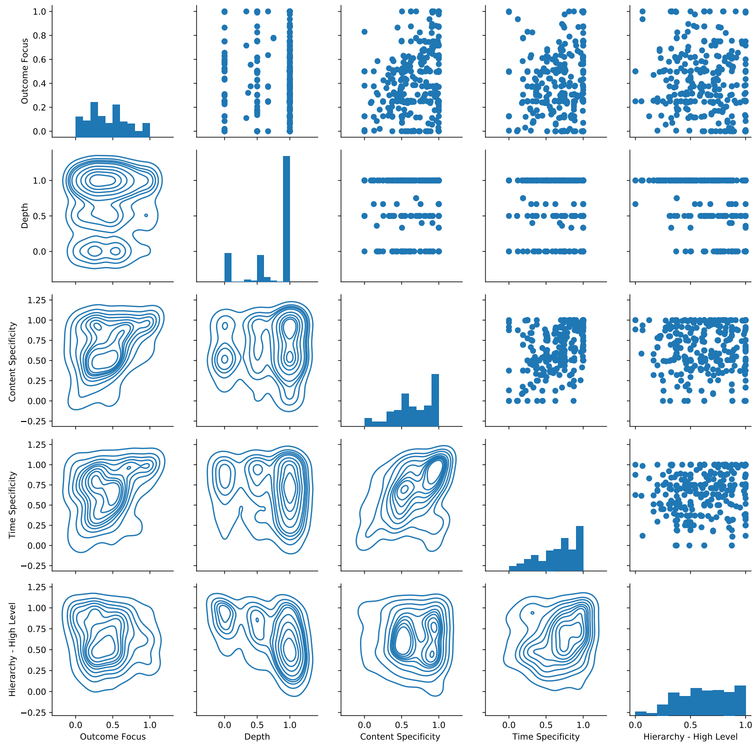

FIGURE F.73: Correlations and KDE for variable Outcome Focus matrix 1.

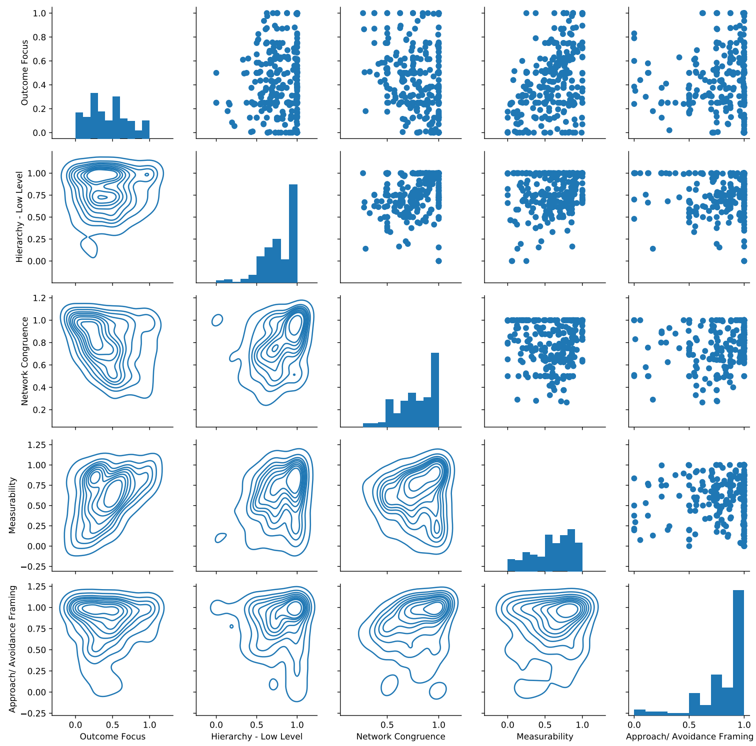

FIGURE F.74: Correlations and KDE for variable Outcome Focus matrix 2.

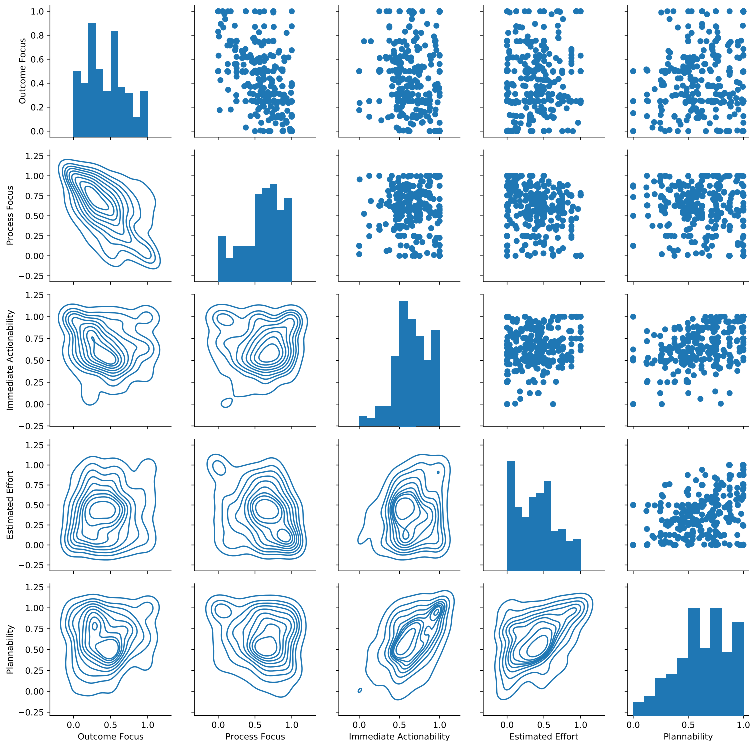

FIGURE F.75: Correlations and KDE for variable Outcome Focus matrix 3.

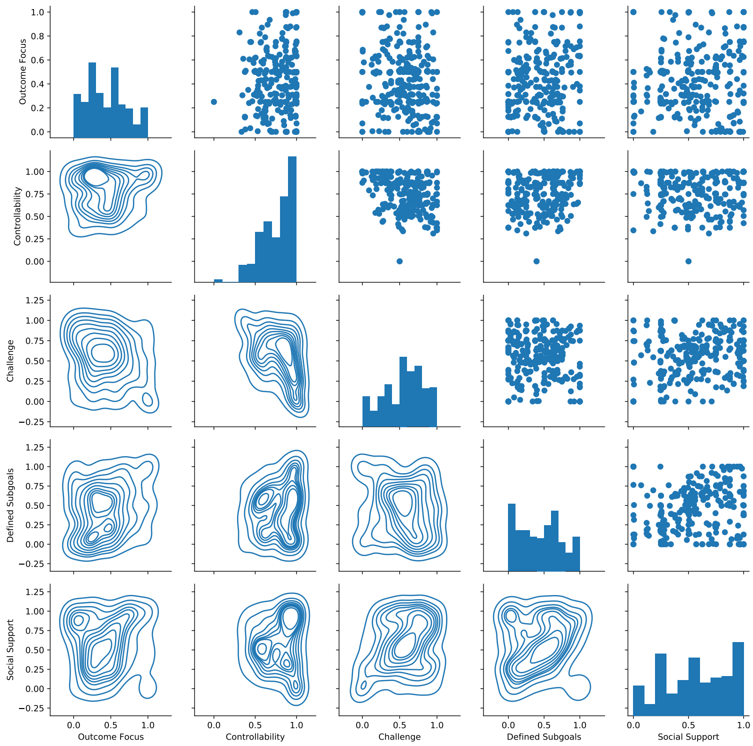

FIGURE F.76: Correlations and KDE for variable Outcome Focus matrix 4.

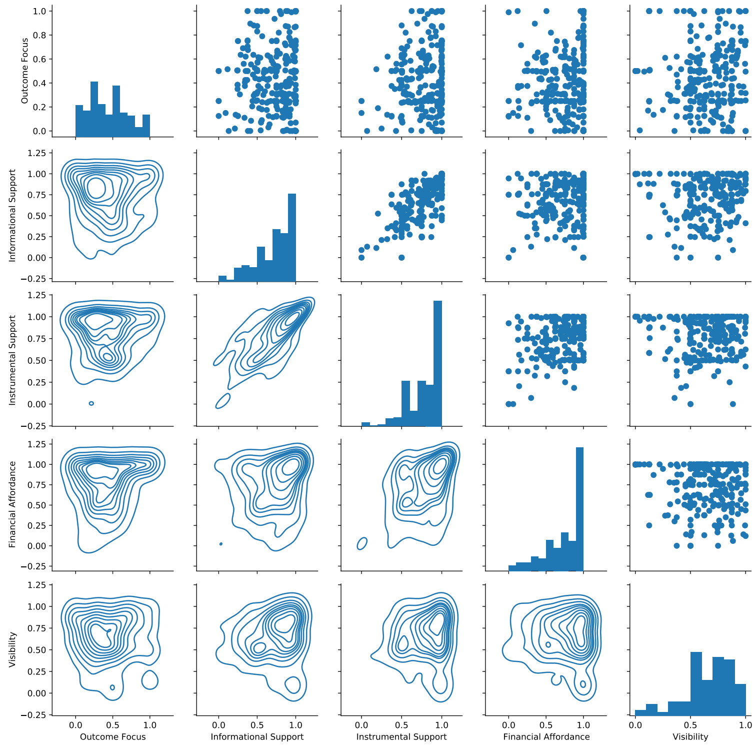

FIGURE F.77: Correlations and KDE for variable Outcome Focus matrix 5.

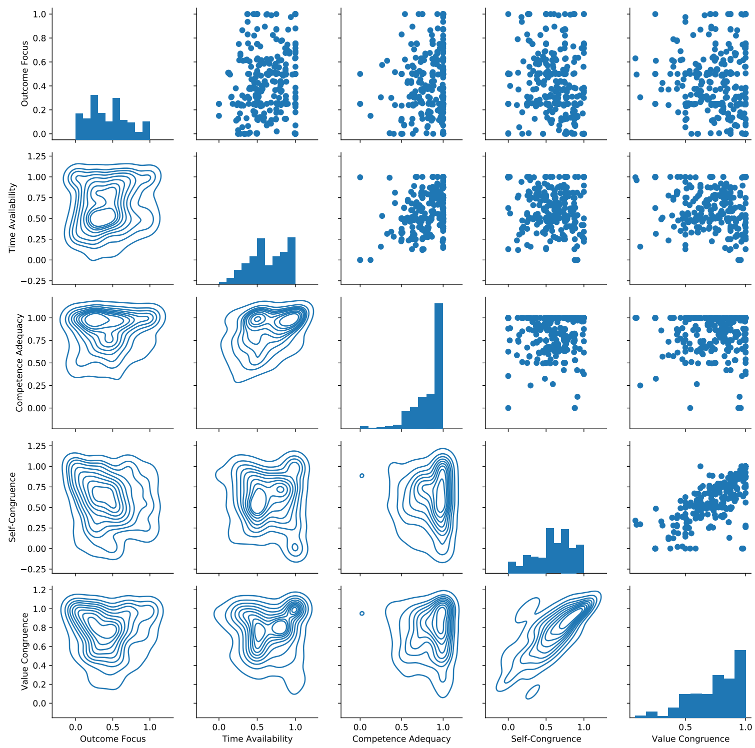

FIGURE F.78: Correlations and KDE for variable Outcome Focus matrix 6.

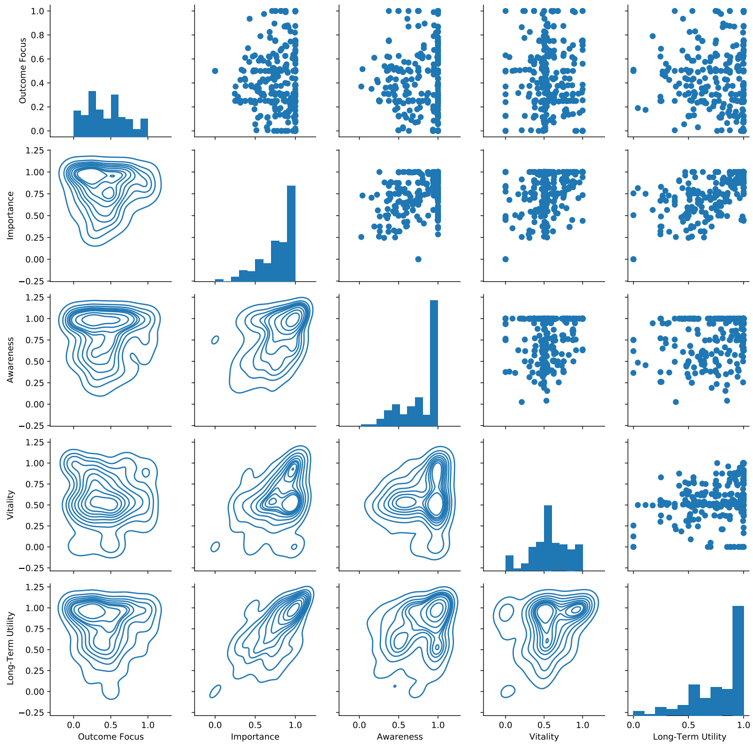

FIGURE F.79: Correlations and KDE for variable Outcome Focus matrix 7.

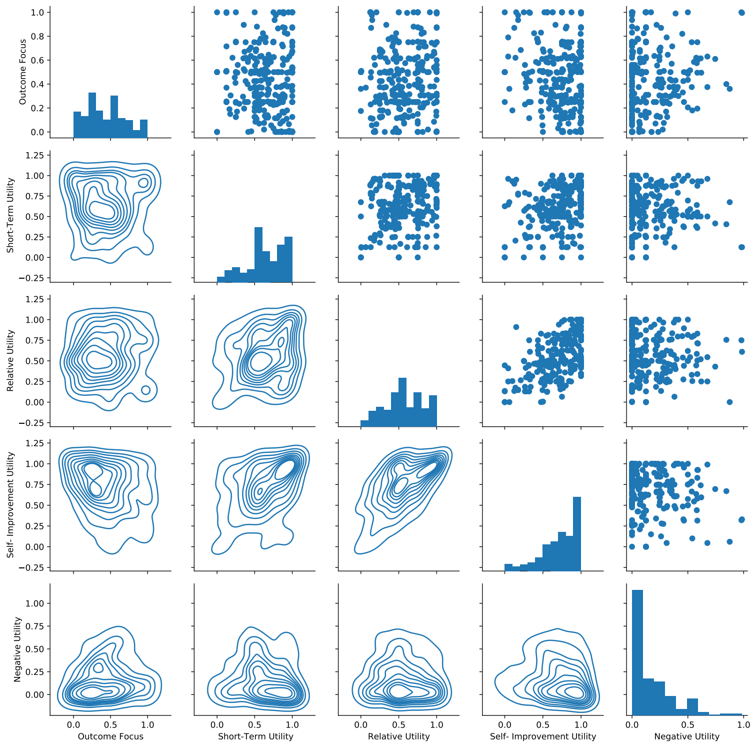

FIGURE F.80: Correlations and KDE for variable Outcome Focus matrix 8.

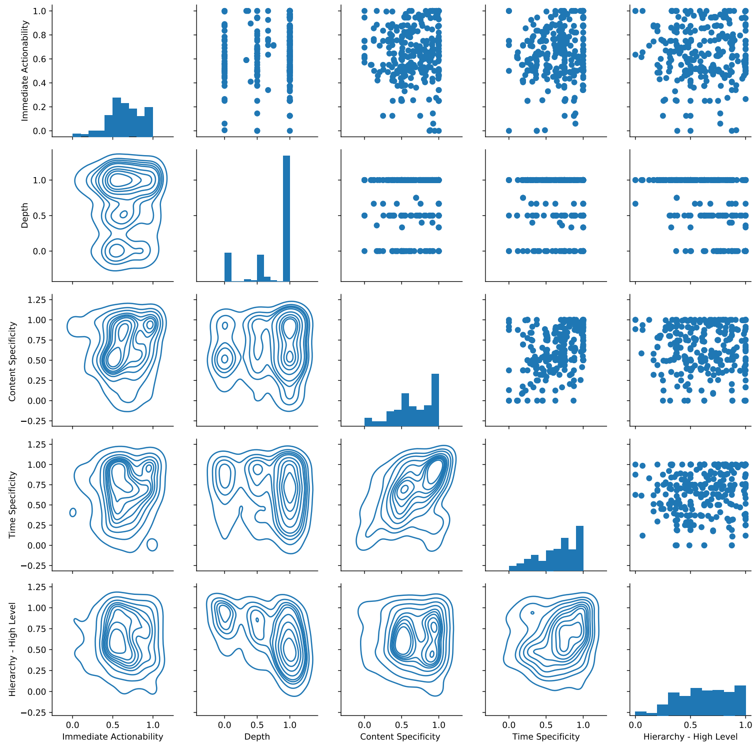

FIGURE F.81: Correlations and KDE for variable Immediate Actionability matrix 1.

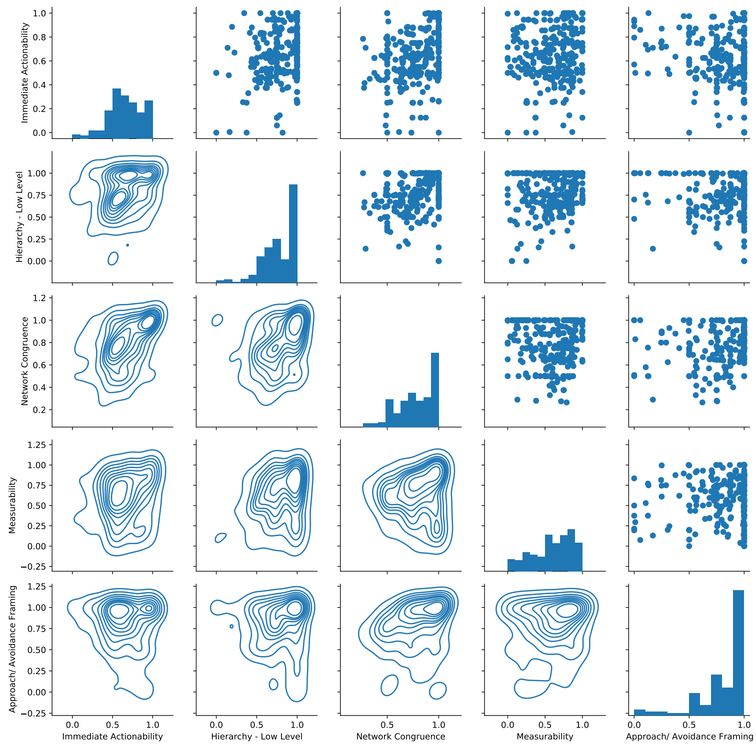

FIGURE F.82: Correlations and KDE for variable Immediate Actionability matrix 2.

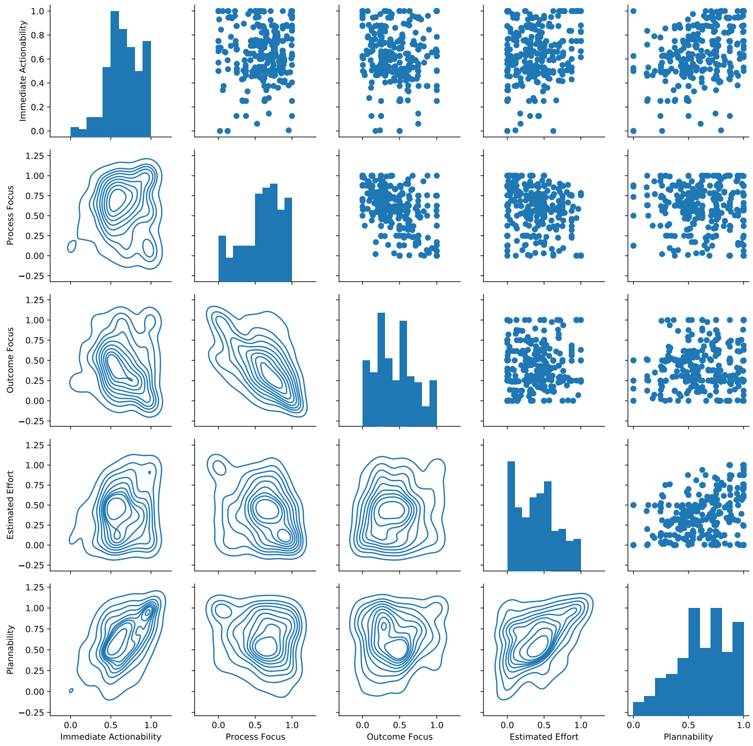

FIGURE F.83: Correlations and KDE for variable Immediate Actionability matrix 3.

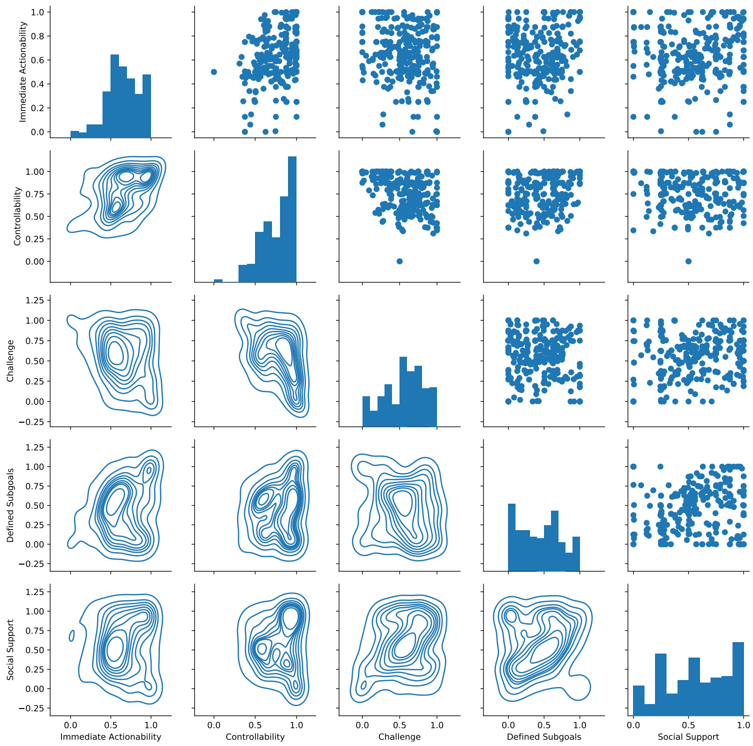

FIGURE F.84: Correlations and KDE for variable Immediate Actionability matrix 4.

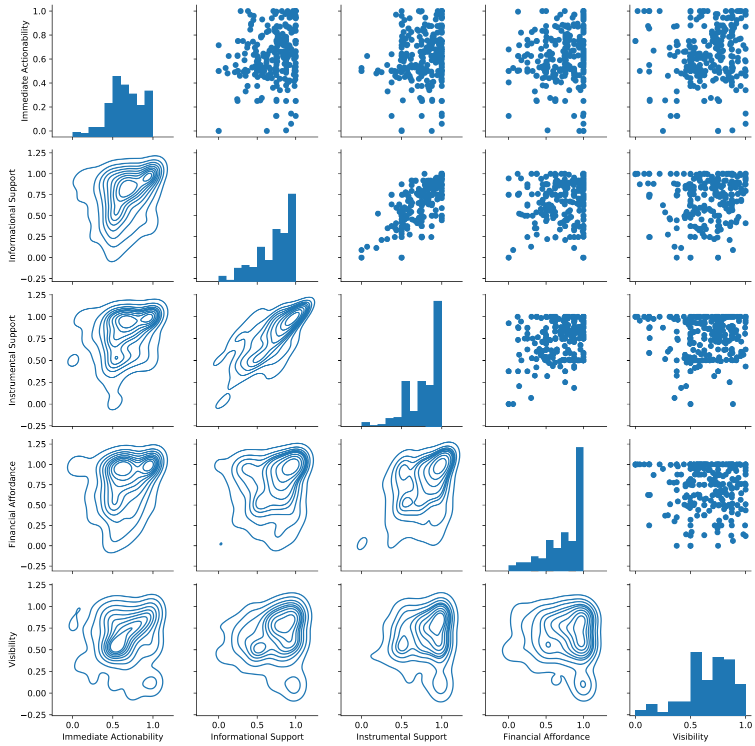

FIGURE F.85: Correlations and KDE for variable Immediate Actionability matrix 5.

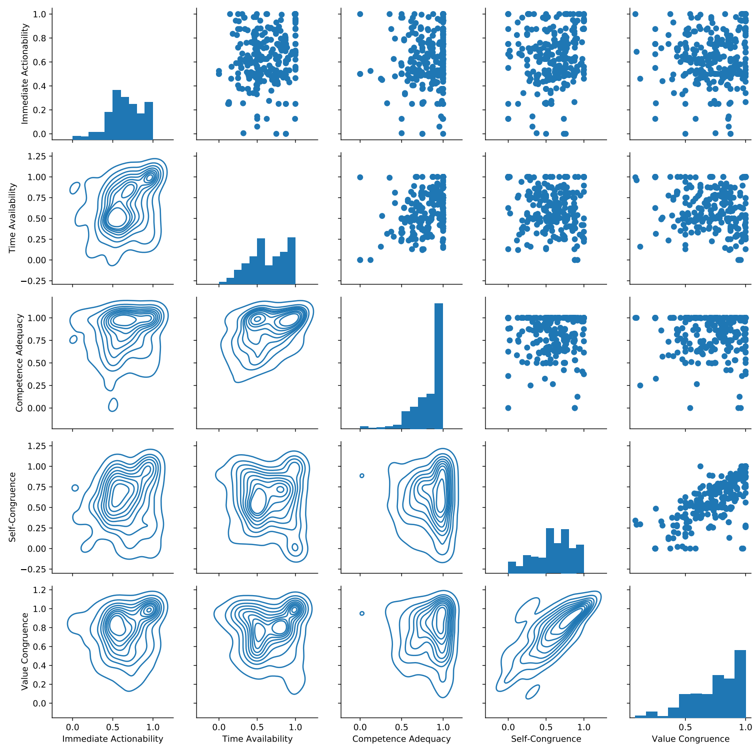

FIGURE F.86: Correlations and KDE for variable Immediate Actionability matrix 6.

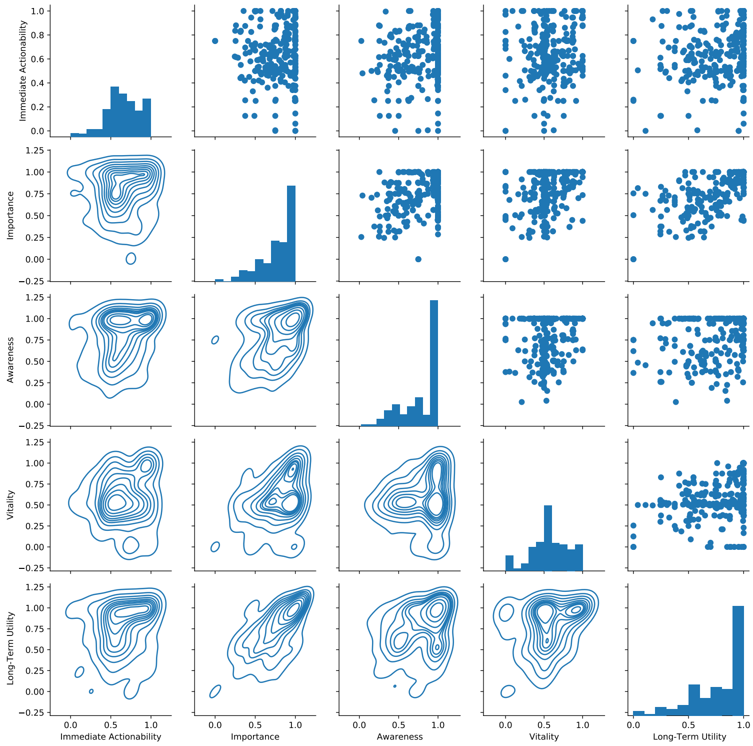

FIGURE F.87: Correlations and KDE for variable Immediate Actionability matrix 7.

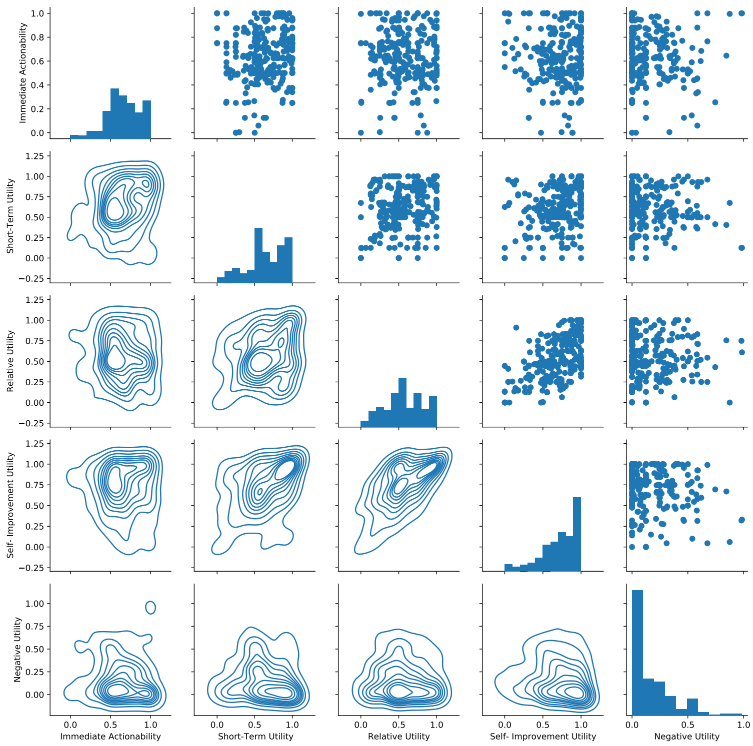

FIGURE F.88: Correlations and KDE for variable Immediate Actionability matrix 8.

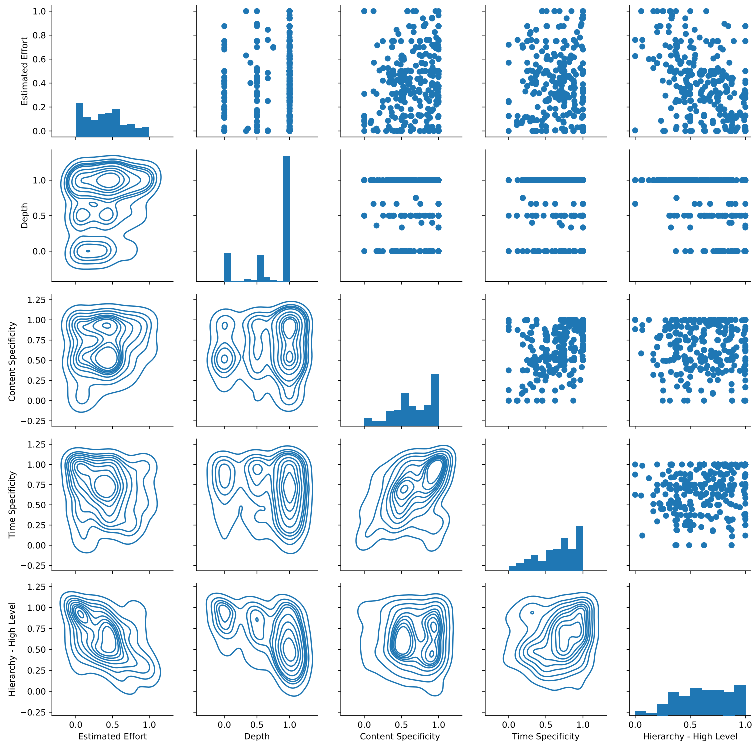

FIGURE F.89: Correlations and KDE for variable Estimated Effort matrix 1.

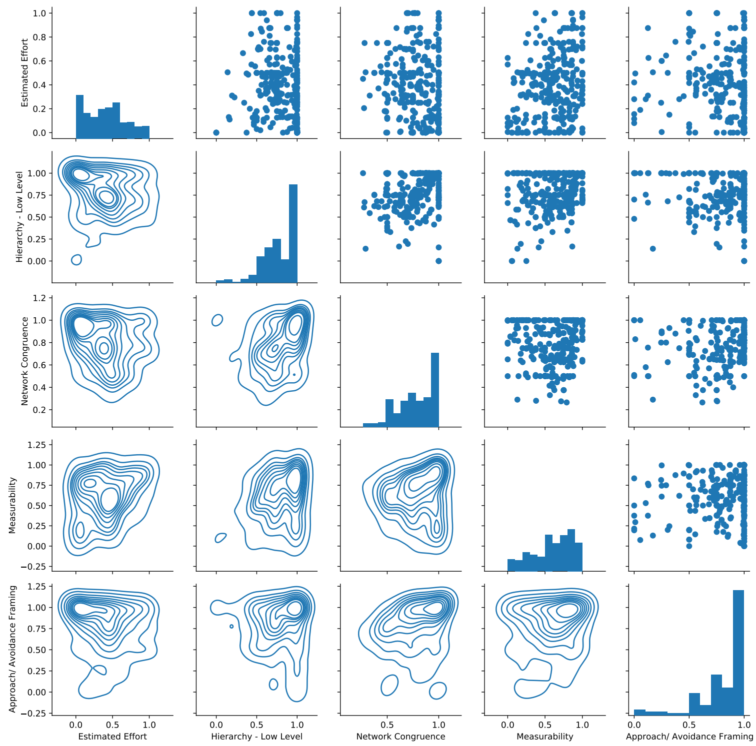

FIGURE F.90: Correlations and KDE for variable Estimated Effort matrix 2.

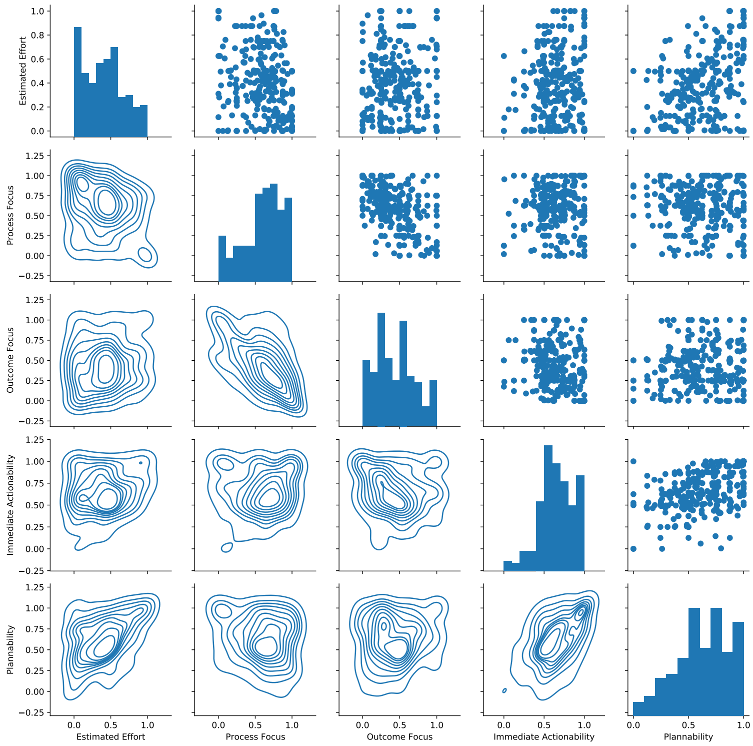

FIGURE F.91: Correlations and KDE for variable Estimated Effort matrix 3.

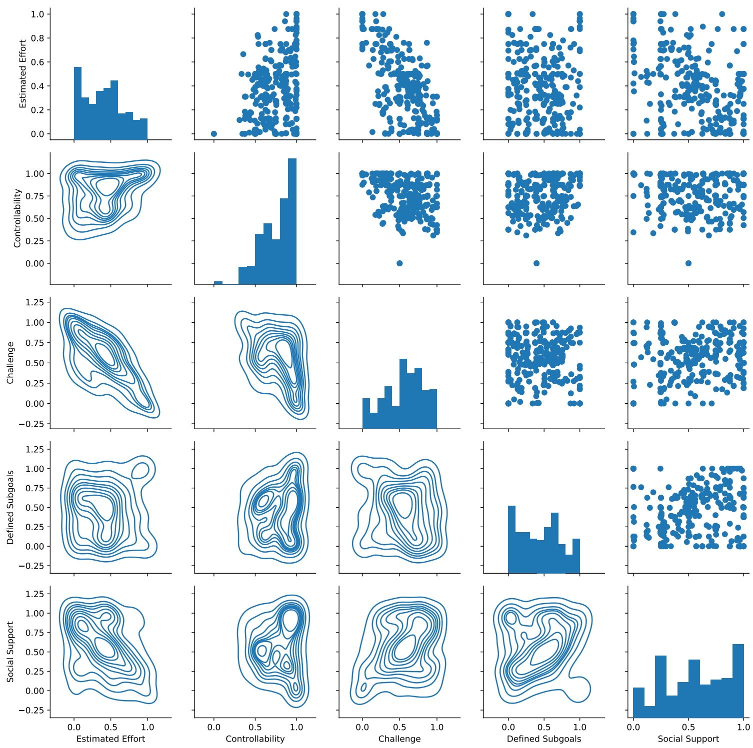

FIGURE F.92: Correlations and KDE for variable Estimated Effort matrix 4.

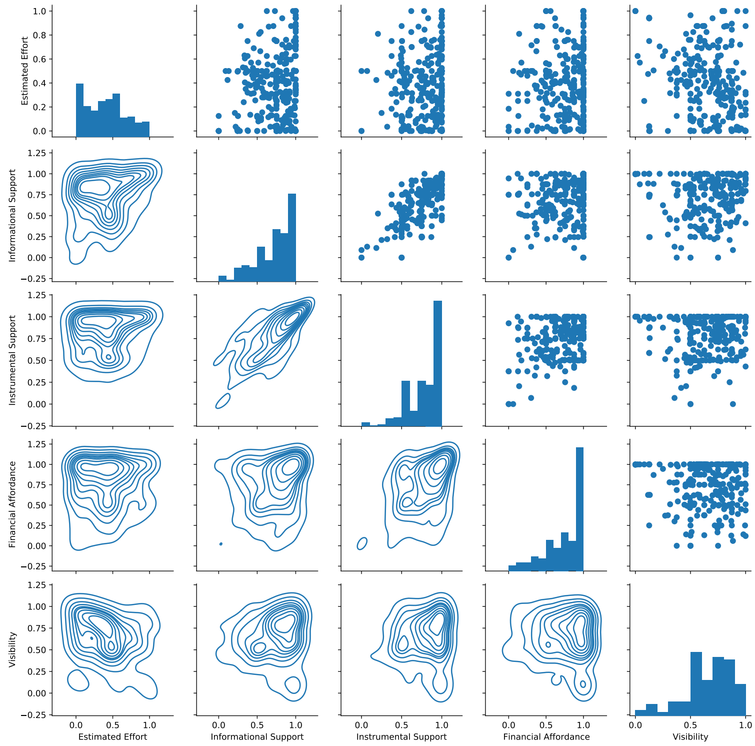

FIGURE F.93: Correlations and KDE for variable Estimated Effort matrix 5.

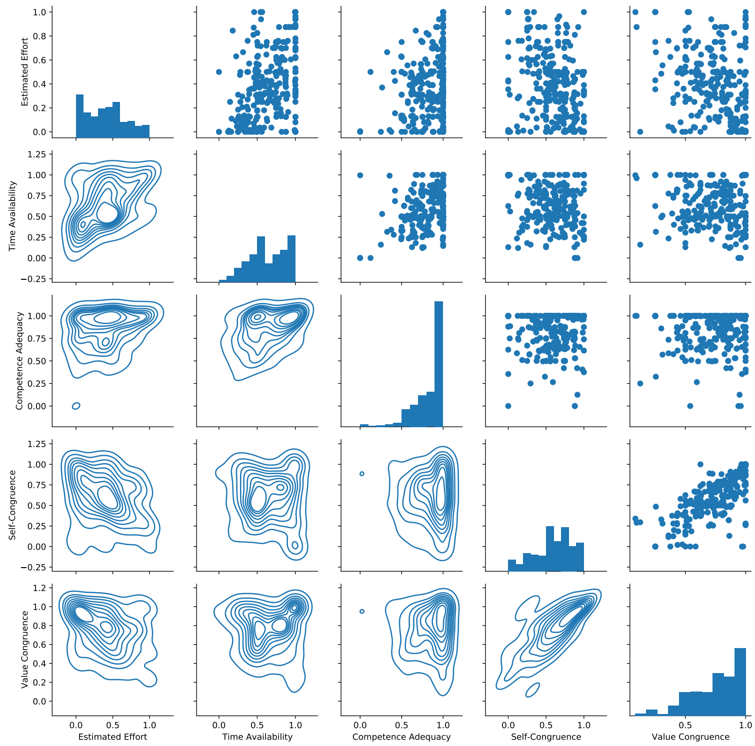

FIGURE F.94: Correlations and KDE for variable Estimated Effort matrix 6.

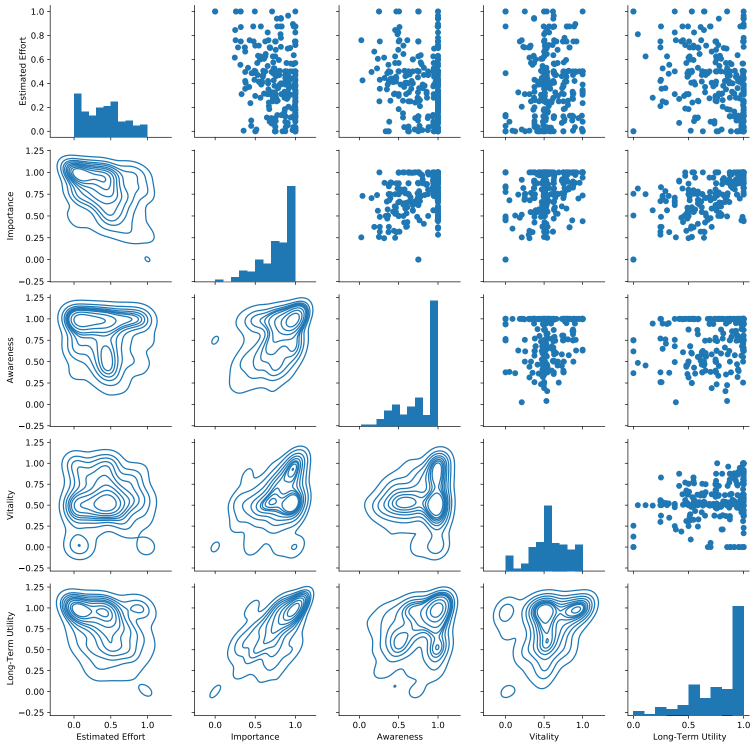

FIGURE F.95: Correlations and KDE for variable Estimated Effort matrix 7.

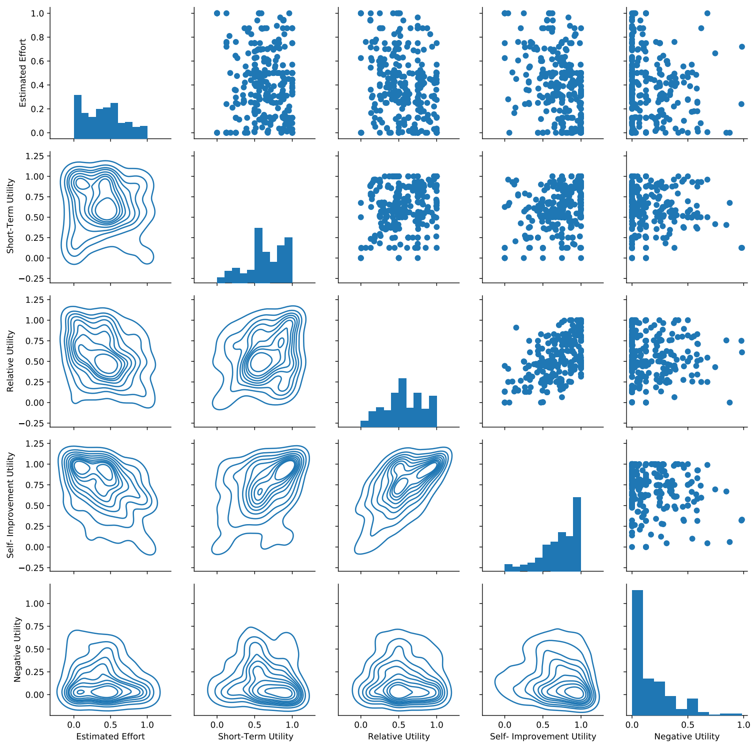

FIGURE F.96: Correlations and KDE for variable Estimated Effort matrix 8.

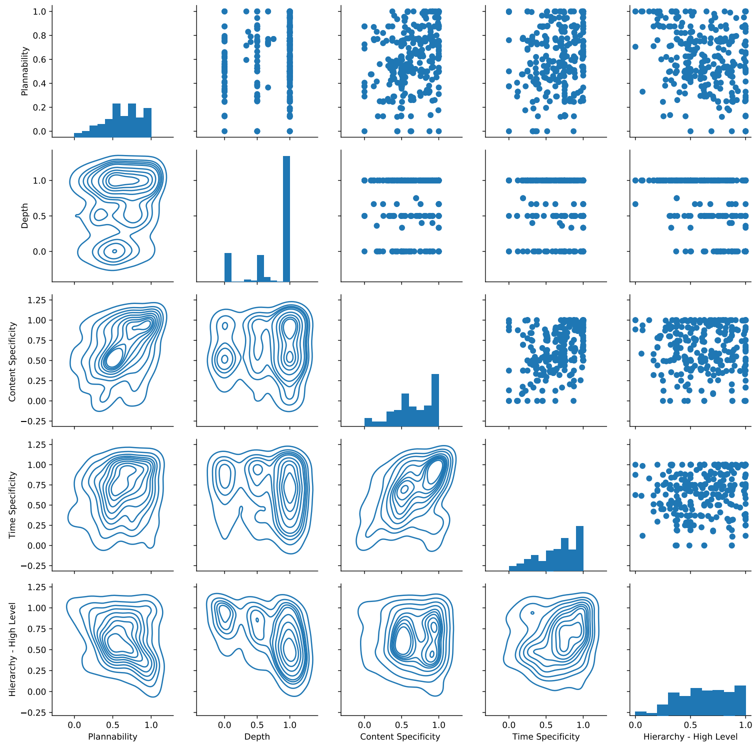

FIGURE F.97: Correlations and KDE for variable Plannability matrix 1.

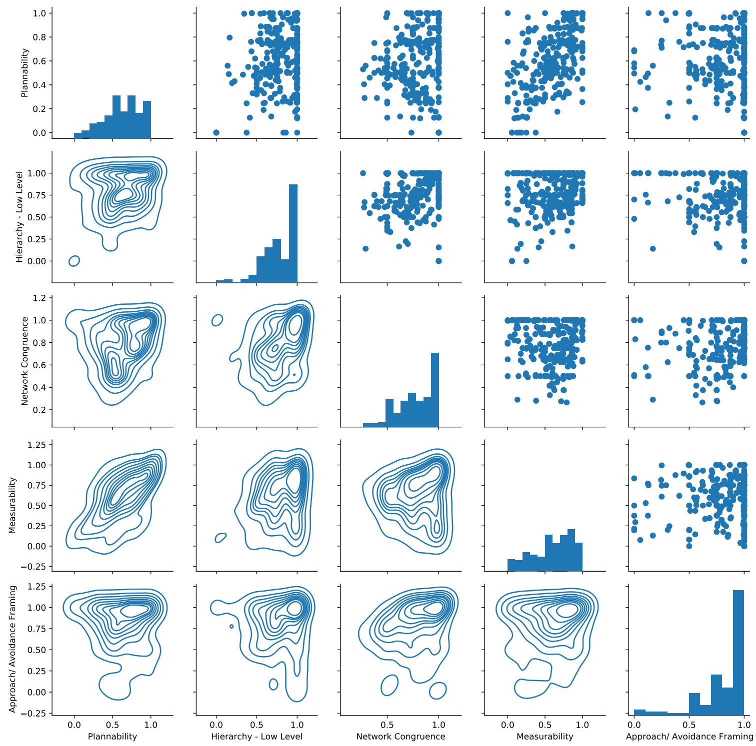

FIGURE F.98: Correlations and KDE for variable Plannability matrix 2.

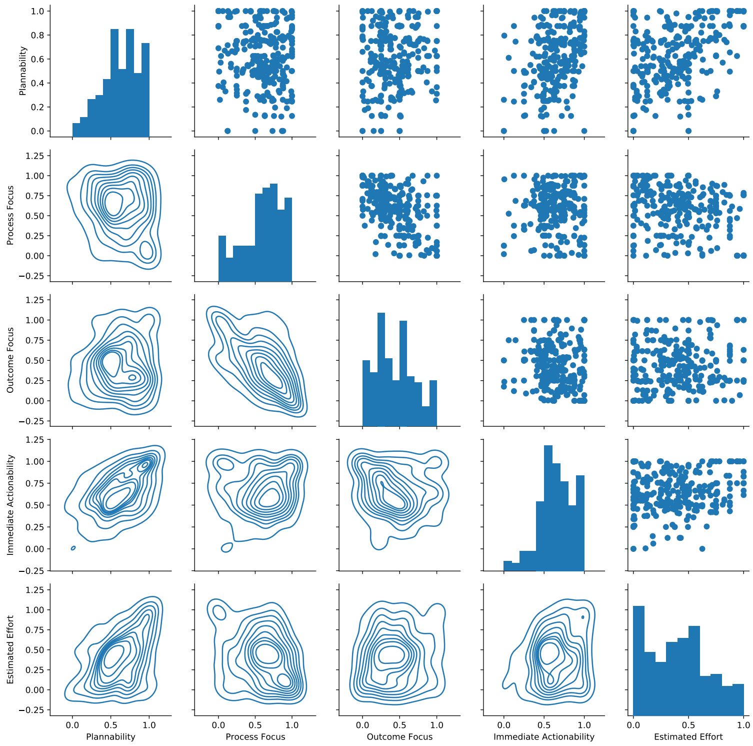

FIGURE F.99: Correlations and KDE for variable Plannability matrix 3.

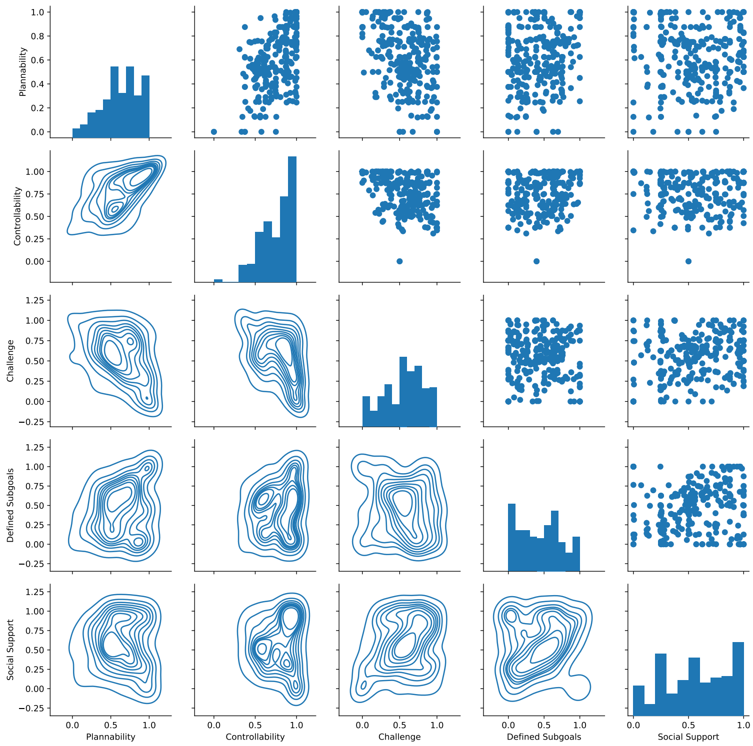

FIGURE F.100: Correlations and KDE for variable Plannability matrix 4.

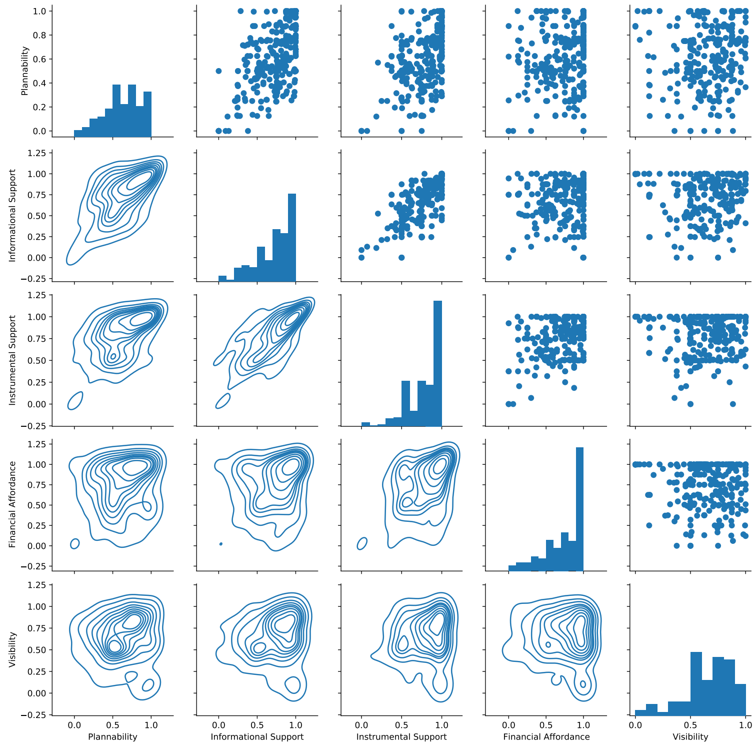

FIGURE F.101: Correlations and KDE for variable Plannability matrix 5.

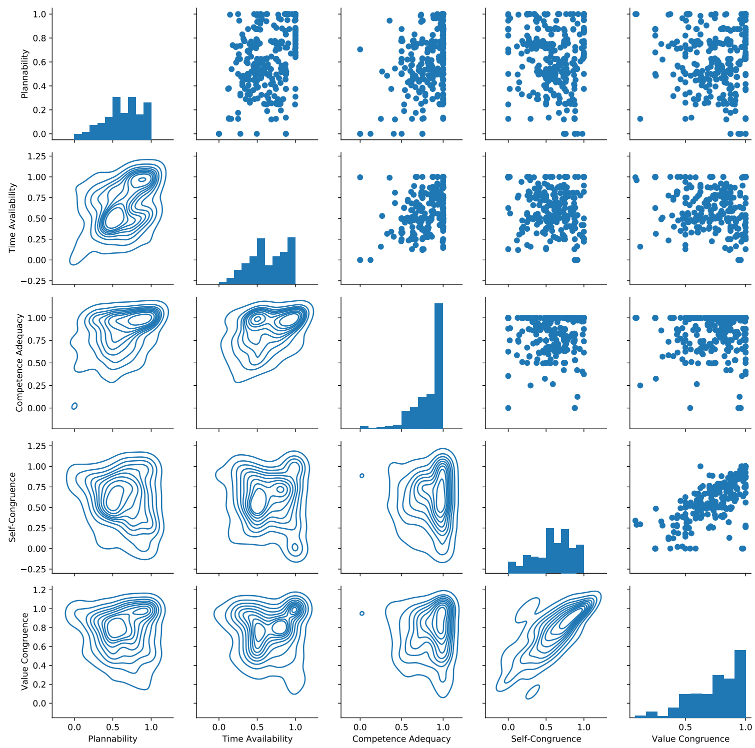

FIGURE F.102: Correlations and KDE for variable Plannability matrix 6.

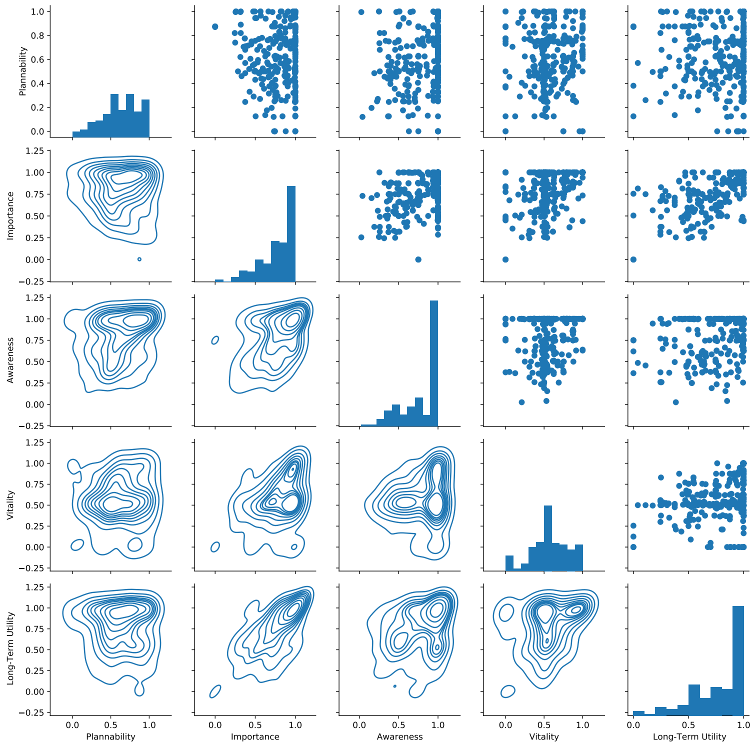

FIGURE F.103: Correlations and KDE for variable Plannability matrix 7.

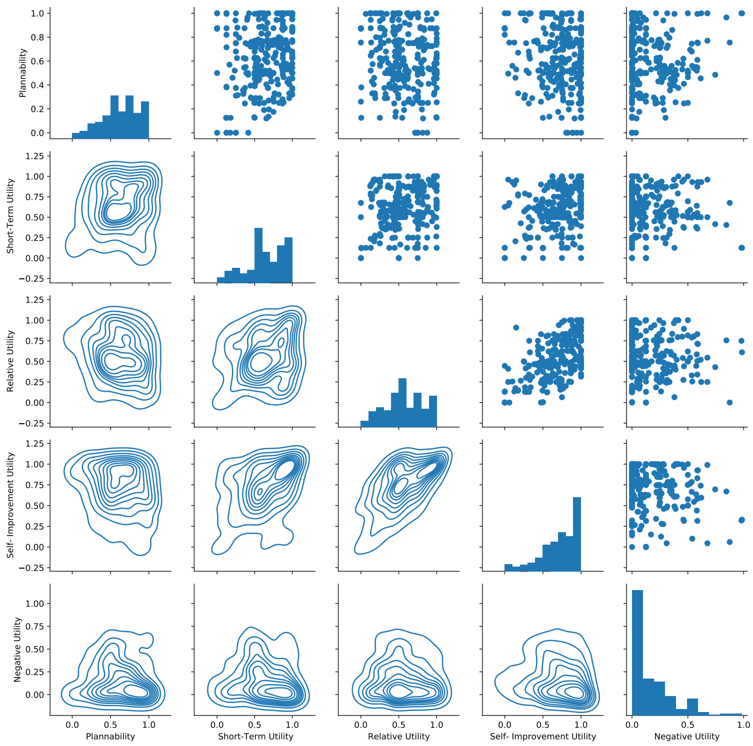

FIGURE F.104: Correlations and KDE for variable Plannability matrix 8.

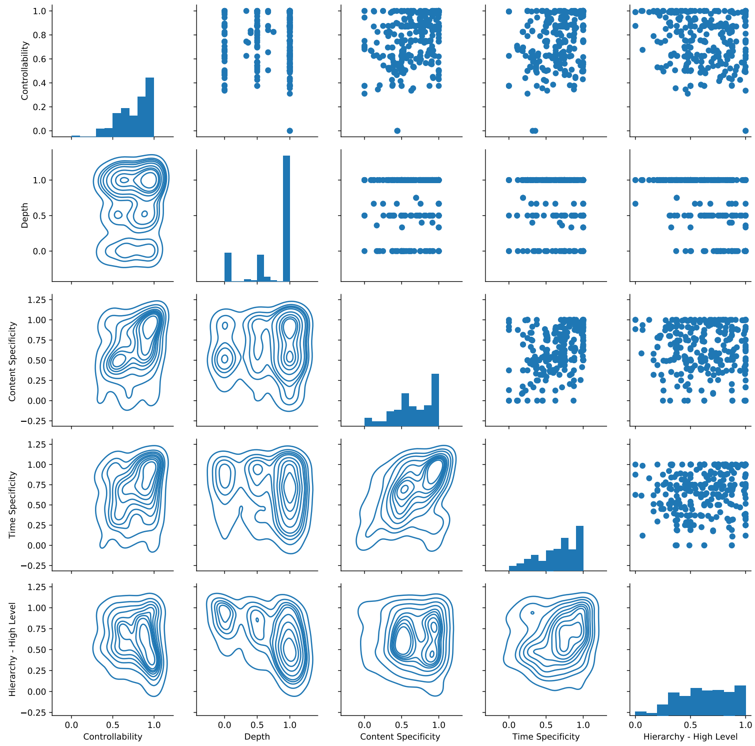

FIGURE F.105: Correlations and KDE for variable Controllability matrix 1.

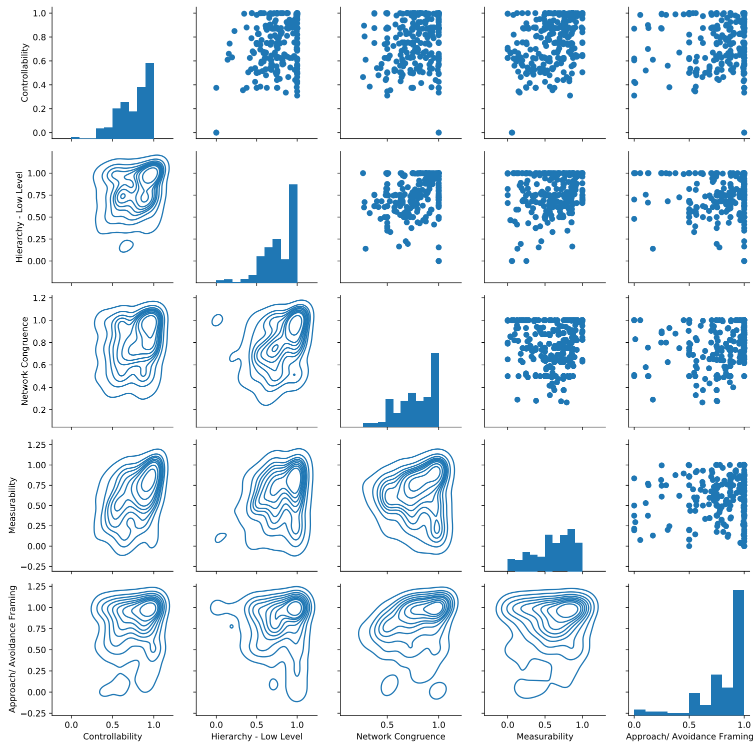

FIGURE F.106: Correlations and KDE for variable Controllability matrix 2.

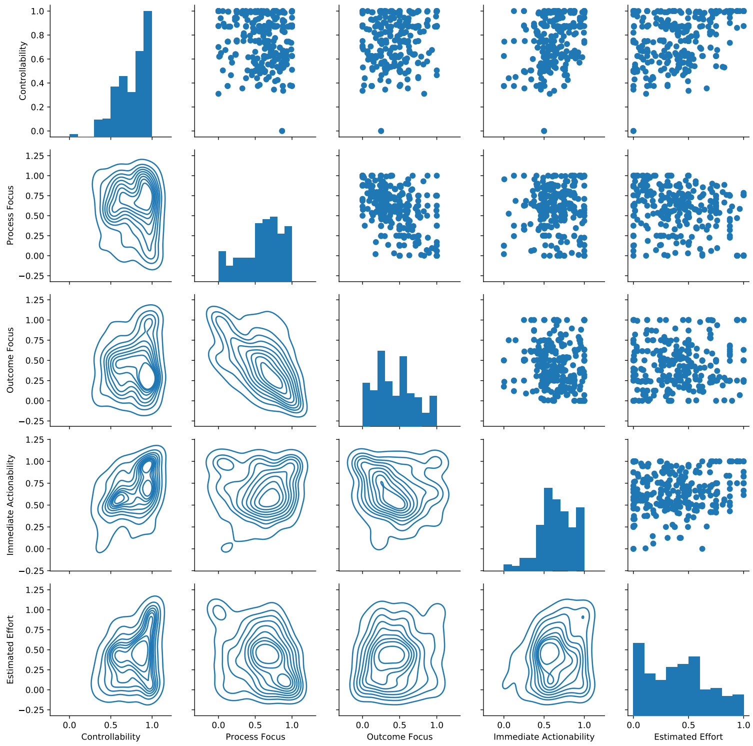

FIGURE F.107: Correlations and KDE for variable Controllability matrix 3.

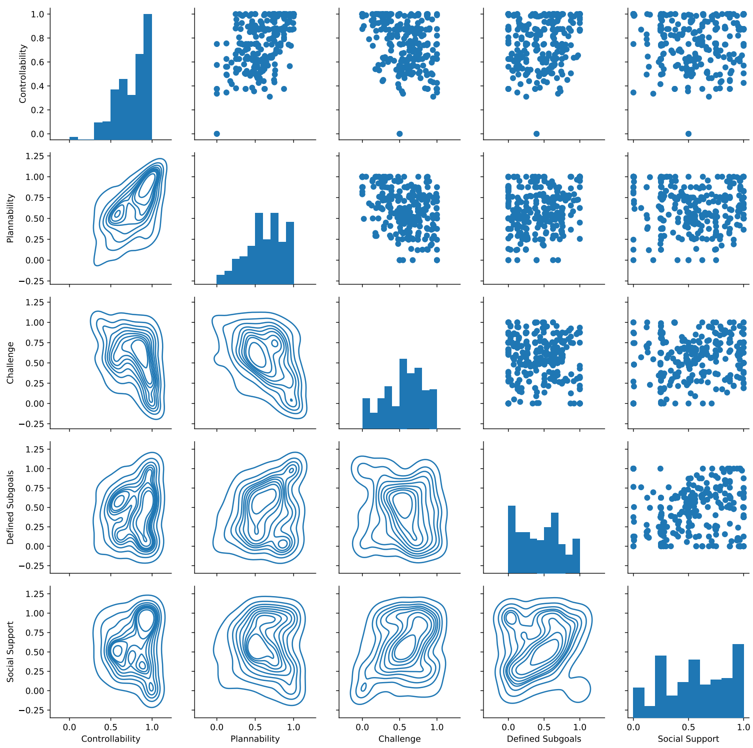

FIGURE F.108: Correlations and KDE for variable Controllability matrix 4.

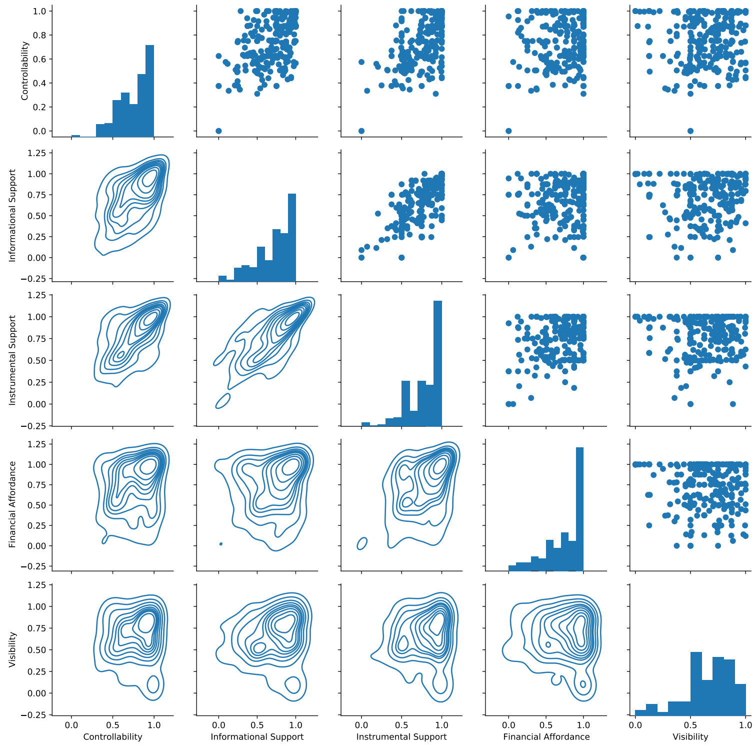

FIGURE F.109: Correlations and KDE for variable Controllability matrix 5.

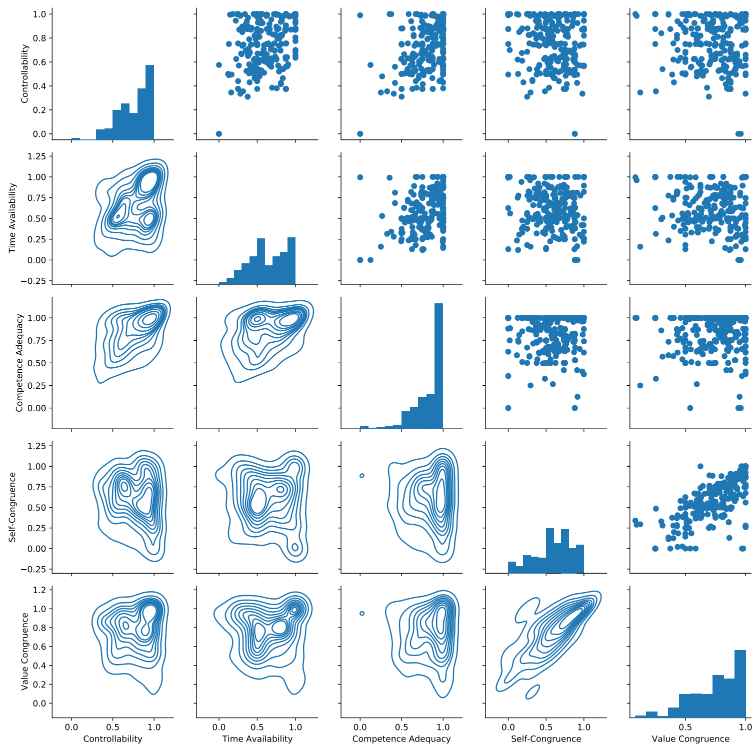

FIGURE F.110: Correlations and KDE for variable Controllability matrix 6.

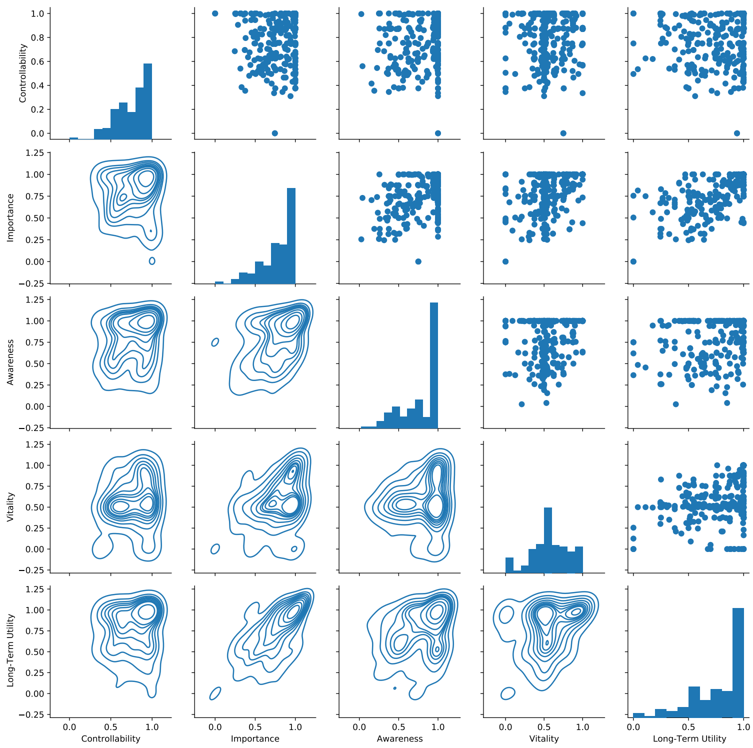

FIGURE F.111: Correlations and KDE for variable Controllability matrix 7.

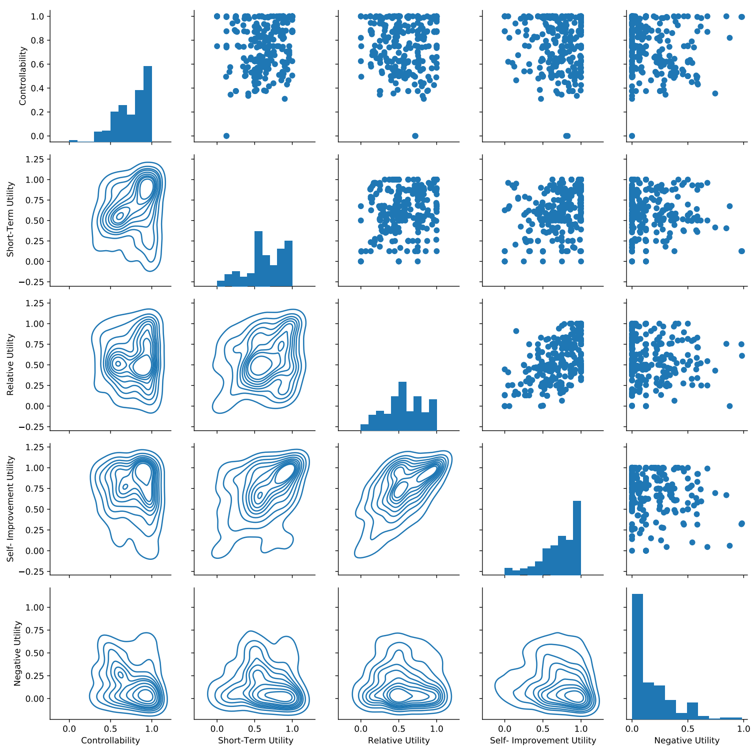

FIGURE F.112: Correlations and KDE for variable Controllability matrix 8.

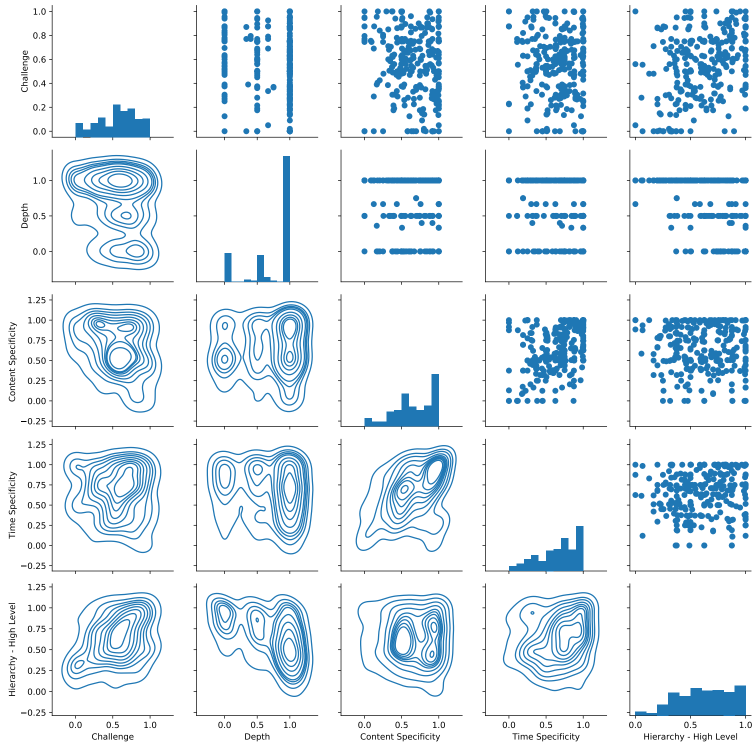

FIGURE F.113: Correlations and KDE for variable Challenge matrix 1.

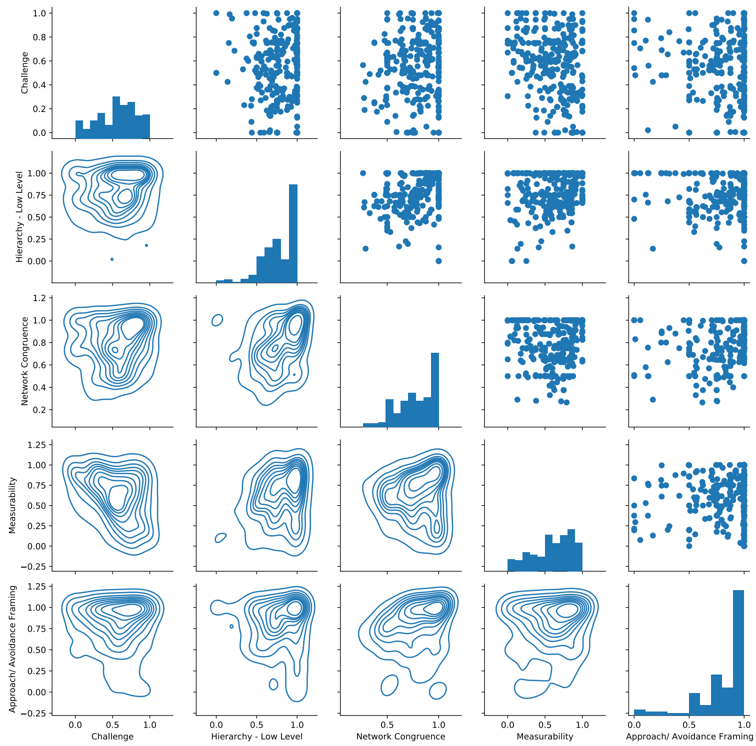

FIGURE F.114: Correlations and KDE for variable Challenge matrix 2.

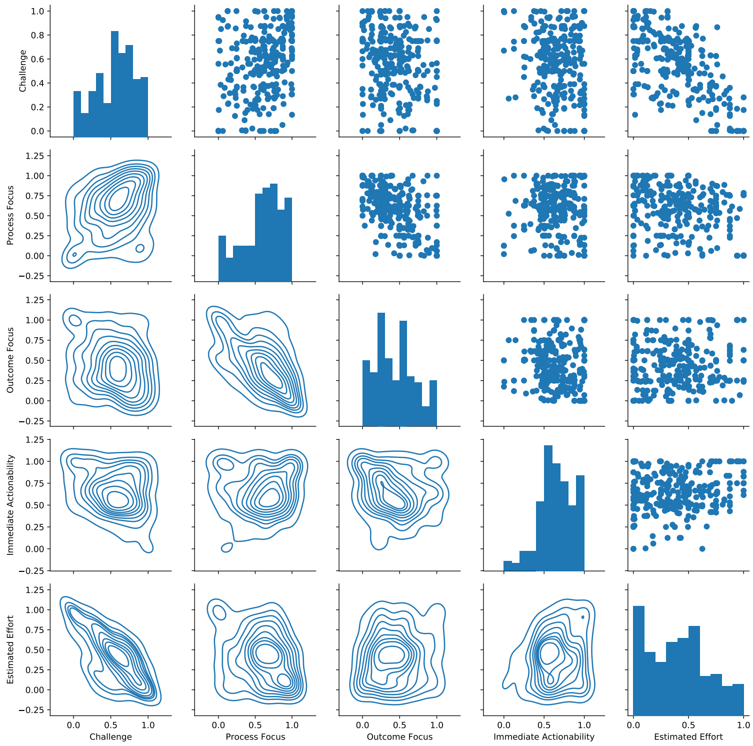

FIGURE F.115: Correlations and KDE for variable Challenge matrix 3.

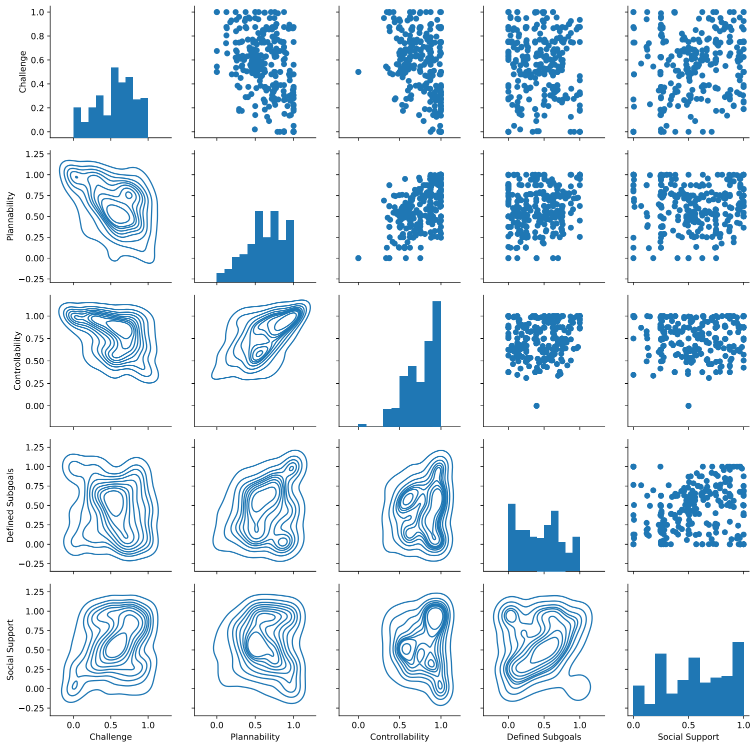

FIGURE F.116: Correlations and KDE for variable Challenge matrix 4.

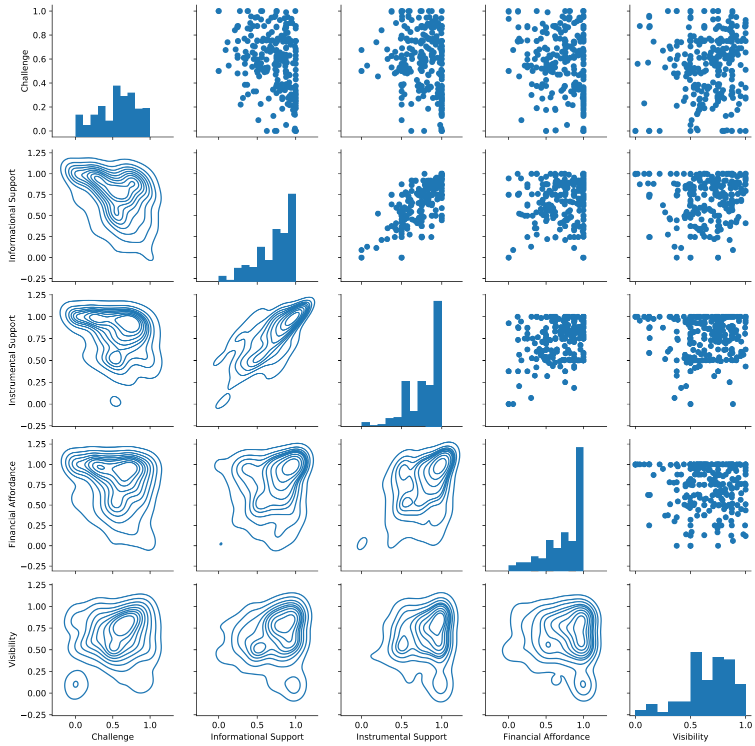

FIGURE F.117: Correlations and KDE for variable Challenge matrix 5.

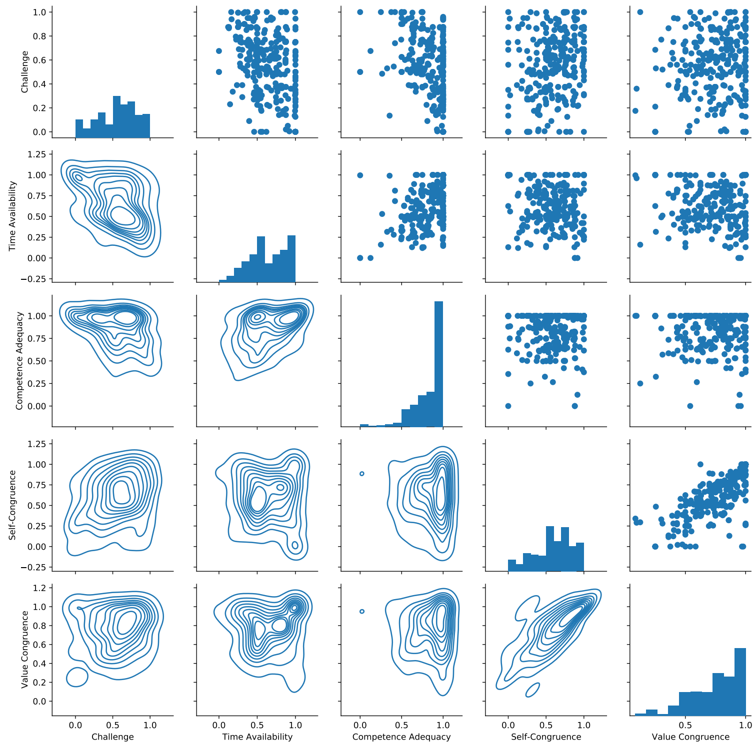

FIGURE F.118: Correlations and KDE for variable Challenge matrix 6.

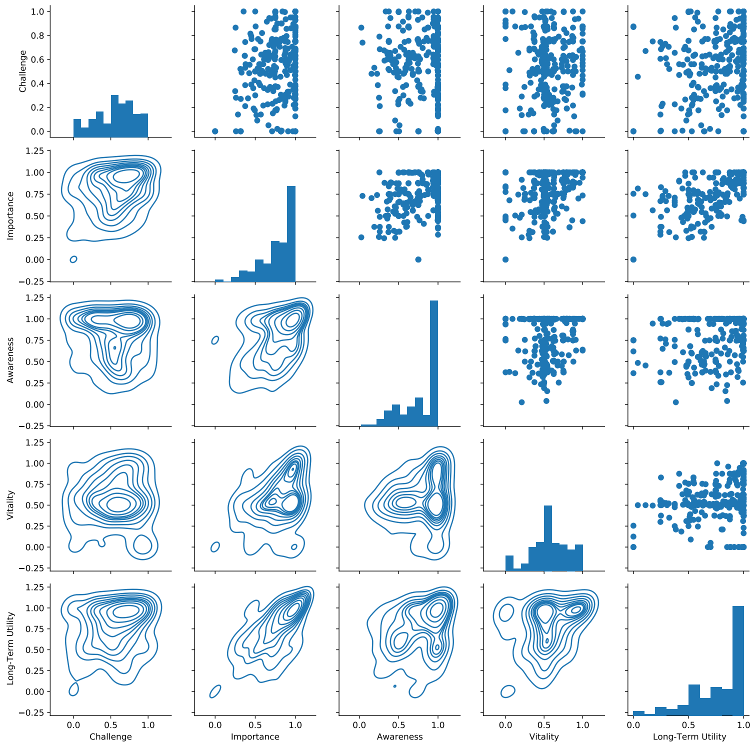

FIGURE F.119: Correlations and KDE for variable Challenge matrix 7.

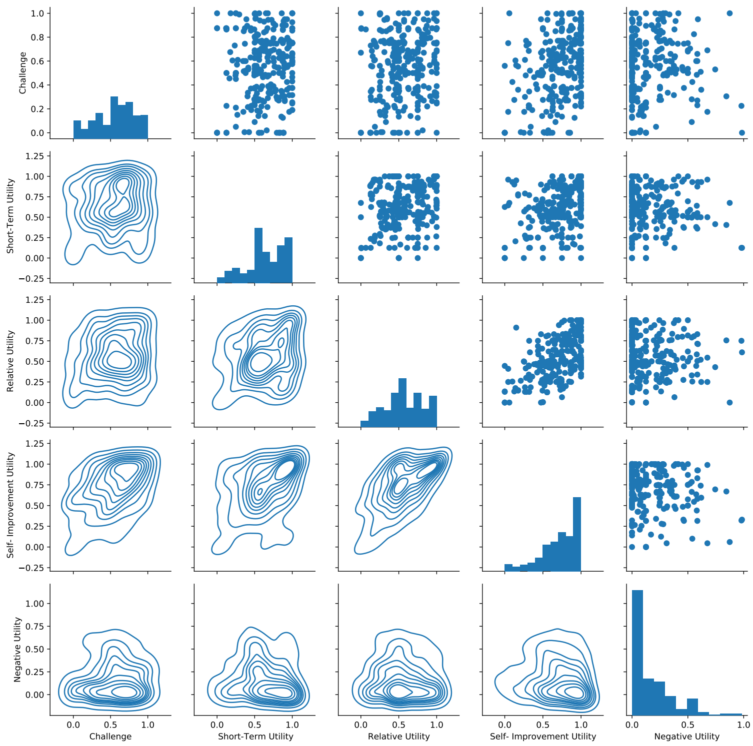

FIGURE F.120: Correlations and KDE for variable Challenge matrix 8.

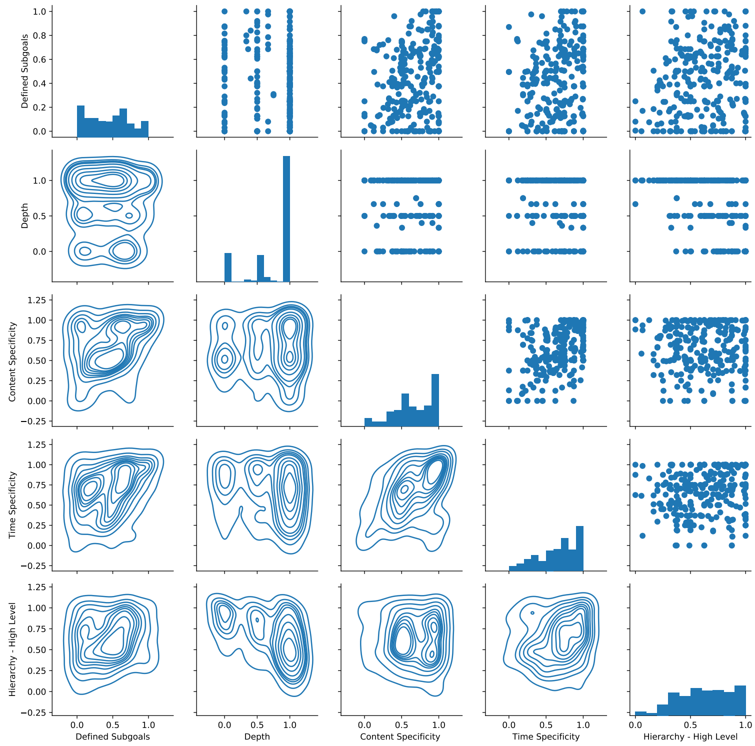

FIGURE F.121: Correlations and KDE for variable Defined Subgoals matrix 1.

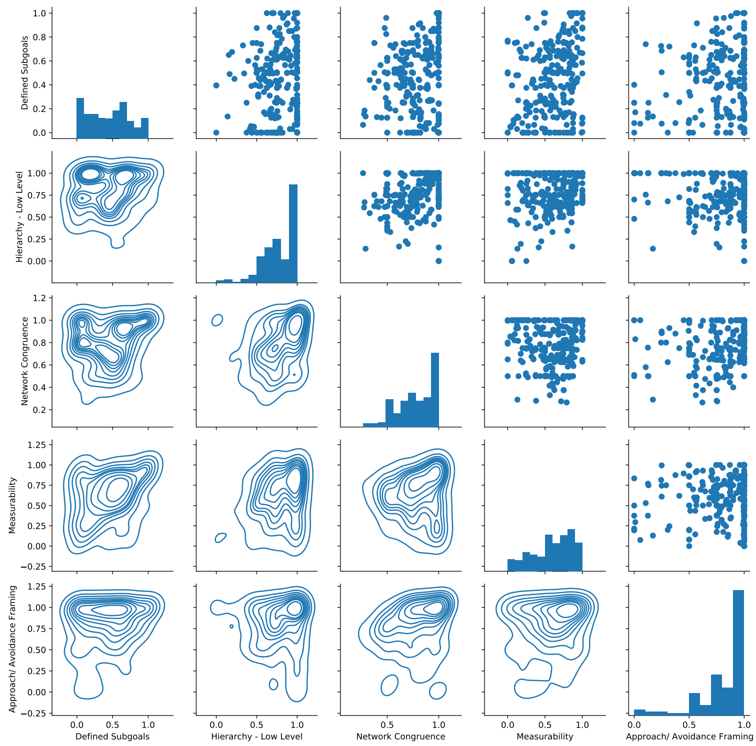

FIGURE F.122: Correlations and KDE for variable Defined Subgoals matrix 2.

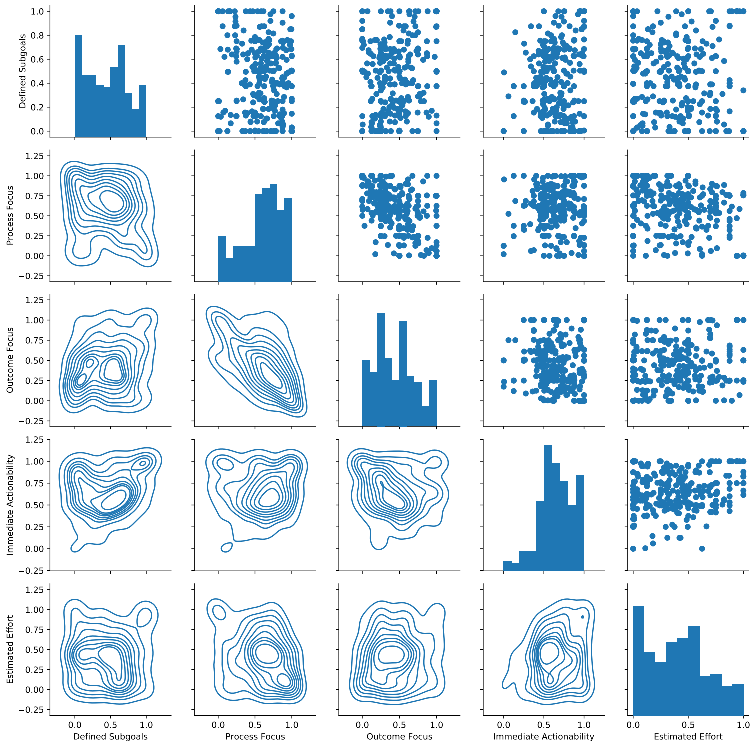

FIGURE F.123: Correlations and KDE for variable Defined Subgoals matrix 3.

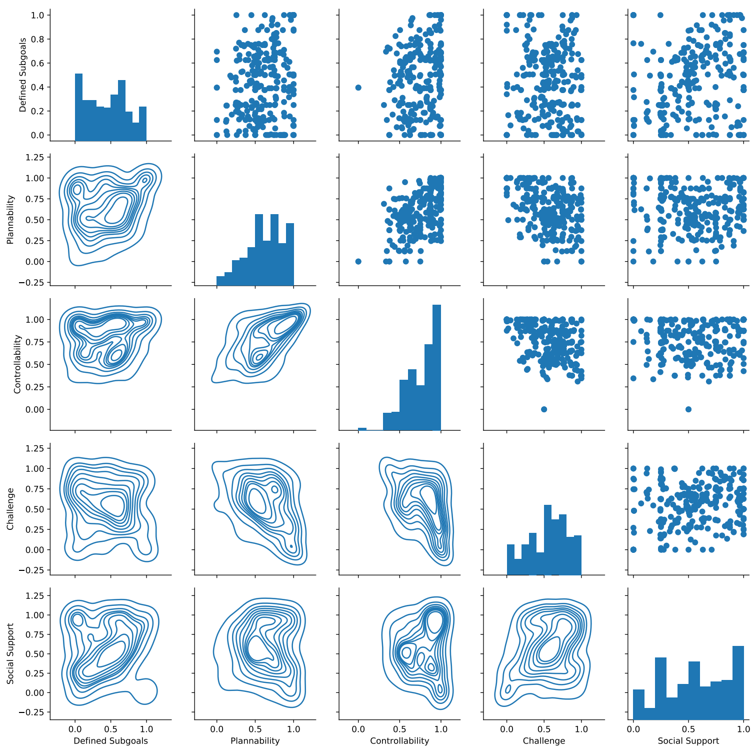

FIGURE F.124: Correlations and KDE for variable Defined Subgoals matrix 4.

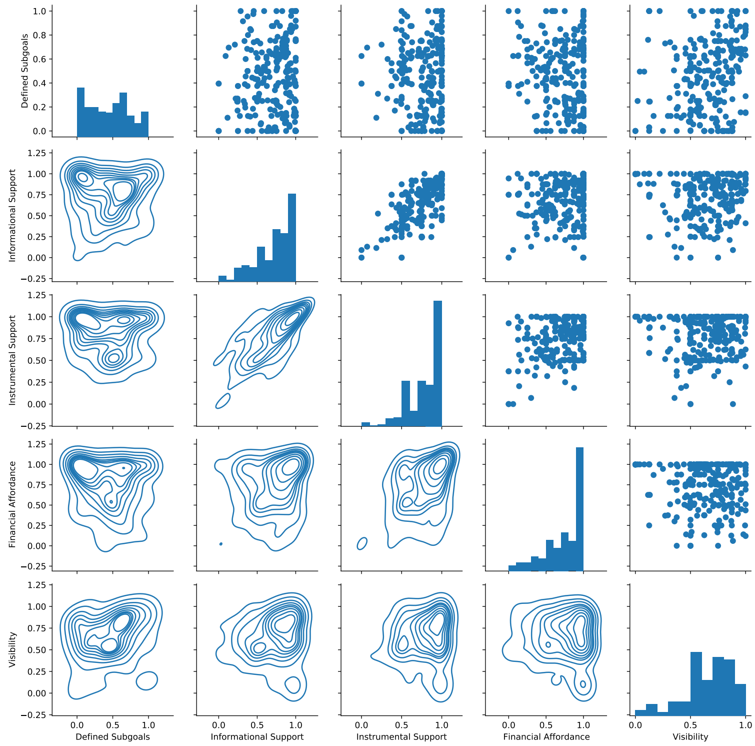

FIGURE F.125: Correlations and KDE for variable Defined Subgoals matrix 5.

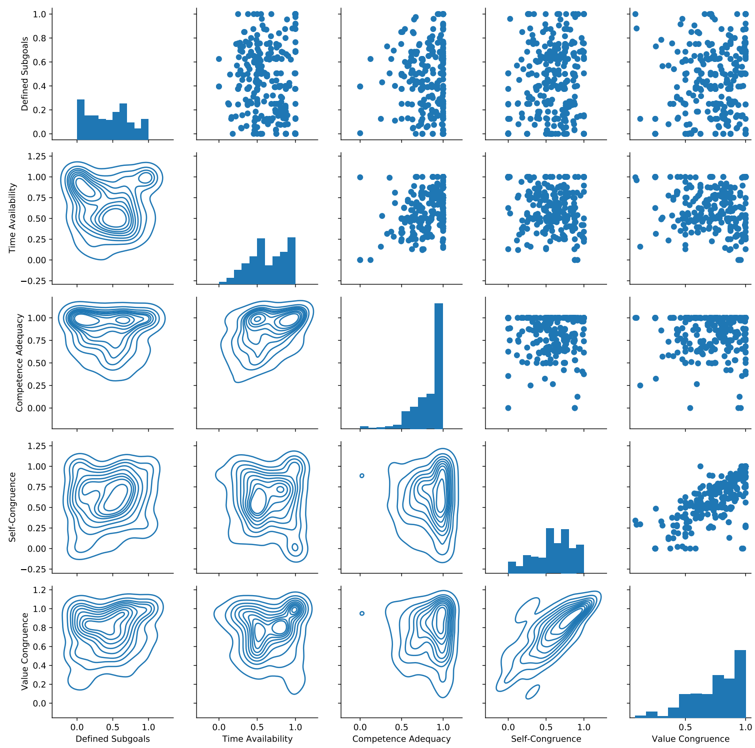

FIGURE F.126: Correlations and KDE for variable Defined Subgoals matrix 6.

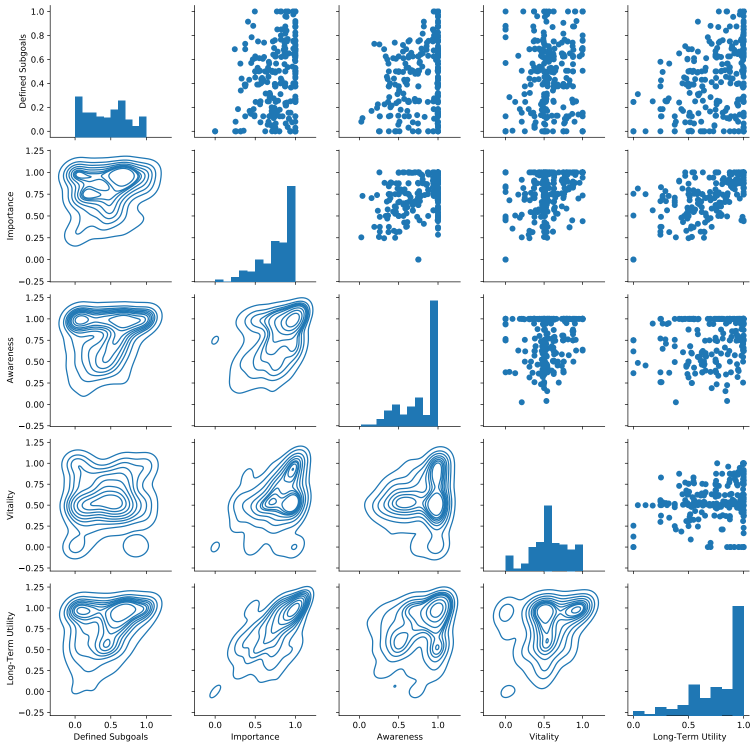

FIGURE F.127: Correlations and KDE for variable Defined Subgoals matrix 7.

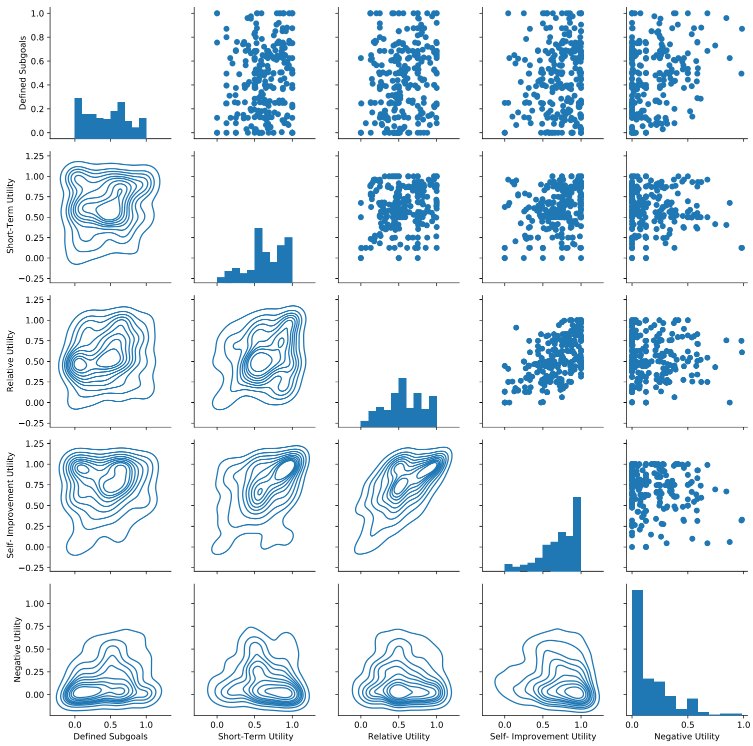

FIGURE F.128: Correlations and KDE for variable Defined Subgoals matrix 8.

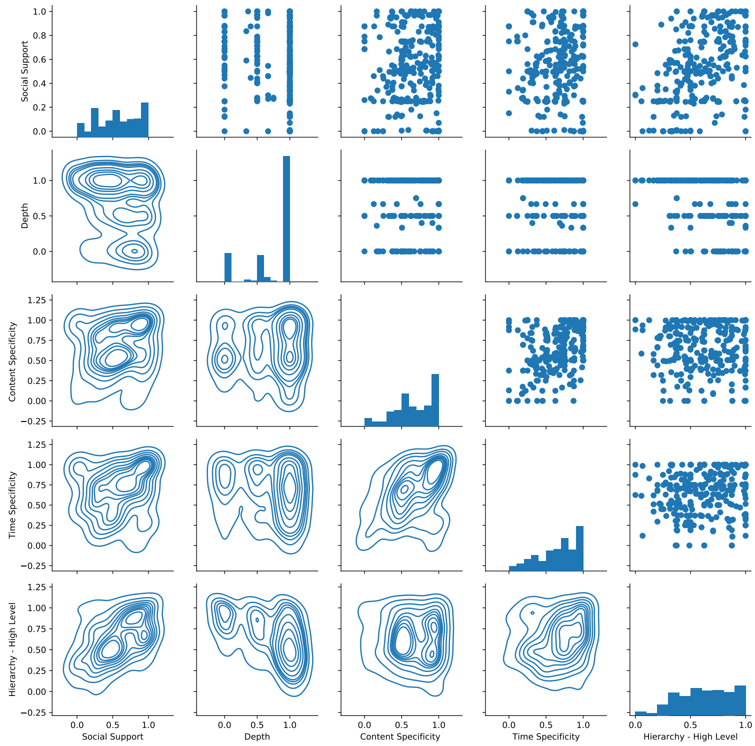

FIGURE F.129: Correlations and KDE for variable Social Support matrix 1.

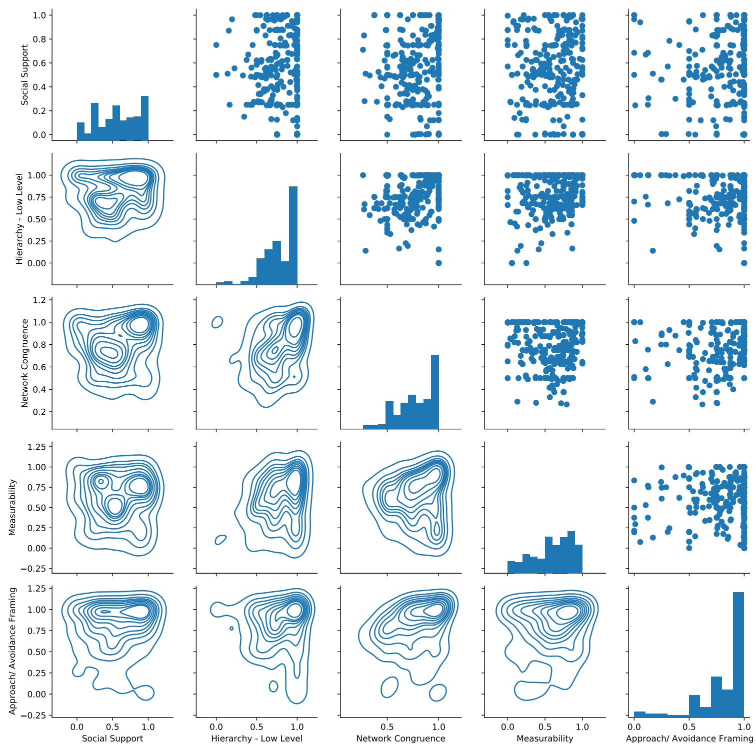

FIGURE F.130: Correlations and KDE for variable Social Support matrix 2.

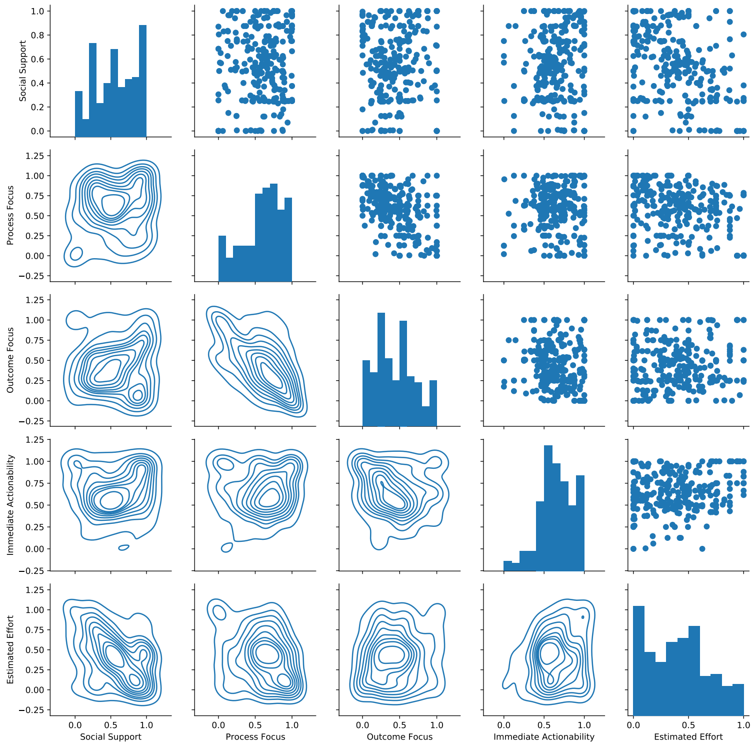

FIGURE F.131: Correlations and KDE for variable Social Support matrix 3.

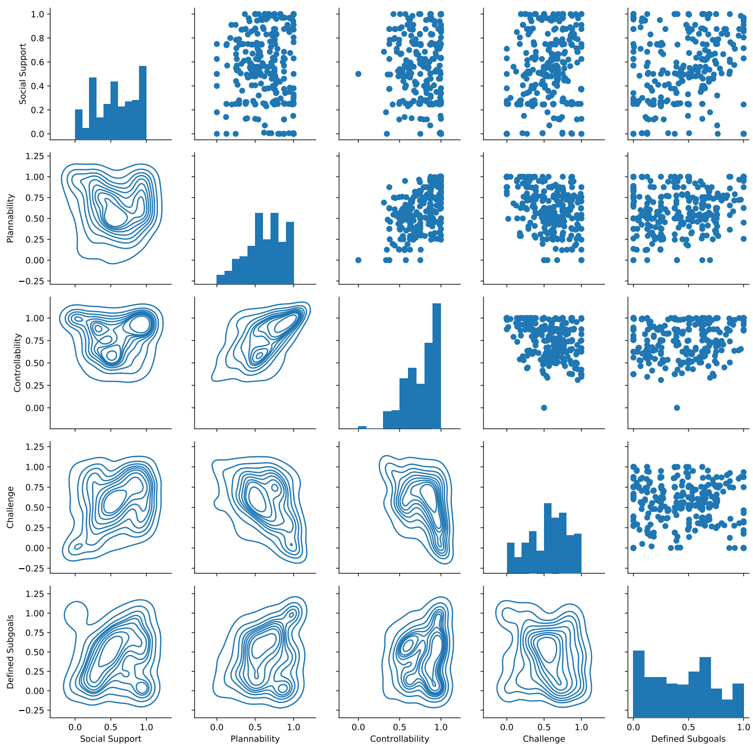

FIGURE F.132: Correlations and KDE for variable Social Support matrix 4.

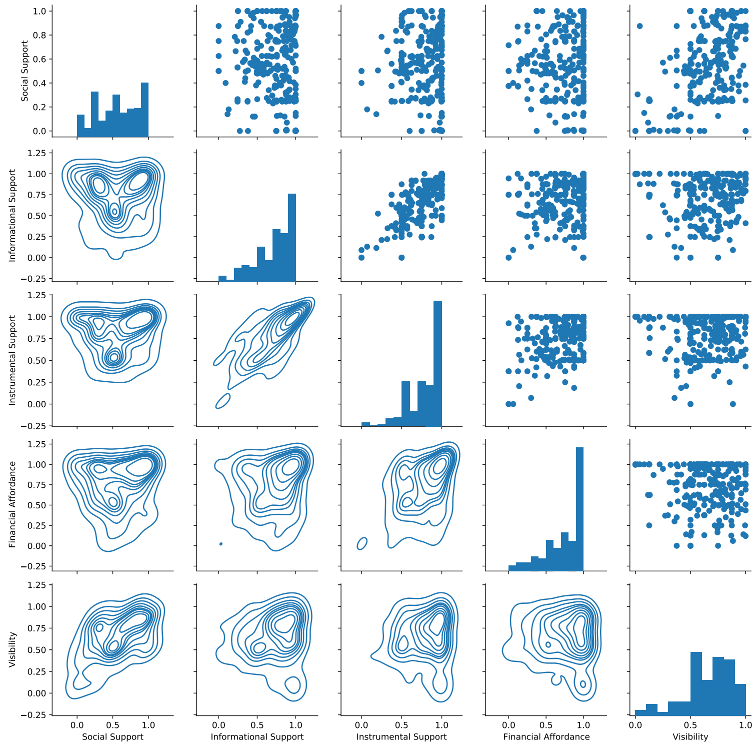

FIGURE F.133: Correlations and KDE for variable Social Support matrix 5.

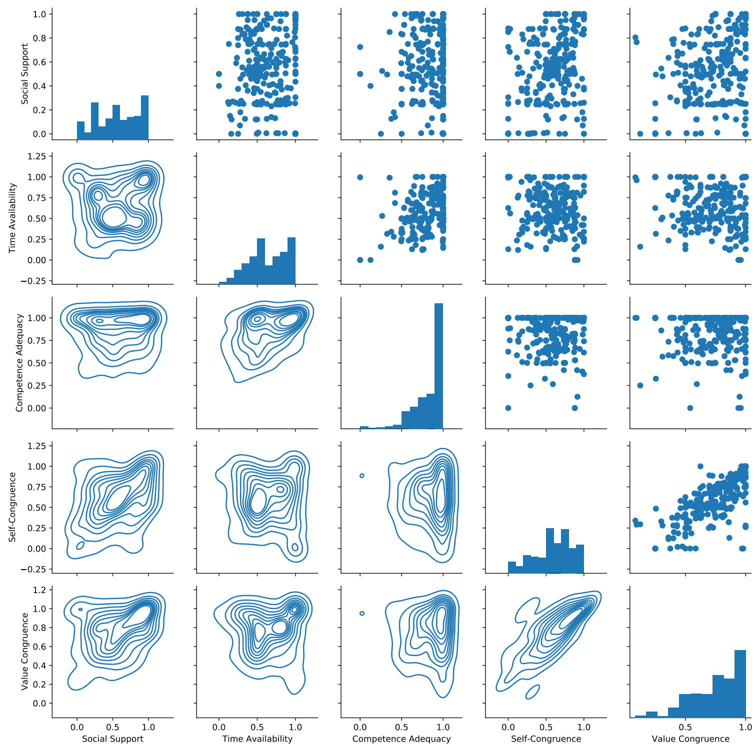

FIGURE F.134: Correlations and KDE for variable Social Support matrix 6.

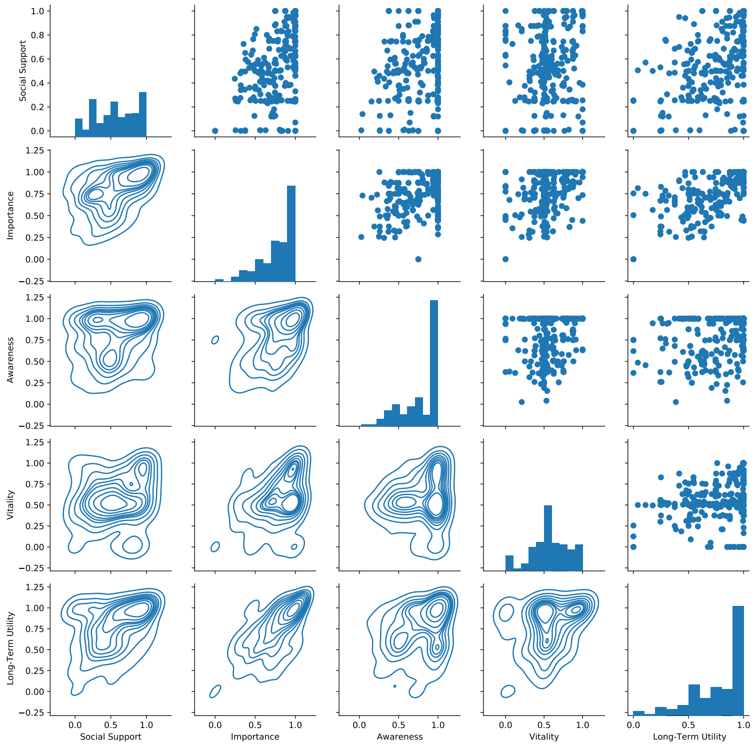

FIGURE F.135: Correlations and KDE for variable Social Support matrix 7.

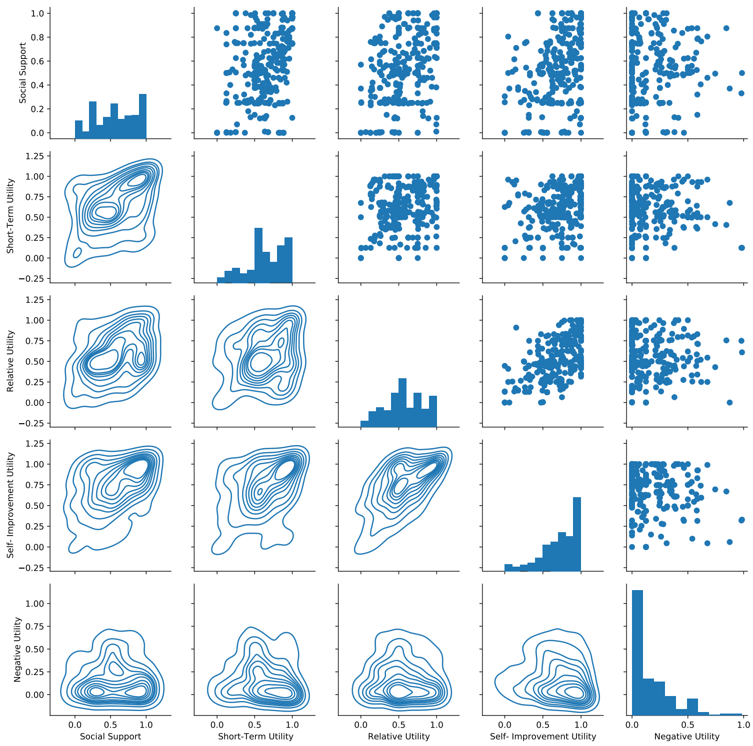

FIGURE F.136: Correlations and KDE for variable Social Support matrix 8.

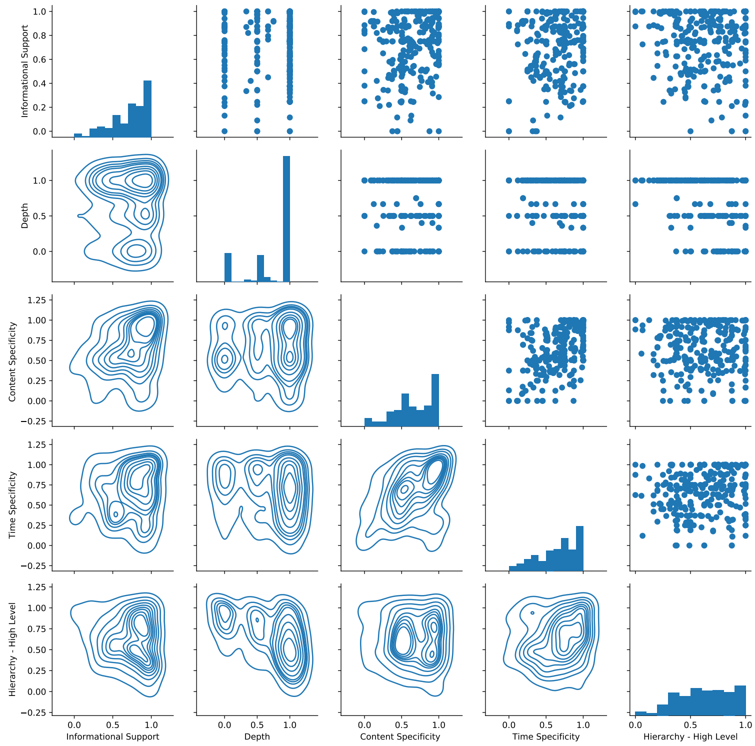

FIGURE F.137: Correlations and KDE for variable Informational Support matrix 1.

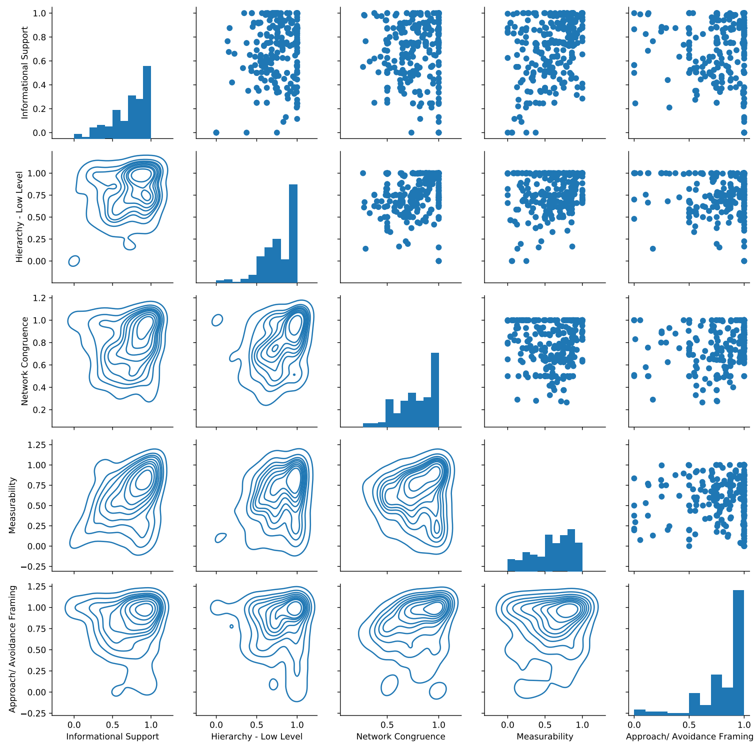

FIGURE F.138: Correlations and KDE for variable Informational Support matrix 2.

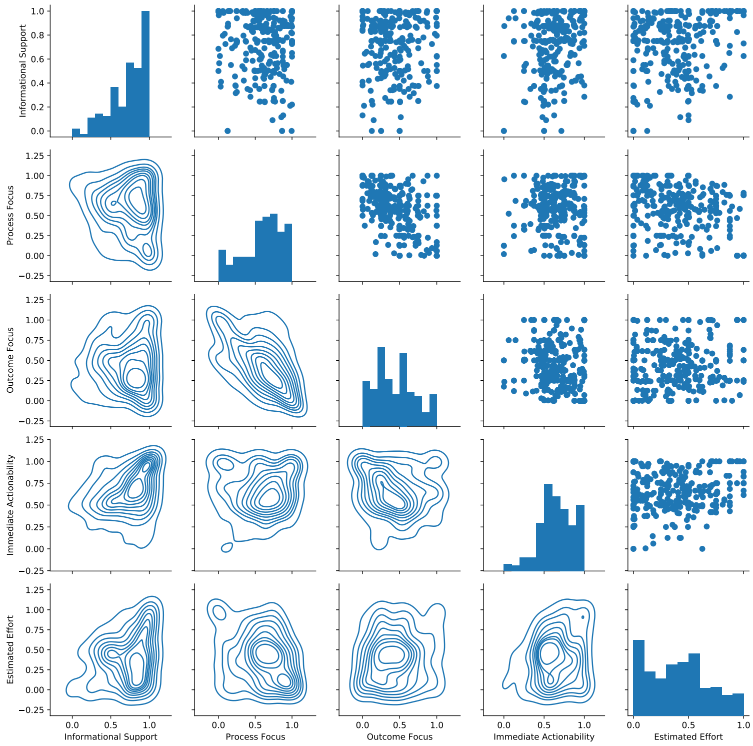

FIGURE F.139: Correlations and KDE for variable Informational Support matrix 3.

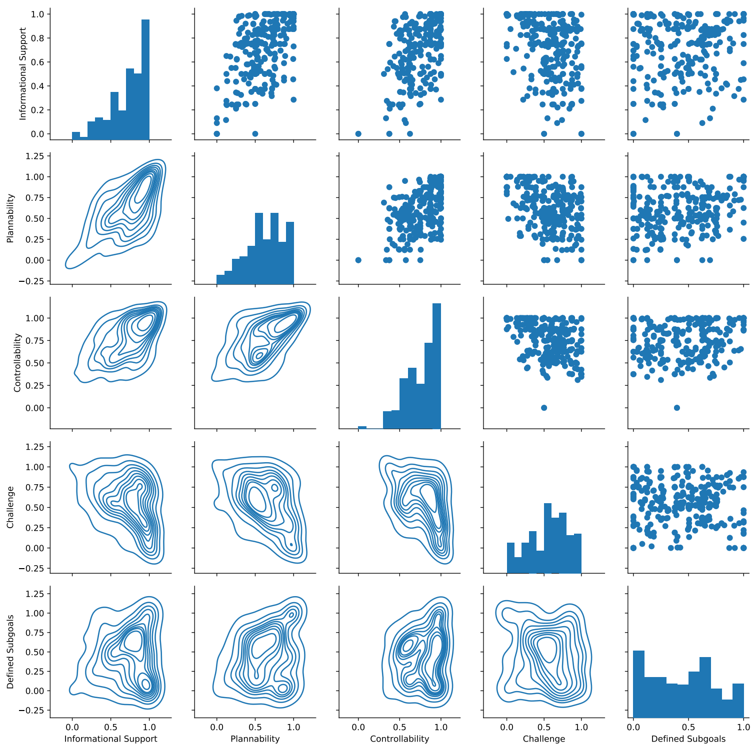

FIGURE F.140: Correlations and KDE for variable Informational Support matrix 4.

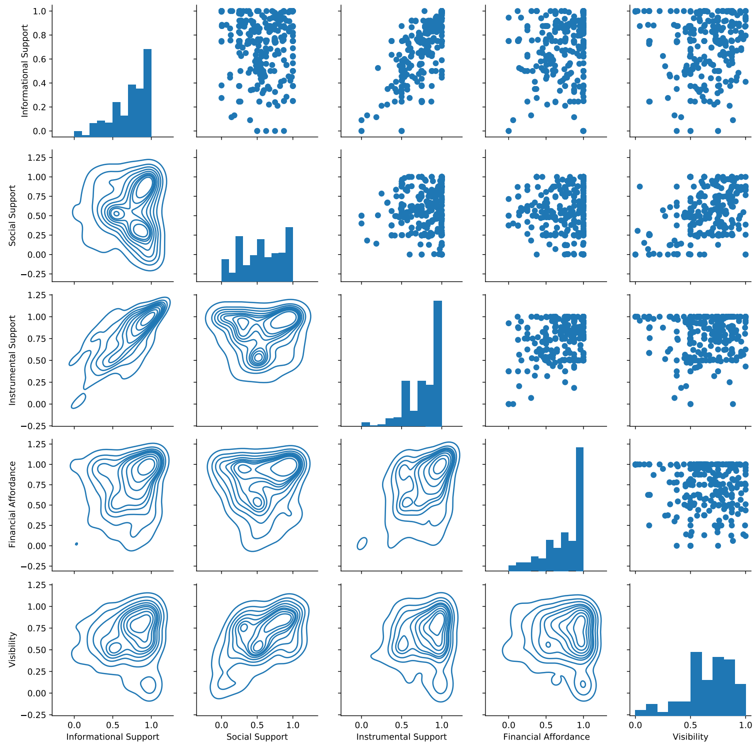

FIGURE F.141: Correlations and KDE for variable Informational Support matrix 5.

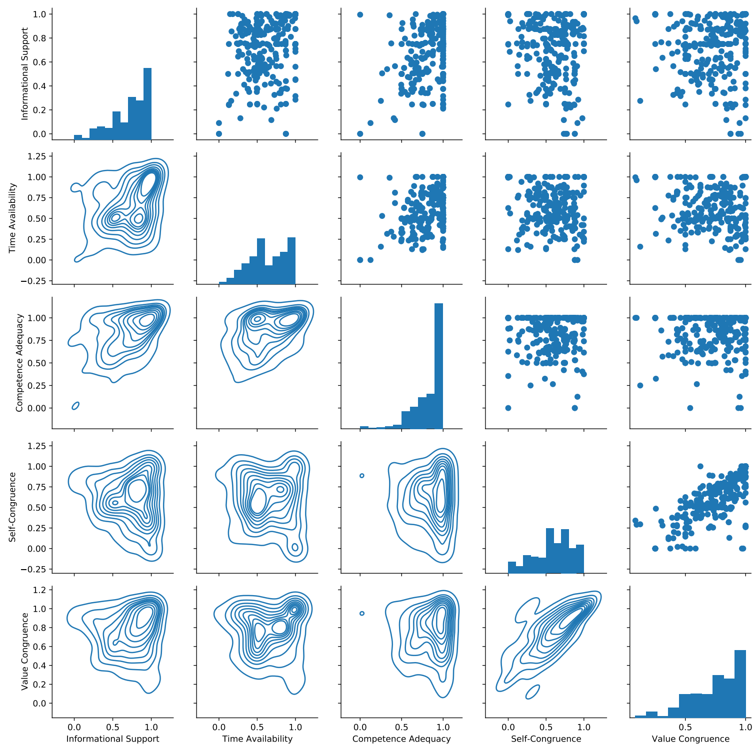

FIGURE F.142: Correlations and KDE for variable Informational Support matrix 6.

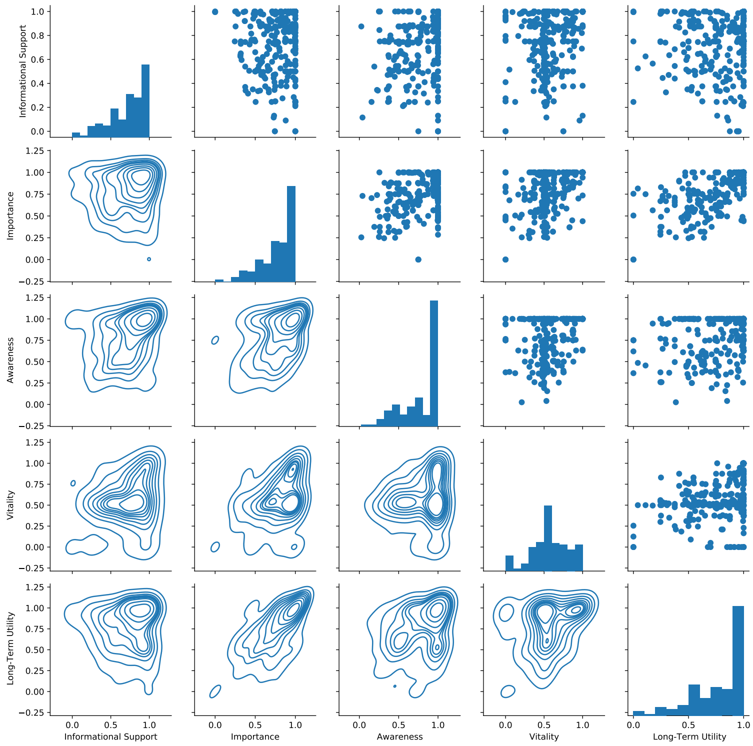

FIGURE F.143: Correlations and KDE for variable Informational Support matrix 7.

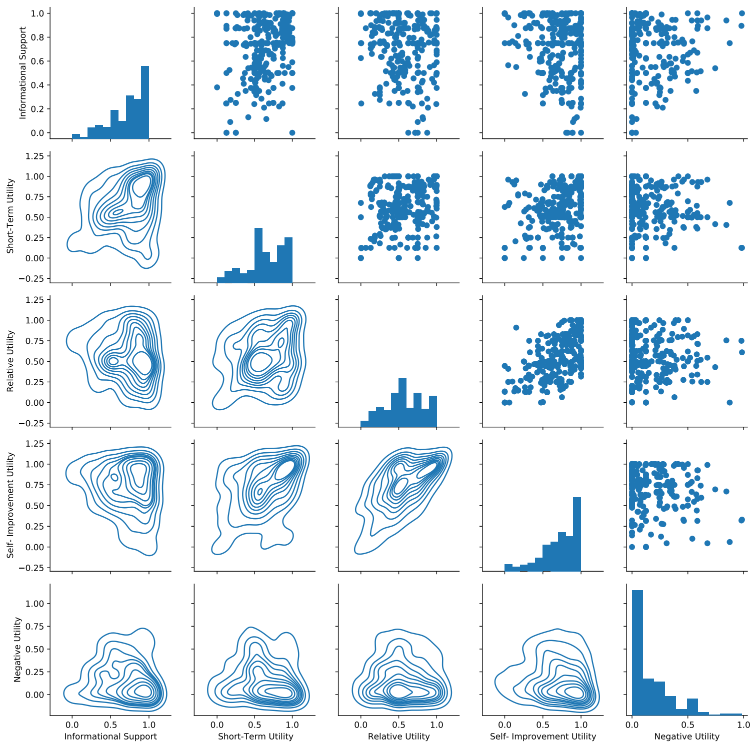

FIGURE F.144: Correlations and KDE for variable Informational Support matrix 8.

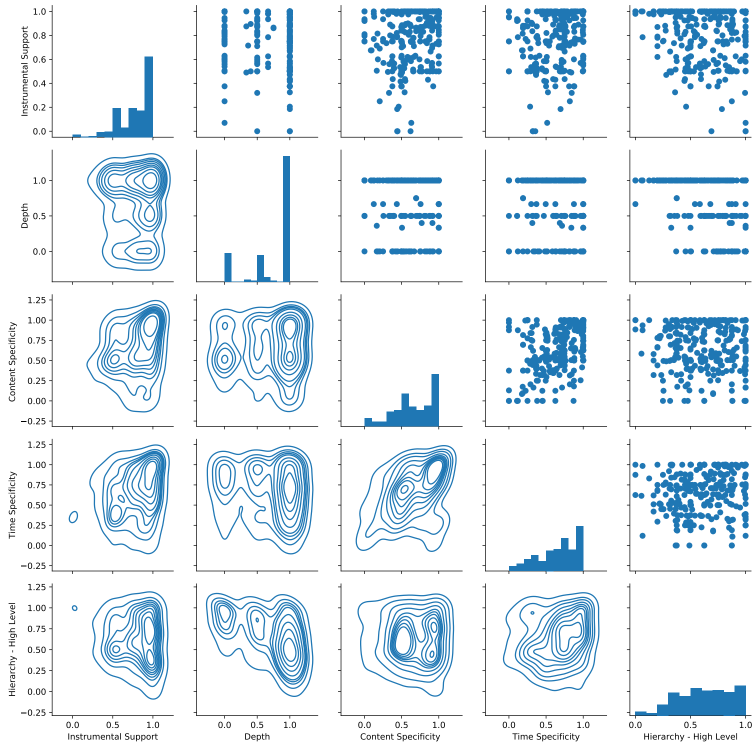

FIGURE F.145: Correlations and KDE for variable Instrumental Support matrix 1.

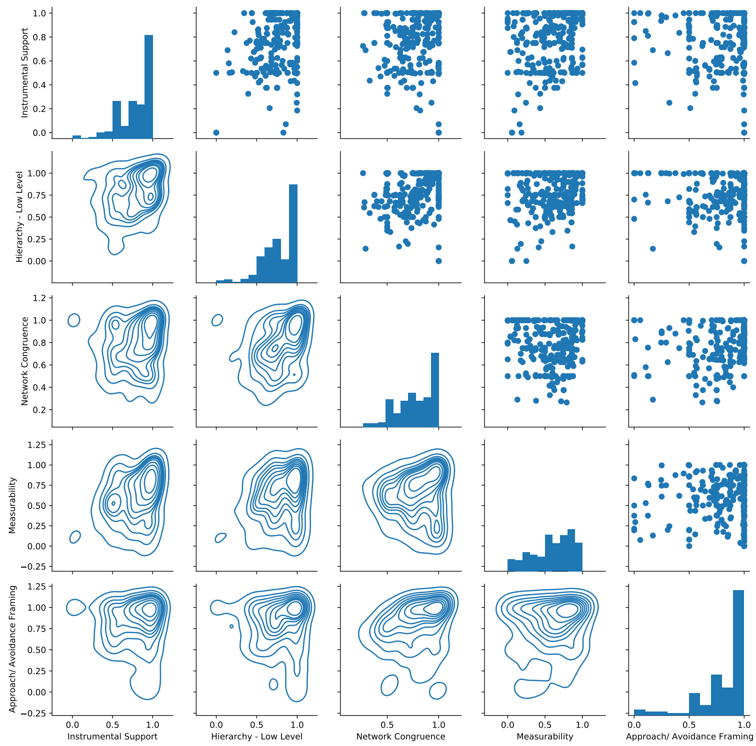

FIGURE F.146: Correlations and KDE for variable Instrumental Support matrix 2.

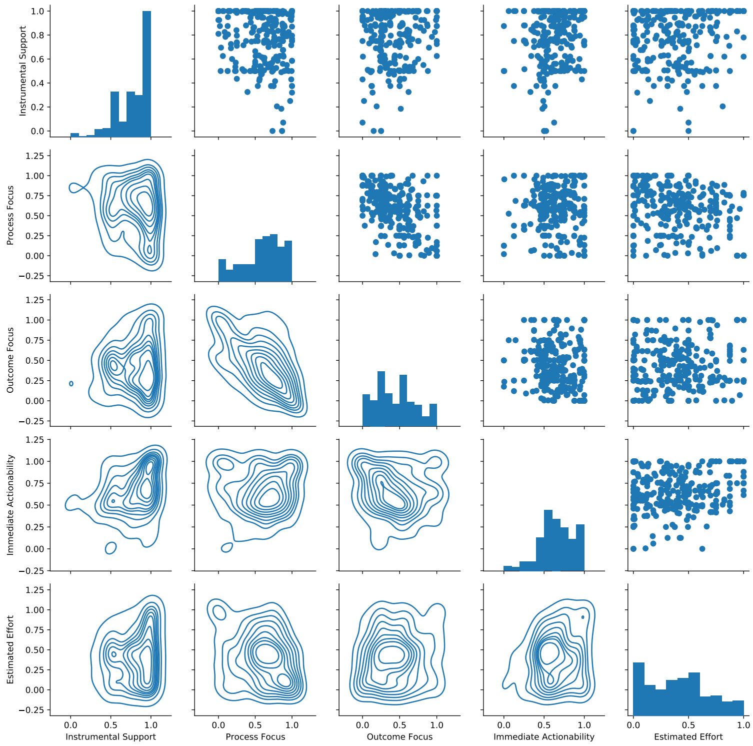

FIGURE F.147: Correlations and KDE for variable Instrumental Support matrix 3.

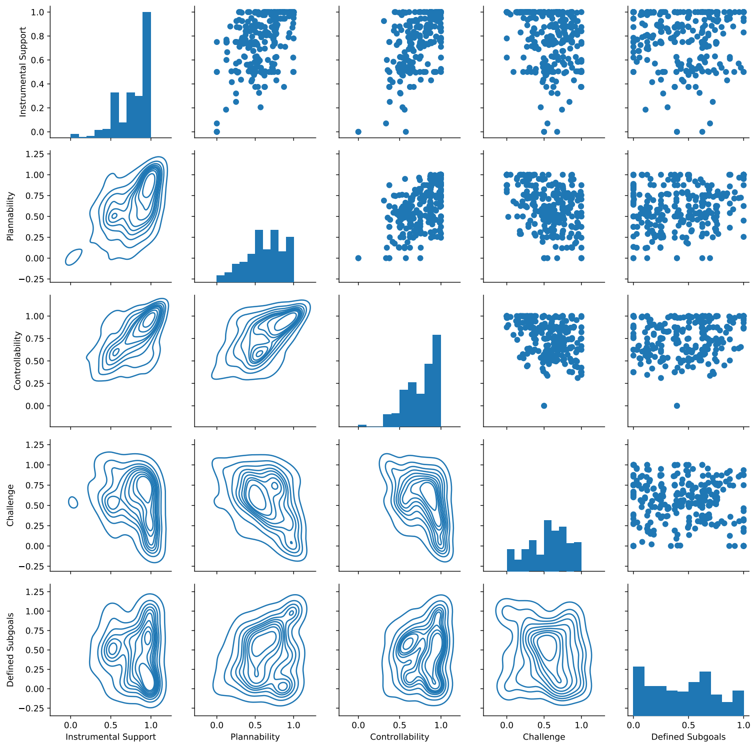

FIGURE F.148: Correlations and KDE for variable Instrumental Support matrix 4.

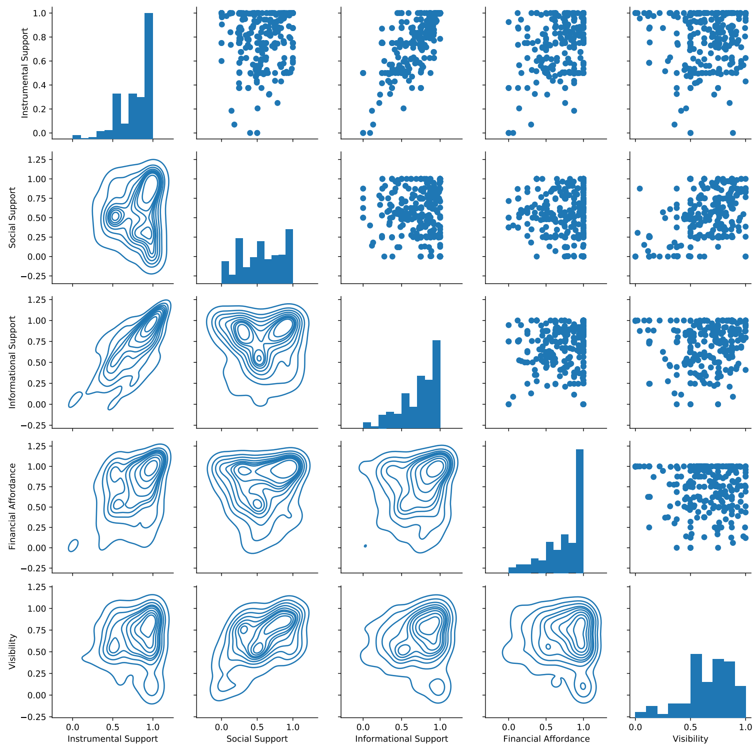

FIGURE F.149: Correlations and KDE for variable Instrumental Support matrix 5.

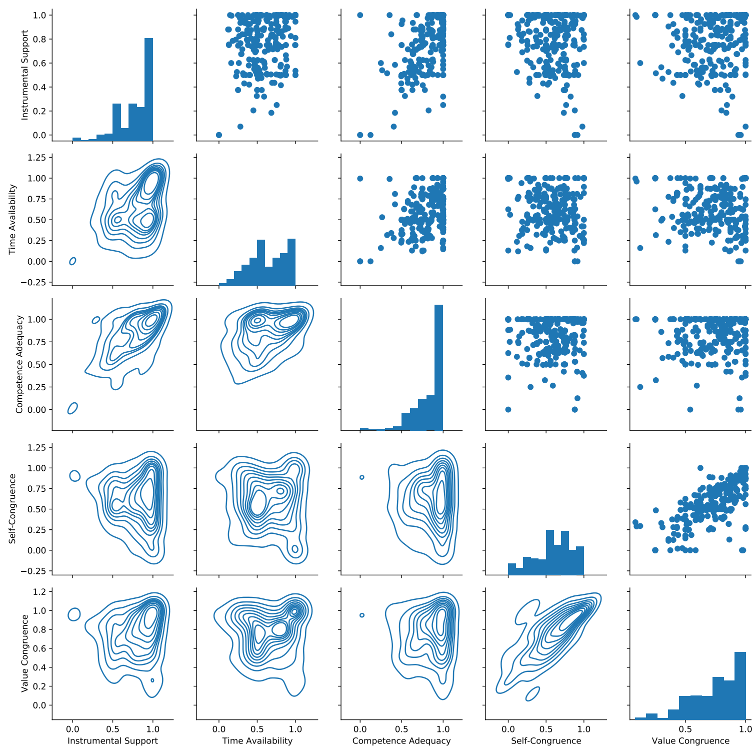

FIGURE F.150: Correlations and KDE for variable Instrumental Support matrix 6.

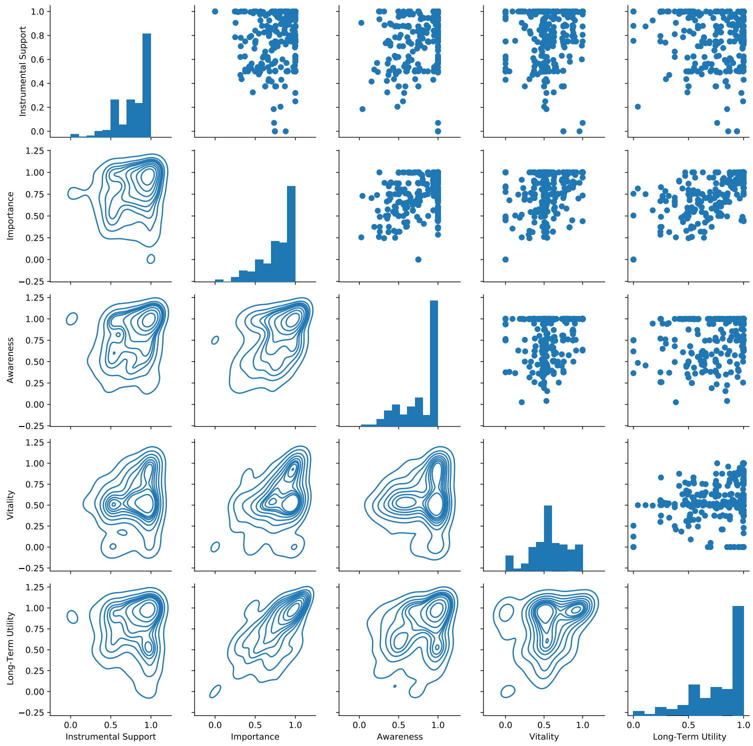

FIGURE F.151: Correlations and KDE for variable Instrumental Support matrix 7.

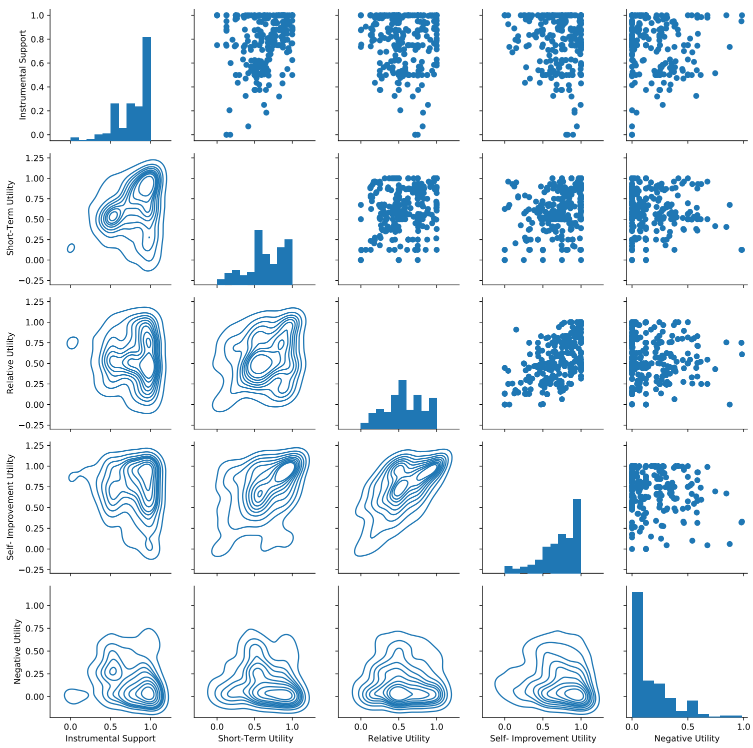

FIGURE F.152: Correlations and KDE for variable Instrumental Support matrix 8.

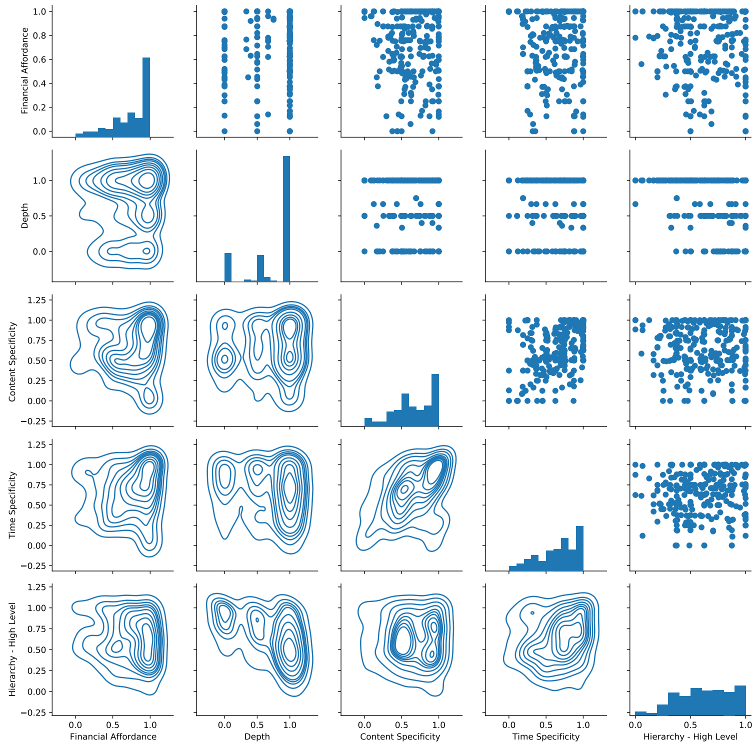

FIGURE F.153: Correlations and KDE for variable Financial Affordance matrix 1.

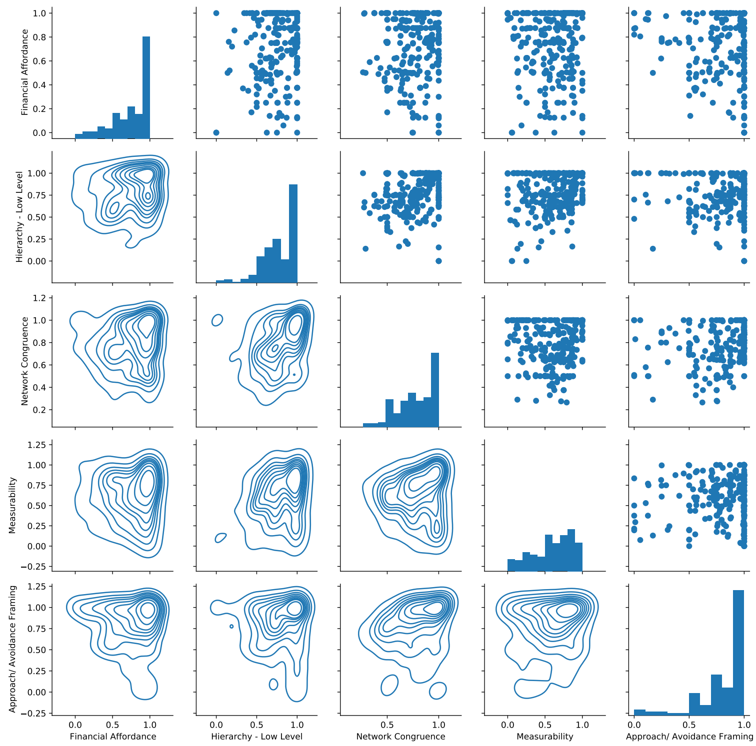

FIGURE F.154: Correlations and KDE for variable Financial Affordance matrix 2.

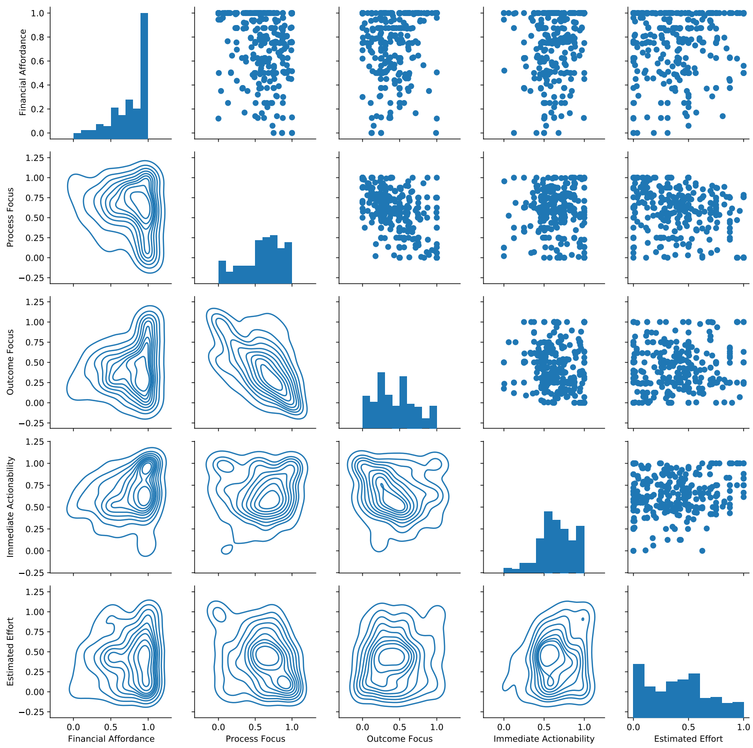

FIGURE F.155: Correlations and KDE for variable Financial Affordance matrix 3.

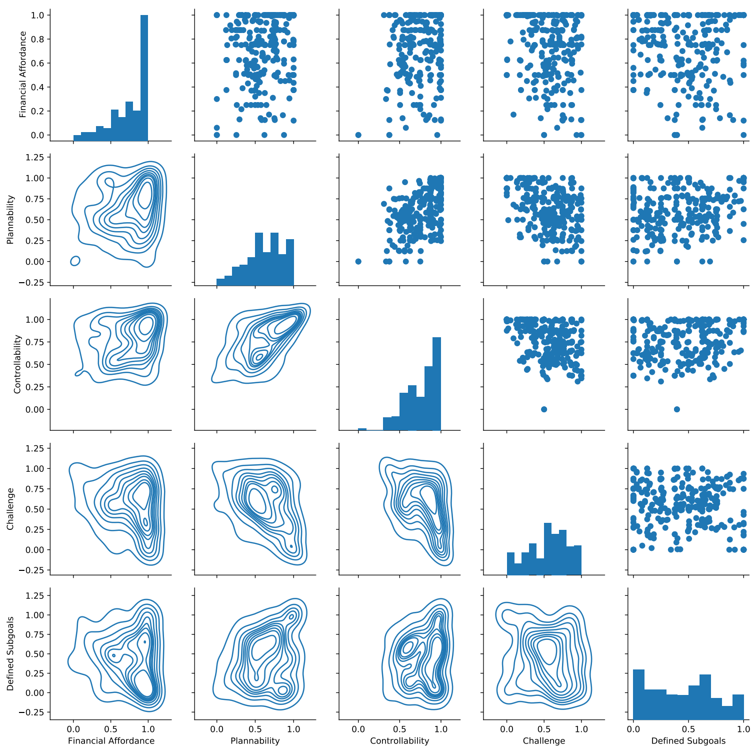

FIGURE F.156: Correlations and KDE for variable Financial Affordance matrix 4.

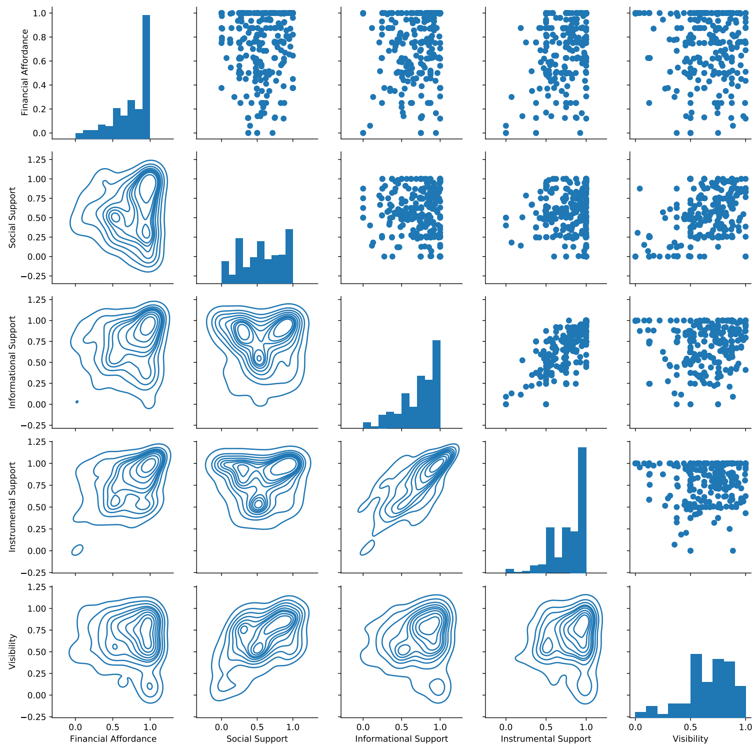

FIGURE F.157: Correlations and KDE for variable Financial Affordance matrix 5.

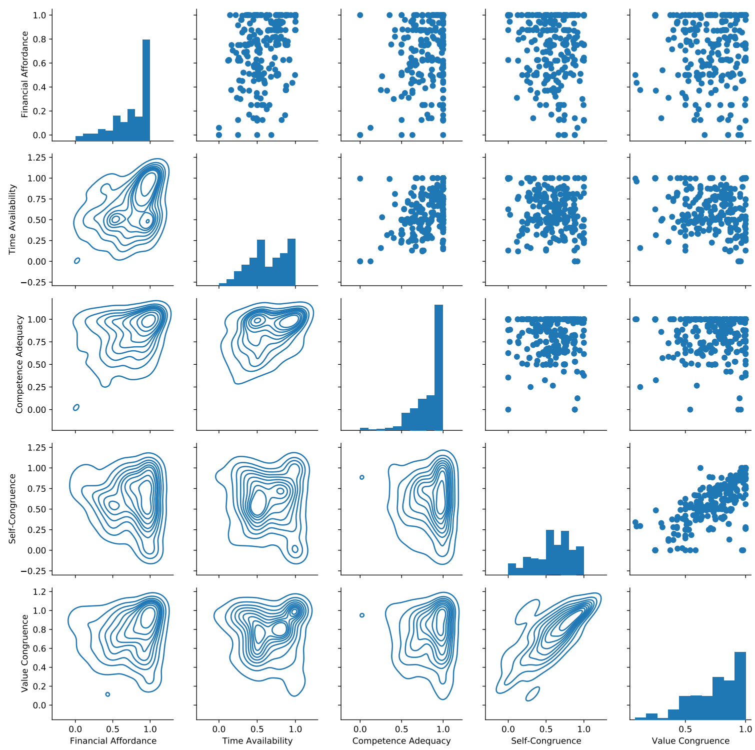

FIGURE F.158: Correlations and KDE for variable Financial Affordance matrix 6.

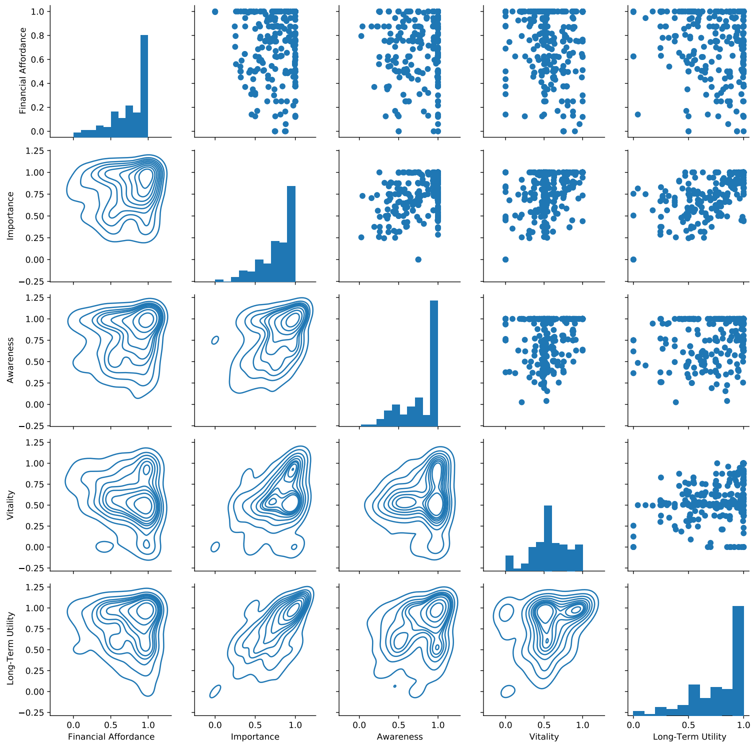

FIGURE F.159: Correlations and KDE for variable Financial Affordance matrix 7.

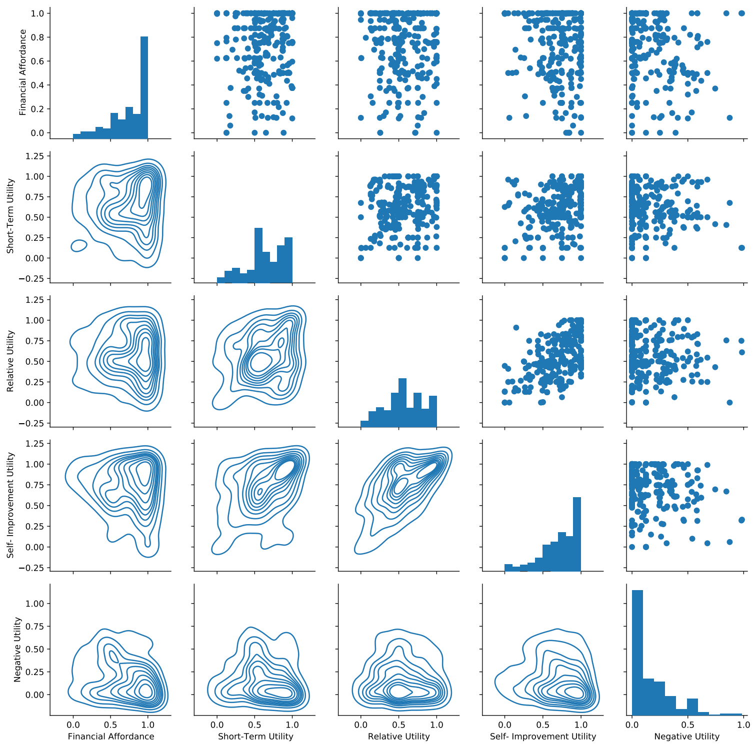

FIGURE F.160: Correlations and KDE for variable Financial Affordance matrix 8.

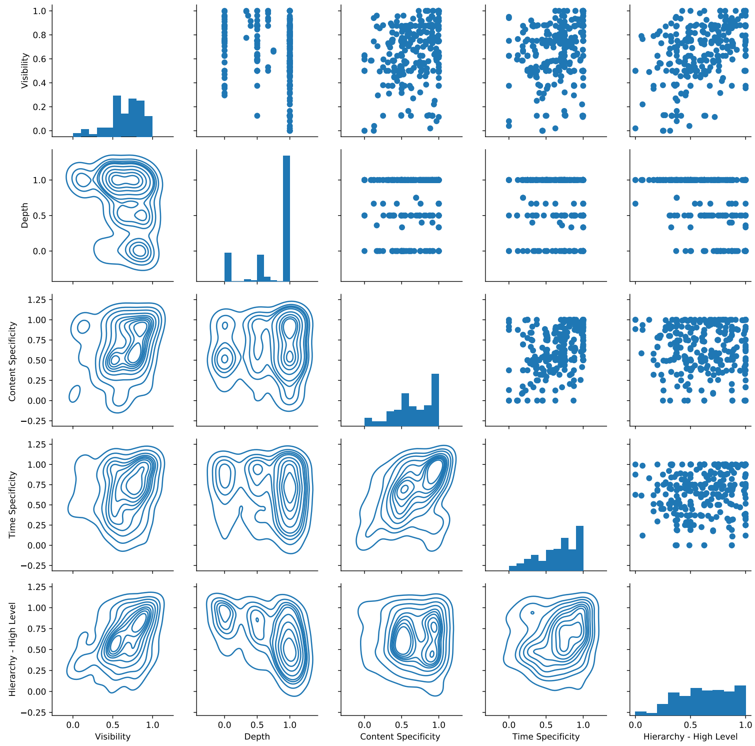

FIGURE F.161: Correlations and KDE for variable Visibility matrix 1.

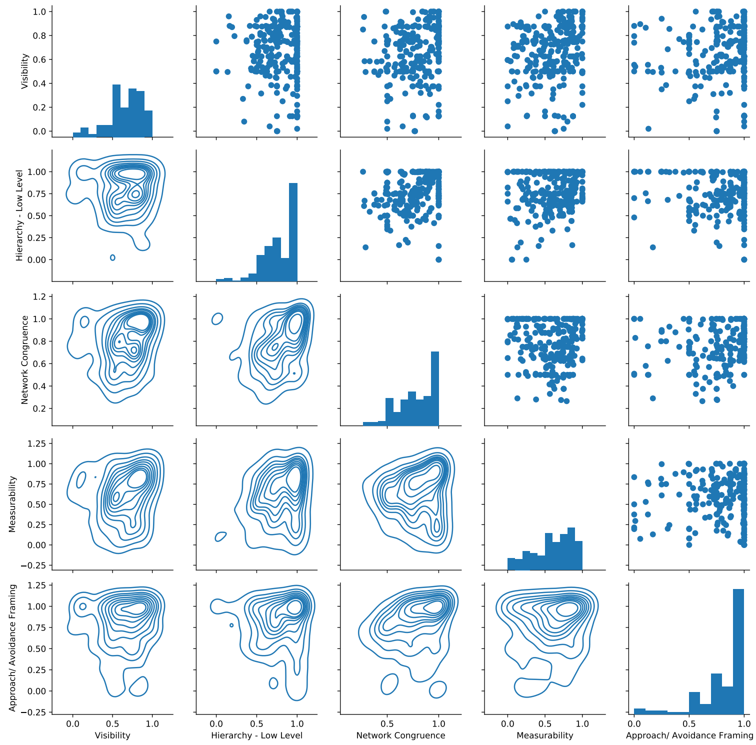

FIGURE F.162: Correlations and KDE for variable Visibility matrix 2.

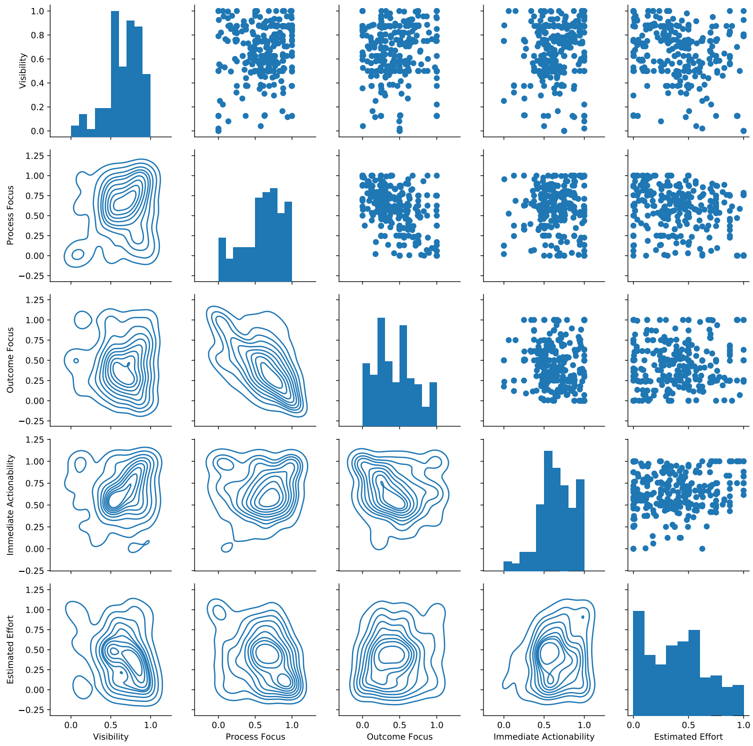

FIGURE F.163: Correlations and KDE for variable Visibility matrix 3.

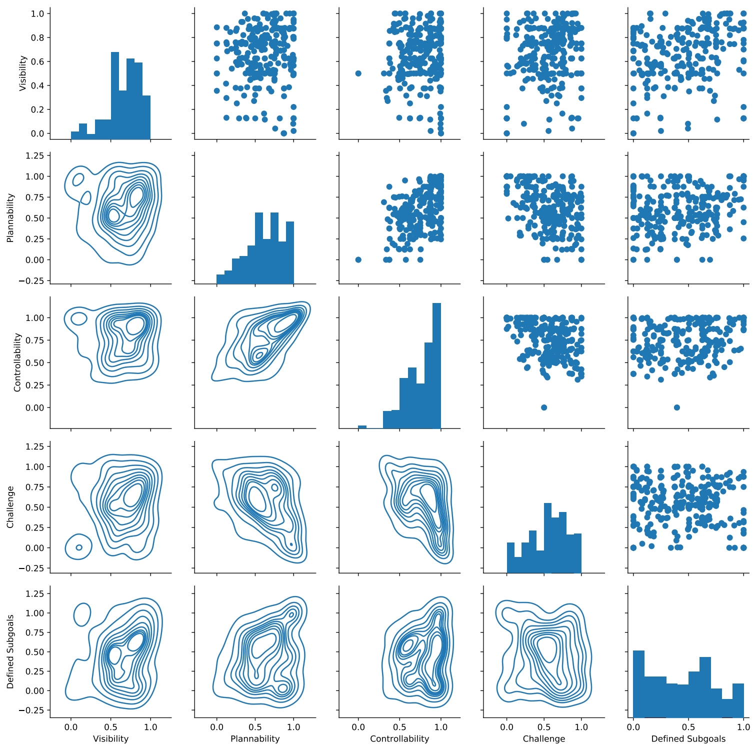

FIGURE F.164: Correlations and KDE for variable Visibility matrix 4.

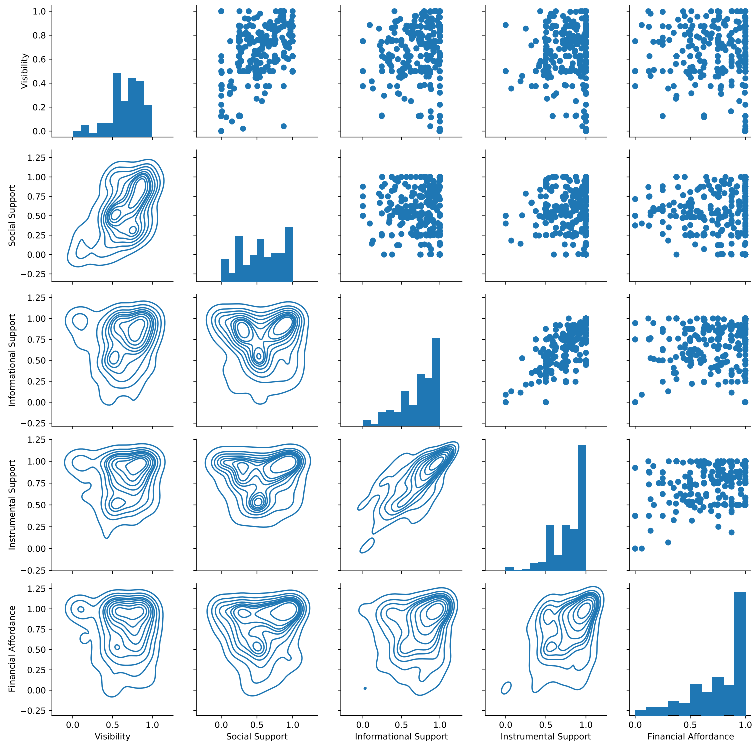

FIGURE F.165: Correlations and KDE for variable Visibility matrix 5.

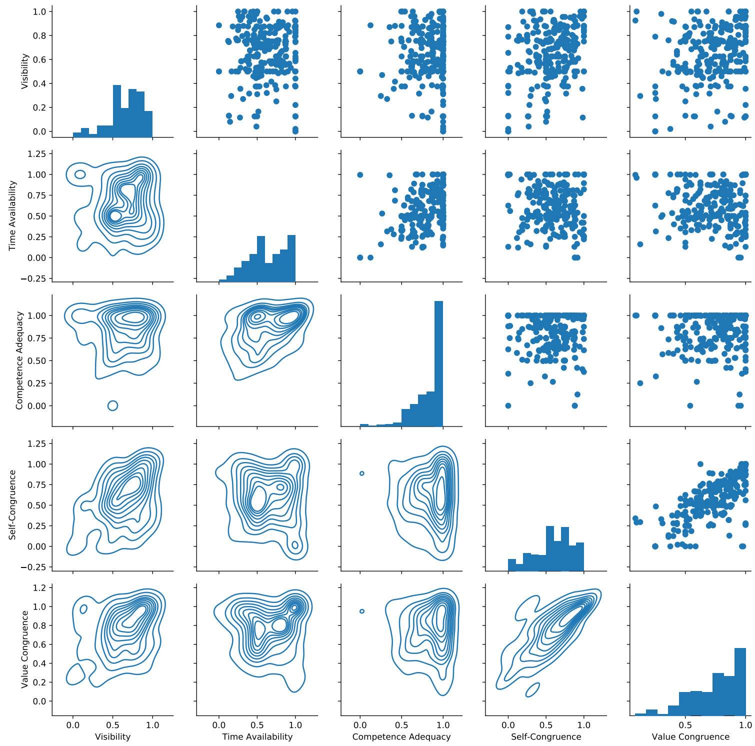

FIGURE F.166: Correlations and KDE for variable Visibility matrix 6.

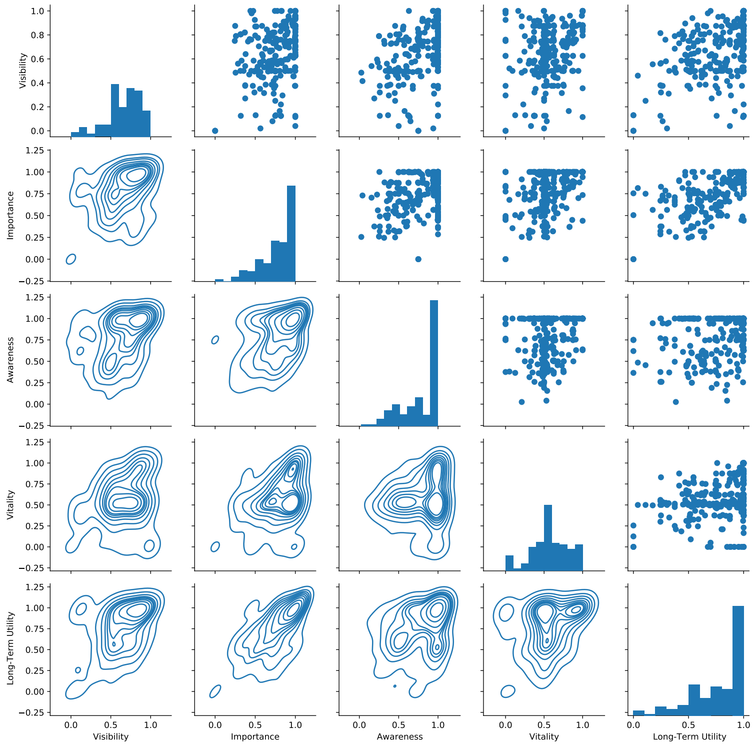

FIGURE F.167: Correlations and KDE for variable Visibility matrix 7.

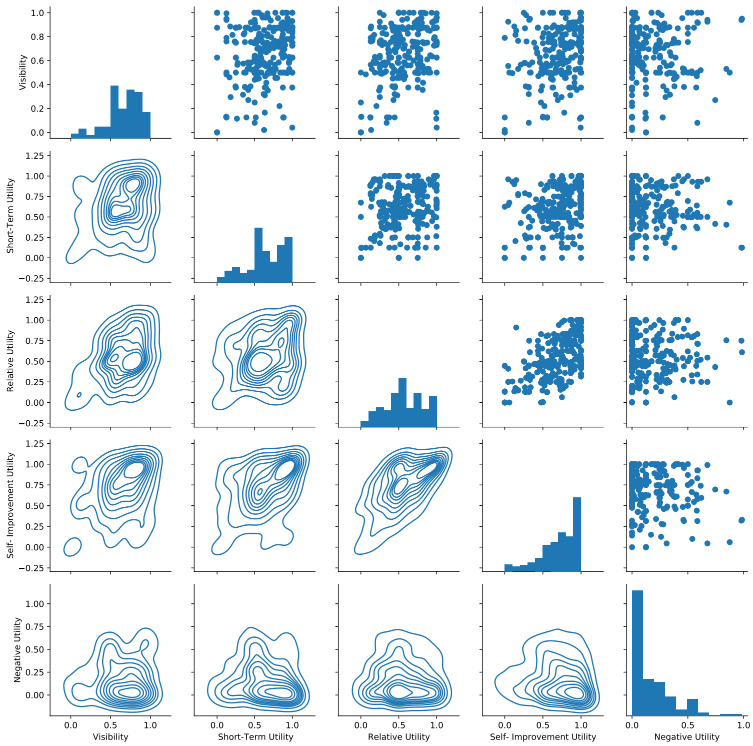

FIGURE F.168: Correlations and KDE for variable Visibility matrix 8.

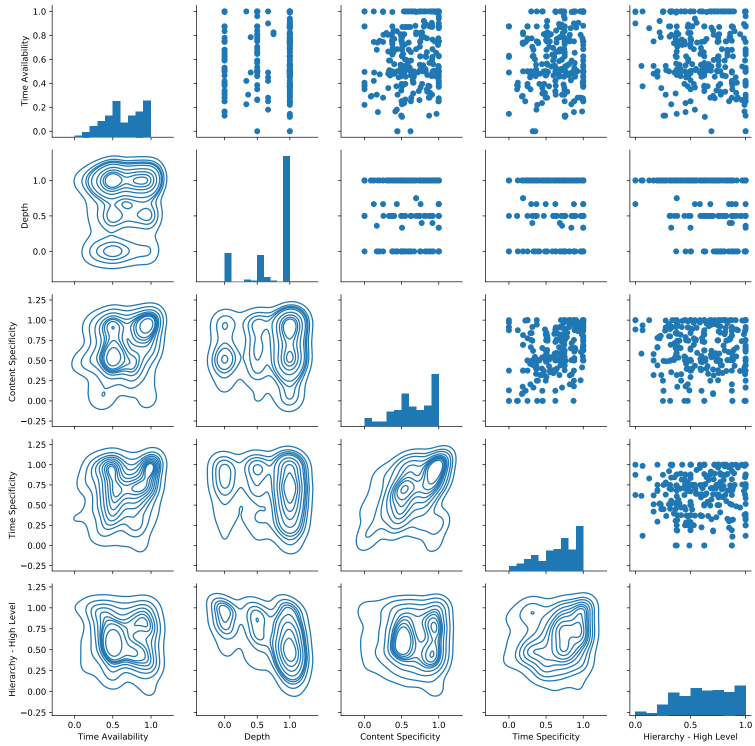

FIGURE F.169: Correlations and KDE for variable Time Availability matrix 1.

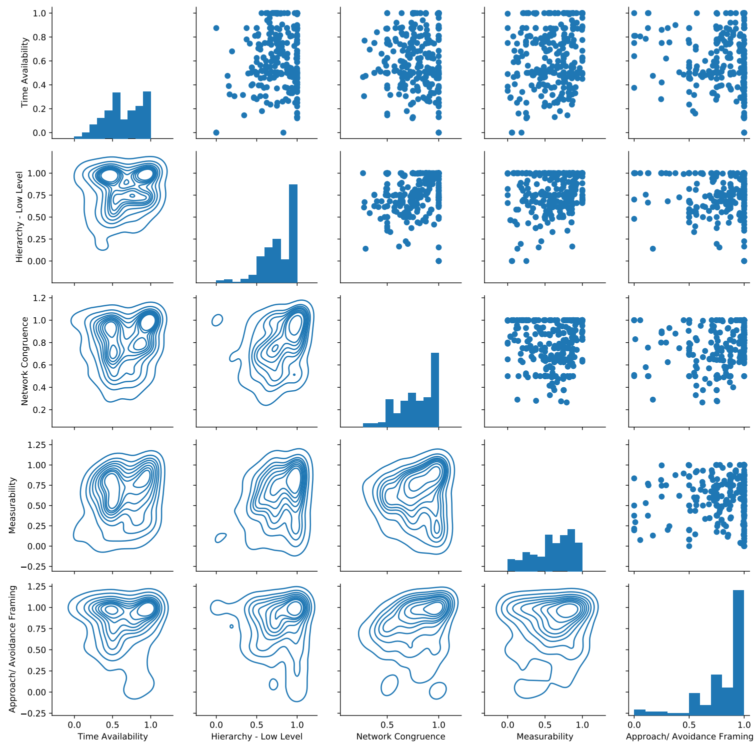

FIGURE F.170: Correlations and KDE for variable Time Availability matrix 2.

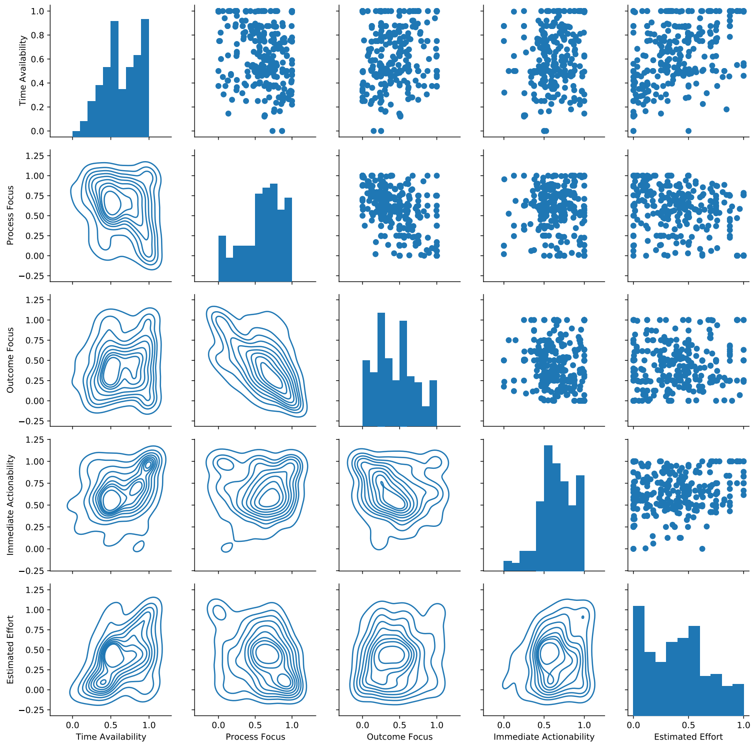

FIGURE F.171: Correlations and KDE for variable Time Availability matrix 3.

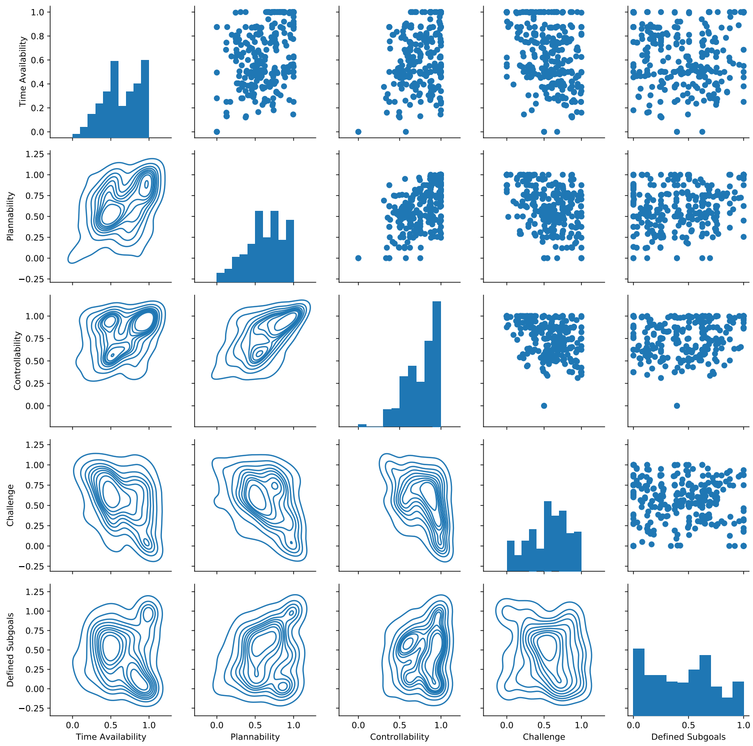

FIGURE F.172: Correlations and KDE for variable Time Availability matrix 4.

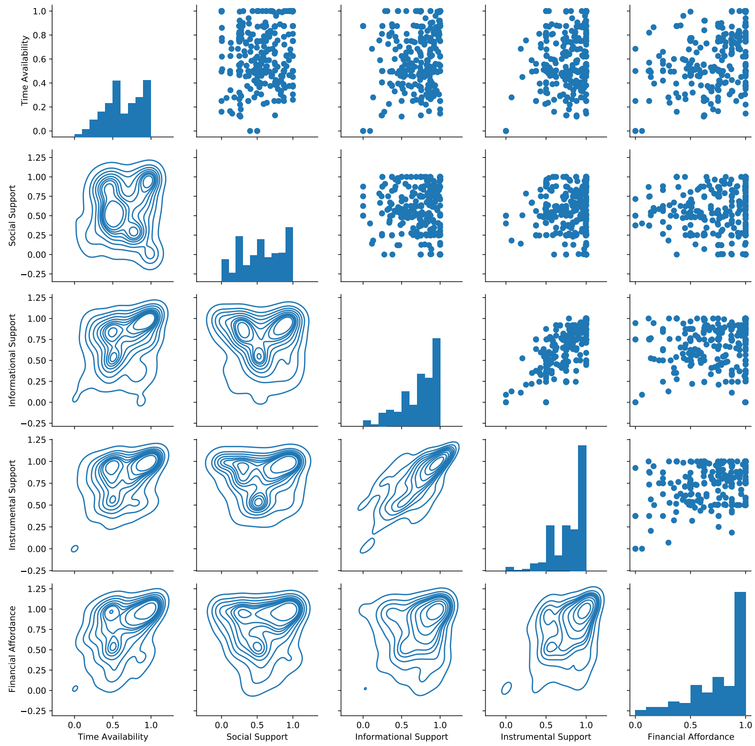

FIGURE F.173: Correlations and KDE for variable Time Availability matrix 5.

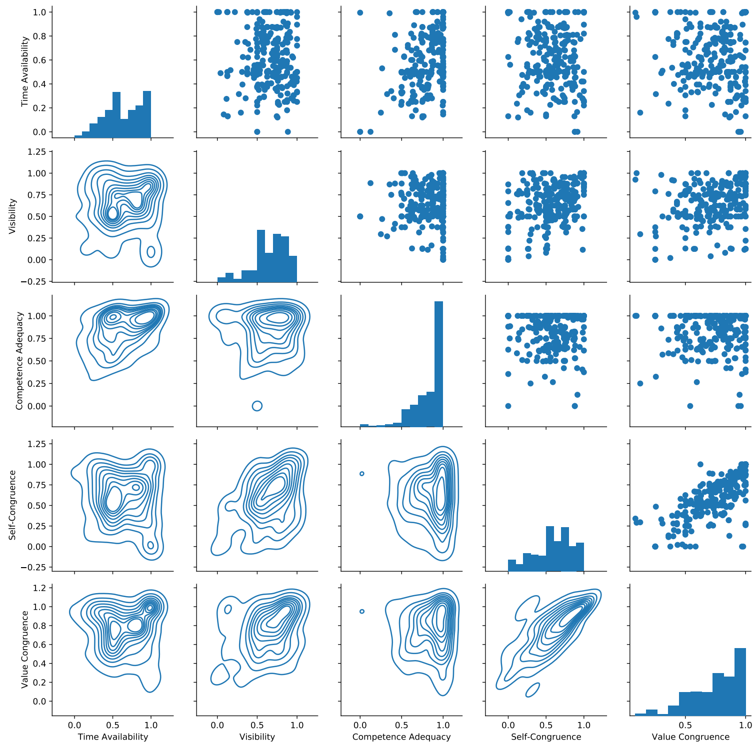

FIGURE F.174: Correlations and KDE for variable Time Availability matrix 6.

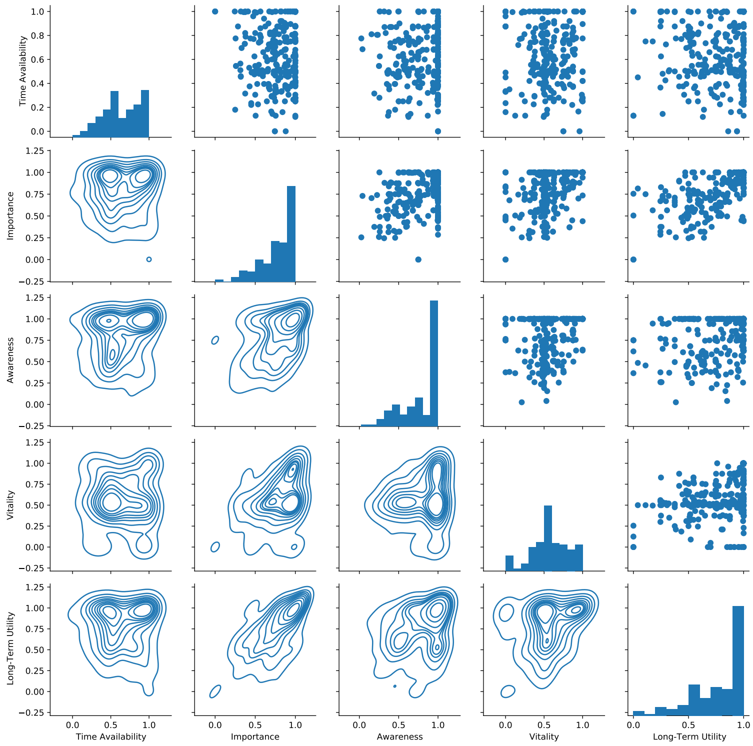

FIGURE F.175: Correlations and KDE for variable Time Availability matrix 7.

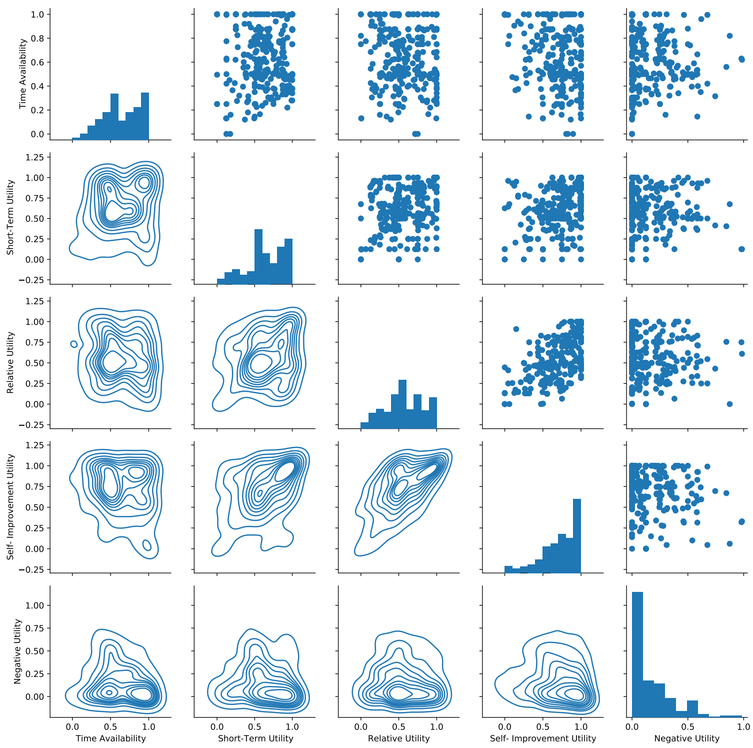

FIGURE F.176: Correlations and KDE for variable Time Availability matrix 8.

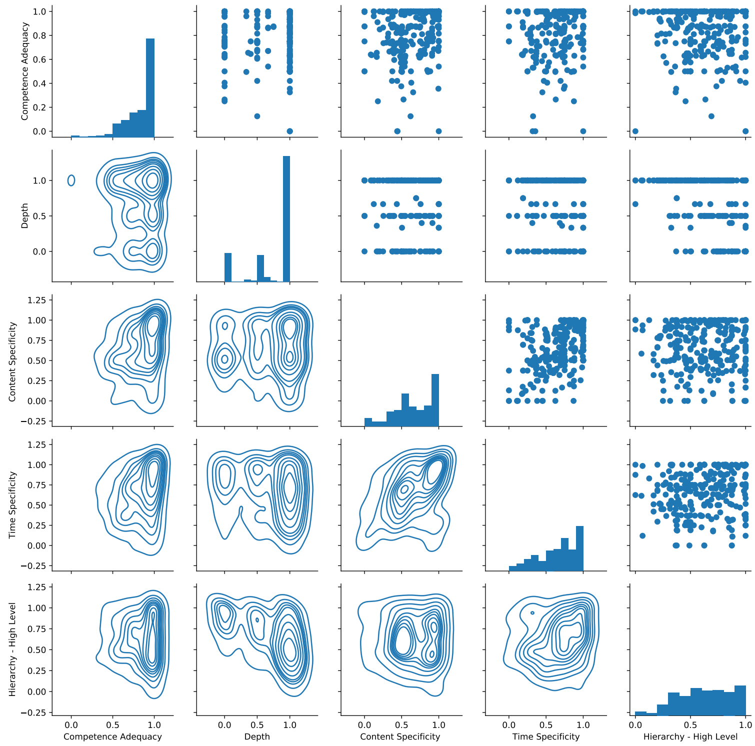

FIGURE F.177: Correlations and KDE for variable Competence Adequacy matrix 1.

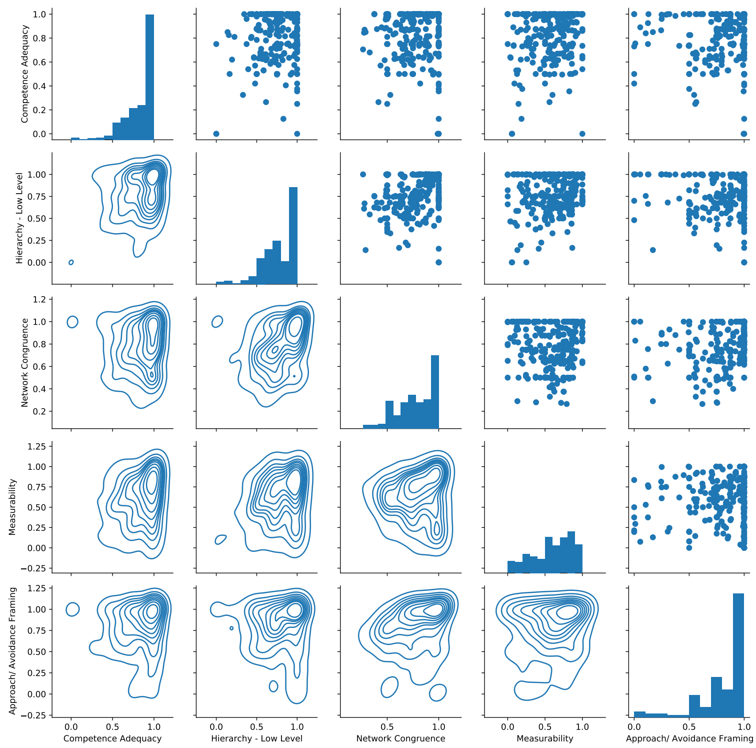

FIGURE F.178: Correlations and KDE for variable Competence Adequacy matrix 2.

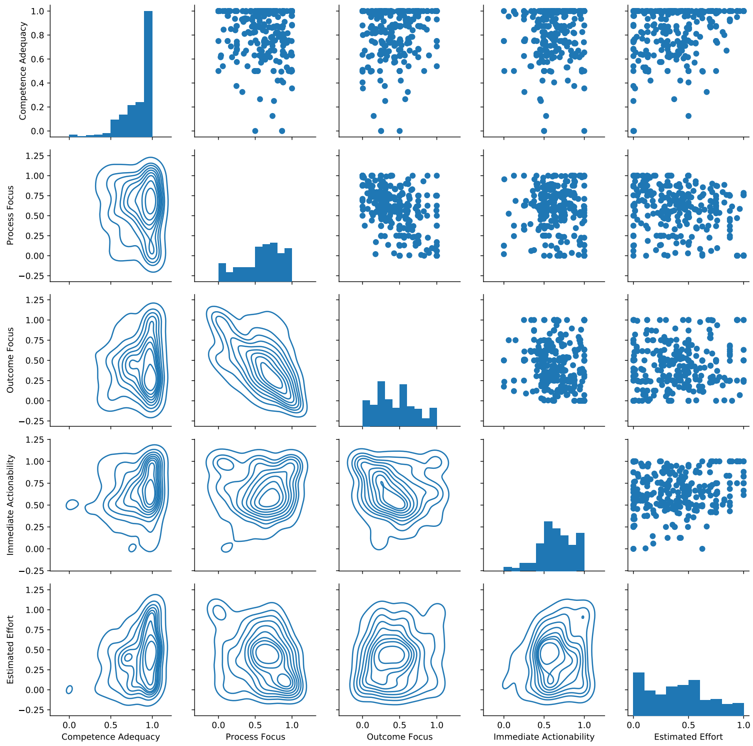

FIGURE F.179: Correlations and KDE for variable Competence Adequacy matrix 3.

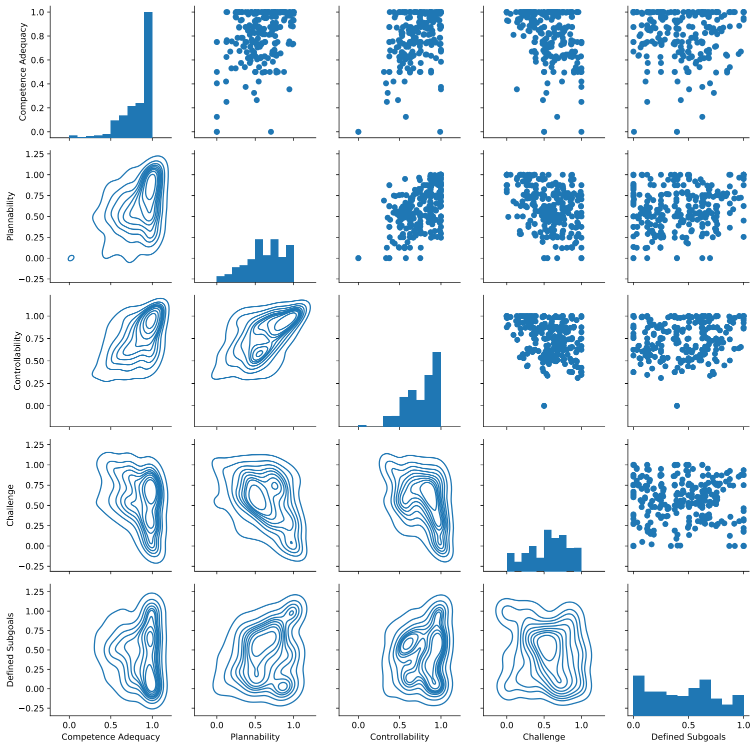

FIGURE F.180: Correlations and KDE for variable Competence Adequacy matrix 4.

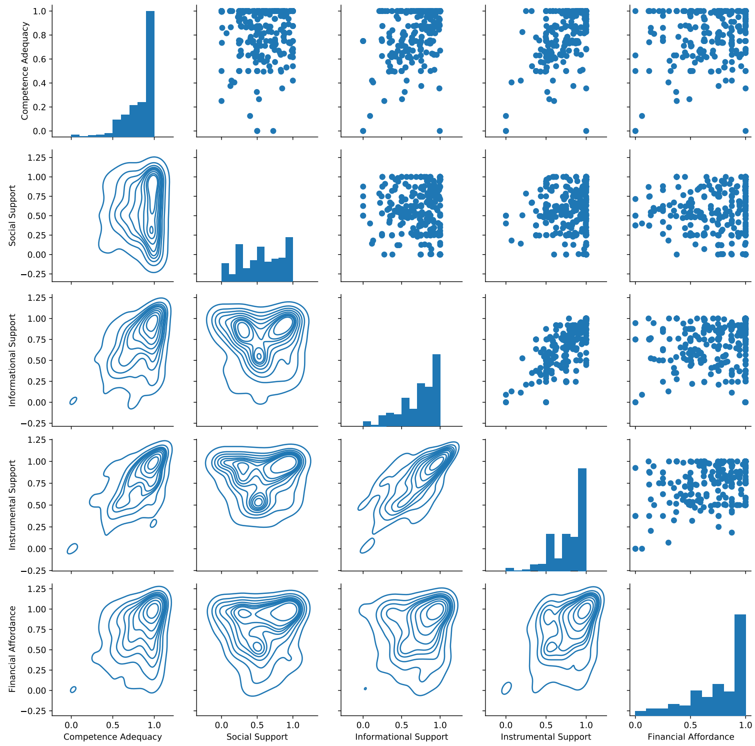

FIGURE F.181: Correlations and KDE for variable Competence Adequacy matrix 5.

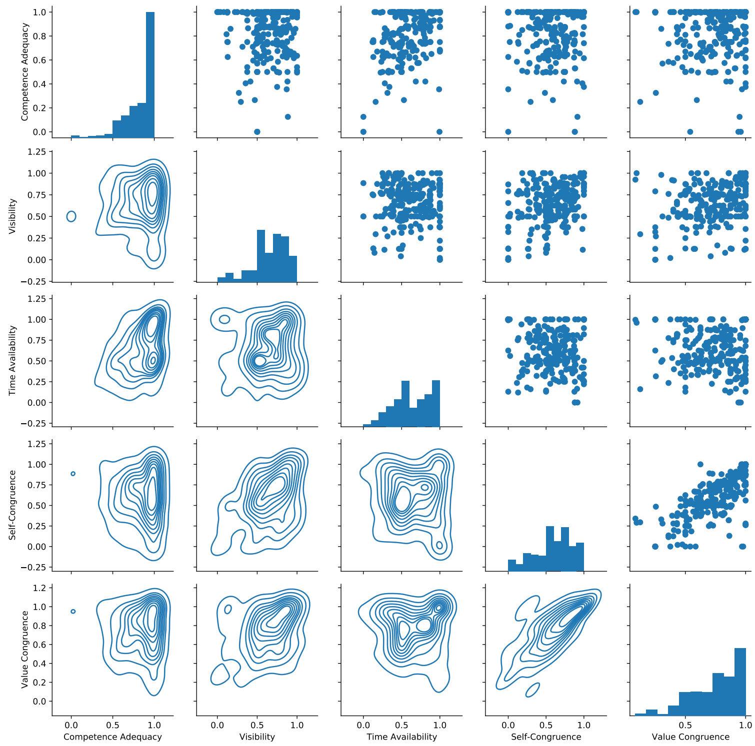

FIGURE F.182: Correlations and KDE for variable Competence Adequacy matrix 6.

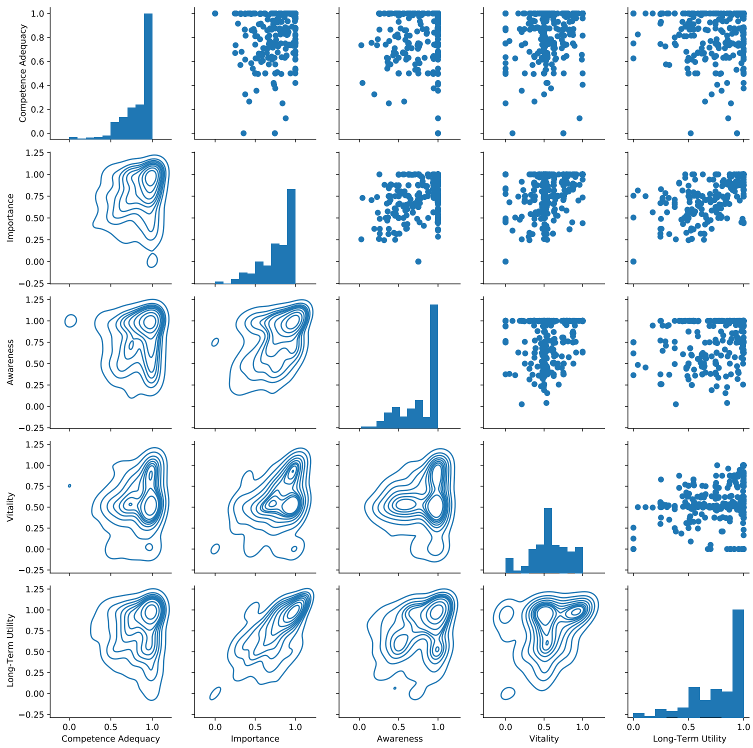

FIGURE F.183: Correlations and KDE for variable Competence Adequacy matrix 7.

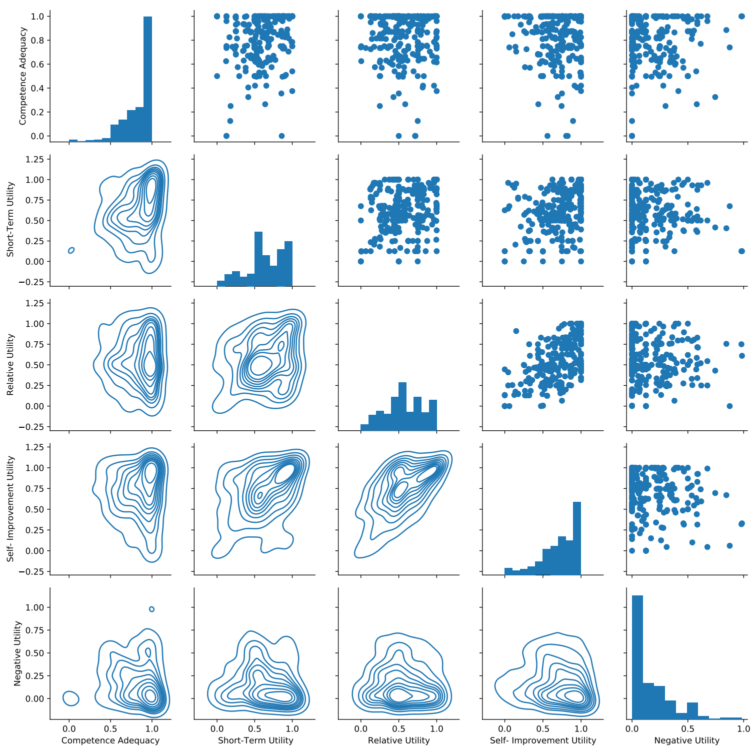

FIGURE F.184: Correlations and KDE for variable Competence Adequacy matrix 8.

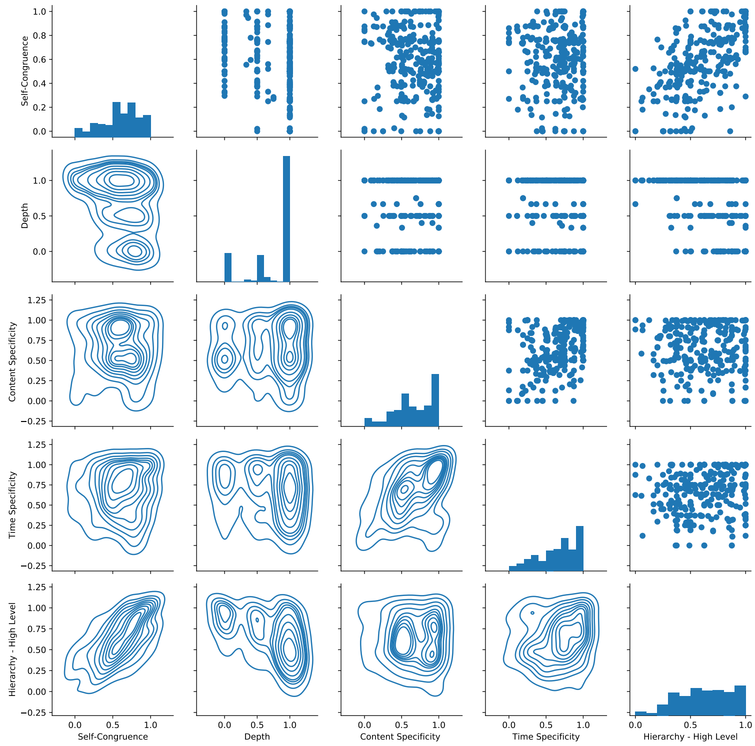

FIGURE F.185: Correlations and KDE for variable Self-Congruence matrix 1.

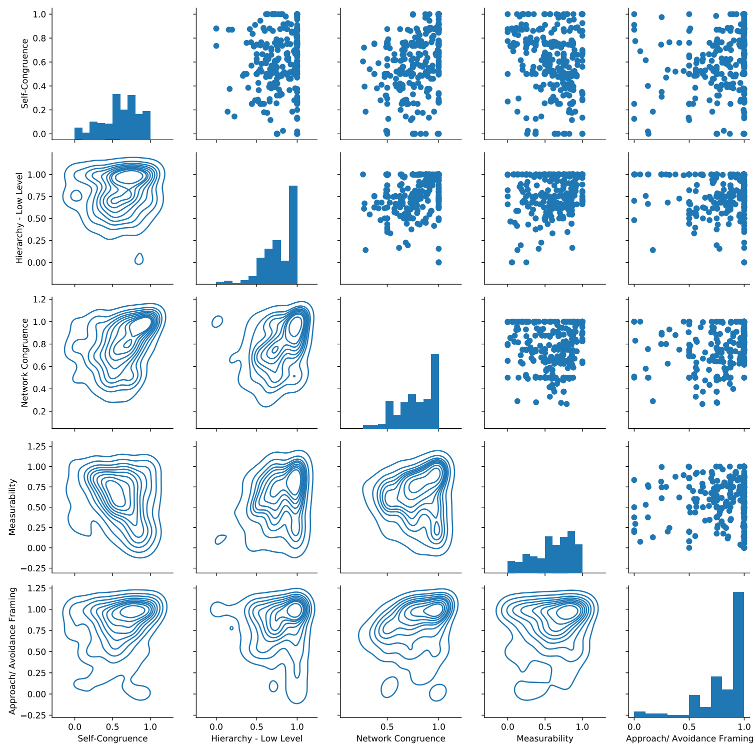

FIGURE F.186: Correlations and KDE for variable Self-Congruence matrix 2.

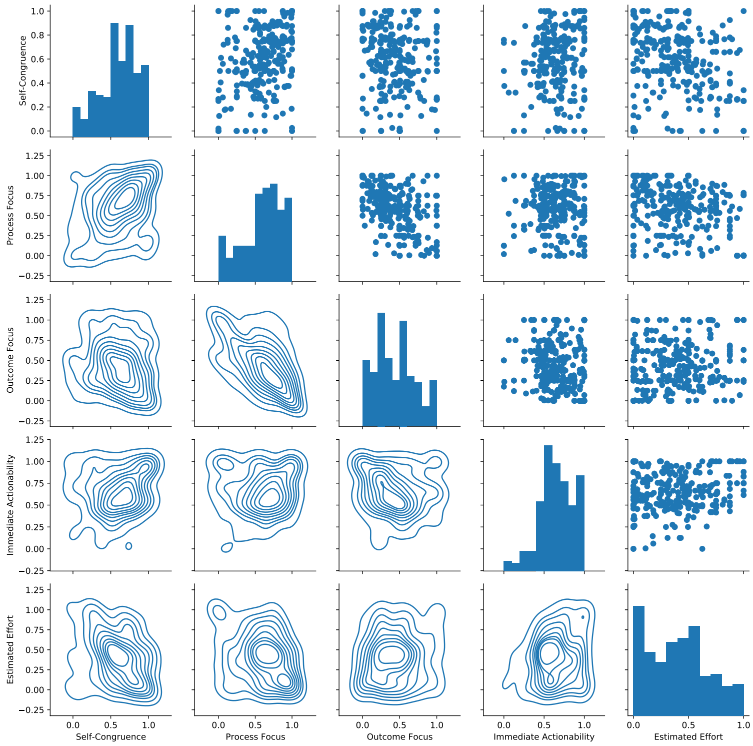

FIGURE F.187: Correlations and KDE for variable Self-Congruence matrix 3.

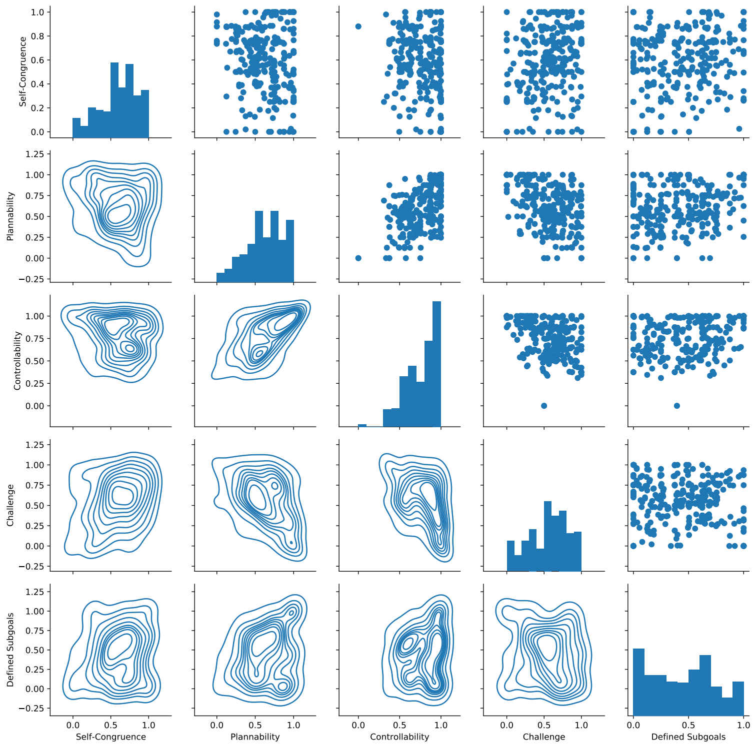

FIGURE F.188: Correlations and KDE for variable Self-Congruence matrix 4.

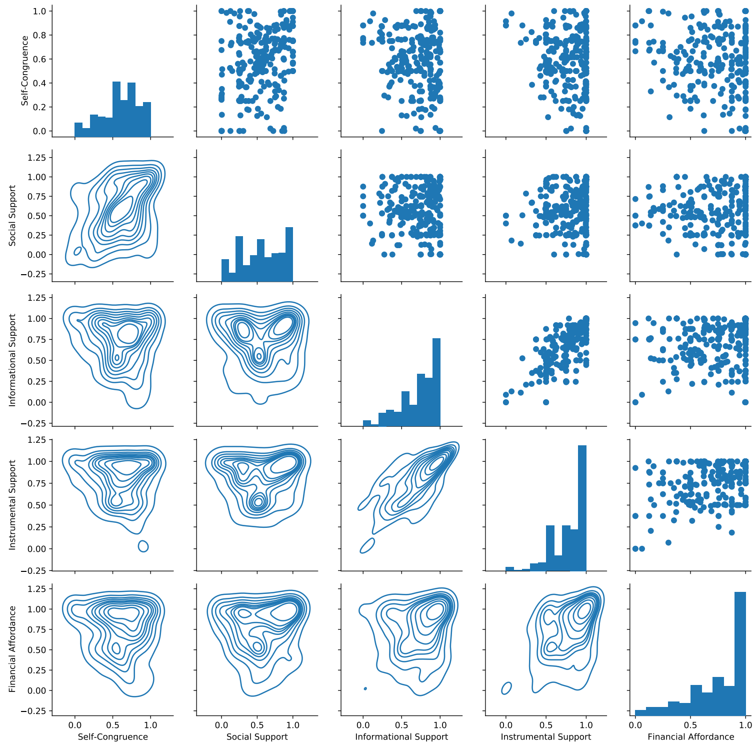

FIGURE F.189: Correlations and KDE for variable Self-Congruence matrix 5.

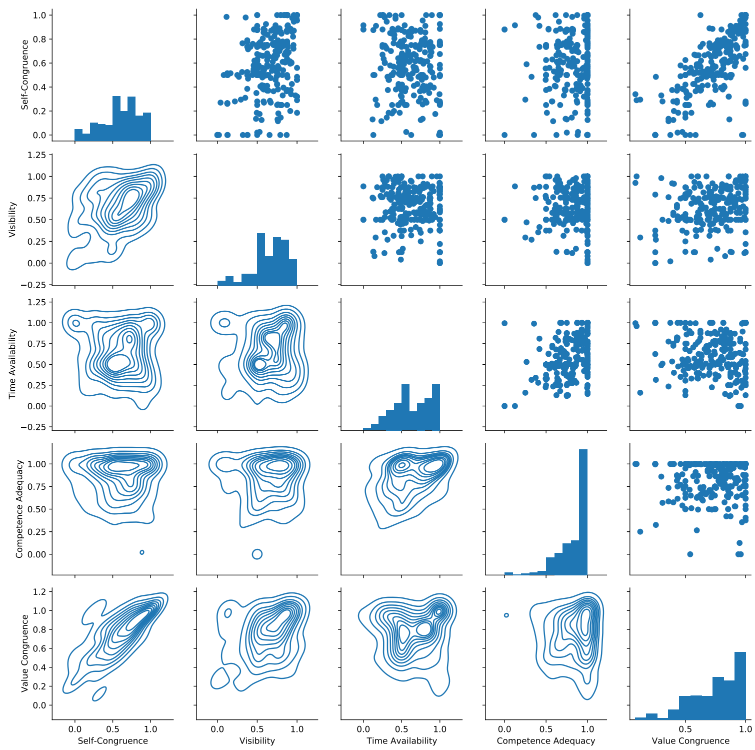

FIGURE F.190: Correlations and KDE for variable Self-Congruence matrix 6.

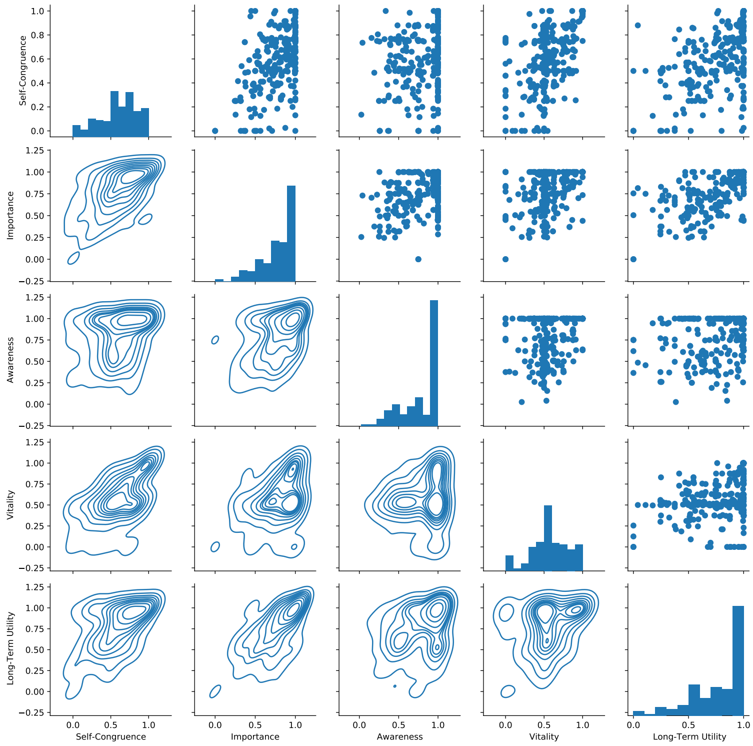

FIGURE F.191: Correlations and KDE for variable Self-Congruence matrix 7.

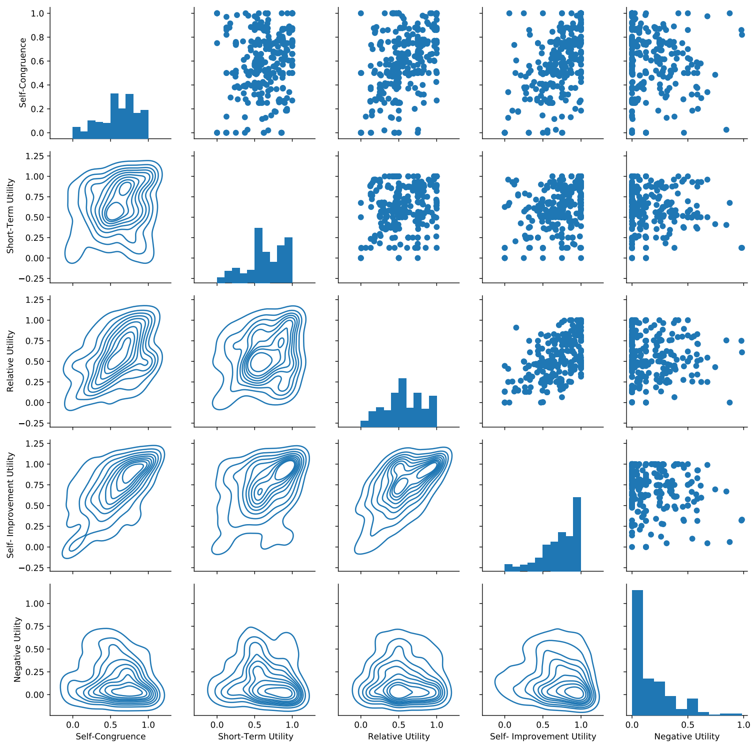

FIGURE F.192: Correlations and KDE for variable Self-Congruence matrix 8.

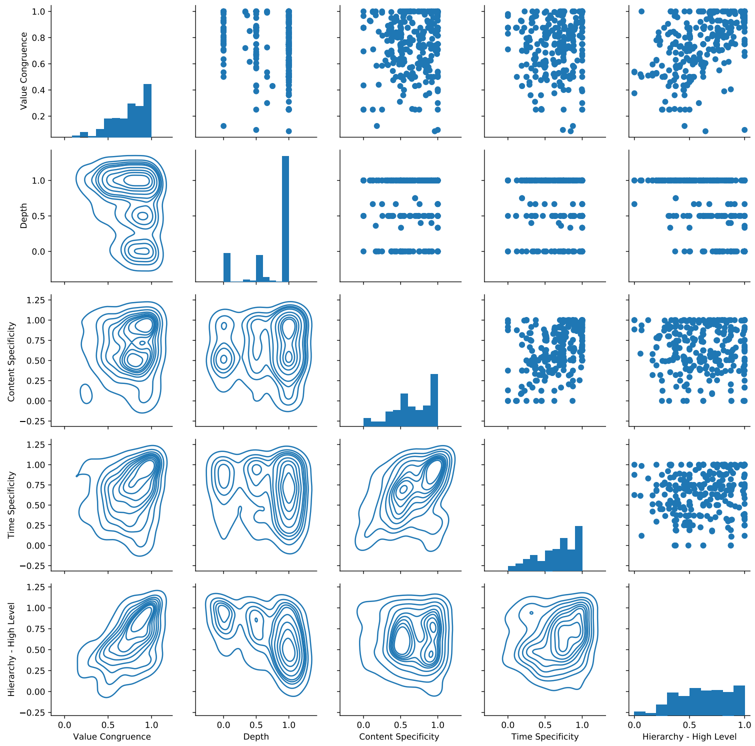

FIGURE F.193: Correlations and KDE for variable Value Congruence matrix 1.

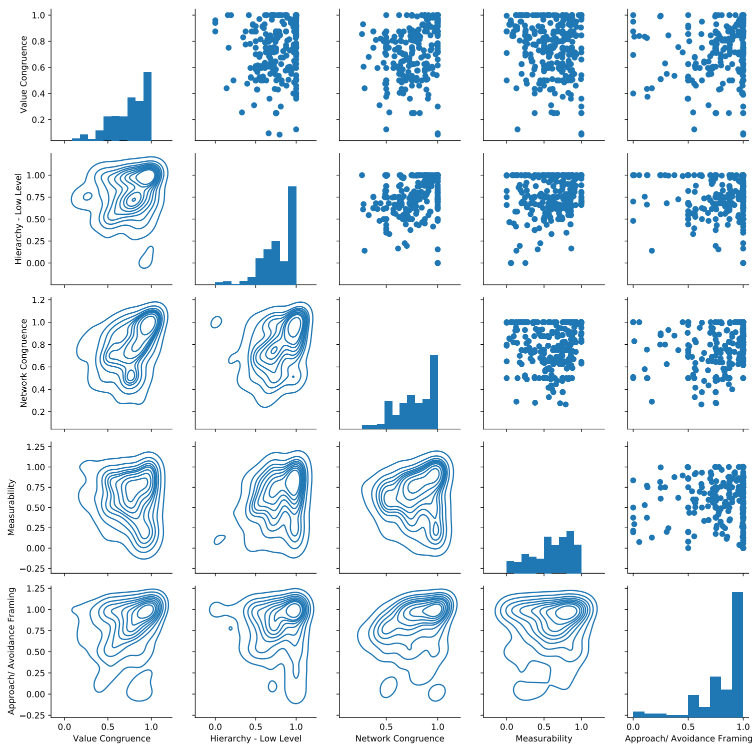

FIGURE F.194: Correlations and KDE for variable Value Congruence matrix 2.

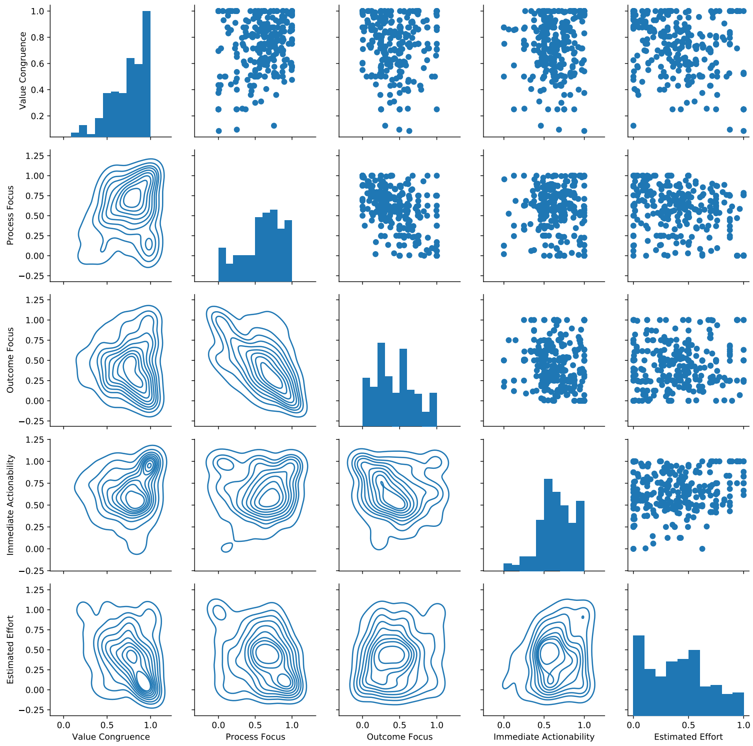

FIGURE F.195: Correlations and KDE for variable Value Congruence matrix 3.

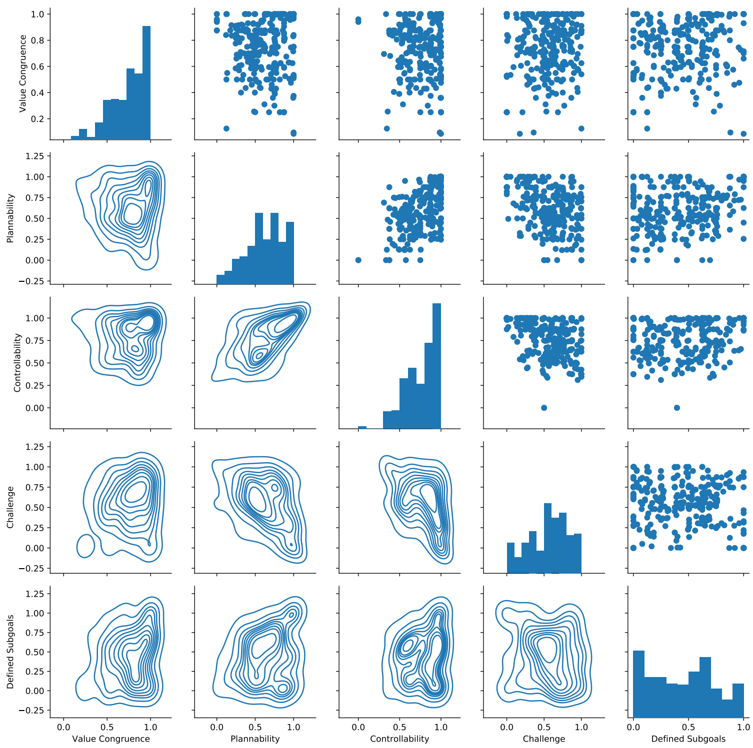

FIGURE F.196: Correlations and KDE for variable Value Congruence matrix 4.

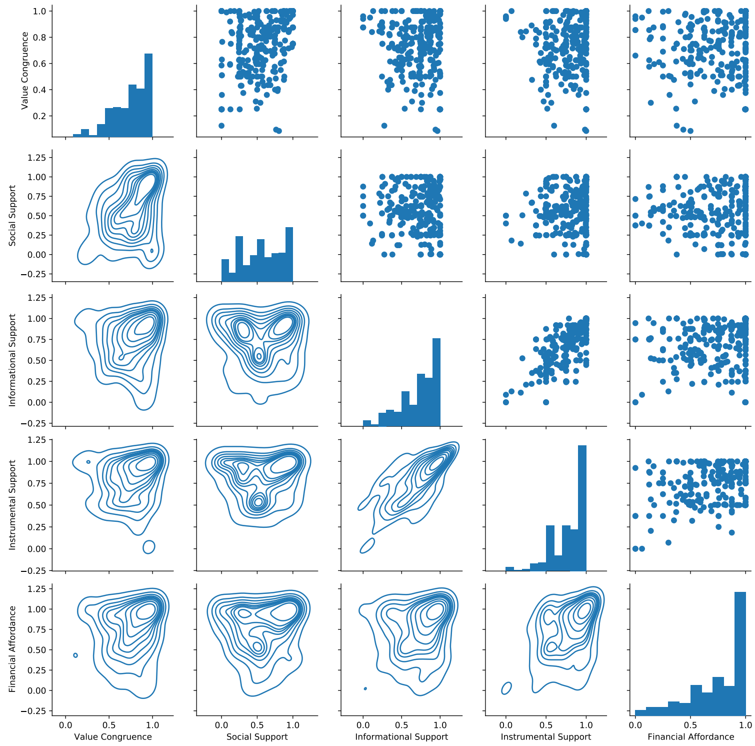

FIGURE F.197: Correlations and KDE for variable Value Congruence matrix 5.

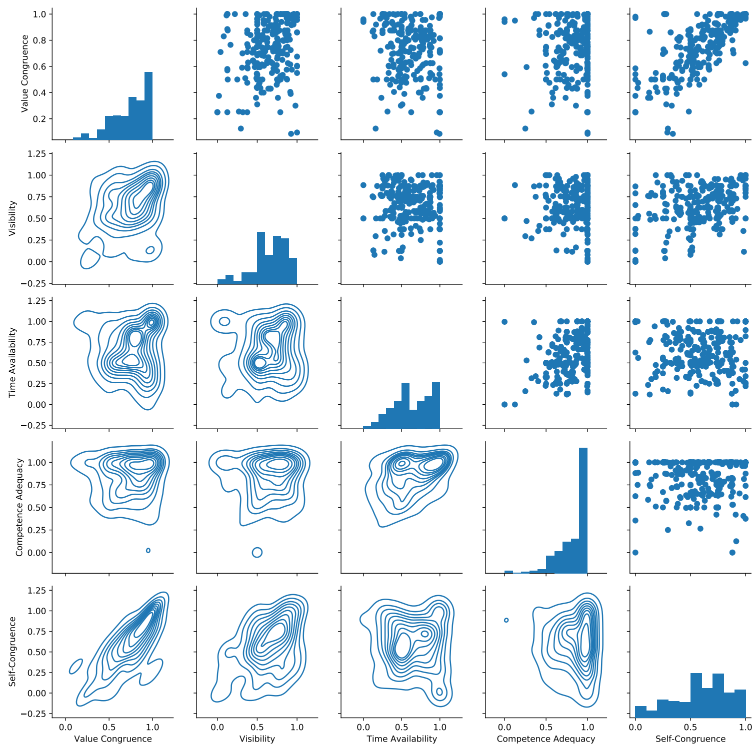

FIGURE F.198: Correlations and KDE for variable Value Congruence matrix 6.

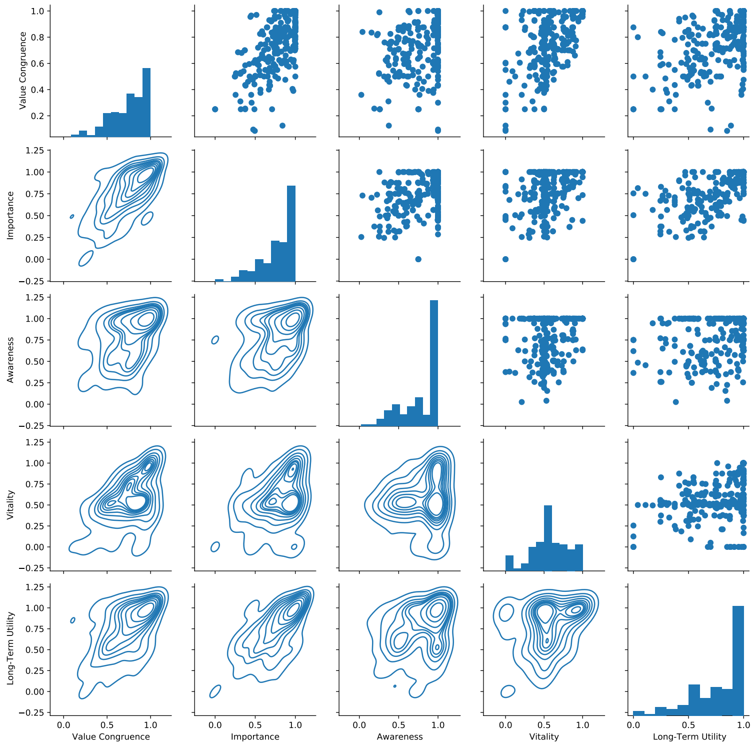

FIGURE F.199: Correlations and KDE for variable Value Congruence matrix 7.

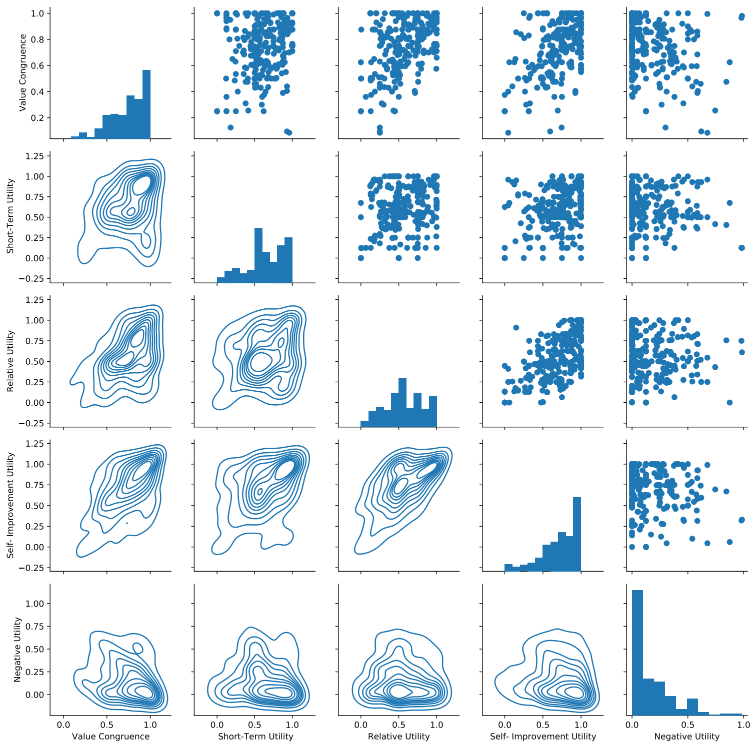

FIGURE F.200: Correlations and KDE for variable Value Congruence matrix 8.

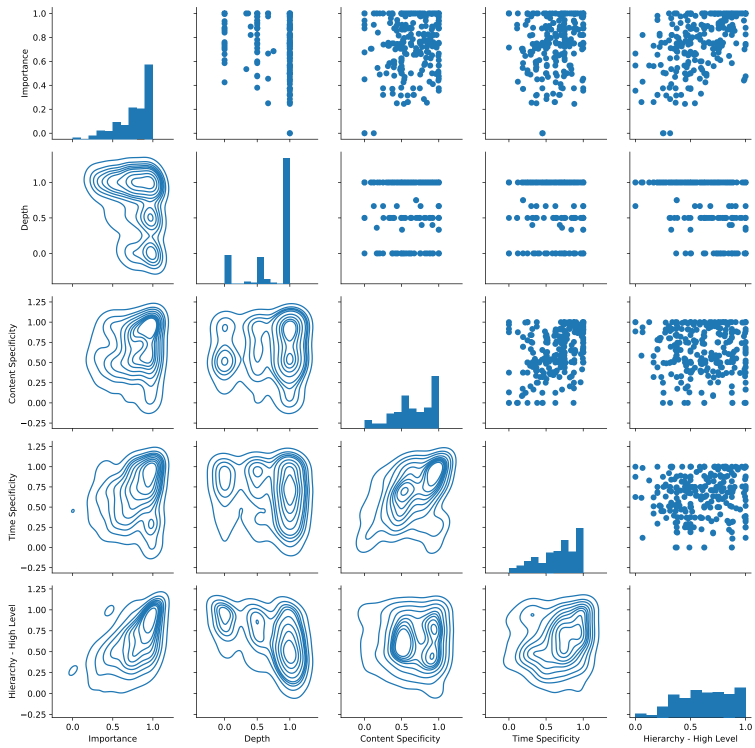

FIGURE F.201: Correlations and KDE for variable Importance matrix 1.

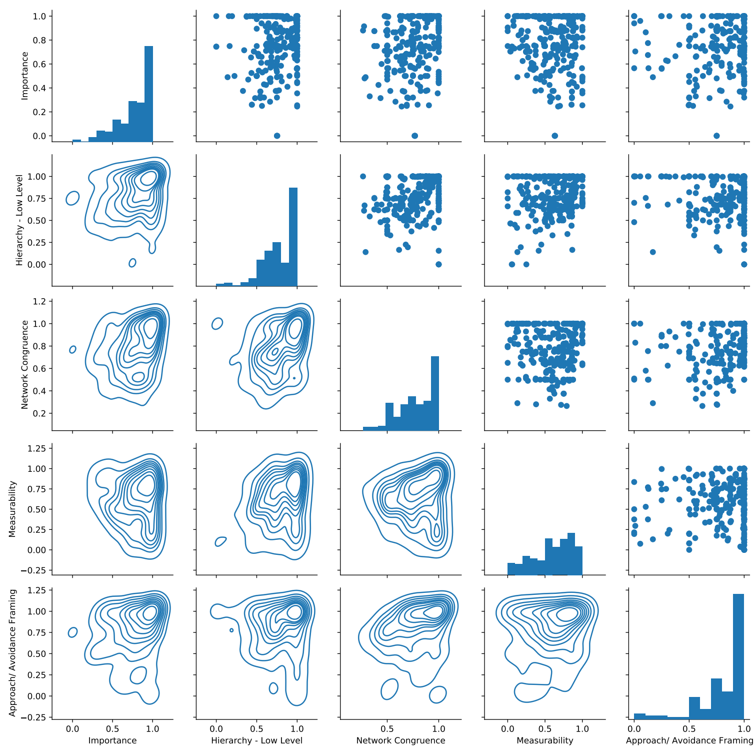

FIGURE F.202: Correlations and KDE for variable Importance matrix 2.

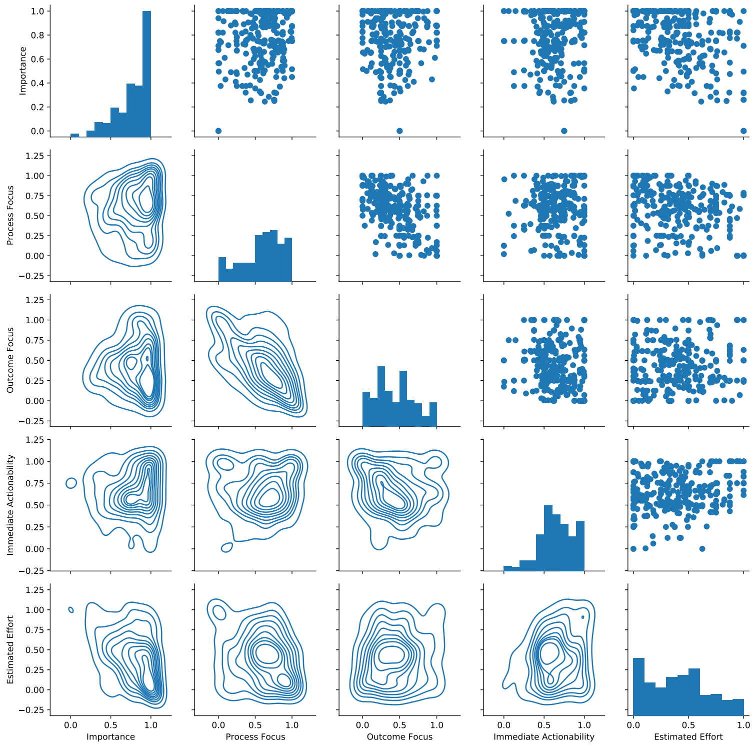

FIGURE F.203: Correlations and KDE for variable Importance matrix 3.

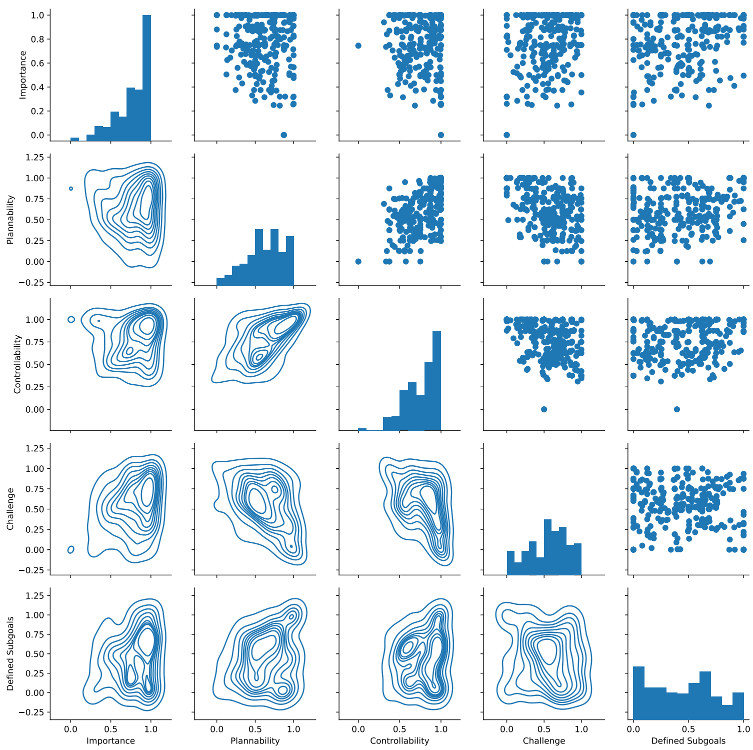

FIGURE F.204: Correlations and KDE for variable Importance matrix 4.

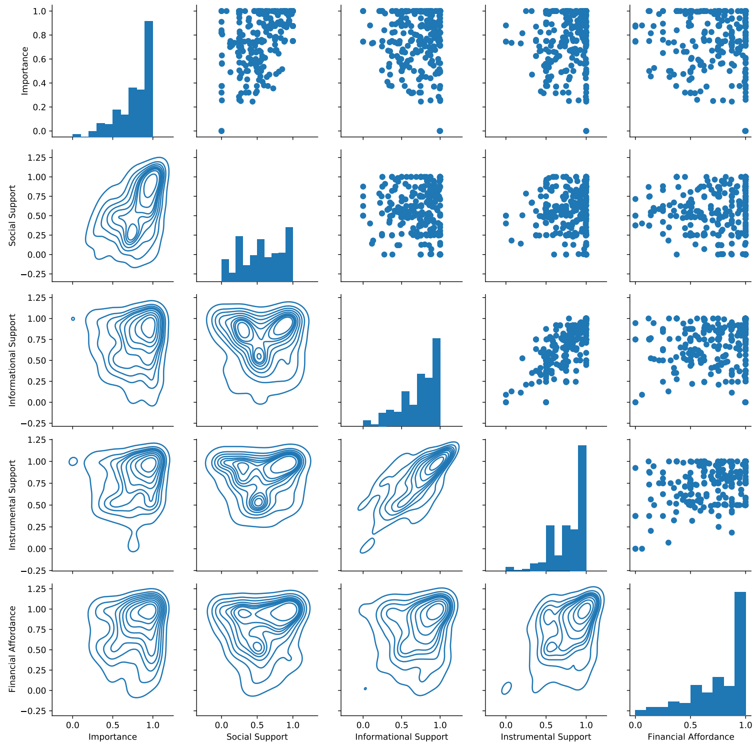

FIGURE F.205: Correlations and KDE for variable Importance matrix 5.

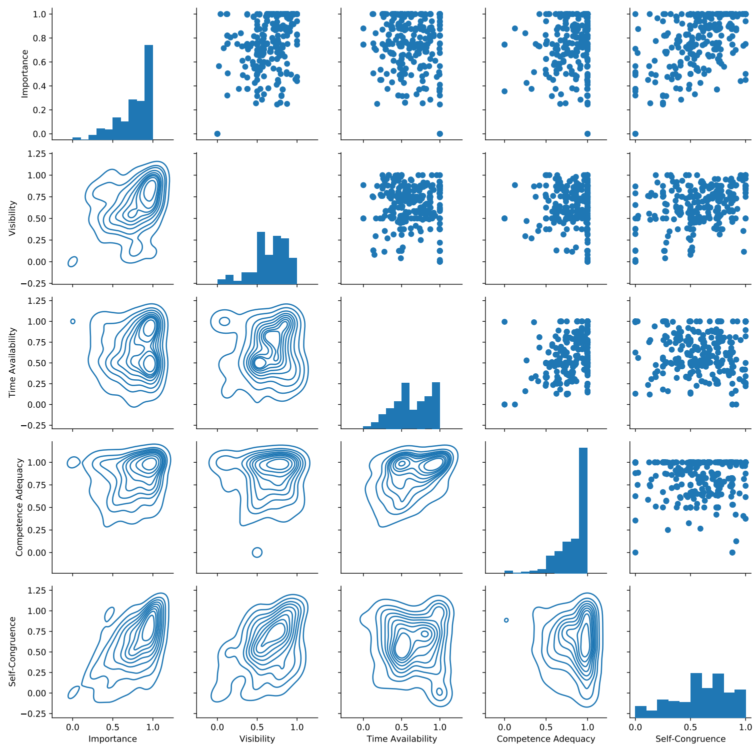

FIGURE F.206: Correlations and KDE for variable Importance matrix 6.

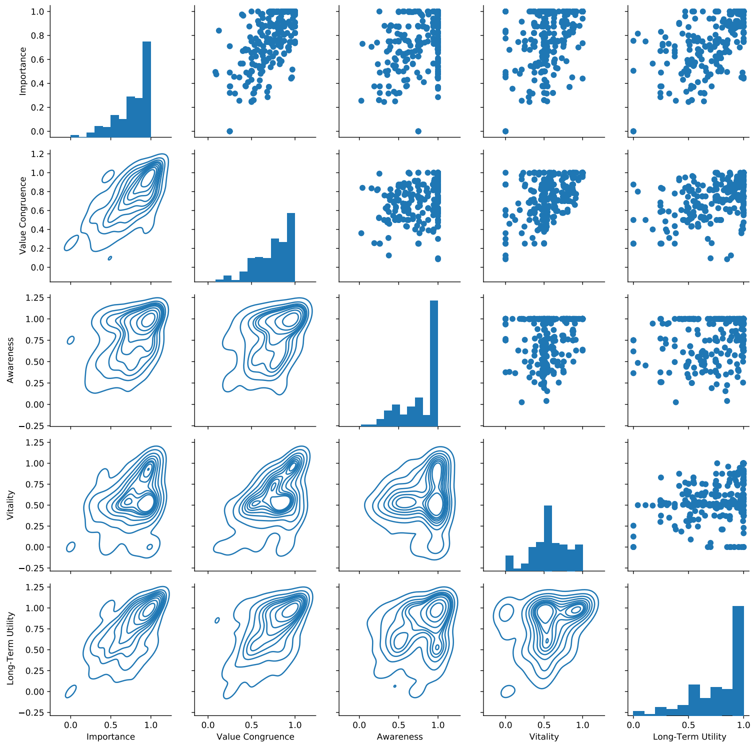

FIGURE F.207: Correlations and KDE for variable Importance matrix 7.

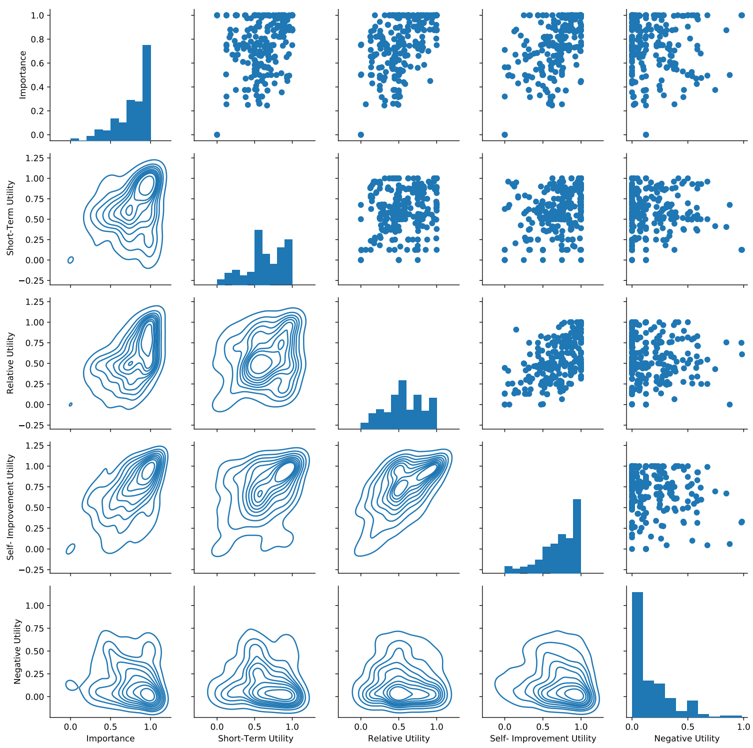

FIGURE F.208: Correlations and KDE for variable Importance matrix 8.

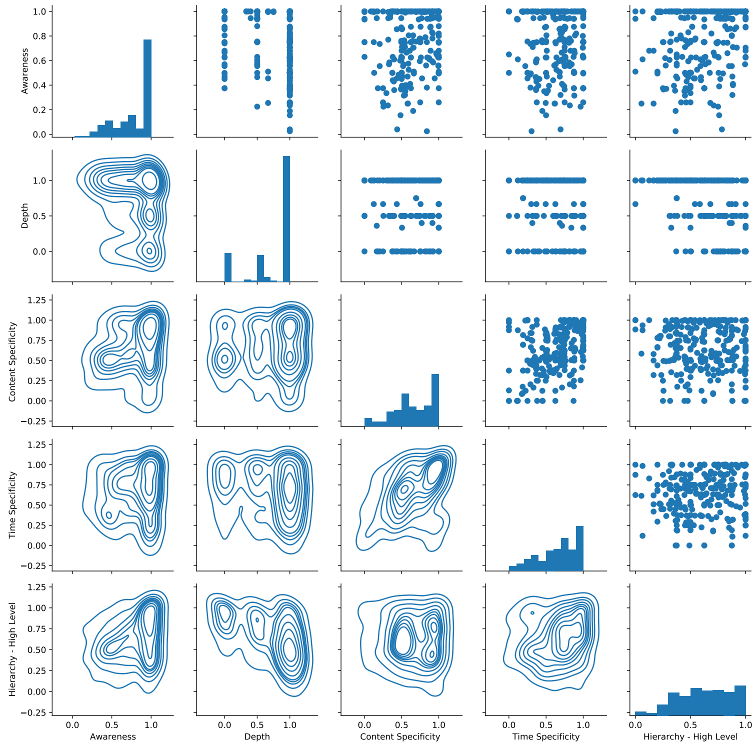

FIGURE F.209: Correlations and KDE for variable Awareness matrix 1.

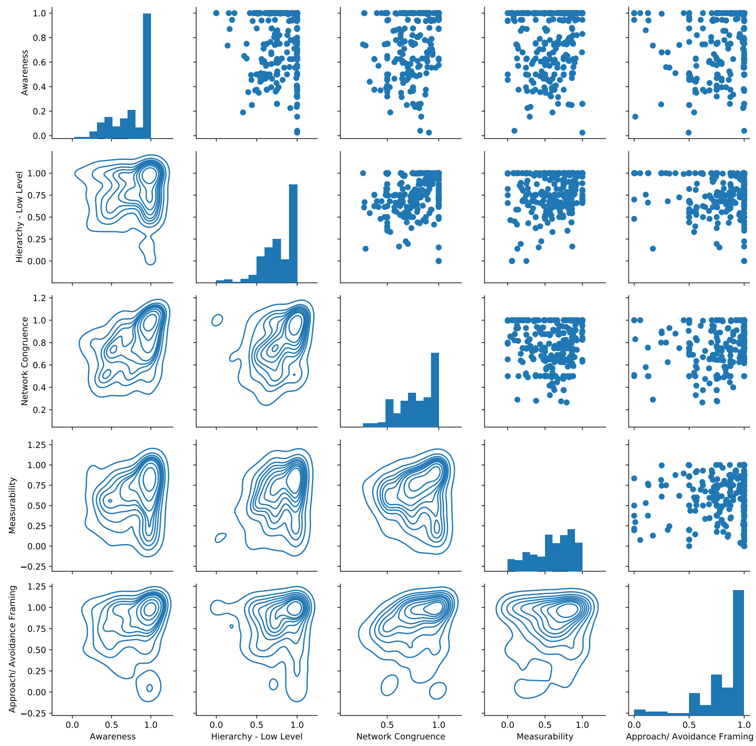

FIGURE F.210: Correlations and KDE for variable Awareness matrix 2.

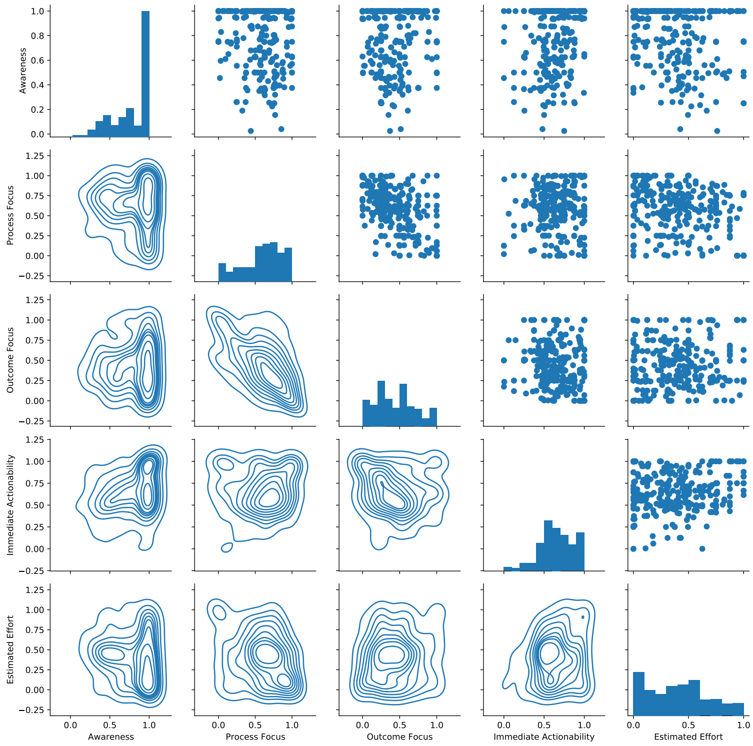

FIGURE F.211: Correlations and KDE for variable Awareness matrix 3.

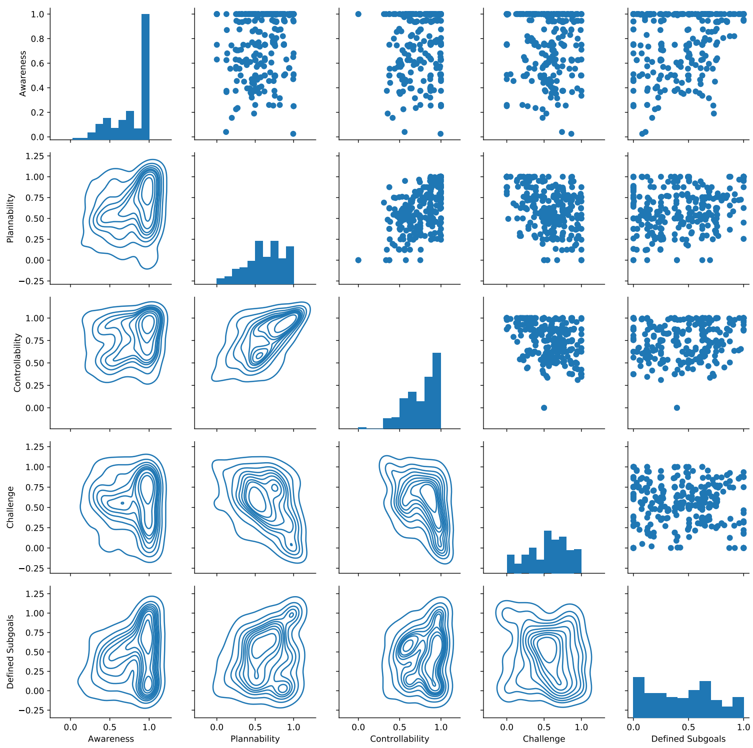

FIGURE F.212: Correlations and KDE for variable Awareness matrix 4.

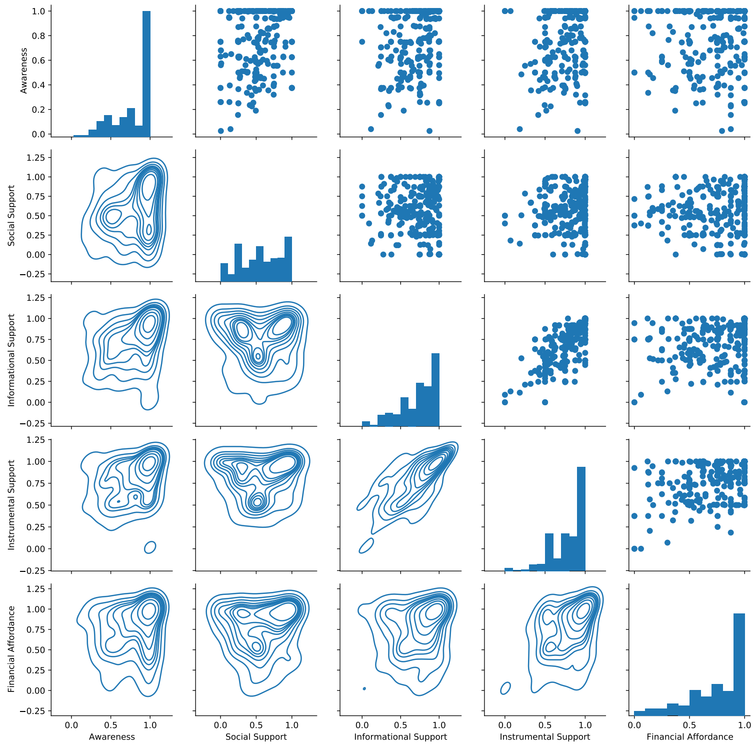

FIGURE F.213: Correlations and KDE for variable Awareness matrix 5.

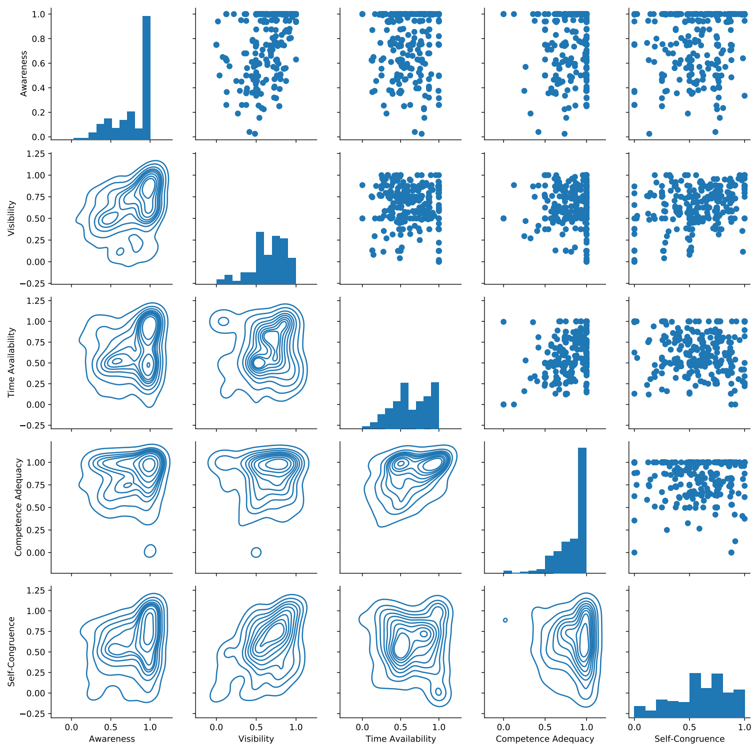

FIGURE F.214: Correlations and KDE for variable Awareness matrix 6.

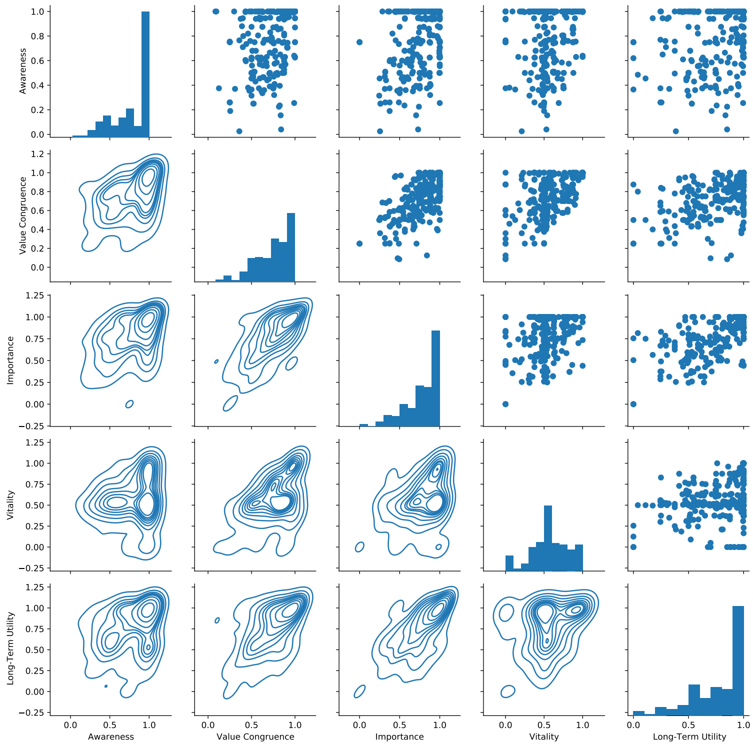

FIGURE F.215: Correlations and KDE for variable Awareness matrix 7.

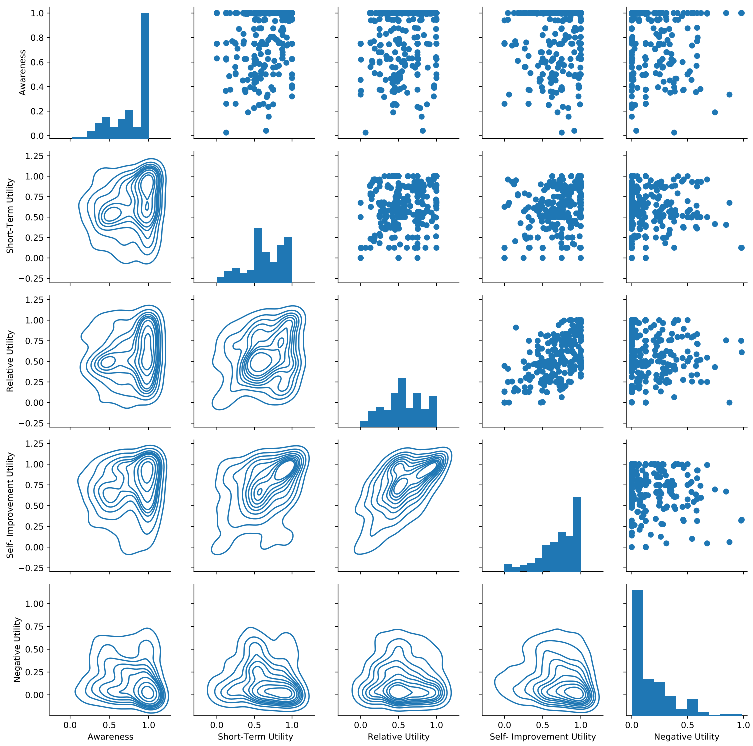

FIGURE F.216: Correlations and KDE for variable Awareness matrix 8.

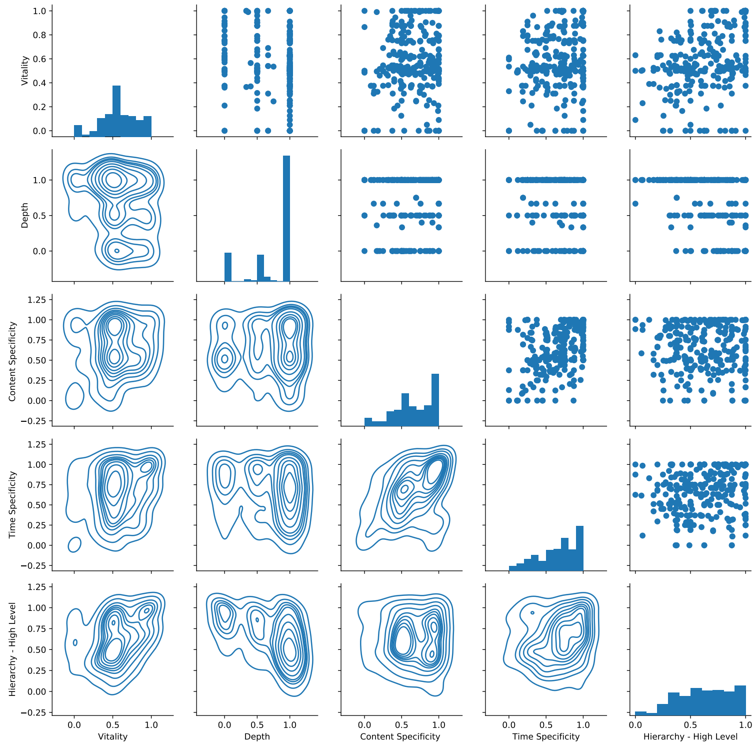

FIGURE F.217: Correlations and KDE for variable Vitality matrix 1.

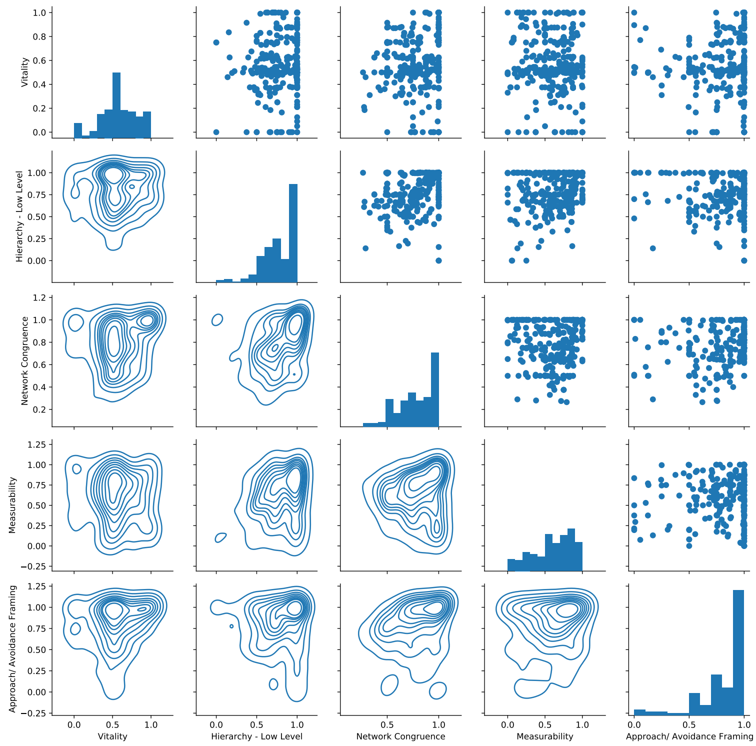

FIGURE F.218: Correlations and KDE for variable Vitality matrix 2.

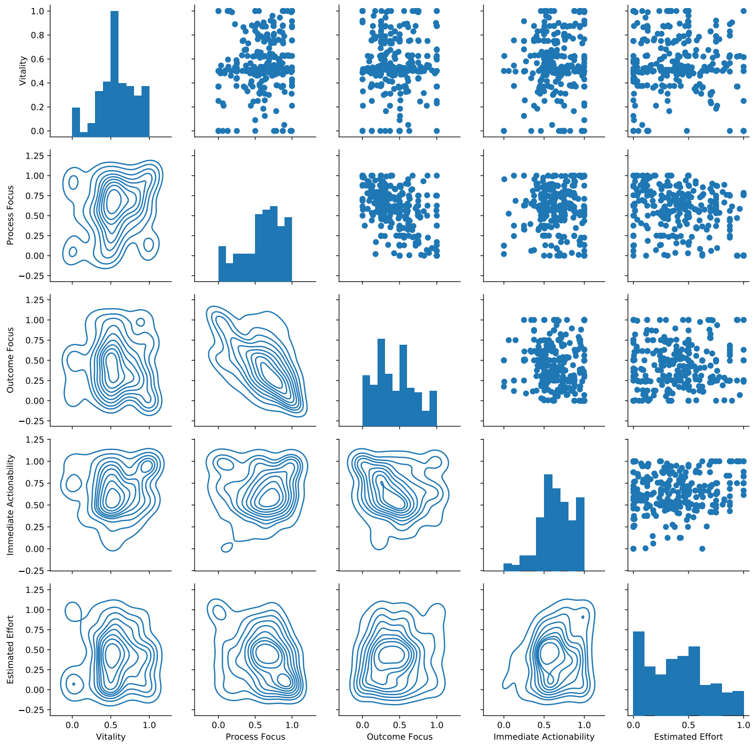

FIGURE F.219: Correlations and KDE for variable Vitality matrix 3.

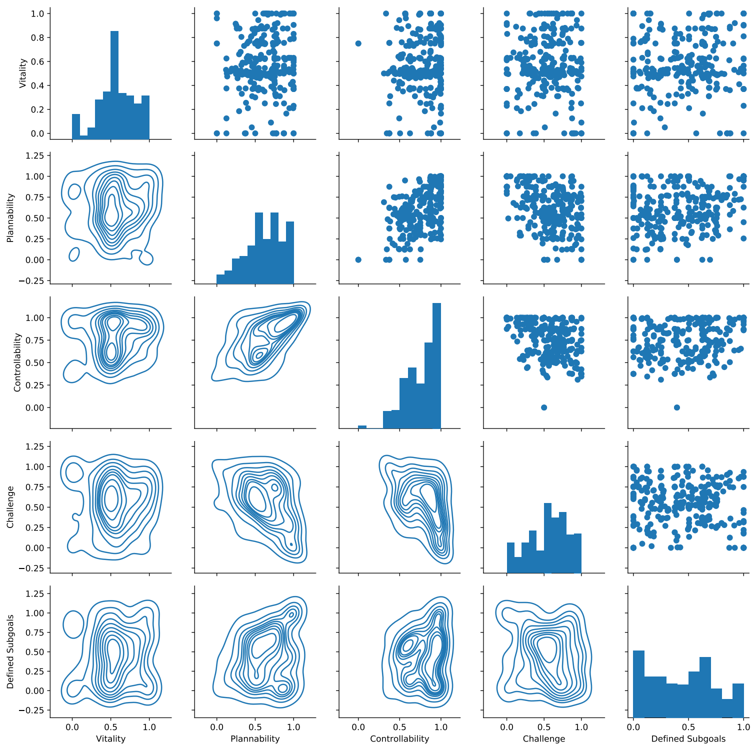

FIGURE F.220: Correlations and KDE for variable Vitality matrix 4.

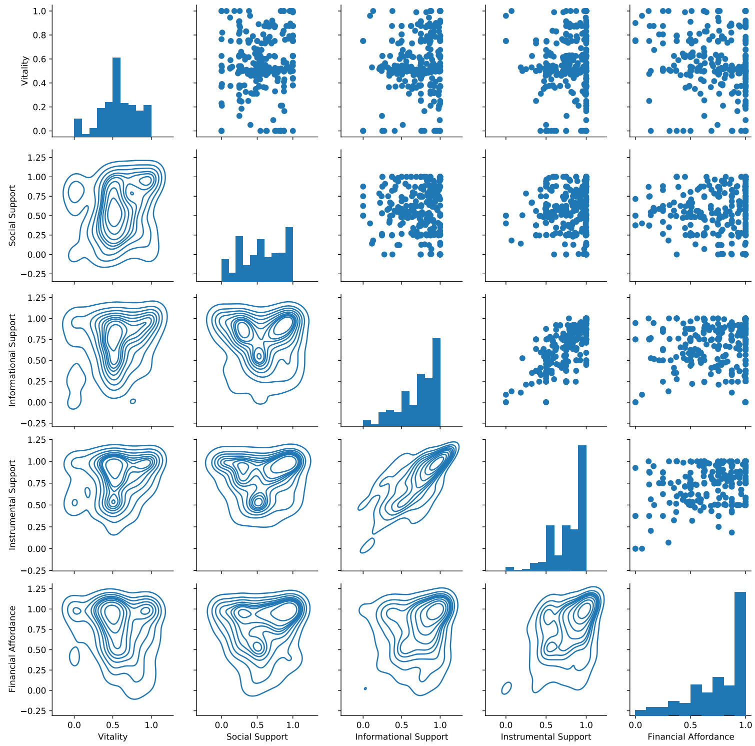

FIGURE F.221: Correlations and KDE for variable Vitality matrix 5.

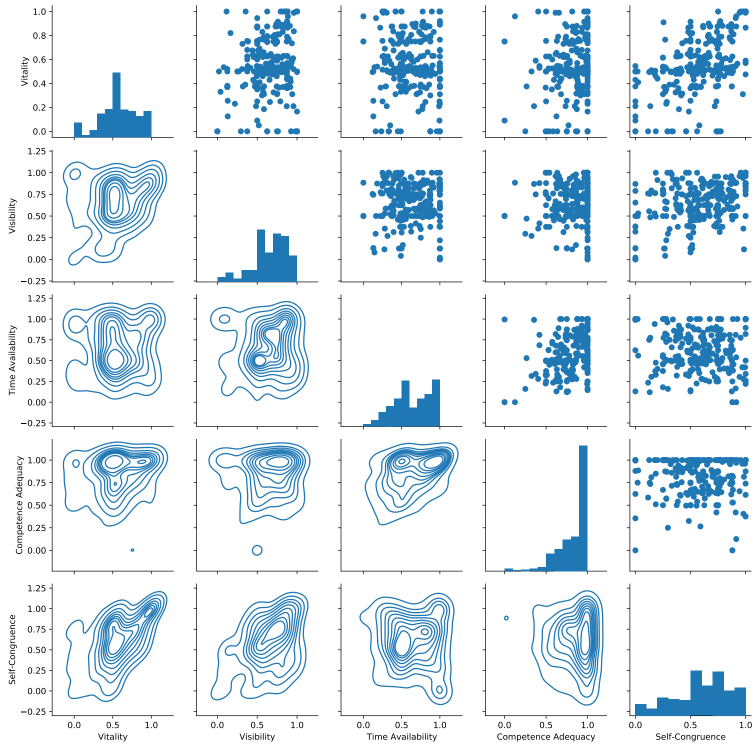

FIGURE F.222: Correlations and KDE for variable Vitality matrix 6.

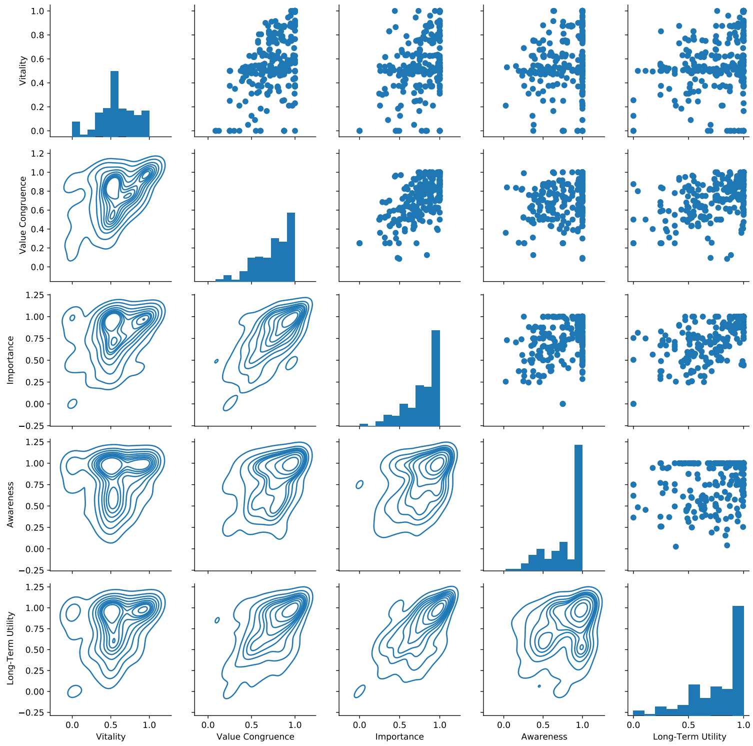

FIGURE F.223: Correlations and KDE for variable Vitality matrix 7.

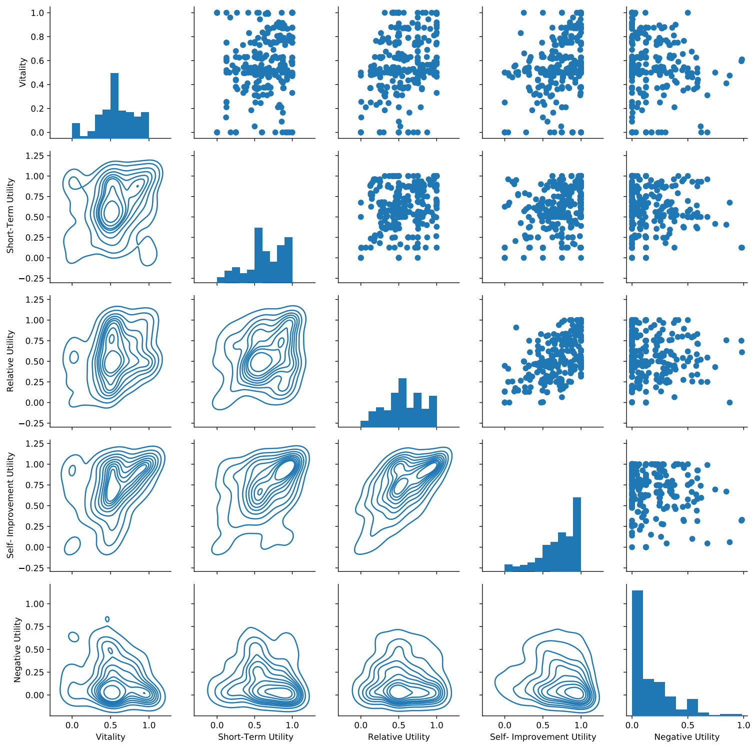

FIGURE F.224: Correlations and KDE for variable Vitality matrix 8.

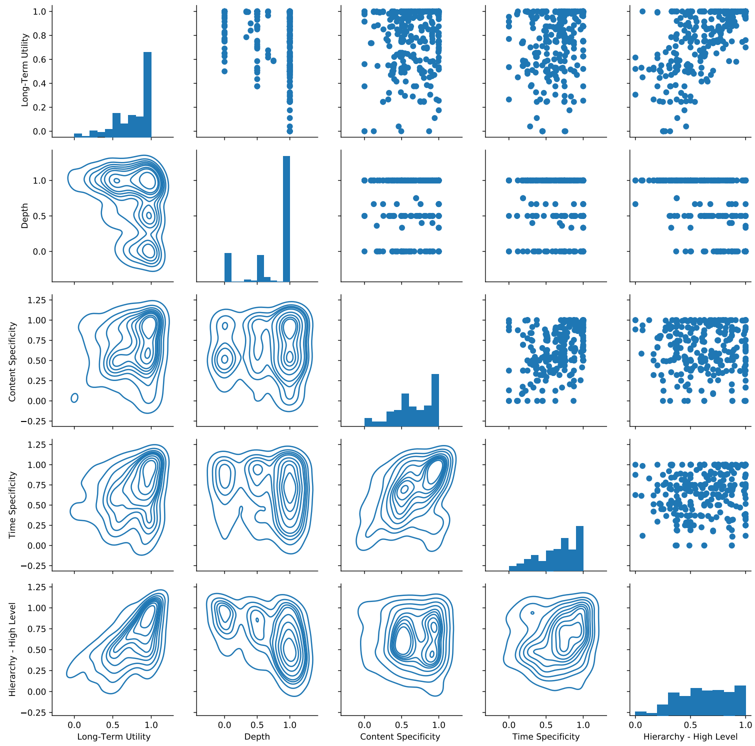

FIGURE F.225: Correlations and KDE for variable Long-Term Utility matrix 1.

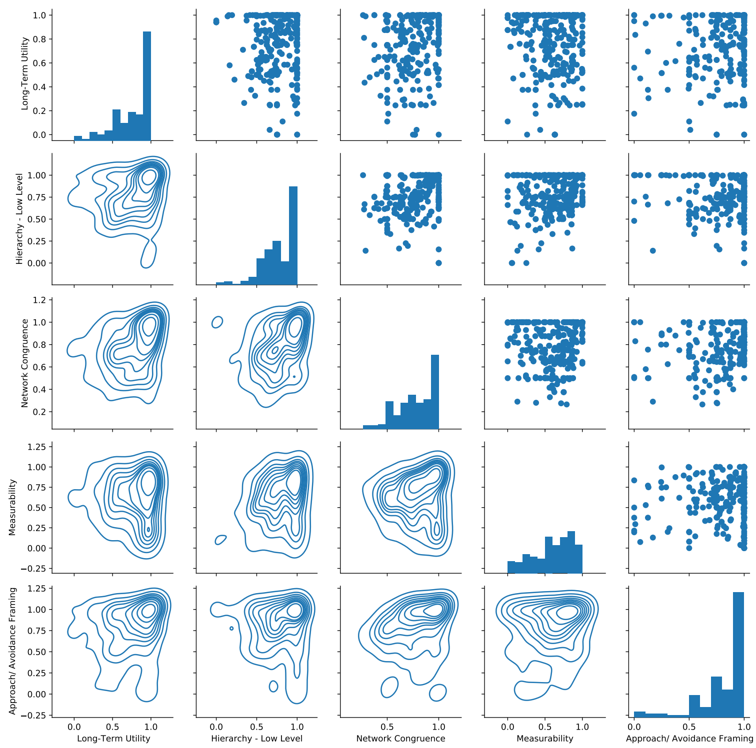

FIGURE F.226: Correlations and KDE for variable Long-Term Utility matrix 2.

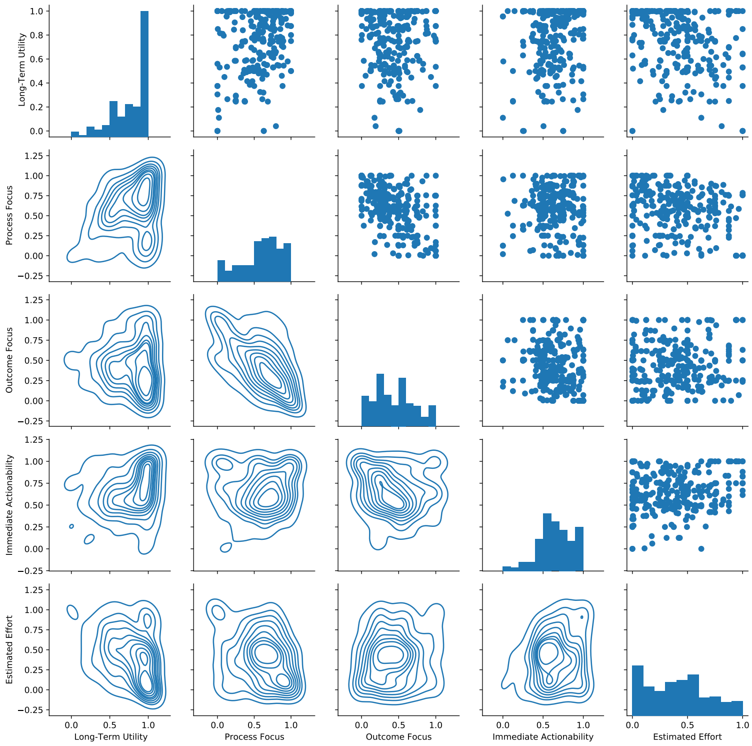

FIGURE F.227: Correlations and KDE for variable Long-Term Utility matrix 3.

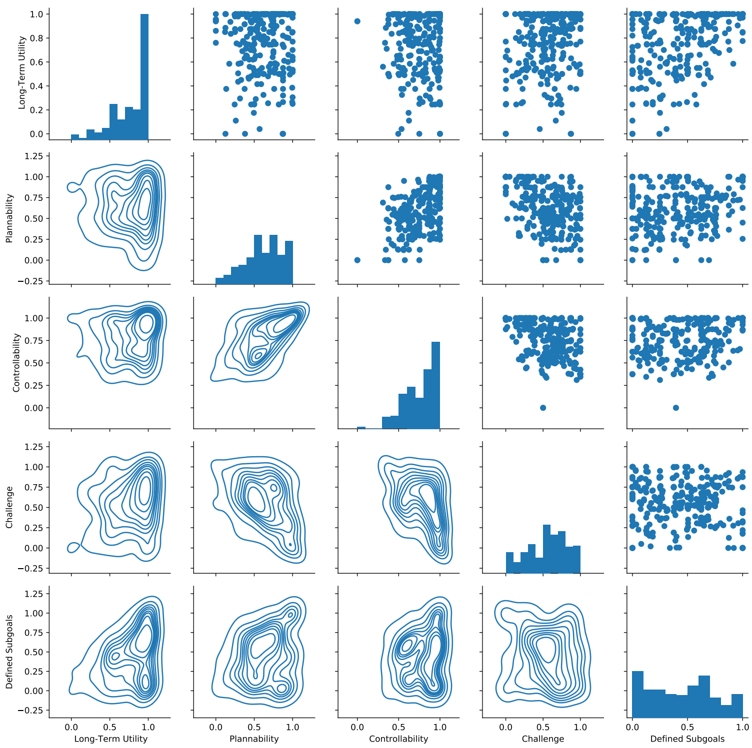

FIGURE F.228: Correlations and KDE for variable Long-Term Utility matrix 4.

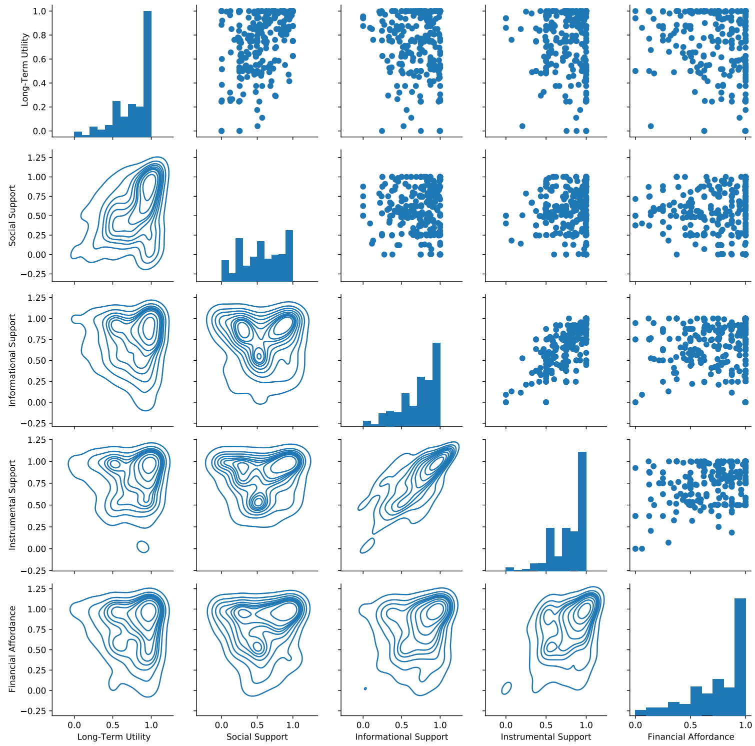

FIGURE F.229: Correlations and KDE for variable Long-Term Utility matrix 5.

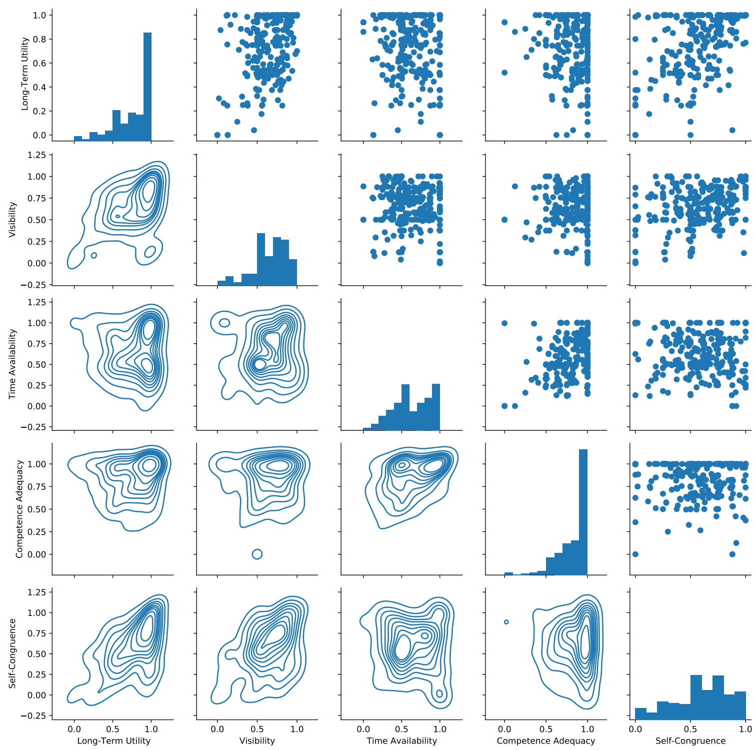

FIGURE F.230: Correlations and KDE for variable Long-Term Utility matrix 6.

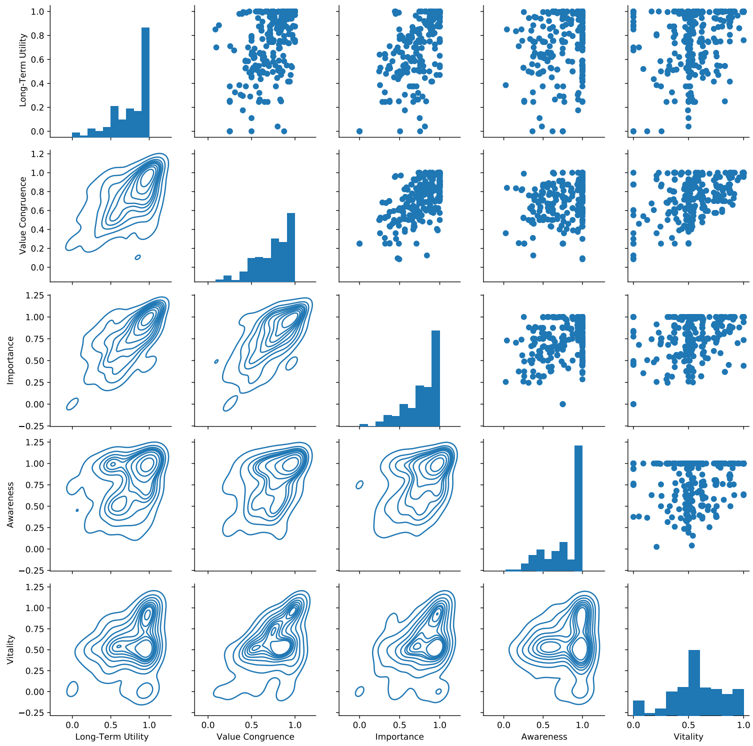

FIGURE F.231: Correlations and KDE for variable Long-Term Utility matrix 7.

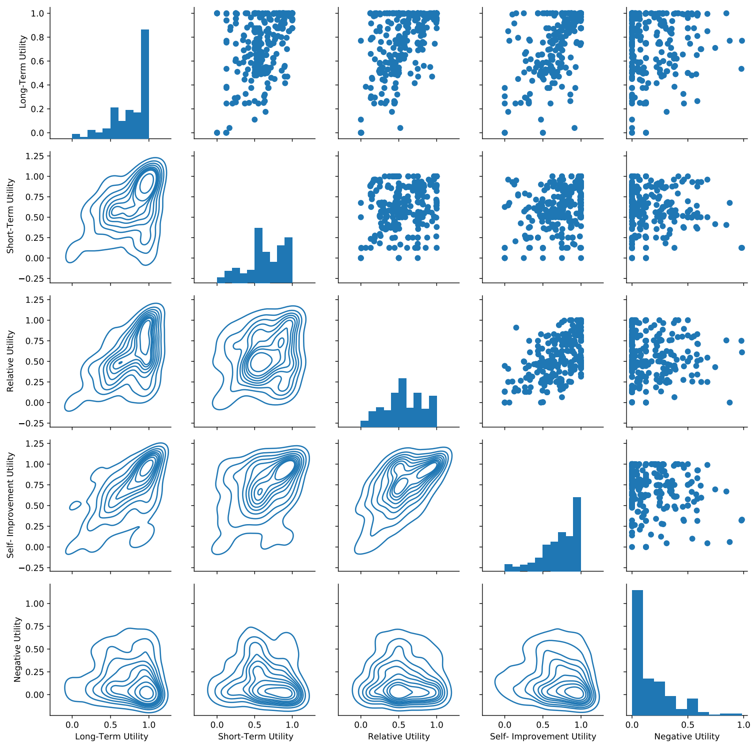

FIGURE F.232: Correlations and KDE for variable Long-Term Utility matrix 8.

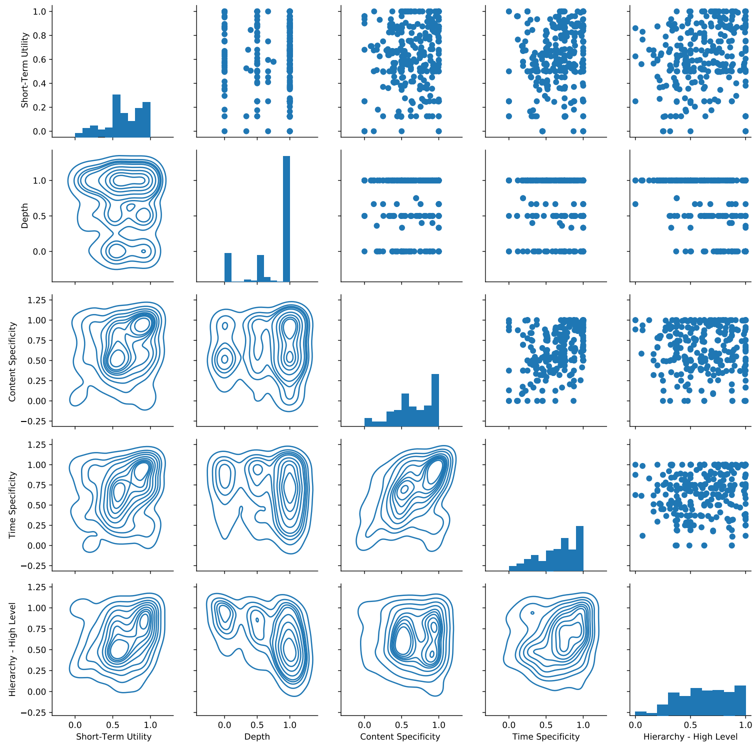

FIGURE F.233: Correlations and KDE for variable Short-Term Utility matrix 1.

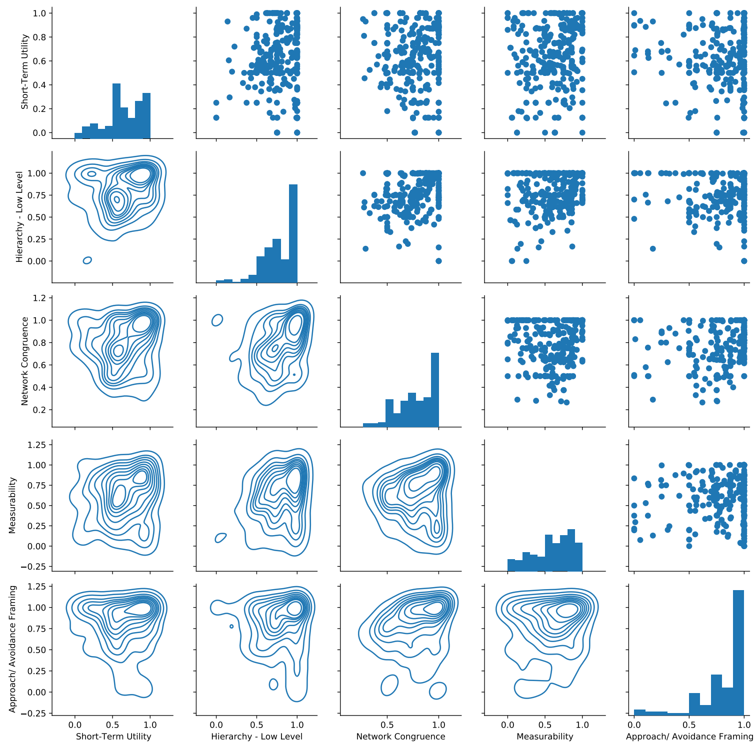

FIGURE F.234: Correlations and KDE for variable Short-Term Utility matrix 2.

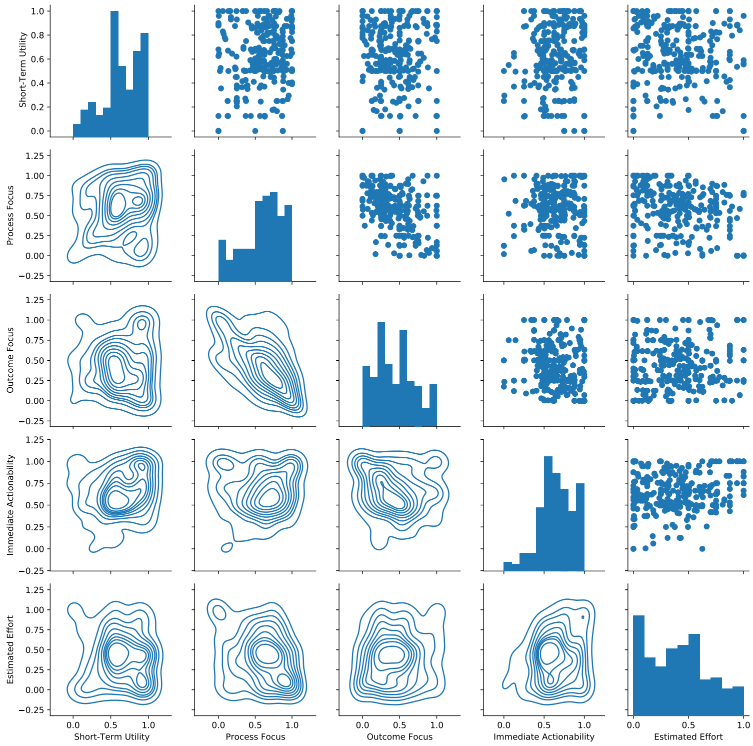

FIGURE F.235: Correlations and KDE for variable Short-Term Utility matrix 3.

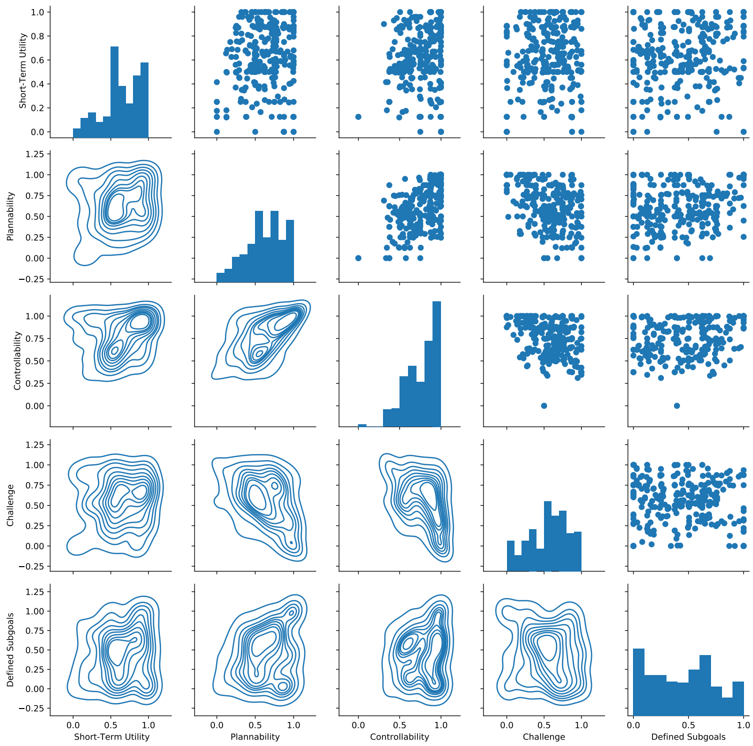

FIGURE F.236: Correlations and KDE for variable Short-Term Utility matrix 4.

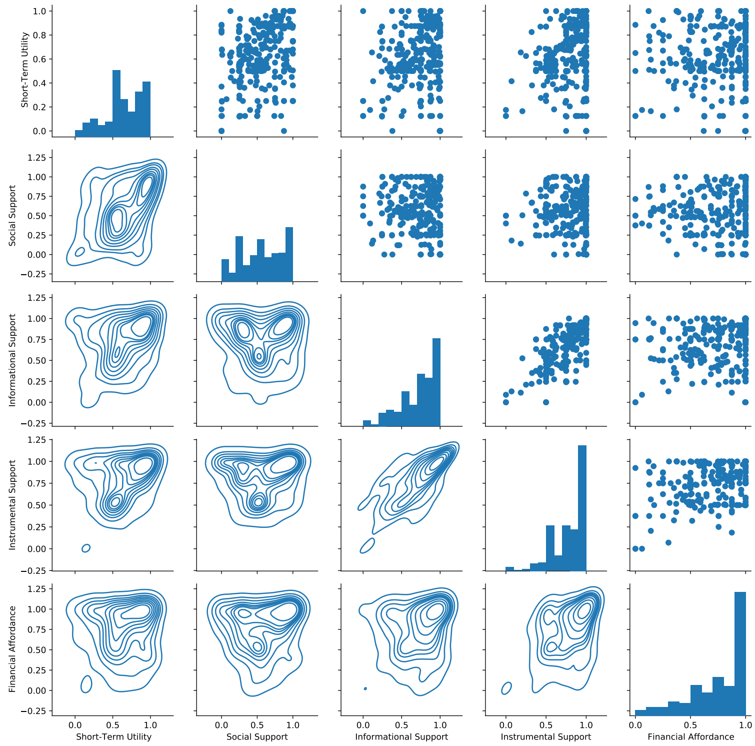

FIGURE F.237: Correlations and KDE for variable Short-Term Utility matrix 5.

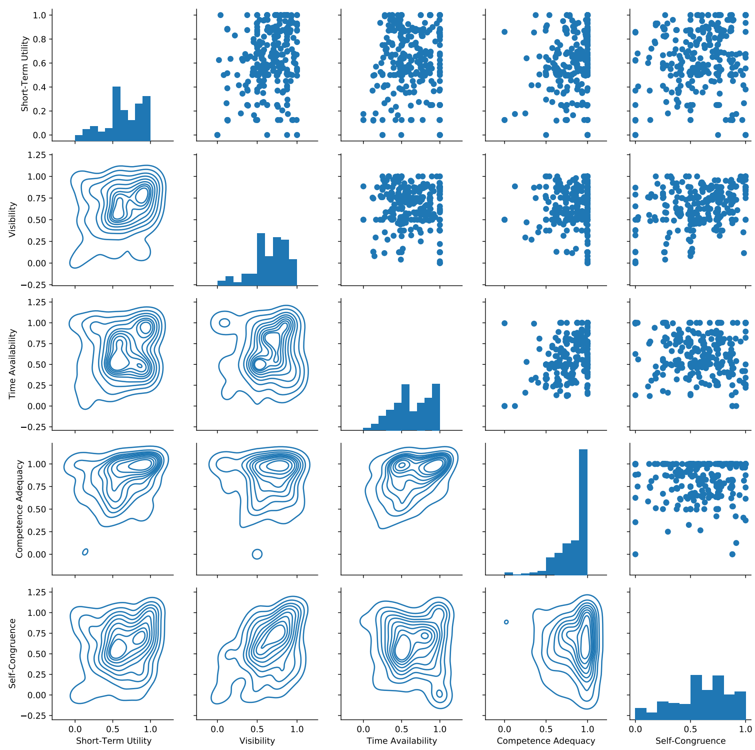

FIGURE F.238: Correlations and KDE for variable Short-Term Utility matrix 6.

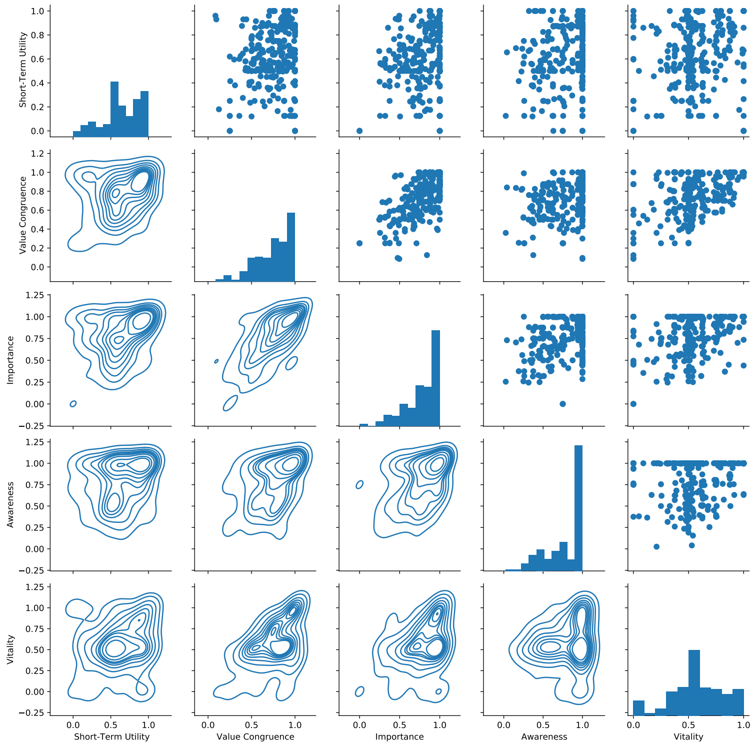

FIGURE F.239: Correlations and KDE for variable Short-Term Utility matrix 7.

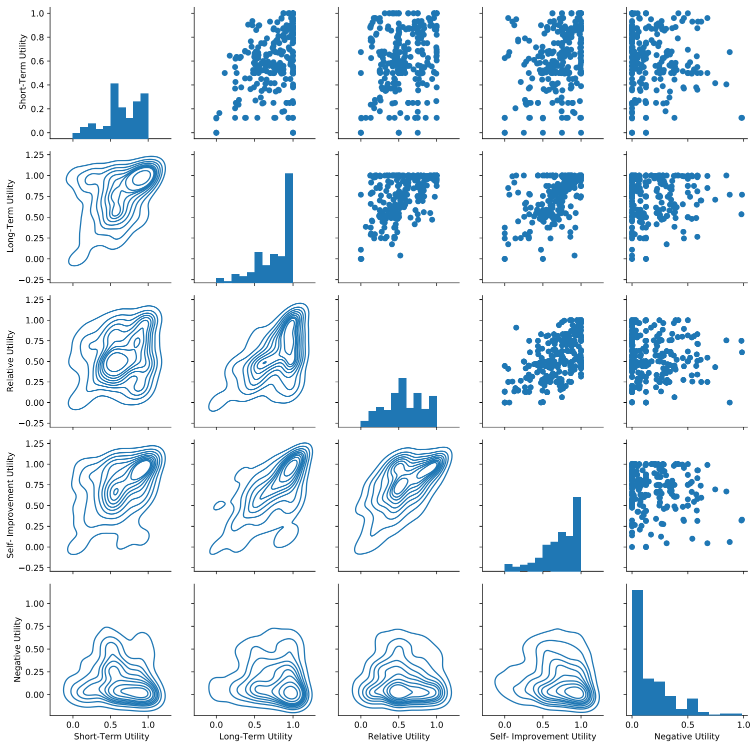

FIGURE F.240: Correlations and KDE for variable Short-Term Utility matrix 8.

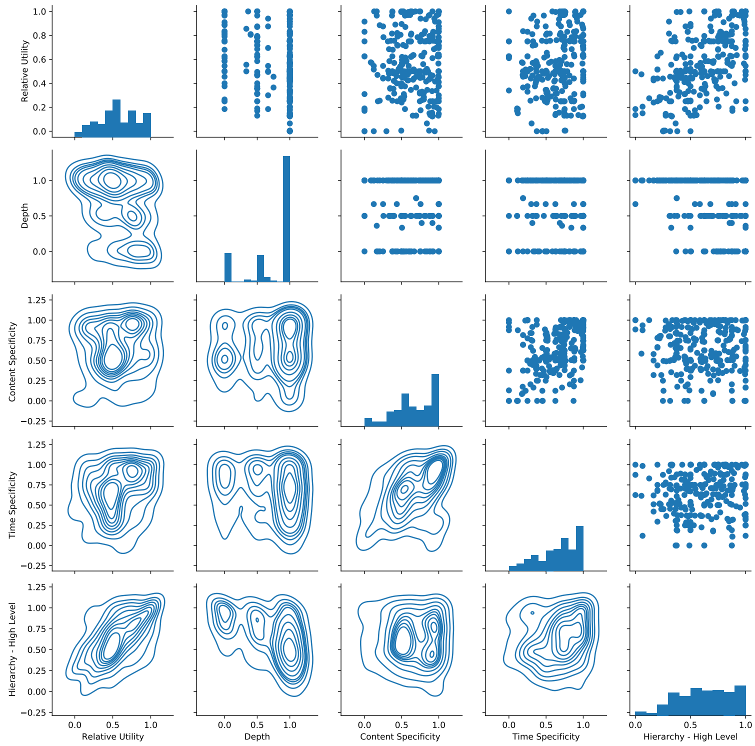

FIGURE F.241: Correlations and KDE for variable Relative Utility matrix 1.

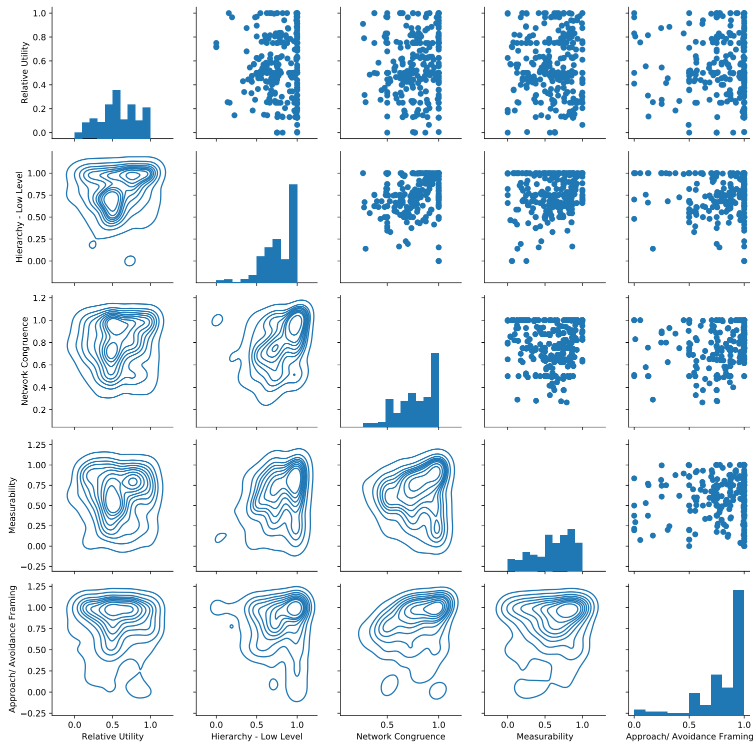

FIGURE F.242: Correlations and KDE for variable Relative Utility matrix 2.

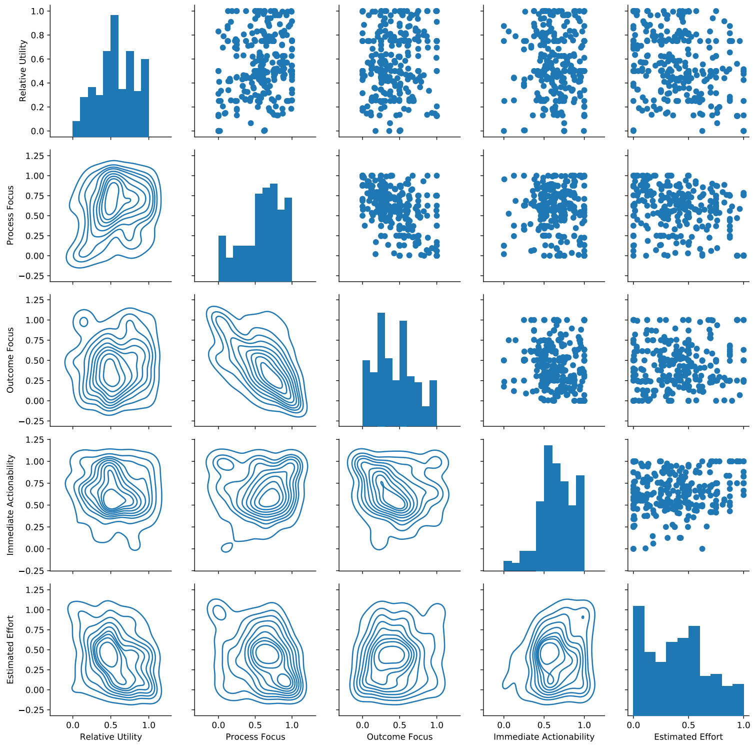

FIGURE F.243: Correlations and KDE for variable Relative Utility matrix 3.

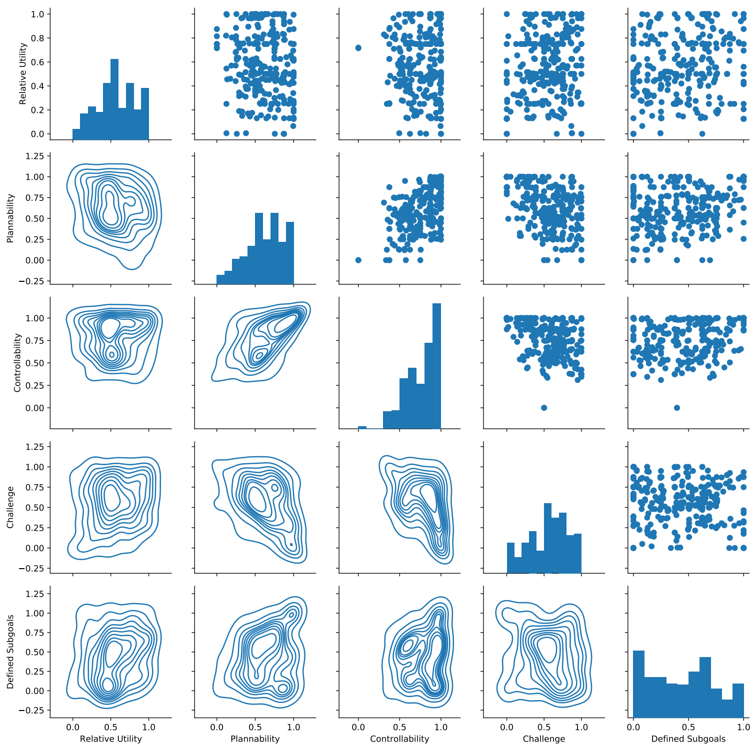

FIGURE F.244: Correlations and KDE for variable Relative Utility matrix 4.

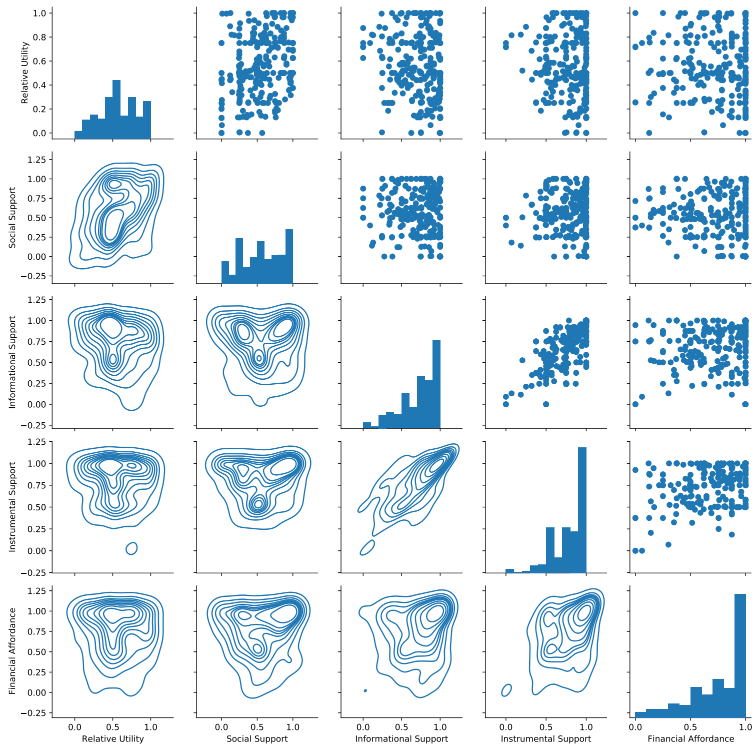

FIGURE F.245: Correlations and KDE for variable Relative Utility matrix 5.

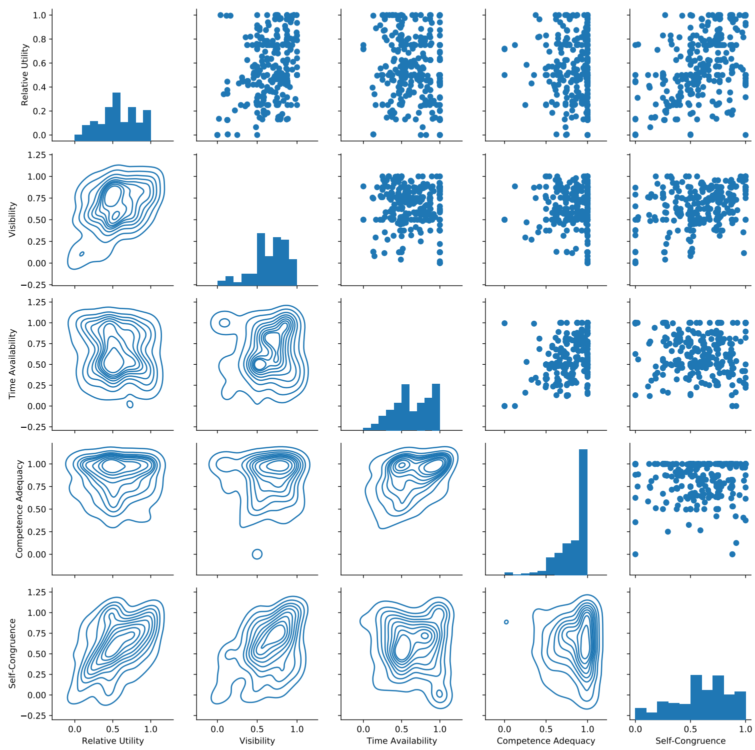

FIGURE F.246: Correlations and KDE for variable Relative Utility matrix 6.

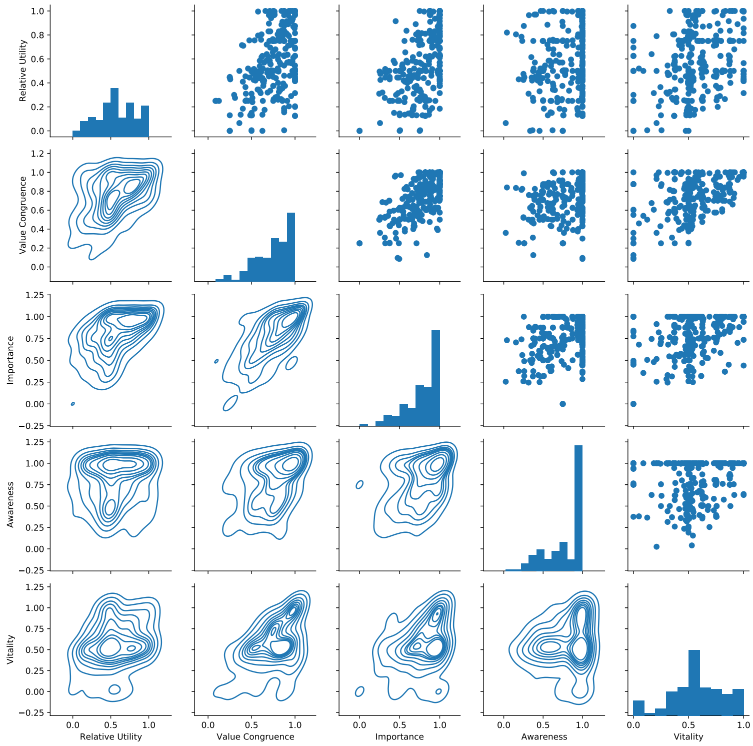

FIGURE F.247: Correlations and KDE for variable Relative Utility matrix 7.

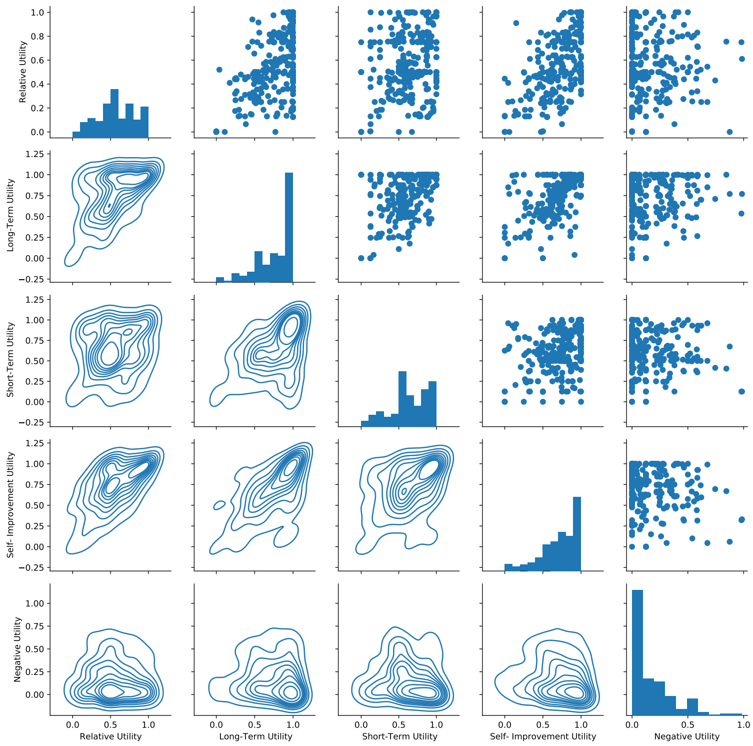

FIGURE F.248: Correlations and KDE for variable Relative Utility matrix 8.

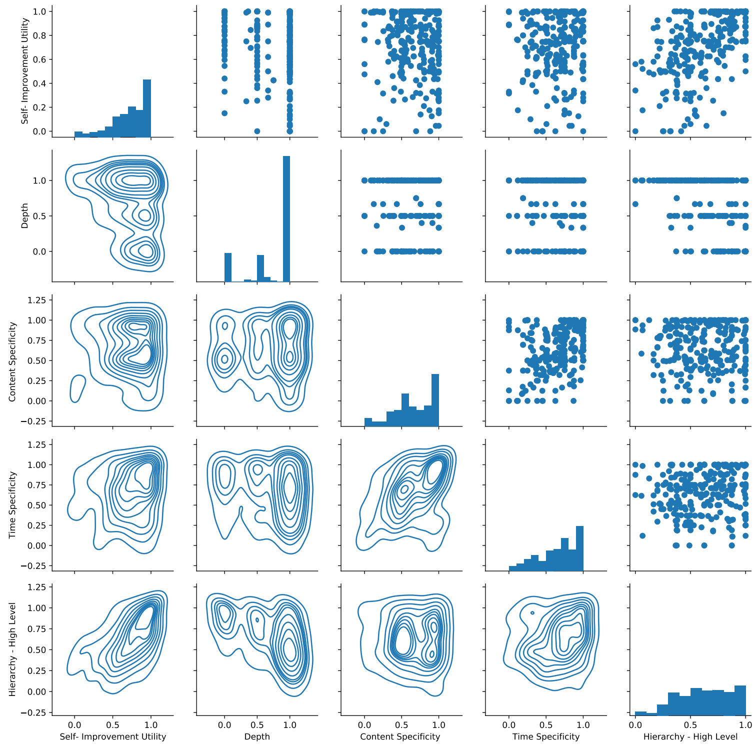

FIGURE F.249: Correlations and KDE for variable Self- Improvement Utility matrix 1.

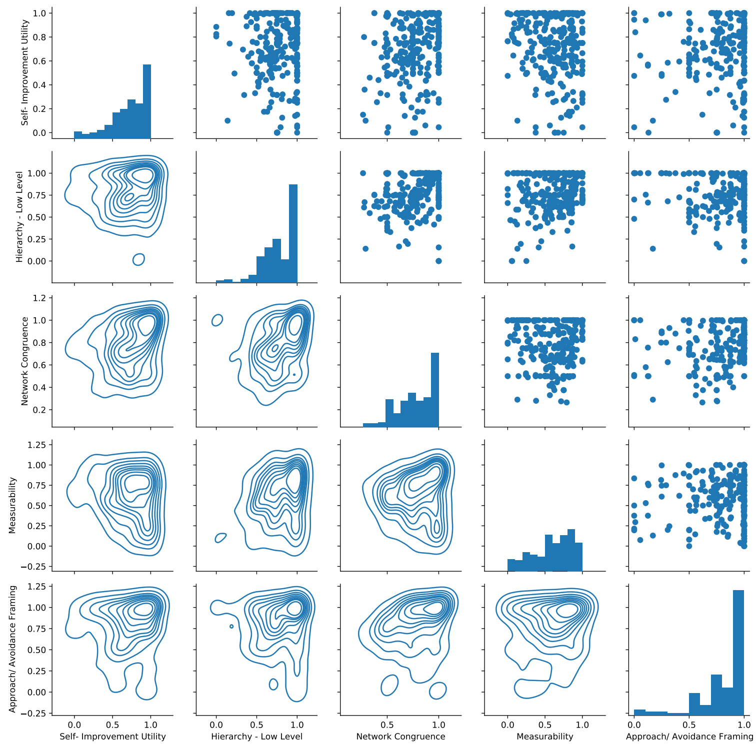

FIGURE F.250: Correlations and KDE for variable Self- Improvement Utility matrix 2.

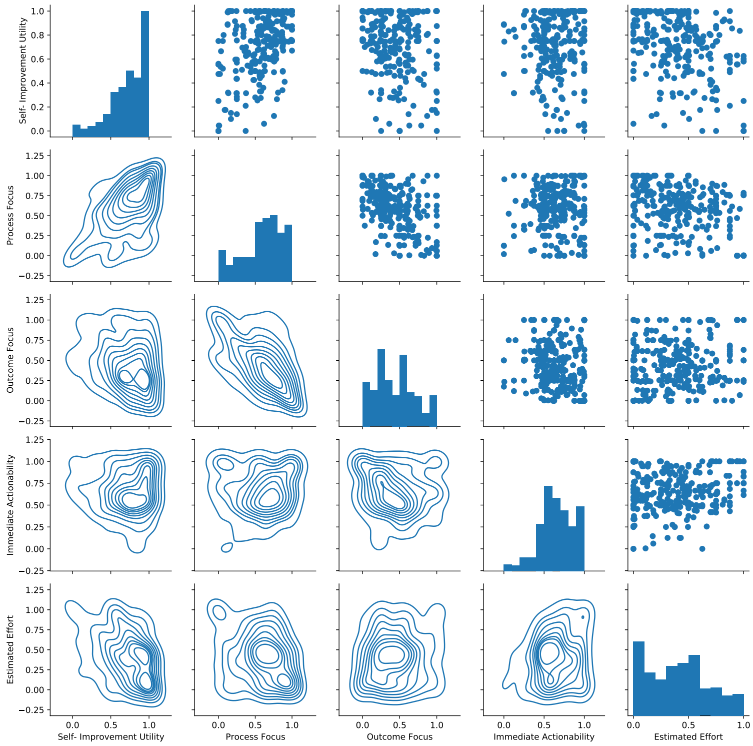

FIGURE F.251: Correlations and KDE for variable Self- Improvement Utility matrix 3.

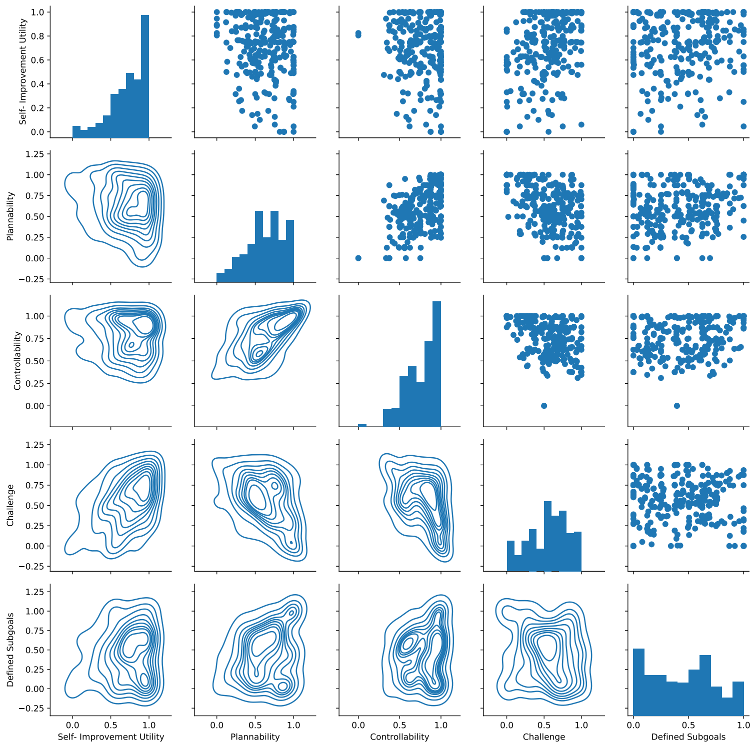

FIGURE F.252: Correlations and KDE for variable Self- Improvement Utility matrix 4.

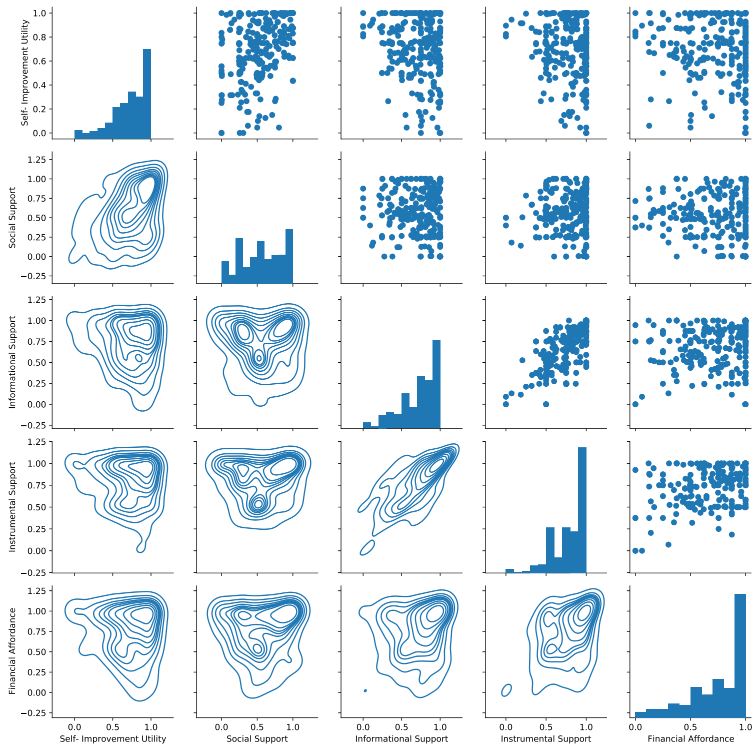

FIGURE F.253: Correlations and KDE for variable Self- Improvement Utility matrix 5.

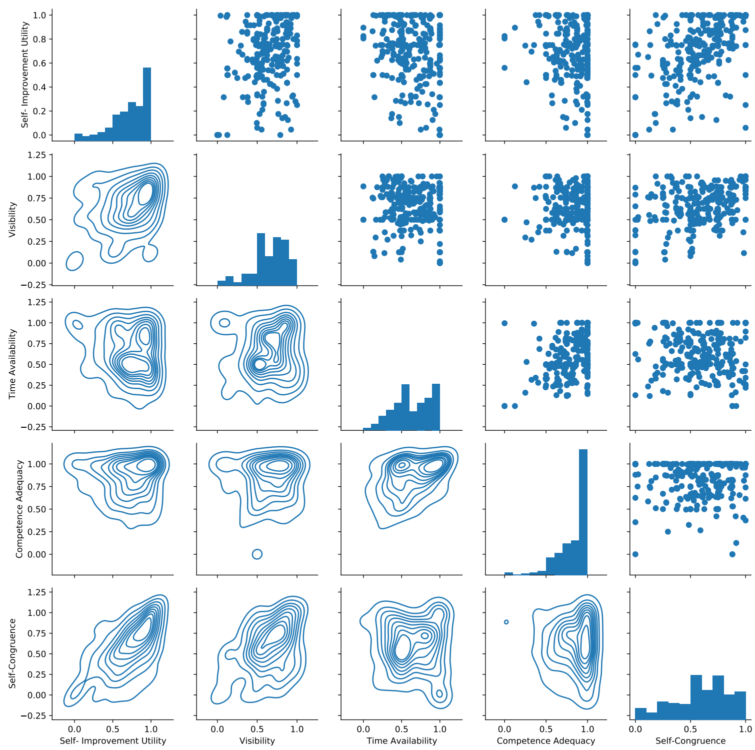

FIGURE F.254: Correlations and KDE for variable Self- Improvement Utility matrix 6.

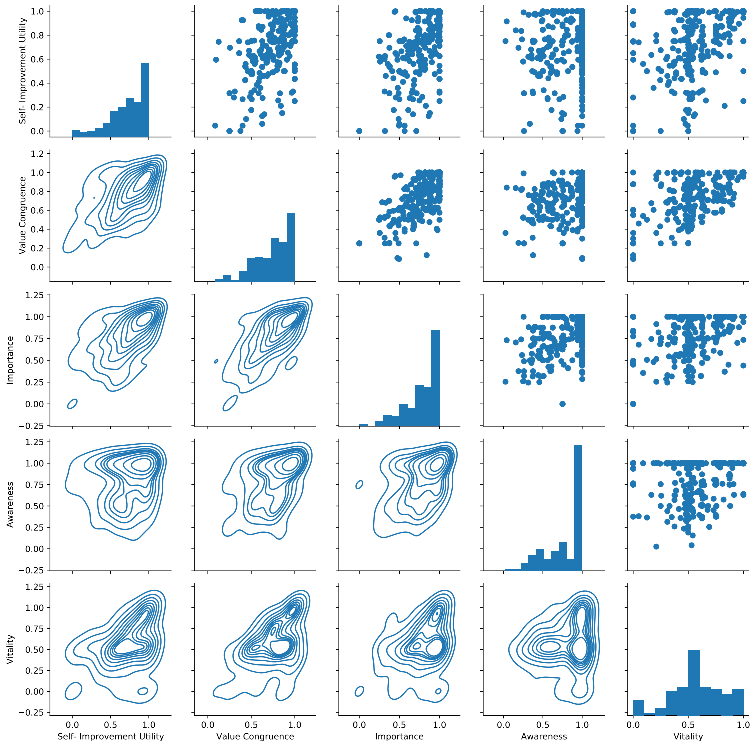

FIGURE F.255: Correlations and KDE for variable Self- Improvement Utility matrix 7.

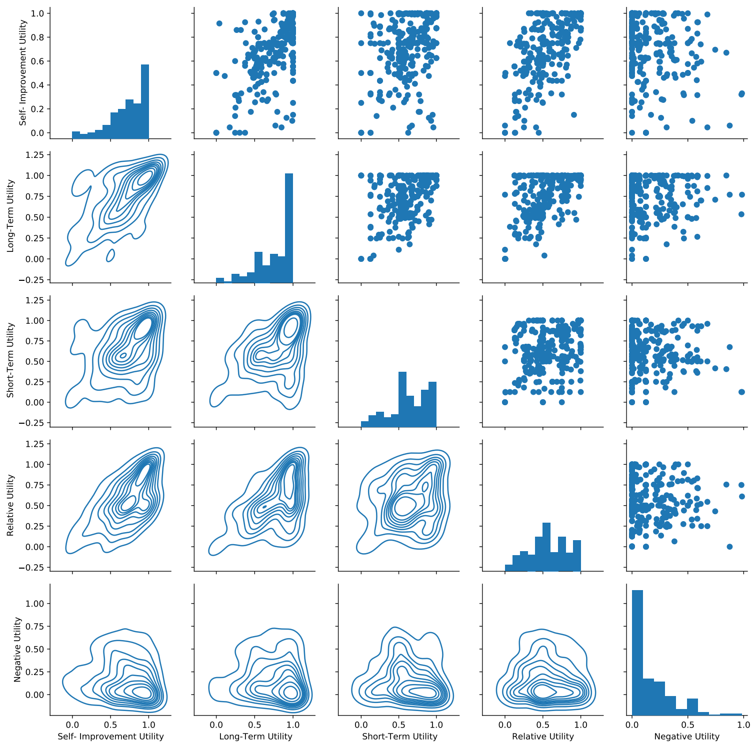

FIGURE F.256: Correlations and KDE for variable Self- Improvement Utility matrix 8.

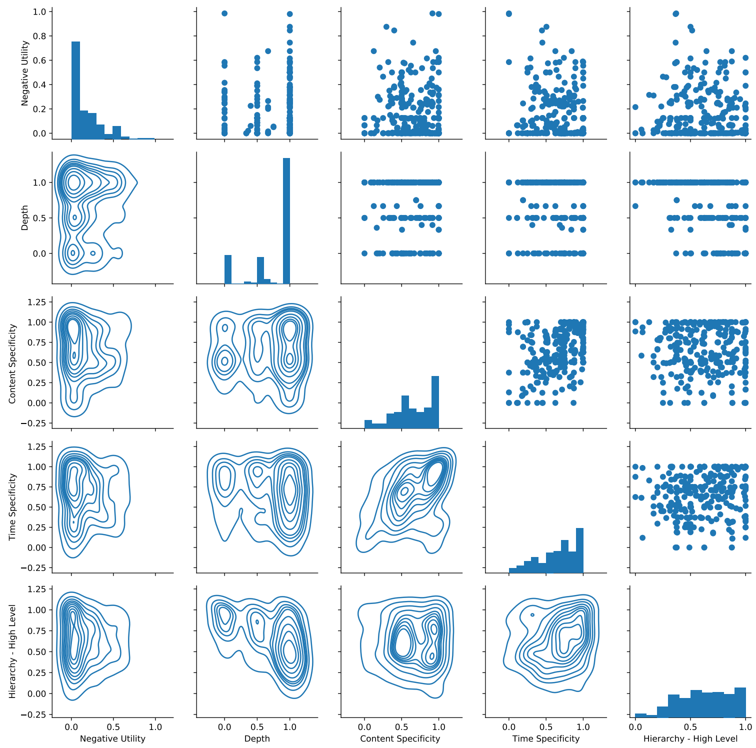

FIGURE F.257: Correlations and KDE for variable Negative Utility matrix 1.

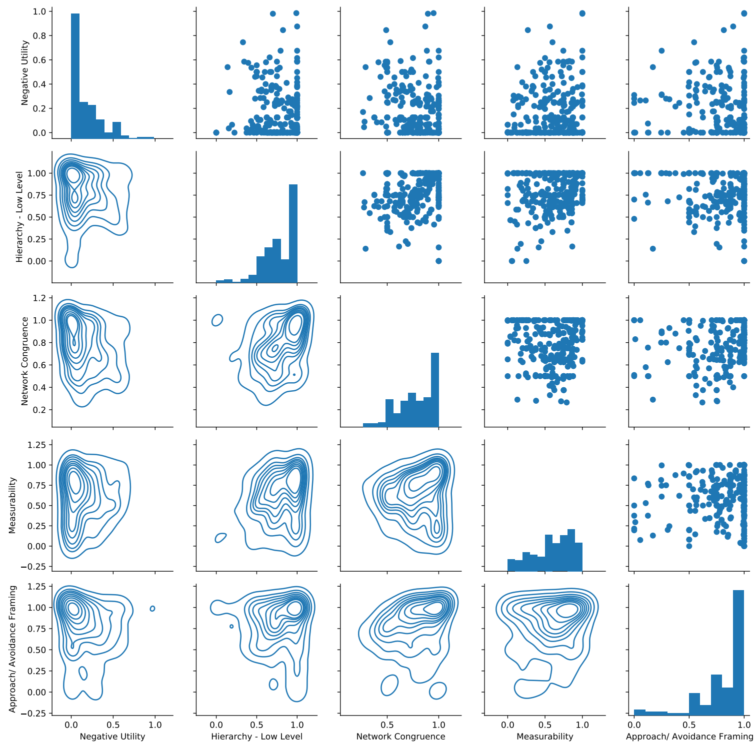

FIGURE F.258: Correlations and KDE for variable Negative Utility matrix 2.

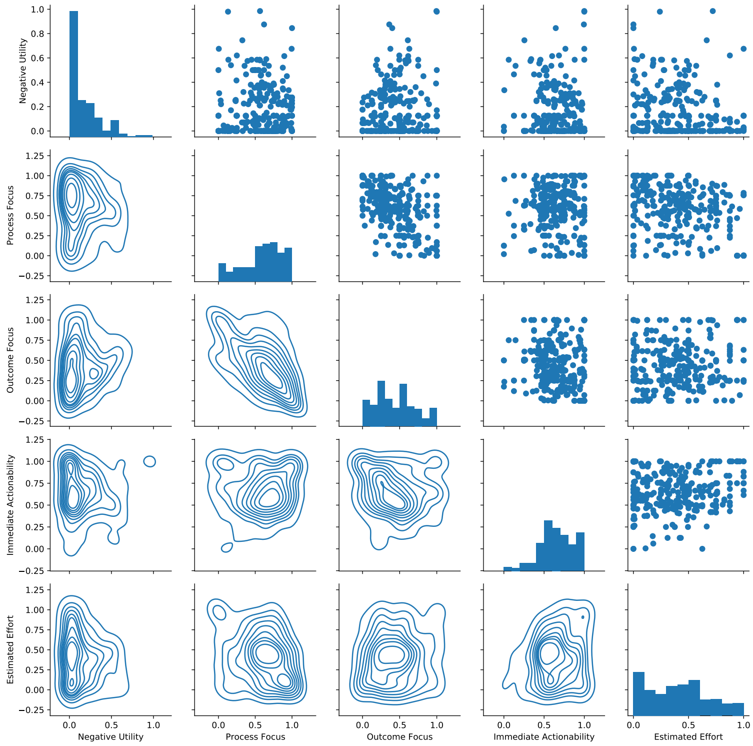

FIGURE F.259: Correlations and KDE for variable Negative Utility matrix 3.

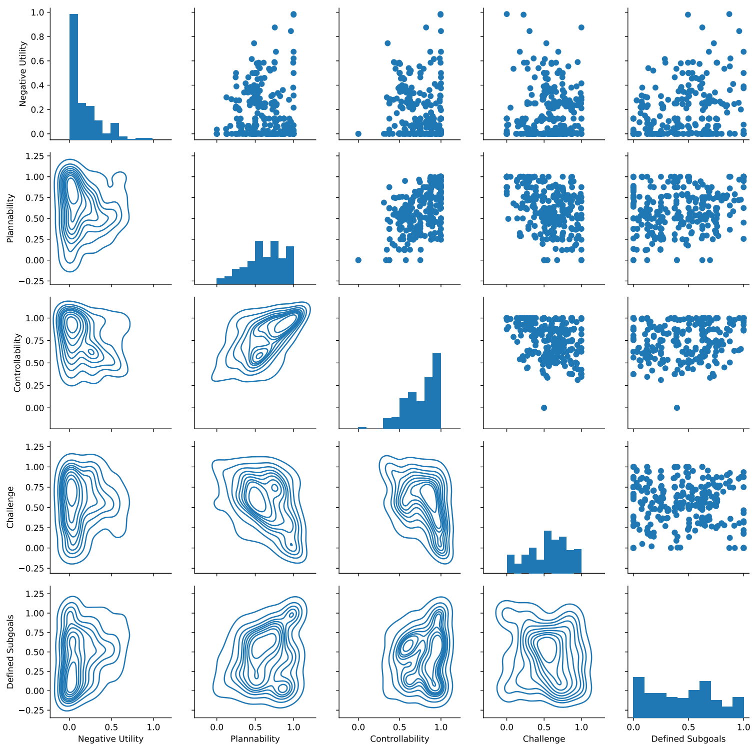

FIGURE F.260: Correlations and KDE for variable Negative Utility matrix 4.

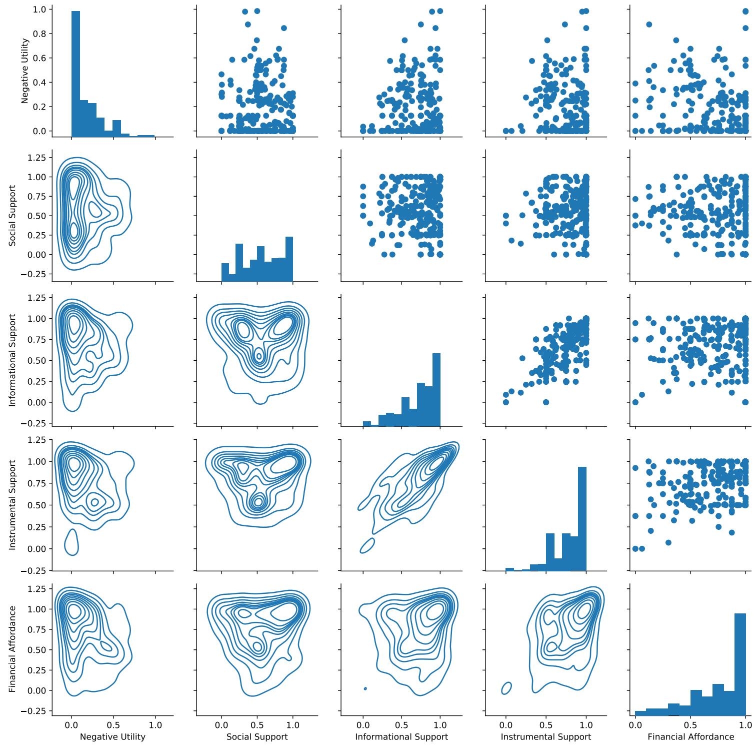

FIGURE F.261: Correlations and KDE for variable Negative Utility matrix 5.

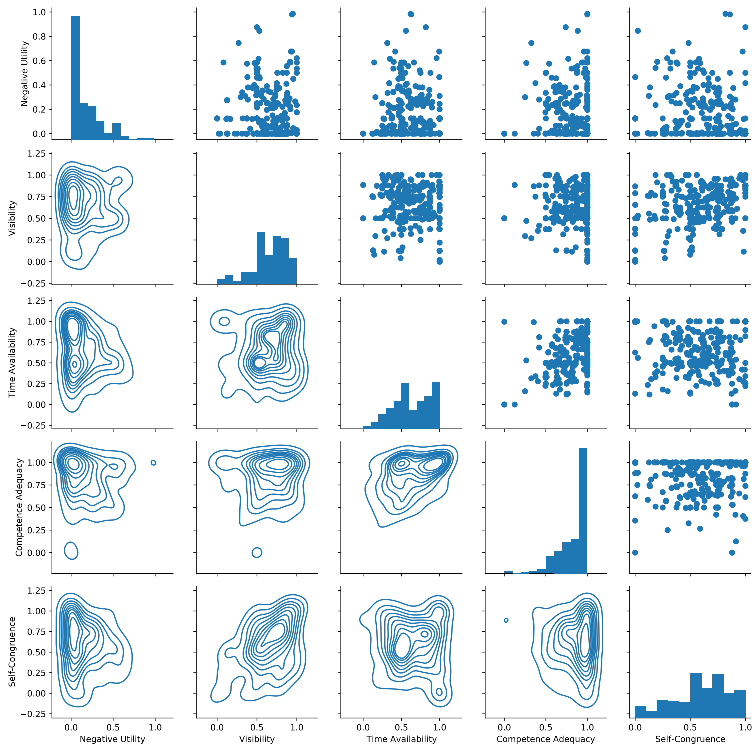

FIGURE F.262: Correlations and KDE for variable Negative Utility matrix 6.

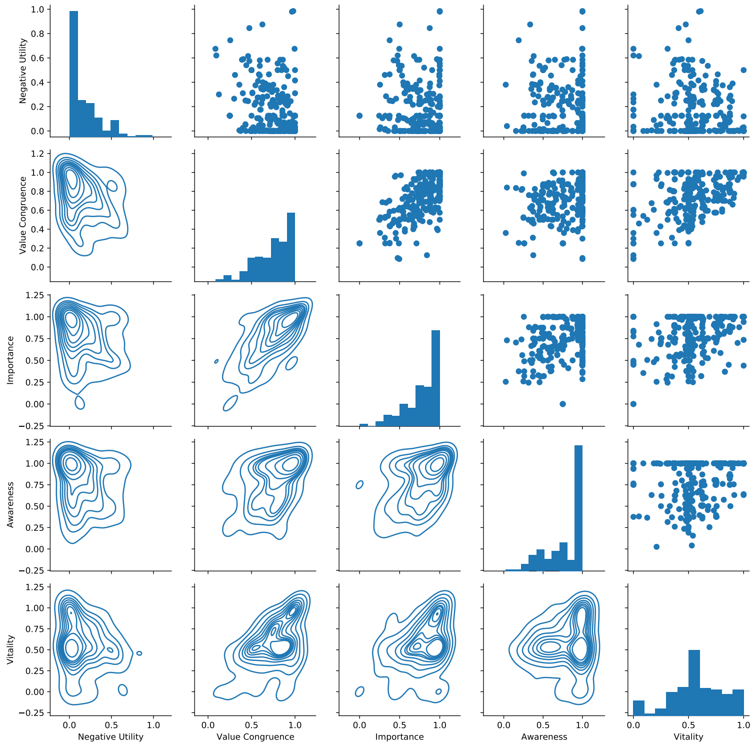

FIGURE F.263: Correlations and KDE for variable Negative Utility matrix 7.

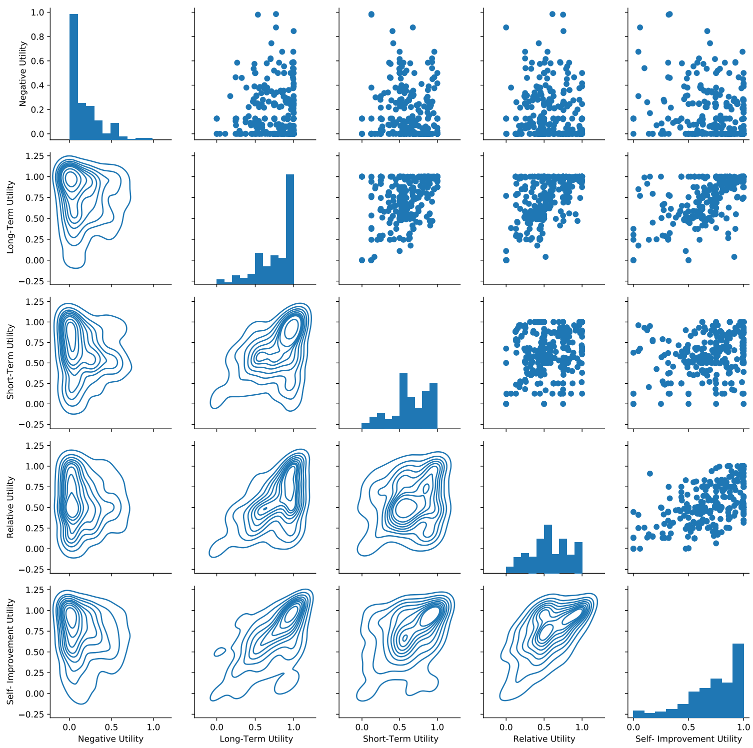

FIGURE F.264: Correlations and KDE for variable Negative Utility matrix 8.

Appendix G

Credit Roles

roles the author of this thesis contributed to the listed publications. The roles are based on the CRediT (Contributor Roles Taxonomy)[1] high-level taxonomy, which includes 14 roles that can be used to represent the roles of contributors to research outputs.

The 14 roles of the taxonomy are: *Conceptualization (1), Data curation (2), Formal Analysis (3), Funding acquisition (4), Investigation (5), Methodology (6), Project administration (7), Resources (8), Software (9), Supervision (10), Validation (11), Visualization (12), Writing – original draft (13), and Writing – review and editing (14).*

The assignments are correct in that the listed authors have filled the assigned roles, but not necessarily complete, insofar that authors may have also contributed in other roles.

Title	Reference	Credit Roles
"Towards a Comprehensive Taxonomy of Study Goals of University Students."	(Weber, Osada, and Thelen, 2019)	Osada: 1, 5, 9, 21; Thelen: 1, 4, 5, 6, 9, 10, 21; Weber: 1, 2, 3, 5, 6, 9, 12, 13, 14;
"Goal Trees as Structuring Element in a Digital Data-Driven Study Assistant"	(Weber, 2019)	Weber: 1, 2, 3, 5, 6, 9, 12, 13, 14;
"A Tagset for University Students' Educational Goals"	(Weber and Le Foll, 2020)	Le Foll: 19, 21; Weber: 1, 2, 3, 5, 6, 9, 12, 13, 14;
"Development of a Digital Goal Setting Companion for Higher Education"	(Weber, Schrumpf, and Thelen, 2021)	Schrumpf: 14; Thelen: 4, 10, 14; Weber: 1, 5, 6, 9, 12, 13
"Towards A Web-Based Hierarchical Goal Setting Intervention for Higher Education"	(Weber et al., 2021)	Grenz: 1, 2, 5, 6, 11, 13, 14; Kernos: 1, 2, 5, 6, 11, 13, 14; Weber: 1, 2, 5, 6, 7, 9, 10, 13, 14; Lee: 1, 2, 5, 6, 11, 13, 14;
"Towards a User Focused Development of a digital Study Assistant Through a Mixed Methods Design"	(Schurz et al., 2021)	Seyfeli: 6, 12, 13, 14; Lübcke: 6, 12, 13, 14; Schrumpf: 1, 2, 5, 6, 9, 12, 14; Schurz: 13, 14; Wannemacher: 1, 4, 13, 14; Weber: 1, 2, 9, 12, 13, 14;

[1]https://credit.niso.org/

A Neural Natural Language Processing System for Educational Resource Knowledge Domain Classification	(Schrumpf, Weber, and Thelen, 2021)	Thelen: 1, 4, 6, 7, 14; Schrumpf: 1, 2, 3, 5, 6, 9, 11, 12, 13, 14; Weber: 14;
"Development and Validation of a Goal Characteristics Questionnaire"	(Iwama et al., 2021)	Iwama: 1, 2, 3, 5, 6, 9, 11, 12, 13, 14; Lieder: 1, 4, 5, 6, 7, 8, 10, 13, 14; Prentice: 5, 6, 14; Weber: 14;
"Characterizing Personal Educational Goals: Inter-rater Agreement on a Tagset Reveals Domain-Specific Limitations of the External Perspective"	(Weber and Thelen, 2022a)	Thelen: 4, 9, 14; Weber: 1, 2, 4, 5, 6, 9, 12, 13, 14;
"Valence Comparison of Hierarchical Diagrams"	(Weber, 2022c)	Weber: 1, 2, 3, 5, 6, 9, 12, 13, 14;
"Structural Characteristics of Hierarchical Goal Systems from Online Field Studies"	(Weber, 2022b)	Weber: 1, 2, 3, 5, 6, 9, 12, 13, 14;
"A Digital Study Assistant for Hierarchical Goal-Setting Campanion Faces the First Real Users"	(Weber, 2022a)	Weber: 1, 2, 3, 5, 6, 9, 12, 13, 14;
"Searching for types of goals in a Conceptual Space of goal characteristics"	(Weber, Abdelfattah, and Kühnberger, 2022)	Abdelfattah: 14; Kühnberger: 14; Weber: 1, 2, 3, 5, 6, 9, 12, 13, 14;
"A Free and Open Dataset from a Prototypical Data-Driven Study Assistant in Higher Education"	(Schrumpf et al., 2022)	Dettmer: 2, 9, 14; Schrumpf: 1, 2, 5, 6, 9, 13, 14; Schurz: 13, 14; Thelen: 4, 14; Weber: 1, 2, 5, 6, 9, 13, 14;
Hierarchical Goal System Diagram Comparison	(Weber and Thelen, 2022b)	
"Comparison of Usability and User Experience of four Hierarchical Goal System Visualizations for a Digital Data-Driven Study Assistant"	(Kernos, 2022)	Kernos: 1, 2, 3, 5, 6, 9, 11, 12, 13; Weber:(Supporting) 1, 9, 10;
"Hierarchical Goal System Visualizations and Personality Traits in a Digital Goal Setting Intervention: A Correlational Study"	(Grenz, 2022)	Grenz: 1, 2, 3, 5, 6, 9, 11, 12, 13; Weber:(Supporting) 1, 9, 10;
"Effects of Motivational Priming on Goal Characteristics"	(Lee, 2022)	Lee: 1, 2, 3, 5, 6, 9, 11, 12, 13; Weber:(Supporting) 1, 9, 10;

"A Web-Based Hierarchical Goal-Setting Intervention for Higher Education"	(Weber et al., 2023)	Grenz: 1, 2, 5, 6, 11, 13, 14; Kernos: 1, 2, 5, 6, 11, 13, 14; Weber: 1, 2, 5, 6, 7, 9, 10, 13, 14; Lee: 1, 2, 5, 6, 11, 13, 14;