

Robo-Advice: The Digitalization and Automation of Financial Advice

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Vorgelegt von:

Albert Torno, M.Sc.

aus Gronau (Leine)

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Betreuungsausschuss

Erstbetreuer

Zweitbetreuer

Drittbetreuer

Prof. Dr. Jan Muntermann

Prof. Dr. Michael H. Breitner

Prof. Dr. Matthias Schumann

Für Felix

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Abstract / Zusammenfassung

This cumulative dissertation consists of and critically discusses five peer-reviewed and co-authored publications by me about the digitalization and automation of financial advice, so-called Robo-Advice (RA). The dissertation thereby covers two main research areas.

The first research area addresses the positioning of RA in science and practice providing a structure for more in-depth analyses. From a scientific perspective the relevant literature about RA is systematized in a new Organizing Framework for RA Research. The practical positioning of RA in the broader landscape of FinTech is approached in the context of mobile personal finance applications.

The second research area addresses the focused analysis and design of certain RA components. One study focuses on the business model of RA, aiming at understanding their distinct elements and finding major similarities and differences. A second study focuses on RA portfolio recommendations, providing an understanding of how they differ, especially in structure, selected products, performance, and risk. Lastly, a third study presents meta-requirements and design principles for RA addressing the problem of unethical behavior that can decrease trust and the adoption of RA.

Diese kumulative Dissertation umfasst fünf von mir mitverfasste und von Experten begutachtete Publikationen über die Digitalisierung und Automatisierung der Finanzberatung, dem sogenannten Robo-Advice (RA), und diskutiert diese kritisch. Die Dissertation behandelt dabei zwei Forschungsbereiche.

Der erste Forschungsbereich befasst sich mit der Positionierung von RA in Wissenschaft und Praxis und bietet eine Struktur für tiefergehende Analysen. Aus wissenschaftlicher Perspektive wird die relevante Literatur über RA in einem neuen Organisationsrahmen für RA-Forschung systematisiert. Die praktische Positionierung von RA in der breiteren FinTech-Landschaft wird im Kontext mobiler Finanzanwendungen aufgezeigt.

Der zweite Forschungsbereich befasst sich mit der gezielten Analyse und Gestaltung bestimmter RA-Komponenten. Eine Studie konzentriert sich dabei auf das Geschäftsmodell von RA und zielt darauf ab, die verschiedenen Elemente zu verstehen und die wichtigsten Gemeinsamkeiten und Unterschiede zu ermitteln. Eine zweite Studie untersucht die von RA empfohlenen Portfolios, um zu verstehen wie sie sich insbesondere in Bezug auf Struktur, ausgewählte Produkte, Performance und Risiko unterscheiden. Schließlich werden in einer dritten Studie Meta-Anforderungen und Gestaltungsprinzipien für ethischeren RA vorgestellt, welche das Vertrauen in und die Akzeptanz von RA steigern können.

Management Summary

Robo-Advisors (RAs) guide investors through an automated financial advice process, recommend personalized portfolio assignments based on their risk-affinity and financial goals, and monitor as well as rebalance their portfolios automatically over time (Jung et al., 2018; Sironi, 2016).

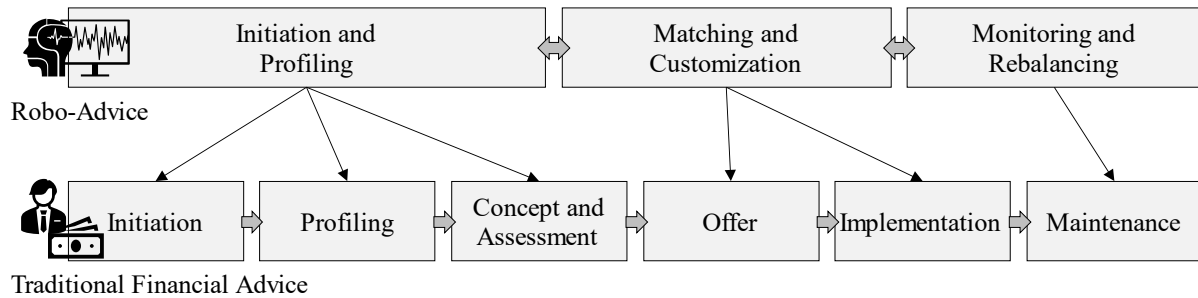


Figure 1. Iterative RA process mapped to the traditional financial advice process

RAs aim at giving more people access to diversified capital market participation, including retail investors with small amounts of capital to invest and often low financial knowledge (Jung et al., 2019; Sironi, 2016). Thereby, RAs take on the role of traditional financial advisors and have promising attributes, e.g., digital accessibility independent of time and location, a certain degree of performance at low costs, lower minimum investment amounts as well as consistent and automated decision making, which reduces risks and decreases psychological pitfalls (e.g., Beketov et al., 2018; Jung et al., 2019). On the other hand Robo-Advice (RA) has potential weaknesses, e.g., a poor assessment of users risk tolerance and a lack of sufficient personalization which can lead to an unfulfilled fiduciary duty and less user acceptance (Beketov et al., 2018; Jung et al., 2019).

Because of its high potential there is a great interest in the introduced digitalization and automation of financial advice in form of RA, both in research and practice. This cumulative dissertation contributes to a better understanding of RA by covering two main research areas. The first research area addresses the positioning of RA in science and practice providing a structure for more in-depth analyses. The second research area addresses the focused analysis and design of certain RA components. In the following, I present brief summaries of the addressed research contributions in their respective research area.

Research Area I. Positioning of Robo-Advice in Science and Practice

The first focus in research area I is on RA from a scientific perspective, systematizing the relevant literature about RA and structuring worthwhile future research directions. In more detail, paper 1 (Torno, Metzler, et al., 2021) conceptualizes RA research by conducting a systematic

literature review, analyzing 42 peer-reviewed articles focusing on RA. We thereby provide descriptive statistics of the articles, including research approaches and regional focuses, and classify the literature in an *Organizing Framework for RA Research* with the three main themes *RA Users*, *RA Service*, and *RA Competition*. We summarize current scientific knowledge about RA by showing important insights on each theme and the interrelation between the themes. Lastly, we provide worthwhile future research directions derived from RA literature for each identified theme.

The *Organizing Framework for RA Research* developed in paper 1 is also used to structure the other research papers that are part of this dissertation. The following Figure 2 illustrates the papers of research area I in a simplified version of the framework in the context of the DT of the financial sector and its associated changes.

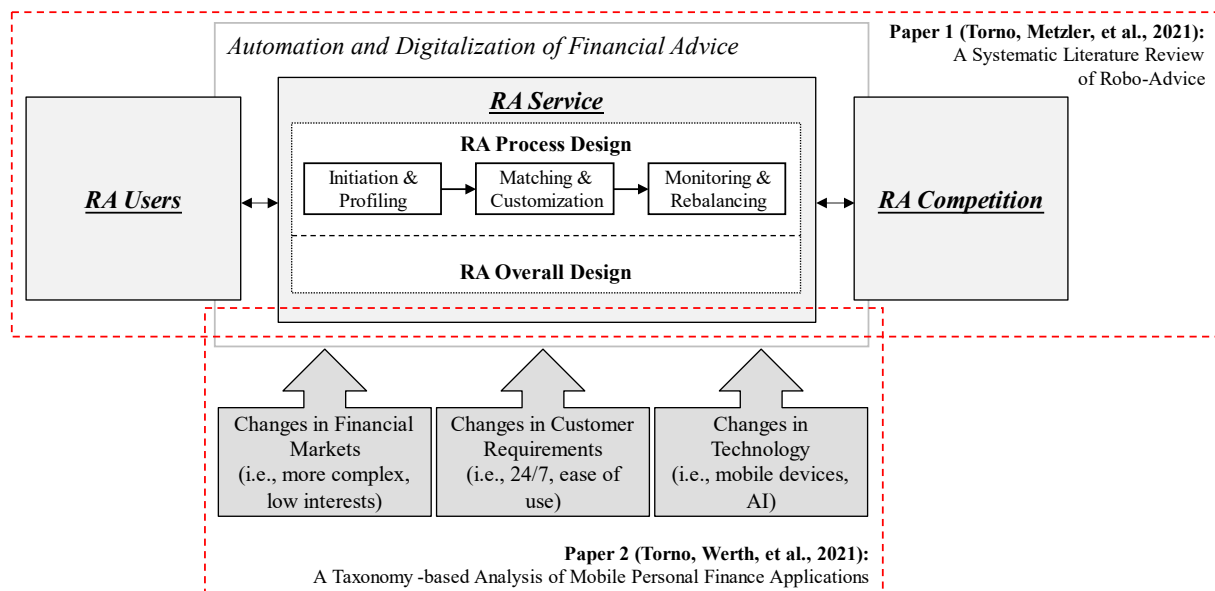


Figure 2. Simplified organizing framework for RA research in the context of the Digital Transformation of the financial sector with systematized research area I papers

The second focus of research area I is on the practical positioning of RA in the broader landscape of FinTech services. As shown in Figure 2, paper 2 (Torno, Werth, et al., 2021) investigates how certain changes associated with the DT of the financial sector led to the present mobile personal finance application landscape. In this case disruptive powers are *changes in financial markets* (e.g., more complex decision making, low interest rates), *changes in customer requirements* (e.g., 24/7 availability, ease-of-use), and *changes in technology* (e.g., ubiquitous mobile device usage, artificial intelligence (AI)). Within that domain, we find the archetype “Investing with advice”, which is the primary theme of RA. Paper 2 therefore provides an overview of the DT in the financial sector in practice with a focused view on mobile applications, while giving a context of real-world RAs in the domain.

In more detail, paper 2 provides insights on mobile personal finance applications which cannot only assist users in daily personal finance activities, e.g., mobile banking, but can also guide users to optimize long-term financial decisions. By developing a taxonomy and conducting a cluster analysis, we classify 170 real-world mobile personal finance applications into twelve dimensions, combining a technical artifact perspective with a financial services perspective. Additionally, we empirically identify ten distinct clusters of archetypical application configurations and analyze their main characteristics. While we classify the field and give inclinations for future research, financial service providers and application developers can understand their competitors and use our insights to improve their applications. Potential users of these applications can use our findings to select mobile applications to optimize their personal finance endeavors.

Research Area II. Analysis and Design of Robo-Advice

The second research area addresses the focused analysis and design of certain RA components. Figure 3 visualizes the three papers in the context of the introduced *Organizing Framework for RA Research* and shows their distinct focuses.

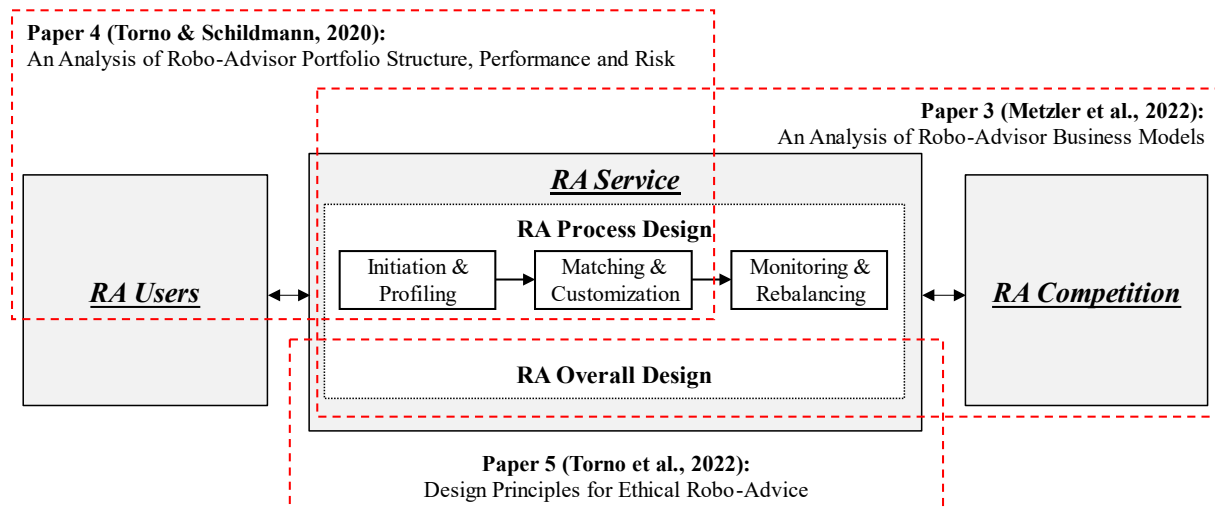


Figure 3. Simplified organizing framework for RA research with systematized research area II papers. The main goal of paper 3 (Metzler et al., 2022) is to provide a comprehensive understanding of the underlying business model of RAs. To do that, we conduct a multiple case study across the fifteen biggest US-based RAs and explain the basic characteristics and special features of RA business models. Through an in-depth analysis of publicly available qualitative data, we contribute to the existing research by unleashing significant elements that underline the power of RAs to disrupt the financial services industry. Thereby, we distinguish between pure algorithm-based RAs and hybrid RAs with dedicated human oversight. The most important insights are thereby presented in the following Figure 4.

In the context of the *Organizing Framework for RA Research* paper 3 provides insights on the *Overall RA Service* configuration, by investigating RAs from a Business Model Canvas perspective, that divides a business model into four business model pillars and nine business model elements. By using data of 15 real-world RAs we also analyze the *RA Competition*, comparing RA with traditional financial advice and describing similarities and differences between the RA business models.

Pure RA				Hybrid RA							
Key Resources	<ul style="list-style-type: none">digital platformsalgorithmsfinancial knowledge		Value Proposition	Key Resources	<ul style="list-style-type: none">digital platformsalgorithmsfinancial knowledge		Value Proposition				
	Key Activities	<ul style="list-style-type: none">platform provision and maintenanceportfolio compilation and rebalancingquality assurancemarketing activities			Key Activities	<ul style="list-style-type: none">platform provision and maintenanceportfolio compilation and rebalancingquality assurancemarketing activities					
		Key Partners				<ul style="list-style-type: none">parent companiesthird-party broker firmsexternal agencies		Key Partners	<ul style="list-style-type: none">parent companiesthird-party broker firmsexternal agencies		
Cost Structure	<ul style="list-style-type: none">transaction costsmarketing costsoperational expenses<u>very low</u> staff payment		Revenue Streams	<ul style="list-style-type: none">AuM-based feessubscription feescash sweep activitiesthird-party compensation		Cost Structure	<ul style="list-style-type: none">transaction costsmarketing costsoperational expenses<u>low</u> staff payment		Revenue Streams	<ul style="list-style-type: none">AuM-based feessubscription feescash sweep activitiesthird-party compensation	
	Channels	Customer Segments		Customer Relationships	Channels		Customer Segments	Customer Relationships			
<ul style="list-style-type: none">websitemobile appssocial media and ads	<ul style="list-style-type: none">retail investors with limited capital amountaccess limited to residents in headquarter’s state<u>mostly no capital minimum</u>	<ul style="list-style-type: none"><u>only</u> automated and digital communication	<ul style="list-style-type: none">websitemobile appssocial media and ads<u>phone</u>	<ul style="list-style-type: none">retail investors with limited capital amountaccess limited to residents in headquarter’s state<u>mostly high capital minimum</u>	<ul style="list-style-type: none"><u>mostly</u> automated and digital communication<u>additional personal communication</u>						

Figure 4. Business model elements for pure and hybrid RAs

In paper 4 (Torno & Schildmann, 2020) we verify the claim that giving basic automated and digitalized investment advice can provide a useful way to reduce risk by diversifying and mitigating biases, while keeping a certain degree of performance at low costs. To do that, we conduct a sophisticated analysis of recommended portfolios of 36 RAs, based on six distinct model customers with different risk-affinities and investment horizons, resulting in 216 recommended portfolios. We find that the analyzed RAs provide distinct recommended portfolios for the different risk/investment horizon combinations, while sharing similarities in used products for portfolio allocation. We also find issues within the recommended portfolios, e. g., a low degree of distinctiveness between different investment horizons and a high amount of equities even in a short-term investment horizon. Both insights are visualized by the following Figure 5.

In the context of the *Organizing Framework for RA Research* paper 4 provides insights on the *RA Service*, especially on the *RA Process Design* of the first two phases “*Initiation & Profiling*” as well “*Matching & Customization*”. For example, we found that the RAs have different levels of information transparency and customization ability. Furthermore, the different recommended and analyzed RA portfolios were based on preferences of model RA users with realistic investment horizon and risk-affinity characteristics.

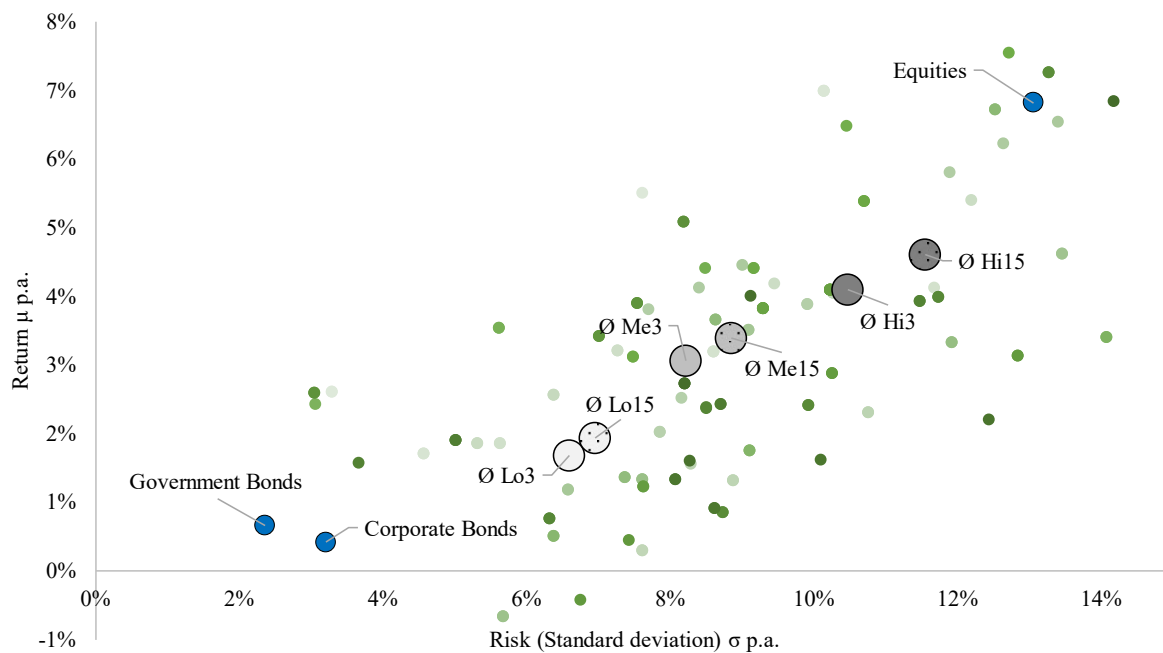


Figure 5. RA recommended portfolios in a μ - σ -chart with benchmark indices (10/2009 to 10/2019)

While automated and digitalized investing in form of RA has promising qualities, e.g., mitigating personal biases through algorithms and enable financial advice for less wealthy clients, RA is criticized for its rudimentary personalization ability questioning its fiduciary duties, nontransparent recommendations and violations of data privacy and security. These ethical issues pose significant risks and can diminish trust, especially for the targeted, less financially educated customers, since they could be exploited by RA. Therefore, in paper 5 (Torno et al., 2022) we derive meta-requirements and develop design principles, based on scientific literature on RA as well as international standards and guidelines of ethical financial advice to guide more ethical and trustworthy RA design. We further evaluate and enhance the design artifact through interviews with domain experts from science and practice, providing design knowledge that enables more ethical RA outcomes.

In the context of the *Organizing Framework for RA Research* paper 5 provides insights on the *RA Overall Design*, focusing on solving ethical issues in RA and thereby increasing its trustworthiness. We provide 15 design principles to ensure ethical considerations in four main

design domains addressing eight meta-requirement that enhance financial advice as depicted in Figure 6.

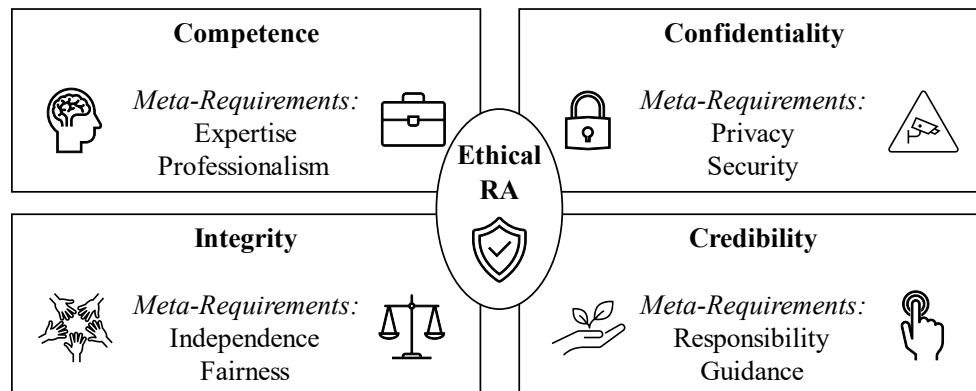


Figure 6. Design dimensions and meta-requirements for ethical RA

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Abbreviations

AI.....	Artificial Intelligence
Apps	Mobile Applications
AuM	Assets Under Management
B2B.....	Business-to-Business
B2C.....	Business-to-Consumer
BM.....	Business Model
BMC	Business Model Canvas
C2E.....	Conceptual-to-Empirical
DD	Design Dimension
DP.....	Design Principle
DLT	Distributed Ledger Technology
DSR	Design Science Research
E2C.....	Empirical-to-Conceptual
ECB	European Central Bank
ESG	Environmental, Social, and Governance
ETF.....	Exchange Trading Fund
FED	US Federal Reserve System
FinTech.....	Financial Technology
IS	Information Systems
ISIN	International Securities Identification Number
IT	Information Technology
MR.....	Meta-Requirement
NLP	Natural Language Processing
RA	Robo-Advice
RAs.....	Robo-Advisors
RQ	Research Question
SEC.....	US Securities and Exchange Commission
SR.....	Sharpe Ratio
VaR.....	Value at Risk
WM.....	Wealth Management

A Foundations

In the foundations part I firstly provide the motivation for the research and derive the examined research questions. This is followed by the overall structure of this dissertation where I introduce the two analyzed research areas and provide their respective contexts. Lastly, I present the research background of this dissertation, which consists of the theoretical background and introductions to the used research methods and approaches as well as the data collection and analysis.

1 Introduction

“Planning is bringing the future into the present so that you can do something about it now.”

Alan Lakein (Author on self-management)

1.1 Motivation

Digital technologies, defined as a combination of information, computing, communication, and connectivity technologies, have the power to fundamentally transform products and services, business processes, interfirm relationships, and business strategies (Hess et al., 2016). The Digital Transformation (DT) enabled by these digital technologies can not only increase the effectiveness and efficiency of business processes but has the potential to provide innovative ways of problem-solving (Bharadwaj et al. 2013; Eickhoff et al. 2017). The DT with its associated technological developments and the increasingly digitalized society lead to a need for more digital and innovative solutions, especially within the financial services industry (Gomber et al., 2017). Thereby, the financial services industry undergoes a substantial disruption triggered by the emergence of digitally enabled financial technologies (FinTech). The term FinTech describes the technology-based design and delivery of products and services within the financial services industry (Gomber et al., 2017; Puschmann, 2017). FinTechs can also be described as relatively new firms providing innovative products and services at the intersection of financial products and services and information technology (IT) (Eickhoff et al., 2017). With innovative business models (BMs) FinTechs try to close the gap between outdated offerings of incumbent financial services firms and new customer demands (Vasiljeva & Lukanova, 2016).

This disruption particularly concerns financial advice service providers within the wealth management (WM) domain. Traditionally, financial advice in the WM domain is based on human interactions and trust between the advisor and the customer, which is a time-consuming and costly process and led to mostly high net worth individuals using these services (Jung et al., 2018; Sironi, 2016). But also, retail customers have the need for financial advice, especially due to changes in financial markets, e.g., reflected in low interest rates and more complex financial products in the recent past (Beketov et al., 2018; Sironi, 2016). Additionally, customers increasingly demand more cost-efficient, easy-to-use, and continuously available services (Blaschke & Kriebel, 2021; Mačijauskaitė, 2018). As a reaction to these changing requirements and enabled by technological advancements financial services firms introduce digitalized and automated financial advice, so called Robo-Advice (RA) (Eickhoff et al., 2017; Gomber et al., 2017).

Robo-Advisors (RAs) guide investors through an automated financial advice process, recommend personalized portfolio assignments based on their risk-affinity and financial goals, and monitor as well as rebalance their portfolios automatically over time (Jung et al., 2018; Sironi, 2016). RAs aim at giving more people access to diversified capital market participation, including retail investors with small amounts of capital to invest and often low financial knowledge (Jung et al., 2019; Sironi, 2016). Thereby, RAs take on the role of traditional financial advisors and have promising attributes, e.g., digital accessibility independent of time and location, a certain degree of performance at low costs, lower minimum investment amounts as well as consistent and automated decision making, which reduce risks and decrease psychological pitfalls (e.g., Beketov et al., 2018; Jung et al., 2019). On the other hand RA has potential weaknesses, e.g., a poor assessment of users risk tolerance and a lack of sufficient personalization which can lead to an unfulfilled fiduciary duty and less user acceptance (e.g., Beketov et al., 2018; Jung et al., 2019).

Because of its high potential there is a great interest in the introduced digitalization and automation of financial advice in form of RA, both in research and practice. This cumulative dissertation contributes to a better understanding of RA by covering two main research areas. The first research area addresses the positioning of RA in science and practice providing a structure for more in-depth analyses. The second research area addresses the focused analysis and design of certain RA components. In the next sections of this introduction, I derive the research questions (RQ) that are addressed within this dissertation and illustrate the structure in which I provide answers to the raised RQs.

1.2 Research Questions

The RQs of this dissertation are structured in two research areas. In this section I briefly introduce the main goals of these two research areas and derive RQs that are answered within each area.

The first research area is about the positioning of RA in science and practice. While RA is still novel, an increasing number of real-world RA and an increasing number of scientific and non-scientific publications, show a determined interest in this FinTech phenomenon. Therefore, the main goal of this research area is to provide a structure for more in-depth analyses of RA. Thereby, I firstly focus on RA from a scientific perspective, considering the relevant literature about RA and systematizing it in a new Organizing Framework for RA research. Also, it is of interest to find and structure worthwhile future research directions that can be derived from the

scientific literature. Accordingly, the first RQ, that is the base for the first paper of this cumulative dissertations, is:

RQ I.1: How can research on RA be systematized and what are worthwhile future research directions regarding RA?

Besides the scientific view on RA, it is important to understand how RA is positioned in the broader range of available FinTech services. This enables research and practice to understand in which combinations RA is embedded in or could be combined with other financial services and thus coming up with innovative ways to provide financial advice. Incumbent banks and insurers as well as FinTechs thereby often provide their services through mobile apps, meeting the customer requirements ease-of-use and ubiquitous availability (e.g., Sarkar et al., 2020; Sharma & Sharma, 2019). Therefore, I decided to approach the practical positioning of RA in the context of mobile personal finance applications. By classifying these mobile personal finance applications in a taxonomy and deriving archetypes, I aim at structuring the FinTech environment in which RA providers operate with their services. Therefore, the second RQ is answered in the second paper of this cumulative dissertations:

RQ I.2: How can mobile personal finance applications be classified and what archetypes can be distinguished?

The second research area provides more focused analyses of certain RA components and gives recommendations for RA design. Based on the beforementioned structure and worthwhile future research directions identified in paper 1, I focus on three perspectives on RA analysis and design. The first perspective deals with the BM of RA, which beforehand was only partially investigated in scientific research. The goal is to provide a rigorous understanding of the distinct BM elements of RA, finding major similarities and differences between RA providers BMs. Therefore, the first RQ in the second research area is the base for the third paper of this cumulative dissertations:

RQ II.1: How can RA business models be characterized and what are major similarities and differences?

The second analysis perspective on RA sheds light on the recommendations that RAs provide. It is important, to investigate and verify the claims of RA to provide low-risk portfolios by diversifying and mitigating biases, while keeping a certain degree of performance at low costs. Thereby, the goal is to understand how the recommended portfolios differ, especially regarding their structure and selected products as well as performance and risk. Therefore, the second RQ of research area II answered in paper 4 is:

RQ II.2: Which similarities and differences do the portfolios recommended by RA have, regarding portfolio structure and selected products, performance, and risk?

Lastly, research area II investigates how to improve the design of RA services. For that I focus on a particular problem of high importance in financial advice: Ethics. With its possible rudimentary personalization ability, nontransparent recommendations and violations of data privacy and security, ethical issues can have a significant impact on the trustworthiness and the adoption of RA. Consequently, the third RQ of research area II, worked on in paper 5, is:

RQ II.3: What are relevant design principles to establish ethical considerations in RA design and increase its trustworthiness?

1.3 Structure of Dissertation

In this section I present the general structure of this dissertation. As shown in Figure 7 the dissertation is structured in three parts. In the first part A, the foundations of the dissertation are stated, beginning with the introduction and motivation for research and a presentation of the RQs, which are addressed within this thesis. I then present the research background in which I provide the theoretical background regarding DT of the financial sector, the digitalization and automation of financial advice and RA, followed by introductions to the used research methods and approaches as well as the data collection and analysis. Part A also provides this overview of the general structure of the dissertation and main contributions of the individual papers, while introducing the two research areas “I. Positioning of Robo-Advice in Science and Practice” as well as “II. Analysis and Design of Robo-Advice”. I thereby also provide the necessary contexts and position the respective papers focuses.

In part B the research areas are elaborated by presenting the five peer-reviewed and co-authored papers, this cumulative dissertation consists of, in full length. While the first research area addresses the positioning of RA in science and practice providing a structure for more in-depth analyses, research area II focuses on the analysis and design of certain RA components.

Finally, part C summarizes the contributions of this dissertation. Thereby, the findings and implications of the two research areas are presented and an understanding of the interrelation between the individual contributions are given. Lastly, limitations and future research directions for both research areas are specified.

A. Foundations			
Introduction		Research Background	
Motivation		Theoretical Background	
Research Questions		Methods and Approaches	
Structure of Dissertation		Data Collection and Analysis	

B. Research Areas			
I. Positioning of Robo-Advice in Science and Practice		II. Analysis and Design of Robo-Advice	
RQ I.1	Paper 1 (Torno, Metzler, et al., 2021): A Systematic Literature Review of Robo-Advice	RQ II.1	Paper 3 (Metzler et al., 2022): An Analysis of Robo-Advisor Business Models
RQ I.2	Paper 2 (Torno, Werth, et al., 2021): A Taxonomy -based Analysis of Mobile Personal Finance Applications	RQ II.2	Paper 4 (Torno & Schildmann, 2020): An Analysis of Robo-Advisor Portfolio Structure, Performance and Risk
		RQ II.3	Paper 5 (Torno et al., 2022): Design Principles for Ethical Robo-Advice

C. Contributions			
Research Areas I & II			
Summary of Findings	Implications	Limitations	Future Research

Figure 7. Structure of dissertation

1.3.1 Research Area I. Positioning of Robo-Advice in Science and Practice

The first research area addresses the positioning of RA in science and practice. Table 1 shows the two papers in this research area, their respective publishing outlets, and research types as well as their main contributions.

Paper No. Citation	Outlet Research Type	Main Contribution
Paper 1 (Torno, Metzler, et al., 2021)	PACIS 2021 Literature Review	Systematization of RA research and presentation of future research directions.
Paper 2 (Torno, Werth, et al., 2021)	PACIS 2021 Taxonomy Development	Classification and clustering of personal finance mobile apps.

Table 1. Papers in research area I

In paper 1 the following RQ is addressed: *How can research on RA be systematized and what are worthwhile future research directions regarding RA?* To answer the RQ, we conceptualize RA research by conducting a systematic literature review, analyzing 42 peer-reviewed articles focusing on RA. We thereby provide descriptive statistics of the articles, including research

approaches and regional focuses, and classify the literature in an Organizing Framework for RA Research with the three main themes RA Users, RA Service, and RA Competition. We summarize current scientific knowledge about RA by showing important insights on each theme and the interrelation between the themes. Lastly, we provide worthwhile future research directions derived from RA literature.

The Organizing Framework for RA Research developed in paper 1 is also used to structure the other research papers that are part of this dissertation. The following Figure 8 illustrates the papers of research area I in a simplified version of the framework in the context of the DT of the financial sector and its associated changes.

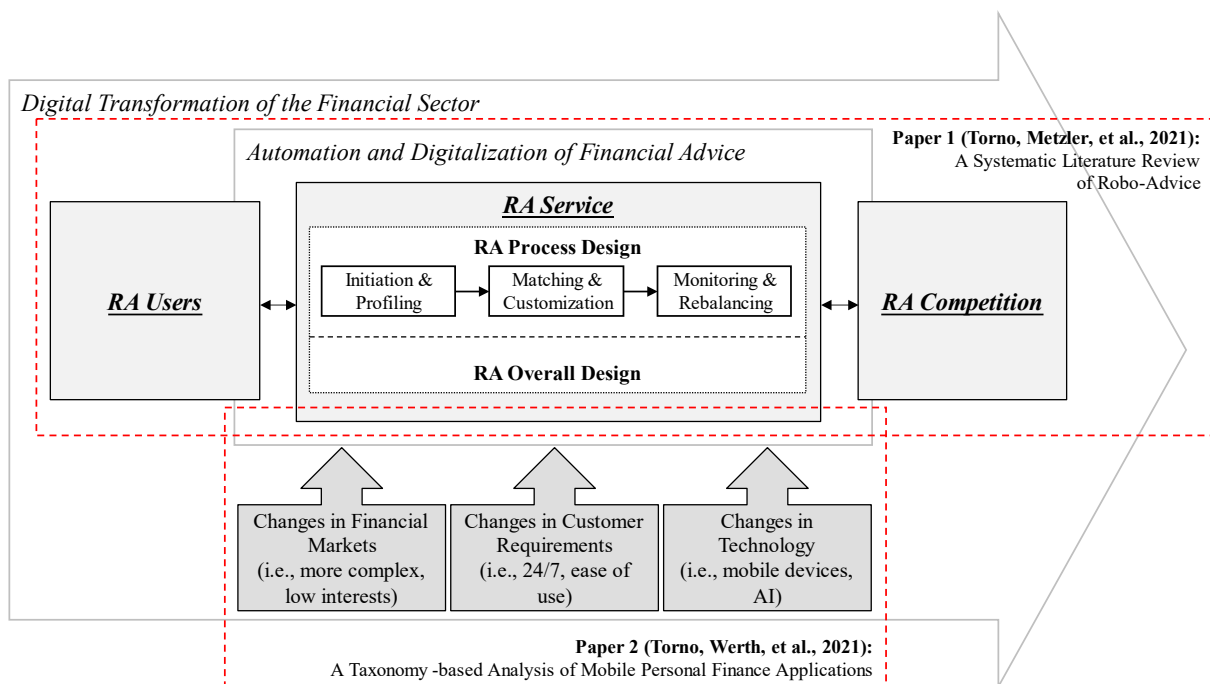


Figure 8. Simplified organizing framework for RA research in the context of the Digital Transformation of the financial sector with systematized research area I papers

In the context of this dissertation, the second paper investigates how certain changes associated with the DT of the financial sector led to the present mobile personal finance application landscape. In this case disruptive powers are changes in financial markets (e.g., more complex decision making, low interest rates), changes in customer requirements (e.g., 24/7 availability, ease-of-use), and changes in technology (e.g., ubiquitous mobile device usage, artificial intelligence (AI)). Within that domain, we find the archetype “Investing with advice”, which is the primary theme of RA. Paper 2 therefore provides an overview of the DT in the financial sector in practice with a focused view on mobile applications, while giving a context of real-world RAs in the domain.

In more detail, paper 2 addresses the following RQ: *How can mobile personal finance applications be classified and what archetypes can be distinguished?* We thereby provide insights on mobile personal finance applications which cannot only assist users in daily personal finance activities, e.g., mobile banking, but can also guide users to optimize long-term financial decisions. By developing a taxonomy and conducting a cluster analysis, we classify 170 real-world mobile personal finance applications into twelve dimensions, combining a technical artifact perspective with a financial services perspective. Additionally, we empirically identify ten distinct clusters of archetypical application configurations and analyze their main characteristics. While we classify the field and give inclinations for future research, financial service providers and application developers can understand their competitors and use our insights to improve their applications. Potential users of these applications can use our findings to select mobile applications to optimize their personal finance endeavors.

1.3.2 Research Area II. Analysis and Design of Robo-Advice

The second research area addresses the focused analysis and design of certain RA components. Table 2 shows the three papers in this research area, their respective publishing outlets, and research types as well as their main contributions.

Paper No. Citation	Outlet Research Type	Main Contribution
Paper 3 (Metzler et al., 2022)	WI 2022 Case Study (Qualitative)	Systematization and analysis of RA BMs.
Paper 4 (Torno & Schildmann, 2020)	FinanceCom 2020 Case Study (Quantitative)	Analysis of structure, performance, and risk of RA recommended portfolios.
Paper 5 (Torno et al., 2022)	PACIS 2022 Design Science Research	Meta-requirements (MR) and design principles (DP) for more ethical and trustworthy RA.

Table 2. Papers in research area II

The three papers can also be systemized by using the established Organizing Framework for RA Research. Figure 9 visualizes the three papers in that context and shows their focuses.

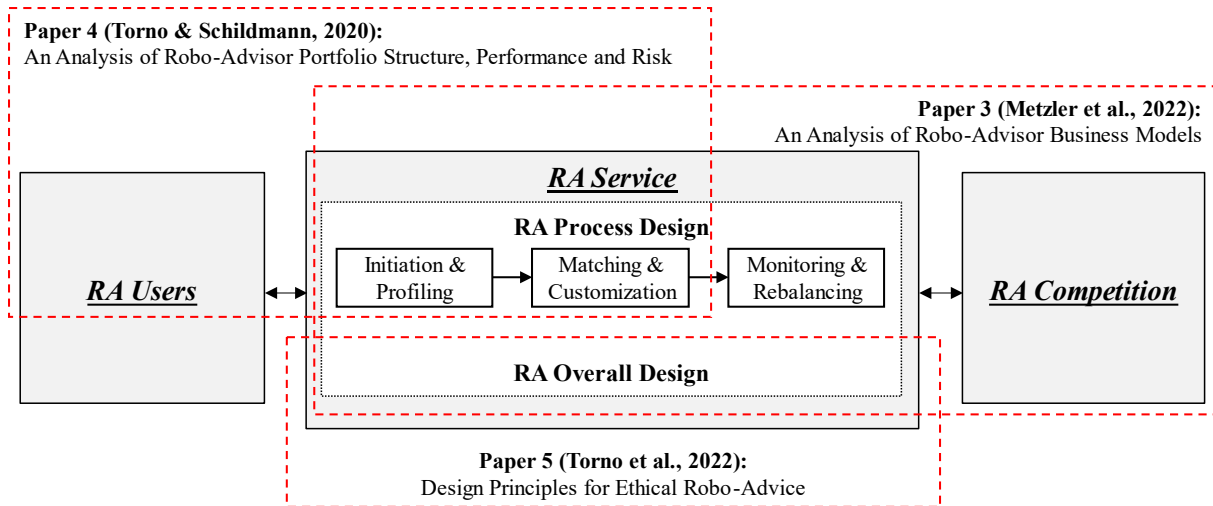


Figure 9. Simplified organizing framework for RA research with systematized research area II papers. The main goal of paper 3 is to provide a comprehensive understanding of the underlying BM of RAs, addressing the RQ: *How can RA business models be characterized and what are major similarities and differences?* To answer the RQ, we conduct a multiple case study across the fifteen biggest US-based RAs and explain the basic characteristics and special features of RA BMs. Thereby, we distinguish between pure algorithm-based RAs and hybrid RAs with dedicated human oversight. Through an in-depth analysis of publicly available qualitative data, we contribute to the existing research by unleashing significant elements that underline the power of RAs to disrupt the financial services industry.

In the context of the Organizing Framework for RA Research paper 3 provides insights on the overall RA Service configuration, by investigating RAs from a Business Model Canvas (BMC) perspective, that divides a BM into four BM pillars and nine BM elements. By using data of 15 real-world RAs, we also analyze the RA Competition, comparing RA with traditional financial advice and describing similarities and differences between the RA BMs.

In paper 4 we verify the claim that giving basic automated and digitalized investment advice can provide a useful way to reduce risk by diversifying and mitigating biases, while keeping a certain degree of performance at low costs. We thereby address the following RQ: *Which similarities and differences do the portfolios recommended by RA have, regarding portfolio structure and selected products, performance, and risk?* To answer the RQ, we conduct a sophisticated analysis of recommended portfolios of 36 RAs, based on six distinct model customers with different risk-affinities and investment horizons, resulting in 216 recommended portfolios. We find that the analyzed RAs provide distinct recommended portfolios for the different risk/investment horizon combinations, while sharing similarities in used products for portfolio allocation. We also find issues within the recommended portfolios, e.g., a low degree of

distinctiveness between different investment horizons and a high amount of equities even in the short-term investment horizon.

In the context of the Organizing Framework for RA Research paper 4 provides insights on the RA Service, especially on the RA process design of the first two phases “Initiation & Profiling” as well “Matching & Customization”. For example, we found that the RAs have different levels of information transparency and customization ability. Furthermore, the different recommended and analyzed RA portfolios were based on preferences of model RA users with realistic investment horizon and risk-affinity characteristics.

While automated and digitalized investing in form of RA has promising qualities, e.g., mitigating personal biases through algorithms and enable financial advice for less wealthy clients, RAs are criticized for their often rudimentary personalization ability questioning its fiduciary duties, nontransparent recommendations and violations of data privacy and security. These ethical issues pose significant risks and can diminish trust, especially for the targeted, less financially educated customers, since they could be exploited by RA. Yet, a distinct ethical perspective on RA design is missing in literature. Therefore, in paper 5 we address the following RQ: *What are relevant design principles to establish ethical considerations in RA design and increase its trustworthiness?* Based on scientific literature on RA as well as international standards and guidelines of ethical financial advice, we derive eight MRs and develop 15 DPs, that can guide more ethical and trustworthy RA design. We further evaluate and enhance the design artifact through interviews with domain experts from science and practice, providing design knowledge that enables more ethical RA outcomes.

In the context of the Organizing Framework for RA Research paper 5 provides insights on the overall RA design, focusing on solving ethical issues in RA and thereby increasing its trustworthiness. We provide 15 design principles to ensure ethical considerations in four main design domains that enhance financial advice: Competence, confidentiality, integrity, and credibility.

2 Research Background

In this section I present the research background of this dissertation. First, the theoretical background introduces the main overarching context of the DT of the financial sector and the focus of this dissertation, the digitalization and automation of financial advice in form of RA. In the consecutive chapters the research methods and approaches used, as well as the collection and analysis of the data are presented.

2.1 Theoretical Background

2.1.1 Digital Transformation of the Financial Sector

The advent of digital technologies has fundamentally changed the way organizations operate, enter the market and relate to their customers (Bharadwaj et al., 2013; Granados & Gupta, 2013). Digital technologies are defined as a combination of information, computing, communication, and connectivity technologies and have the power to fundamentally transform products and services, business processes, interfirm relationships, and business strategies (Bharadwaj et al., 2013; Hess et al., 2016). Furthermore, digital technologies have the potential to use heterogeneous knowledge and information to enable the development of entirely new products, services, and BMs (Lyytinen et al., 2016; Nambisan et al., 2017). The most important digital technologies that are driving transformational changes can be summarized under the acronym SMACIT. This acronym refers to social, mobile, analytics, cloud computing, internet of things, and other related technologies like AI, distributed ledger technology (DLT), robotics, and virtual reality (Sebastian et al., 2017).

The changes these digital technologies can bring to a company's BM, resulting in changed products, the automation of processes or changed organizational structures can be described as DT (Hess et al., 2016). Similarly, Fitzgerald et al. (2013, p. 2) describes DT as "the use of new digital technologies to enable major business improvements," such as enhancing the customer experience, streamlining operations, or creating new BMs. Furthermore, DT is a "process where digital technologies create disruptions triggering strategic responses from organizations that seek to alter their value creation paths while managing the structural changes and organizational barriers that affect the positive and negative outcomes of this process" (Vial, 2019, p. 118). This process has the potential to redefine a company's value proposition and changing its whole identity (Wessel et al. 2021).

The financial services industry is one of the most affected industries by digital technologies and the DT, since almost all business processes and services are based on information and can be potentially digitized and automated (Gomber et al., 2017, 2018; Puschmann, 2017). During the

last decade, the financial services industry has steadily integrated digital technologies and concepts in its value chain and transformed into innovative BMs with the goal of building a sustainable competitive advantage (Arner et al., 2016; Imerman & Fabozzi, 2020). This is also necessary, since the financial services industry faces major challenges forced by the DT that need to be addressed to be competitive in the constantly changing environment (Yoo et al., 2010). First, consumer preferences and expectations change fundamentally, which is reflected by an increasing use of digital technologies to interact and share information, to access financial services online and/or mobile through smartphones (Berman, 2012; Sebastian et al., 2017). Second, the recent financial services market is characterized by tighter regulations, low interest rates, and high cost pressure (Gomber et al., 2017). Additionally new competitors, for example, BigTechs (e.g., Apple, Google, Amazon) and FinTech startups with BMs based on the use of digital technologies and the convergence between IS and financial services enter the industry (Gomber et al., 2017; Puschmann, 2017). Especially the “born-digital” and agile FinTechs have the potential to close the gap between new customer demands and outdated service offerings of incumbent financial services firms that are often hampered through regulations and their corporate structures and culture (Vasiljeva & Lukanova, 2016). Therefore, FinTech companies are considered as an endogenous response to innovation opportunities created by new digital technologies, that were left commercially unexploited by traditional financial service firms (Schuelke-Leech, 2018; Vasiljeva & Lukanova, 2016). Due to their digital nature, FinTechs can create new value propositions, e.g., increasing financial inclusion and decreasing income inequality (Demir et al., 2020; Lagna & Ravishankar, 2022), or reshaping the financial system and the monetary policy implementation through financial disintermediation (Mumtaz & Smith, 2020). Eickhoff et al., (2017, p. 2) define FinTech as companies that “operate at the intersection of financial products and services and IT and are usually relatively new companies (often startups) with their own innovative product or service offerings”. Also, FinTech can be described more openly as financial innovations enabled by IT resulting in new financial instruments, services and/or intermediaries (Arner et al., 2016). To characterize the different novelty levels of FinTech, Gomber et al. (2017) describes two degrees of FinTech innovation, i.e., “sustaining FinTech” and “disruptive FinTech.” While sustaining FinTechs comprise of financial services in which incumbents incorporate digital technologies to maintain their position in the market, disruptive FinTechs comprise of new market competitors providing novel digital financial products and services.

RAs represent one of the most prominent examples of FinTech (Chen et al., 2019; Eickhoff et al., 2017) that disrupt existing BMs by using digital technologies to introduce automated and digitalized financial advice (D'Acunto et al., 2019; Gomber et al., 2017).

2.1.2 Digitalization and Automation of Financial Advice

Traditionally, financial advice in the WM domain focuses on investment management services for high-net-worth individuals and families aiming at sustaining and expanding long-term wealth (Jennings et al., 2011). The provided WM services comprise various types of investment, insurance, and banking products and services. More precisely WM includes portfolio management and rebalancing, investment management and strategies, trust and estate management, private banking and financing and tax consulting (C.-R. Wu et al., 2010). Traditionally, these services are based on human interactions and trust between the financial advisor and client (Jung et al., 2017; Sironi, 2016).

In advising practices, conflicts of interest might occur due to the different knowledgebases of clients and advisors in the domain of interest. This problem is described by the principal-agent-theory, which suggests that financial advisors may act in their own interests when there is a information asymmetry between the principal (client) and agent (financial advisor) and both do not have congruent interests (Bai, 2021; Baker & Dellaert, 2018; Eisenhardt, 1989a). Resolving these principal-agent conflicts often consist of reducing the information asymmetry and providing sufficient incentives for the advisor to act in the best interest of the client (Eisenhardt, 1989a).

Due to the complex, time-consuming and costly process of highly personalized financial advice in the WM domain, the target clientele has typically a net worth of US\$150,000 to US\$1,000,000 (Beketov et al., 2018; C.-R. Wu et al., 2010). The DT and digital technologies enable financial service providers to enhance the digitalization and automation of their financial advisory services. The associated scalability makes it possible to provide WM services to retail customers with lower net worth and thus have the potential to democratize financial advice (Jung et al., 2018; Sironi, 2016). Additionally, changes in financial markets, in customer requirements, and in technology result in an increased adoption probability of automated and digitized financial advice. First, new financial products, e.g., Exchange Trading Funds (ETFs), resembling index-based investment vehicles, enabled low-cost, diversified, and passively managed investment strategy implementations (Gomber et al., 2018). Also, the generally low interest rate in the last decade made investing in assets like stocks and bonds more attractive than saving money in saving accounts, even for less wealthy customers (Sironi, 2016). Secondly,

new customer requirements emerged due to new customer generations becoming affluent and a generally more digitized society. These new requirements comprise, e.g., more digitized, 24/7 available, and user-friendly services (Berman, 2012). Also, since customers can compare services fast and easily through the internet, they are more price-sensitive and want more personalized services when higher fees are charged for the service. Not only the internet and emerging digital platforms, but the ubiquitous use of technology, e.g., of smartphones, led to the high usage of technology in all domains and its high status in society (Berman, 2012). Additionally, advancements in AI, especially Natural Language Processing (NLP), enabled the appearance of chatbots, which are often used by financial service providers to deliver a certain degree of customer service, without human intervention (Gomber et al., 2018). Altogether, these changes led to the emergence of RAs, which aim to fulfill these new requirements.

2.1.3 Robo-Advice

The term Robo-Advice is comprised of two components: “Robo” as an abbreviation of robot meaning “a machine controlled by a computer that is used to perform jobs automatically” and “Advice” meaning an opinion offered about what to do or how to act in a particular situation (Cambridge Dictionary, 2021). Based on these meanings, a RA can be outlined as an automated system that advises on finance, especially WM. Thereby, RA providers aim at digitizing and automating the entire financial advisory process (Jung et al., 2018). RAs can be defined as IS that guide investors through an automated financial advice process, recommend personalized portfolio assignments based on their risk-affinity and financial goals, and monitor as well as rebalance their portfolios automatically over time (Jung et al., 2018; Sironi, 2016). In this dissertation I use the terms Robo-Advisors (as actors) and Robo-Advice (as a practice/service), abbreviated with “RAs” respectively “RA”.

According to Jung et al. (2018, 2019), the RA-process can typically be divided into three iterative phases, matching the traditional financial advice process, as illustrated in Figure 10: (1) “Initiation and Profiling,” (2) “Matching and Customization,” and (3) “Monitoring and Rebalancing.”

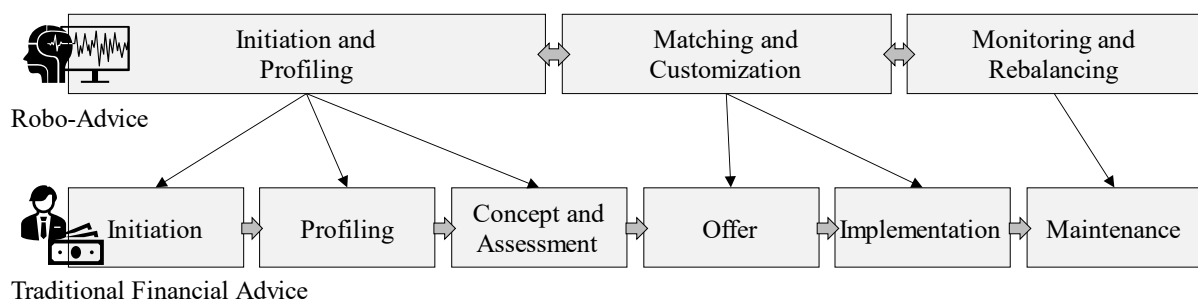


Figure 10. Iterative RA process mapped to the traditional financial advice process

Within the first phase of the process, the Initiation and Profiling, information asymmetries between the RA and the customers are dismantled (Jung et al., 2018). In online questionnaires, customers go through a self-assessment of their risk-affinity and investment characteristics and provide investment goals (Tertilt & Scholz, 2018). Based on that information, the RAs create a (risk) profile of the customer, which is the portfolio recommendation's foundation. Also, in this phase, RA providers pre-select products (mostly ETFs) from which their recommended portfolios are compiled (Rühr et al., 2019a). Within the Matching and Customizing phase, the risk profile is transferred automatically into the recommendation of a portfolio allocation. When presenting the recommended portfolio to the customer, RAs often let them customize their risk class association and the portfolio structure, but in a way that it does not derive too widely from the recommendations (Jung et al., 2018). Typically, the end of the Matching and Customizing phase is marked by an offer and the implementation of the portfolio for the customer. In the last phase of the process, RAs Monitor and Rebalance the portfolios of their customers. The customers have permanent online access to their portfolio and get reports about the performance as well as financial news and occasionally educational content. RAs thereby rebalance their customer's portfolios, aiming to maintain the portfolio's initial risk-to-performance ratio by buying and selling individual assets. This ensures that the portfolio's risk remains stable and within the risk profile associated with the customer, despite changing financial markets (Jung et al., 2018).

RAs have several competitive advantages compared to traditional human financial advice, e.g., accessibility independent of time and location, lower costs, lower minimum investment amounts as well as a consistent and possibly transparent decision making process that decrease psychological pitfalls (Beketov et al., 2018; Jung et al., 2019). However, RAs also encompass problems. For example, fast-evolving technologies are often criticized of unintended negative consequences such as algorithmic bias or discrimination (e.g., Müller & Kerényi, 2019; Veale & Binns, 2017). Respectively, RAs can be seen as “black-boxes” of algorithms with a high scalability of possibly bad advice, violating client and stakeholder interests (Baker & Dellaert, 2018; Ji, 2017). Additionally, due to RAs often rudimentary personalization ability, RA's compliance with fiduciary duties has been questioned (Tertilt & Scholz, 2018). Despite these problems an increasing number of RA managed assets (Statista, 2021) and RA publications show a determined interest of practice and research in RA.

Within a literature review on RA, performed in paper 1 (Torno, Metzler, et al., 2021), we found that RA research can be distinguished into three main themes: RA Users, RA Service, and RA

Competition. These themes, their respective components and interrelations form an Organizing Framework for RA Research, as illustrated in Figure 11.

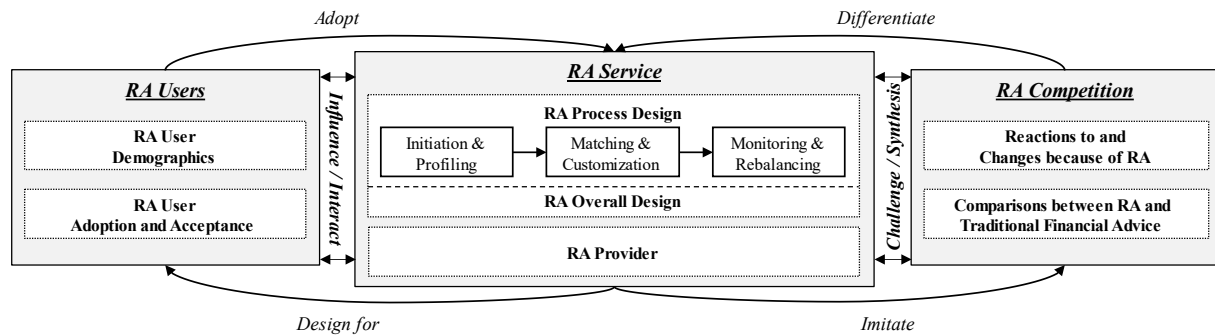


Figure 11. Organizing framework for RA research

On the left side, the framework incorporates studies and information on what RA users have in common and how their behavior regarding RA can be explained or predicted. Thereby, the framework differentiates between RA User Demographics (i.e., who uses RA) and RA User Adoption and Acceptance Factors (i.e., why using and trusting in RA). The actual RA Service is in the middle of the framework. The visualization thereby distinguishes between RA Process Design, organized into the three RA phases (i.e., how RA should be designed in each phase), RA Overall Design (i.e., how RA should be designed overall and nudge its users to overcome behavioral biases), and the RA Provider (i.e., who develops and offers RA services and how they can be differentiated). Finally, on the right side, the RA Competition is depicted. Within this theme, the framework separates between the Reactions to and Changes because of RA (i.e., how the competition is reacting to the changing circumstances and disruption through RA) and Comparisons between RA and Traditional Financial Advice (i.e., what are differences and similarities between the two).

The themes also relate to each other in various ways: First, a bidirectional relation between RA Users and the RA Service is characterized by mutual Influence and Interaction. On the other side, there is a degree of Challenge or Synthesis unfolding the bidirectional relation between RA Competition and the RA Service. Additionally, unidirectional links between the main themes moderate these relationships. On the left side, the RA Users adopt the RA Service, while the RA Service is designed for specific user groups. On the right side, the framework shows that the RA Service tries to imitate its traditional financial services competition. In contrast, the RA Competition aims at differentiation from the less comprehensive RA Service.

2.2 Methods and Approaches

In this section I introduce the main research methods and approaches used in the papers of this dissertation. While the literature review and taxonomy development are the main methods used

in research area I, the case study research and design science research (DSR) approaches are the base for research area II. In the next sections I introduce these research methods and approaches and describe briefly how they were used in the papers of this dissertation.

2.2.1 Literature Review

Literature reviews are crucial for any research project, because of the importance of knowing what has already been done in the domain of interest (Webster & Watson, 2002). Thereby, the strength of literature reviews is to integrate various research findings, e.g., to build or test theories or to provide a concise state of the specific review topic (Webster & Watson, 2002). More precisely, literature reviews can be used (1) to understand the topic of interest, (2) to reveal research gaps, (3) to justify the research by demonstrating its relevance, (4) to synthesize the existing literature, (5) to examine the evolution of ideas, (6) to identify research methods, strategies and active authors in the field of inquiry, and (7) to overcome conflicts in the literature (vom Brocke et al., 2015).

In general, literature reviews comprise three phases that are passed through sequentially or iteratively: Literature search, literature selection, and literature analysis (vom Brocke et al., 2015). Thereby, an ever-growing number of newly published scientific publications make it more difficult to assess the quality and relevance of publications (vom Brocke et al., 2015). Therefore, several seminal publications (e.g., Brendel et al., 2020; Fettke, 2006; Levy & Ellis, 2006; vom Brocke et al., 2015; Wolfswinkel et al., 2013) have developed frameworks to structure literature reviews, providing effective methods for literature search, relevance determination and analysis. Hereby, Webster & Watson's (2002) literature review framework stands out, since it is the most used approach in IS research, is applied in many domains of interest and is well documented (e.g., Brendel et al., 2020). In this framework, firstly the search terms for the domain of interest and the journals and databases need to be determined and the initial search executed (Webster & Watson, 2002). Afterwards, the authors should filter out duplicates and assess the relevance of the discovered publications by considering their titles, abstracts, and keywords. These filtered publications need to be reviewed in detail by comparing their content to predefined criteria based on the research goal, excluding irrelevant articles. After this search and filtering process, a forward search (who has quoted the relevant articles?) and a backward search (references of the relevant article) can further increase the number of relevant articles. This final selection of relevant literature is then analyzed (inductively or deductively) and systematized (e.g., in a concept matrix).

In paper 1 (Torno, Metzler, et al., 2021) we used the literature review by Webster & Watson (2002) as a method explicitly, providing a systematical analysis of scientific RA publications, focusing on literature in the IS, business and finance domains. In the context of the literature review typology in IS research by Paré et al. (2015) we conducted a descriptive literature review. In other papers of this dissertation, we used the literature review method embedded into other research approaches: In paper 2 (Torno, Werth, et al., 2021) in conceptual-to-empirical iterations of the taxonomy development and in paper 5's (Torno et al., 2022) DSR approach in deriving MRs and developing DPs for more ethical and trustworthy RA. Furthermore, all papers of this dissertation employed literature review techniques implicitly, e.g., to identify research gaps, synthesize the respective current body of research, and discuss the respective results in the context of former scientific publications.

2.2.2 Taxonomy Development

Taxonomies are typical representations of theories for analyzing, providing definitions of selected key concepts of a phenomenon and “belongs-to” relationships between them (Gregor, 2006). Taxonomies play an important role in research, e.g., to structure, organize and produce a common terminology and understanding in a domain of interest (Nickerson et al., 2013). They can explain differences and similarities of objects and can uncover and classify non-existent object configurations or knowledge gaps (Muntermann et al., 2015). Thereby, a taxonomy is suitable for analyzing complex domains and building more in-depth knowledge about the objects in a domain. Taxonomies as structure-giving frameworks are used to understand, grasp and analyze, and provide a foundation for other types of theory, e.g., theories of explanation and prediction (Gregor, 2006; Hevner et al., 2004).

Nickerson et al. (2013) proposed a methodological framework for taxonomy development, unifying deductive (conceptual) and inductive (empirical) approaches into one integral method. This gives developed taxonomies rigor and comprehensiveness while providing structural flexibility (Nickerson et al., 2013; Szopinski et al., 2019). Because of these strengths, the framework has been widely proven and used for taxonomy development in IS research, where IT-enabled phenomena steadily emerge (Kundisch et al., 2021; Oberländer et al., 2019). Figure 12 shows the taxonomy development method of Nickerson et al. (2013), which serves as the foundation of the research approach presented in paper 2 (Torno, Werth, et al., 2021).

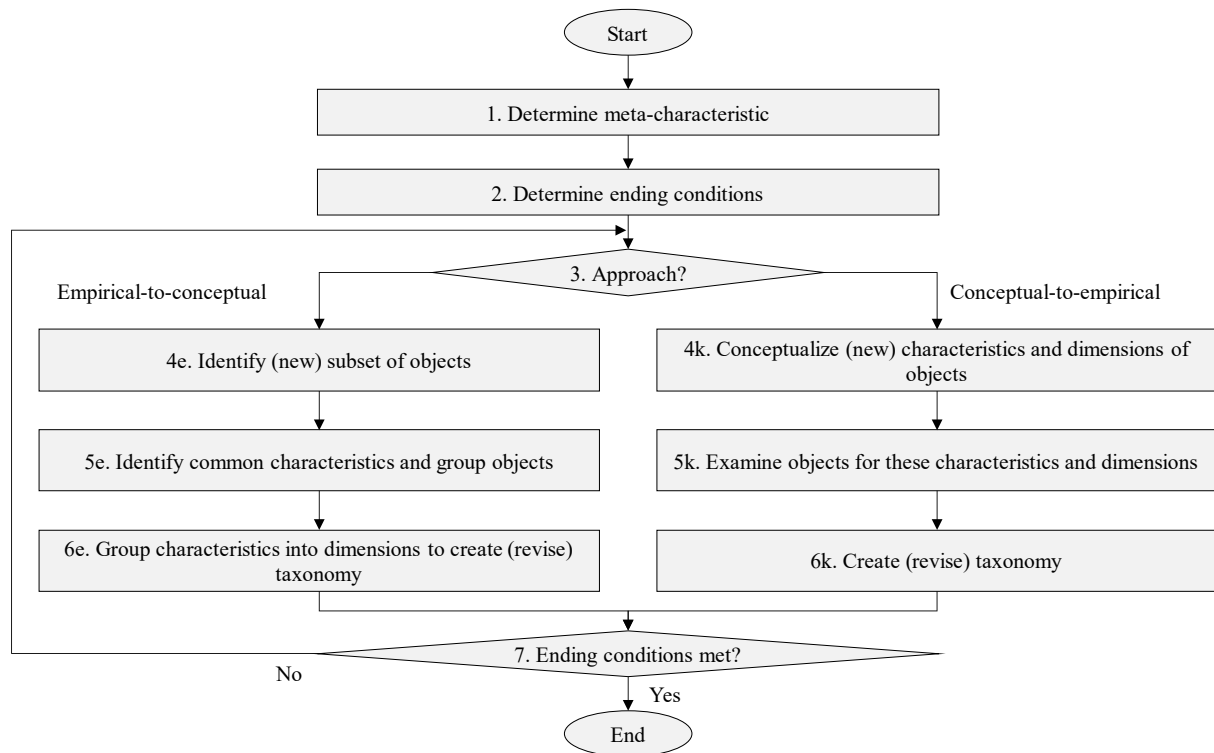


Figure 12. Taxonomy development method (Nickerson et al., 2013)

The first development step of a taxonomy is the determination of a meta-characteristic. It is defined as the most comprehensive characteristic that serves as the basis for all dimensions and characteristics that follow (Nickerson et al., 2013). To be useful, the meta-characteristic must reflect the expected users and purpose of the taxonomy (Nickerson et al., 2013). After outlining the meta-characteristic, ending conditions must be determined, which, if met, end the taxonomy development. Besides the two defining factors of a taxonomy, namely its mutual exclusivity and collective exhaustiveness, Nickerson et al. (2013) present and explain seven objective and five subjective ending conditions. Afterwards either a Conceptual-to-Empirical (C2E) or an Empirical-to-Conceptual (E2C) is iteratively undergone to develop the taxonomy further. In C2E-approaches, existing knowledge within the domain of interest is reviewed, including identifying main concepts from literature (Eickhoff et al., 2017). Based on that knowledge and the taxonomy's key intention in the form of the meta-characteristic, the researchers deduce relevant dimensions and characteristics (Nickerson et al., 2013). In E2C-approaches, real-world objects within the domain of interest are categorized, thereby modifying, merging, adding, and deleting dimensions and characteristics of the taxonomy (Nickerson et al., 2013). At the end of each approach, the taxonomy is checked, thus continuing the development with a C2E- or E2C-approach, when the ending conditions are not met or terminating the development when the ending conditions are met.

2.2.3 Case Study Research

A case study is an empirical investigation that examines a contemporary phenomenon in its real-world context (Yin, 2014). Thereby, Yin (2014) describes case study research as an all-encompassing approach including research design logic, data collection, and data analysis techniques. Case studies are thereby an appropriate way of doing research when “how” or “why” RQs are being asked about a set of contemporary events over which the researcher has little or no control (Yin, 2014). After determining the RQ the researcher needs to decide what data to use. Thereby, analyzable data comprise, e.g., observations, documents, interviews, physical artifacts, or audio-visual materials (Yin 2014; Creswell 2014). Coding, as the main method to evaluate qualitative data, describes the process of linking parts of data, e.g., certain text excerpts with selected terms or categories. The resulting codes express the content of the data excerpt in a short, concise, and comparatively abstract way (Mayring, 2014; Yin, 2014). When thematically related codes are combined, a category system arises. This category system can thereby be determined deductively or inductively. While in deductive coding the categories are pre-determined based on theory, inductive category systems emerge from the material itself (Mayring, 2014).

In paper 3 (Metzler et al., 2022) we collected data from the official websites, published whitepapers, annual reports, and ADV forms of relevant RA-providers. For the analysis of this dataset we used the deductive qualitative content analysis approach by Mayring (2014), based on the BMC framework by Osterwalder & Pigneur (2010). In contrast, we used observations on portfolio recommendations of relevant RAs in paper 4 (Torno & Schildmann, 2020). This observational data was analyzed using descriptive statistics and quantitative risk and performance measurements. Both papers utilized multiple case studies, each investigating 15 or more RAs, to strengthen the replication logic and robustness of the study insights (Eisenhardt, 1989b; Yin, 2014).

2.2.4 Design Science Research

The general idea of DSR is to provide innovative solutions to relevant problems. Its main goal is to design artefacts of immediate value for the society and economy and generate knowledge about the problem and the solution (Gregor & Hevner, 2013). Thereby, designing artefacts both need and create knowledge of a certain kind; in other words, they are built on theories (e.g., from behavioral science) and in turn contribute to theory. This is reflected in the two primary DSR activities described by Vaishnavi et al. (2004, p. 1): “The creation of new knowledge through design of novel or innovative artifacts (things or processes) and the analysis of the artifact’s use and/or performance with reflection and abstraction.”

Gregor & Hevner (2013) differentiate three levels of contribution in DSR. While level 1 DSR contributions are more specific, limited and provide less mature knowledge (e.g., instantiation of software products or processes), level 3 contributions are more abstract, complete and provide mature knowledge (e.g., design theories). In between, level 2 DSR contributions describe nascent design theories, that provide knowledge as operational principles or architectures (e.g., in form of constructs, models or design principles) (Gregor & Hevner, 2013).

The artifact design process can be structured in various ways. For example, Vaishnavi et al. (2004) describe five process steps (problem awareness, suggestion, development, evaluation, conclusion), with interlinked knowledge flows between the steps and distinct deliverables at the end of each step. Another DSR process model provide Peffers et al. (2007), who propose a iterative six step process with different possible research entry points: (1) Problem identification and motivation, (2) definition of solution objectives, (3) design and development, (4) demonstration, (5) evaluation, and (6) communication. We used the most frequently referenced DSR frameworks by Hevner (2007) and Hevner et al. (2004) (Brendel et al., 2021) to develop design principles for more ethical and trustworthy RA in paper 5 (Torno et al., 2022). This framework links existing knowledge with the practical environment in an iterative process and divides its activities into three respective research cycles: A relevance cycle establishes the initial context, determines the requirements for the design artifact, and defines the criteria that characterize the artifact as useful. A rigor cycle provides the scientific grounding and includes the communication of the design knowledge gained. A design cycle represents the core of the structured research process and is used to develop and evaluate the design artifact, including the beforementioned insights from the environment and knowledge base (Hevner 2007; Hevner et al. 2004). An overview of the used DSR approach and its employed process steps aiming at developing a level 2 DSR contribution are shown in Figure 23.

2.3 Data Collection and Analysis

In this section I introduce the data used for the various analyses of the papers in this cumulative dissertation. I thereby provide information on how the data was collected and subsequently analyzed.

2.3.1 Literature

All papers in this dissertation use scientific literature to a certain extent to form their individual insights. While paper 1 (Torno, Metzler, et al., 2021), paper 2 (Torno, Werth, et al., 2021), and paper 5 (Torno et al., 2022) used literature as a primary resource for their results, paper 3 (Metzler et al., 2022) and paper 4 (Torno & Schildmann, 2020) used literature partially to augment

and support the results of the studies and provide the research background. In all cases the literature was found by applying the previously described literature review framework by Webster & Watson (2002) with different parameters, based on the research design and goal of each study.

Our goal for the systematic literature review on RA, performed in paper 1 (Torno, Metzler, et al., 2021), was to provide a comprehensive state-of-the-art and set of future research directions for the RA domain. Firstly, we searched for “Robo-adv*” in Google Scholar to find a sample of frequently cited RA articles to derive more keywords for the primary search cycle. We found relevant keywords in the domains “Digitalization” and “Financial Advice”, assembled a keyword string combining both domains, as well as frequently used “RA” terms, and executed the literature search on four databases. After filtering for relevance, using predefined exclusion criteria (see Table 4), a final pool of 42 relevant scientific RA articles originated (see Table 5).

The derivation of MRs and development of DPs for more ethical and trustworthy RA in paper 5 (Torno et al., 2022) was also based on a systematic literature review. Thereby, we searched five databases for scientific publications containing keywords of the domains “Robo-Advice” and “Financial Advice” in conjunction with “Ethic” and ethical values such as “competence”, “confidentiality”, “integrity” and “credibility”. In this case, we checked for relevance using the following main inclusion criterium: Articles must allude to descriptions of ethical issues in the RA domain and/or provide ideas for their solution. The final pool comprised 34 relevant scientific articles.

To classify mobile personal finance apps in paper 2 (Torno, Werth, et al., 2021) we used scientific literature in the C2E-iterations of the taxonomy development. We thereby incorporated papers regarding personal finance, digital finance, and related aspects of mobile apps in the domain.

In all cases, we used the qualitative content analysis approach by Mayring (2014) to code the articles inductively. Thereby, the categorization of collected data results from the material itself, not from theoretical considerations, mitigating possible biases owing to preconceptions of the researchers (Mayring 2014). As recommended by Mayring (2014) the analysis was approached by coding half of the relevant articles independently by each author, creating separate category systems. These category systems were discussed, revised, and verified in the author team, creating a unified system that was then used to analyze the whole pool of relevant articles.

2.3.2 Personal Finance Mobile Apps

In paper 2 (Torno, Werth, et al., 2021) we developed a taxonomy and conducted a cluster analysis of mobile personal finance applications. To develop the taxonomy, we used the before-mentioned method by Nickerson et al. (2013), in which the E2C-approaches used Personal Finance Mobile Apps as objects and main inputs. We thereby classified native mobile apps found in the corresponding “finance” sections in both Apple App Store and Google Play Store offered in Germany. To obtain a relevant and workable app sample size, we used the apps that are highest ranked in each app store. Thereby, the app stores sort apps into three classes: free, paid, and grossing, e.g., by in-app purchases. We captured the top-ranked apps for each app store and beforementioned class by using the databases Similarweb and Appbrain. To ensure a decent quality of our app sample, we only included apps whose download count was at least 5000+ and that were updated within the last two years. Furthermore, we also excluded apps that, even though listed in the finance category, did not meet our personal finance definition.

To analyze the final pool of 170 apps, we first read the description given in both app stores, if applicable. For more complex apps or less expressive descriptions in the app stores, we also considered the app provider's website. If characteristics could not be determined by store description or internet search, we downloaded the app, tried the functionalities in detail and discussed them in the author team.

2.3.3 Qualitative Data of Robo-Advisors

In paper 3 (Metzler et al., 2022) we investigate the underlying BM of RAs. We therefore conducted a multiple case study to explain the basic characteristics and special features of their BMs. To get a comprehensive overview and to consider a large industry share, the analysis focused on the 15 biggest US-based RAs with a minimum of one billion USD assets under management (AuM). To find relevant RAs, we considered industry reports (e.g., BackendBenchmarking, 2021; Zavialova, 2021) and online-based statistics (Statista, 2021) and checked whether the services provided really encompass RA. We then collected publicly available information and documents provided by these RA-providers, including their official websites, published whitepapers, annual reports, and ADV forms.

We analyzed this data with the qualitative content analysis approach by Mayring (2014) using a deductive category application based on the BMC framework introduced by Osterwalder and Pigneur (2010). The analysis was performed in two major steps. First, we highlighted for all RAs every statement within the dataset associated with its BM and linked each statement to at least one suitable BM element resulting in an illustration of the BM for each RA. In next step,

the results of each RA were compared to all other RAs to get a cross-case overview. Using a dual coder approach, the first researcher coded all available documents. Afterwards, another researcher verified all codes by checking all documents and the associated codes. As proposed by Mayring (2014), we questioned and revised the categorization after coding half of the data. Lastly, we finalized the coding based on discussions within the author team.

2.3.4 Portfolio Data of Robo-Advisors

In paper 4 (Torno & Schildmann, 2020) we conducted a sophisticated analysis of recommended portfolios of 36 RAs, based on six distinct model customers with different risk-affinities and investment horizons, resulting in 216 recommended portfolios. We started by developing distinct model customers, to ensure a neutral, transparent, and replicable analysis procedure. We thereby choose three distinct risk and two distinct investment horizons for differentiation between recommended portfolios. These dynamic characteristics had the biggest impact on the differing recommendations of RAs portfolios. Additionally, we choose static characteristics based on the target group of RAs in Europe and the US, that had only a low impact on the portfolio recommendation (e.g., age, sex, investable capital, savings ratio). Not changing these characteristics reduced the complexity of the profiling runs and focused the subsequent portfolio analysis.

After defining the model customers, we selected RAs based on literature references and an explorative internet research (Beketov et al., 2018; Brokervergleich 2019. Statistiken und Daten. <https://www.brokervergleich.de/>. Zugriff am 10. November 2019, 2019). We only considered the RAs if their profiling phase led to a portfolio recommendation without registering with personal data (e.g., social security number). We thus obtained three categories of data availability of the RAs portfolio recommendations. While in *category A* RAs provided fully transparent portfolio structures, including weightings per asset class as well as associated products, RAs in *category B* provided semi-transparent portfolio structures with weightings per asset class, but no associated products. Lastly, *category C* consists of RAs not providing enough portfolio structure data and were therefore excluded for the analysis. For each of the considered 36 RAs in *categories A and B*, the profiling phase was gone through six times, matching the distinct risk/investment horizon combinations of the defined model customers.

In *category A* RAs allowed a comprehensive analysis not only of the structure but also of risk and performance measurements of the recommended portfolios. The analysis was thereby based on historical prices of the products in the portfolios identified through its International Securities Identification Number (ISIN). For these products, historical daily closing prices in U.S.

dollars between 2009 and 2019 were retrieved from Thomson Reuters via DataStream. Based on that data, we calculated annual averages of various performance and risk measures (i.e., average historical portfolio returns p.a., mean portfolio variance p.a., mean portfolio standard deviation p.a., Value at Risk, Sharpe Ratio) to simulate how the recommended portfolios would have performed in the given timeframe backwards. The 13 RAs in *category B* allowed at least the analysis of the portfolio structure, since they present a portfolio allocation at the end of the matching phase which we used as a risk indicator (Tertilt & Scholz, 2018).

2.3.5 International Standards and Guidelines for Ethical Financial Advice

In paper 5 (Torno et al., 2022) we derived MRs and developed DPs that can guide more ethical and trustworthy RA design. Thereby the MRs and DPs based on literature as well as on international standards and guidelines for ethical financial advice. To find relevant standards and guidelines that met our main inclusion criterium (“must allude to descriptions of ethical issues in the RA domain and/or provide ideas for their solution”), we performed a systematic Google search: We used the parameters from the previously executed systematic literature review (financial advice OR robo-advice AND ethics) and added the search terms “standard*” or “guide*”. To provide an international perspective, we excluded national standards e.g., from the German BaFIN or the American Institute of CPAs.

To analyze the standards and guidelines we employed the qualitative content analysis approach by Mayring (2014) coding the data inductively to extract requirements and possible solutions for ethical RA. In our approach, the first two researchers coded half of the relevant documents openly, creating two separate category systems. As proposed by Mayring (2014), these categorizations were questioned and revised in the entire author team after coding half of the data. We agreed on and verified a unified category system and used it to analyze all documents for ethical RA requirements and possible solutions.

2.3.6 Interviews to Evaluate Ethical RA Design Artifact

To evaluate and enhance the design artifact developed in paper 5 (Torno et al., 2022) we conducted five semi-structured expert interviews. Our goal was to receive answers to selected predetermined questions concerning the beforementioned MRs and DPs and to clarify the reasoning behind the answers (Yin, 2014). Thereby, two interviewees were researchers in the RA domain and three practitioners of large RAs operating in Germany.

Each interview was separated into three parts. In the first part we talked about the current state of ethics in RA and ensured a common understanding of the topic by providing our definition of ethical financial advice. In the second part, we sequentially asked the interviewees to state

their opinions on our preliminary MRs and DPs for more ethical RA design. We thereby illustrated the MRs with examples that are present in the DP elaborations and asked questions about their importance, reasonableness, and applicability. The third section closed the interview with general opinions concerning the MRs and DPs and the possibility to report related thoughts, which might be useful for the design of more ethical RA.

The interviews were held in German language and lasted between 46 and 73 minutes, with an average of 57 minutes. After transcribing the interviews, we analyzed them by utilizing the qualitative content analysis approach by Mayring (2014) and using a deductive approach based on the previously developed coding system for ethical RA. We thereby coded the given answers, e.g., regarding a certain MR or DP and categorized comparable and related statements. This enabled us to not only analyze the similarities and differences of statements regarding one MR or DP but to find similarities across design dimensional statements. The coding was performed separately by two researchers and unified and finalized in a discussion of the entire author team.

B Research Areas

In this part I present the five research papers this cumulative dissertation consists of. The papers are thereby divided into the two previously introduced research areas “Positioning of RA in science and practice” as well as “RA analysis and design”. Figure 13 illustrates the forthcoming structure by grouping the individual papers and their respective RQ to the specific research areas.

B. Research Areas	
I. Positioning of Robo-Advice in Science and Practice	II. Analysis and Design of Robo-Advice
<div>RQ I.1</div> Paper 1 (Torno, Metzler, et al., 2021): A Systematic Literature Review of Robo-Advice	<div>RQ II.1</div> Paper 3 (Metzler et al., 2022): An Analysis of Robo-Advisor Business Models
<div>RQ I.2</div> Paper 2 (Torno, Werth, et al., 2021): A Taxonomy -based Analysis of Mobile Personal Finance Applications	<div>RQ II.2</div> Paper 4 (Torno & Schildmann, 2020): An Analysis of Robo-Advisor Portfolio Structure, Performance and Risk
	<div>RQ II.3</div> Paper 5 (Torno et al., 2022): Design Principles for Ethical Robo-Advice

Figure 13. Research papers and research questions in their respective research areas

Research Area I. Positioning of Robo-Advice in Science and Practice

The first research area addresses the positioning of RA in science and practice. As stated in the foundations part, the main goal is to provide a structure for more in-depth analyses of RA.

Thereby, the first focus is on RA from a scientific perspective, considering the relevant literature about RA and systematizing it in a new Organizing Framework for RA research as well as structuring worthwhile future research directions. Paper 1 (Torno, Metzler, et al., 2021) provides answers to the following research question:

RQ I.1: How can research on RA be systematized and what are worthwhile future research directions regarding RA?

The second focus is on the practical positioning of RA in the broader landscape of FinTech services. By employing the relevant customer requirements of ease-of-use and ubiquitous availability, the practical positioning of RA is approached in the context of mobile personal finance applications. Paper 2 (Torno, Werth, et al., 2021) provides answers to the following RQ:

RQ I.2: How can mobile personal finance applications be classified and what archetypes can be distinguished?

1 Robo-What?, Robo-Why?, Robo-How? – A Systematic Literature Review of Robo-Advice

<i>Authors & Contributions</i>	Albert Torno, albert.torno@uni-goettingen.de	Idea, data acquisition, data preparation, data analysis, writing, visualization, text revision
	Dennis Renee Metzler, dennis.metzler@uni-goettingen.de	Ideation of analysis structure, text revision
	Vanessa Torno, vanessa.torno@sks-group.eu	Data preparation for future research agenda, text revision
<i>Citation</i>	(Torno, Metzler, et al., 2021): Torno, A., Metzler, D. R., and Torno, V. 2021. “Robo-What?, Robo-Why?, Robo-How? – A Systematic Literature Review of Robo-Advice,” in <i>Proceedings of the 25th Pacific Asia Conference on Information Systems (PACIS), Dubai, VAE</i> .	
<i>Abstract</i>	Robo-advisors (RAs) guide investors through an automated financial advice process, recommend personalized portfolio assignments based on their risk-affinity and goals, and rebalance their portfolio automatically over time. While still a novel instantiation of FinTechs, an increased number of RA publications, especially in 2019 and 2020, shows a determined interest of research in the subject. However, no comprehensive state-of-the-art nor a set of future research directions is available. We, therefore, conduct a systematic literature review, analyzing 42 peer-reviewed articles focusing on RA. We provide descriptive statistics of the articles, including research approaches and regional focuses, and classify the literature in an Organizing Framework for RA Research with the three main themes RA Users, RA Service, and RA Competition. We summarize RA's current scientific knowledge by showing important insights on each theme and the interrelation between the themes. Lastly, we provide fruitful future research directions derived from RA literature.	
<i>Keywords</i>	Robo-Advice, FinTech, Automated Financial Advice, Literature Review	

Table 3. Fact sheet of paper 1

1.1 Introduction

Disruptive innovations and the usage of new digital technologies challenge common practices in many areas of life. For example, traditionally relying on face-to-face consultancy, the financial advisory sector has not remained untouched from the on-going digitalization (Gomber et al., 2017; Sironi, 2016). Traditionally, financial advice in the wealth management domain is based on human interactions and trust between the advisor and the customer, which is a time-consuming and costly process and led to mostly high net worth individuals using these services. One particularly dominant phenomenon among digitally enabled financial technologies (FinTech) is Robo-Advice (RA) (Gomber et al., 2017). Robo-Advisors (RAs) guide investors through an automated financial advice process, recommend personalized portfolio assignments based on their risk-affinity and financial goals, and monitor as well as rebalance their portfolios automatically over time (Jung et al., 2018; Sironi, 2016). Therefore, RAs aim to give more people access to diversified capital market participation, including retail investors with small amounts of capital to invest and often low financial knowledge (Jung et al., 2019; Sironi, 2016).

Despite RAs relative novelty, scientific research emerged remarkably, especially in the last two years. The increased interest by researchers in the subject brought a variety of studies addressing different aspects of RA, e.g., design principles (e.g., Jung and Weinhardt 2018), adoption and acceptance factors (e.g., Tauchert and Mesbah 2019), or recommended portfolio analysis (e.g., Torno and Schildmann 2020). Due to the increasing number of publications focusing on differing aspects of RAs, it is valuable to structure the existing research and derive potential future research directions. Still, no systematic literature review on the RA phenomenon is available. Only the working paper by D’Acunto and Rossi (2020) tries to summarize current knowledge about RA, but without utilizing a systematic literature review. To close this research gap, we aim to analyze and structure the field and derive fruitful future research directions by conducting a systematic literature review, answering the following research questions (RQs):

RQ1: How can research on RA be systematized and which insights emerged?

RQ2: What are worthwhile future research directions regarding RA?

We conduct a systematic literature review in the IS and business-related research domains to address these questions. Based on relevant articles, we present the current scientific knowledge in an *Organizing Framework of RA Research*. Additionally, we analyze all the relevant articles' limitations and future research statements to present a research agenda for RA in line with the framework themes. This paper thereby provides a current state-of-art of RA that structures the current scientific knowledge and presents worthwhile and verified avenues for future research.

In the following, we provide the theoretical background of our study and introduce our literature review approach. We then explain our descriptive results, as well as the main insights of existing literature. Subsequently, we present worthwhile future research directions and discuss our findings as well as the implications and limitations of our study. Our conclusions summarize the most important insights by answering the RQs.

1.2 Theoretical Background

1.2.1 Digitalization of Financial Advice

Digital technologies, defined as a combination of information, computing, communication, and connectivity technologies, have the power to fundamentally transform products and services, business processes, interfirm relationships, and business strategies (Hess et al., 2016). Especially the financial services industry is affected by an ongoing digitalization. Emerging FinTechs that use digital technologies challenge incumbent financial service providers, for example, by introducing automated and digitalized financial advice and financial management in the form of RA (Gomber et al., 2017).

Three main factors are driving the digitalization of financial advice: *(I) Changes in financial markets*, *(II) Changes in customer requirements*, and *(III) Changes in technology*. New financial products, e.g., Exchange Trading Funds (ETFs), resembling index-based investment vehicles, enabled low-cost, diversified, and passively managed investment strategy implementations (Gomber et al., 2018). The generally low interest rate in the last decade made investing in assets like stocks and bonds more attractive than saving money in saving accounts, even for less wealthy customers (Sironi, 2016). With new customer generations becoming affluent and a generally more digitized society, new customer requirements emerged, e.g., more digitized, 24/7 available, and user-friendly services (Berman, 2012). Also, since customers can compare services fast and easily through the internet, they are more price-sensitive and want more personalized services when higher fees are charged for the service. Not only the internet and emerging digital platforms, but the ubiquitous use of technology, e.g., of smartphones, led to the high usage of technology in all domains and its high status in society (Berman, 2012). Also, advancements in artificial intelligence (AI), especially Natural Language Processing (NLP), enabled the upcoming of chatbots, which are often used by RA providers to deliver a certain degree of customer service, without human intervention (Gomber et al., 2018). Altogether, these changes led to the emergence of RA, which aims to fulfill these new requirements.

1.2.2 Robo-Advice and its Process Phases

The term Robo-Advice is comprised of two components: *Robo* as an abbreviation of robot meaning “a machine controlled by a computer that is used to perform jobs automatically” and *Advice* meaning an opinion offered about what to do or how to act in a particular situation (Cambridge Dictionary, 2021). Based on these meanings, a RA can be outlined as an automated system that advises on finance, especially wealth management. RA providers aim at digitizing and automating the entire traditional financial advisory and wealth management process (Jung et al., 2018). RAs can be defined as IS that guide investors through an automated financial advice process, recommend personalized portfolio assignments based on their risk-affinity and financial goals, and monitor as well as rebalance their portfolios automatically over time (Jung et al., 2018; Sironi, 2016). While RAs are usually named “Robo-Advisors” that give “Robo-Advice,” they are also labeled, more broadly as “Digital Investment Management Systems,” “Automated Financial Advisors,” or “Automated Financial Management”. While articles that focus on portfolio allocation and rebalancing call them “Robo-Investors” or “Automation of Asset Management,” articles that emphasize AI within the traditional financial advice process call these systems “AI in Personal Financial Planning” or “Robotic Advisory for Personalized Wealth Management”. For this paper, we use the terms Robo-advisors and Robo-advice, abbreviated with “RAs” respectively “RA”.

Instead of a human financial advisor analyzing the financial situation of a customer, a typical RA uses algorithms to associate customer information to a suitable portfolio allocation and implements its recommendation (Beketov et al., 2018). According to Jung et al. (2018, 2019), this process can typically be divided into three phases, matching the traditional financial advice process: (1) “Initiation and Profiling,” (2) “Matching and Customization,” and (3) “Monitoring and Rebalancing.” Within the first phase of the process, the *Initiation and Profiling*, information asymmetries between the RA and the customers are dismantled (Jung et al., 2018). In online questionnaires, customers go through a self-assessment of their risk-affinity and investment characteristics and provide investment goals (Tertilt & Scholz, 2018). Based on that information, the RA creates a (risk) profile of the customer, which is the portfolio recommendation's foundation. Also, in this phase, RA providers pre-select products (mostly ETFs) from which their recommended portfolios are compiled (Rühr et al., 2019a). Within the *Matching and Customizing* phase, the risk profile is transferred automatically into the recommendation of a portfolio allocation. When presenting the recommended portfolio to the customer, RAs often let them customize their risk class association and the portfolio structure, but in a way that it does not derive too widely from the recommendations (Jung et al., 2018). Typically, the end of the

matching phase is marked by an offer and the implementation of the portfolio for the customer. In the last phase of the process, RAs *Monitor and Rebalance* the portfolios of their customers. The customers have permanent online access to their portfolio and get reports about the performance as well as financial news and occasionally educational content. RAs thereby rebalance their customer's portfolios, aiming to maintain the portfolio's initial risk-to-performance ratio by buying and selling individual assets. This ensures that the portfolio's risk remains stable and within the risk profile associated with the customer, despite changing financial markets (Jung et al., 2018).

1.3 Systematic Literature Review Approach

To review the scientific literature on RA, we conducted a systematic literature review. We used the method by Webster and Watson (2002) since it is the most commonly used approach in IS research and well documented (Brendel et al., 2020). A visual representation with details of the systematic literature review can be obtained from Figure 14.

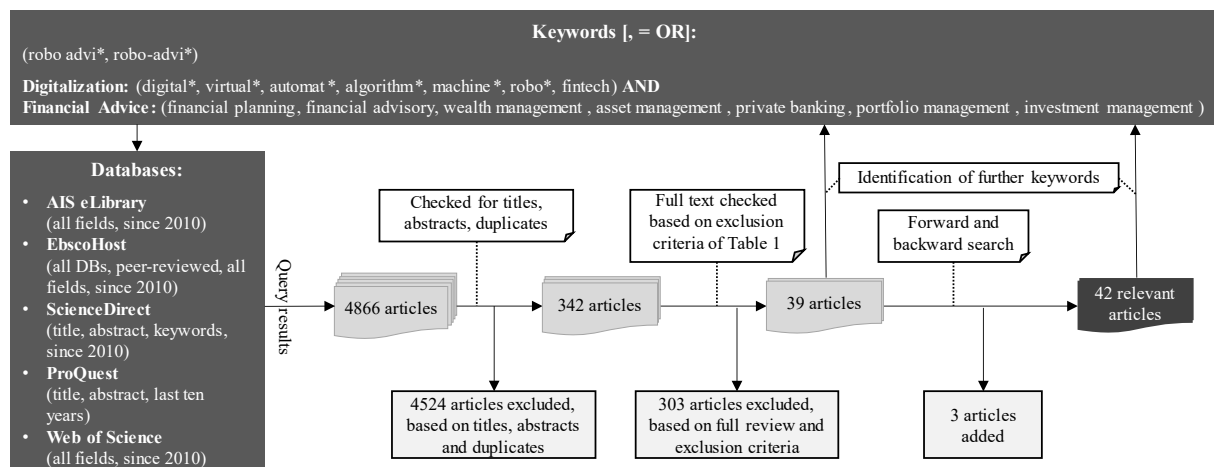


Figure 14. Process of the systematic literature review

First, we searched for “Robo-adv*” in Google Scholar to find a sample of frequently cited RA articles to derive more keywords for our primary search cycle. We found relevant keywords in the domains *Digitalization* and *Financial Advice*. An assembled keyword string combining both domains, as well as frequently used “RA” terms, was applied on four different databases. Afterward, we checked the articles found for titles and abstracts and excluded duplicates. Further, we thoroughly reviewed the resulting long list of articles. We checked the articles for relevance and quality using our exclusion criteria in Table 4. Exemplary excluded articles for each exclusion criterion can be obtained from Appendix Table 2. We performed a forward and backward search for this shortlist of articles, resulting in our final pool of 42 relevant RA articles, presented in Table 5.

Studies outside the IS, finance, or other business literature domains, e.g., law
Studies not focusing on the RA or digitalization and automation of traditional financial advice
Not peer-reviewed studies and studies without rigorous research method such as whitepapers, market analyses, commentaries, research-in-progress articles, or books

Table 4. Exclusion criteria

This pool of relevant articles was first classified along descriptive dimensions. We thereby distinguished between quantitative, qualitative, and mixed-method approaches. For further insights, we determined the research method(s) used by each article according to the classification of Palvia et al. (2015). We also determined the articles' regional focus, if possible, and differentiated between Asia/Pacific, Europe, and North America. We read the final pool of articles extensively and employed the qualitative content analysis approach by Mayring (2014) to code the articles inductively to “extract what the literature genuinely has presented to date and derive themes as they evolve” (Bandara et al. 2015, p. 169). These emerging themes were organized into an *Organizing Framework of RA Research*, visualized in Figure 17 and explained in the following chapters.

1.4 Findings

In this section, we elaborate on our findings, beginning with the results of the literature review in Table 5 and an explanation of descriptive statistics. Afterward, we present the emerged *Organizing Framework for RA Research* in Figure 17 and explain its overarching themes *RA Users*, *RA Service*, and *RA Competition*, including its subthemes.

1.4.1 Descriptive findings

As depicted in Figure 15, the amount of published research on RA increased dramatically in the last years. Articles before 2017 were excluded due to our exclusion criteria. However, since 2017, more sophisticated conference and journal articles were published, especially in 2019 and 2020. Most of the IS domain articles are conference articles. In contrast, the other business domains, including finance, publish articles exclusively in journals. Still, many of the articles are not published in top journals of each domain or provide advanced theories. We also find that RA's scientific literature is diverse, with many business domains interested in different aspects of RA, as presented in Figure 16. While approximately two-thirds of the relevant literature were almost equally published in IS and finance outlets, most article outlets can be summarized in other business domains, including economics, social sciences, management, marketing, or accounting.

Article	Outlet	Domain	Research Method							Regional Focus				Organizing Framework for RA Research							
			Case study	Design science / Classification	Experiment	Interview	Literature / Qual. content analysis	Portfolio analysis	Simulation / Quant. data analysis	Survey	Asia/Pacific	Europe	North America	Not specified	RA Users		RA Service		RA Competition		
															RA User Demographics	RA User Adoption and Acceptance	RA Process Design	RA Overall Design	RA Provider	Reactions to and Changes because of RA	Comparisons between RA and Traditional Financial Advice
Adam et al. 2019	Conf.	IS							x			x			o		x				
Beketov et al. 2018	Journal	Finance					x				x	x				x				o	
Belanche et al. 2019	Journal	Other							x		x	x			x	x					
Brenner and Meyll 2020	Journal	Finance							x			x			x					x	
Britton and Atkinson 2017	Journal	Other				x					x								x		
Cheng 2021	Journal	Other							x	x					x						
Cheng et al. 2019	Journal	Other				x			x				x		o						
Coombs and Redman 2018	Conf.	IS				x					x								x		
D'Acunto et al. 2019	Journal	Finance						x	x	x					x		x	x		o	
D'Hondt et al. 2020	Journal	Finance						x			x				x		x			o	
Fan and Chatterjee 2020	Journal	Finance							x			x			x	o					
Fulk et al. 2018	Journal	Finance							x				x	x						o	
Guo et al. 2019	Conf.	IS				x							x		x			x			
Harrison and Samaddar 2020	Journal	Finance						x						x						x	
Hayes 2019	Journal	Other	x									x		x			o	o			
Hildebrand and Bergner 2021	Journal	Other			x						x	x			x		o	x			
Hodge et al. 2020	Journal	Other			x							x			x		x				
Hohenberger et al. 2019	Journal	Finance							x				x		o	x					
Jung and Weinhardt 2018	Conf.	IS		x	x						x				o	o	x	x			
Jung et al. 2017	Journal	IS		x							x				o		x	x			
Jung et al. 2018	Journal	IS		x			x						x			x			o	o	
Jung et al. 2019	Journal	Other					x						x		o	x		o	x	x	
Litterscheidt and Streich 2020	Journal	Other			x						x				x	x					
Lourenço et al. 2020	Journal	Other			x						x				x	o		x			
Mesbah et al. 2019	Conf.	IS							x		x				x					x	
Morana et al. 2020	Conf.	IS			x						x				x		x	x			
Niszczoła and Kaszás 2020	Journal	Other							x				x	x	o			o		x	
Ostern et al. 2020	Conf.	IS		x			x							x		x		x			
Phoon and Koh 2018	Journal	Finance	x								x	x	x		o			x	o	o	
Puhle 2019	Journal	Other					x					x					x				
Reher and Sun 2020	Journal	Finance	x				x					x			x		x		x	o	
Rühr 2020	Conf.	IS			x						x				o		x				
Rühr et al. 2019a	Conf.	IS		x							x	x	x				o	x		o	
Rühr et al. 2019b	Conf.	IS			x							x			o		x				
Tan 2020	Journal	Other	x								x				x			o	o	o	
Tauchert and Mesbah 2019	Conf.	IS			x							x			x					o	
Tertilt and Scholz 2018	Journal	Finance	x									x	x				x		o	x	
Torno and Schildmann 2020	Conf.	IS					x				x	x	x				x				
Waliszewski and Warchlewska 2020	Journal	Other							x	x	x	x			x	o					
Warchlewska and Waliszewski 2020	Journal	Other							x			x			o	o				x	
Wexler and Oberlander 2021	Journal	Other					x							x				x			
Woodyard and Grable 2018	Journal	Finance													x					x	
Sum	42	42	5	5	9	4	5	3	3	14	7	22	16	9	16	22	17	13	9	8	18
Sums Outlet: 30 Journal / 12 Conf.; Sums Domain: 16 Other / 14 IS / 12 Finance Legend: x = used / investigate; o = mentioned only																					

Sums Outlet: 30 Journal | 12 Conf.; **Sums Domain:** 16 Other | 14 IS | 12 Finance **Legend:** x = used / investigate; o = mentioned only

Table 5. Results of the systematic literature review

Research on RA is done under several different research methods. While almost two-thirds of the articles use quantitative methods, one-fourth uses qualitative methods, and 10% mixed-method research approaches. Quantitative research primarily consisted of surveys of potential users of RA, traditional investors, or actual RA users. Experiments, portfolio analyses, and simulations were also common quantitative research approaches. Qualitative research includes interviews, literature-based studies, or qualitative content analyses, e.g., of RA websites. Mixed-methods research was used in design science studies where different research methods and data were used for obtaining requirements and evaluating artifacts. Also, case studies derive insights from different viewpoints, e.g., from a user's perspective, when researchers use RAs in self-experiments and analyze alongside SEC documents of the RAs.

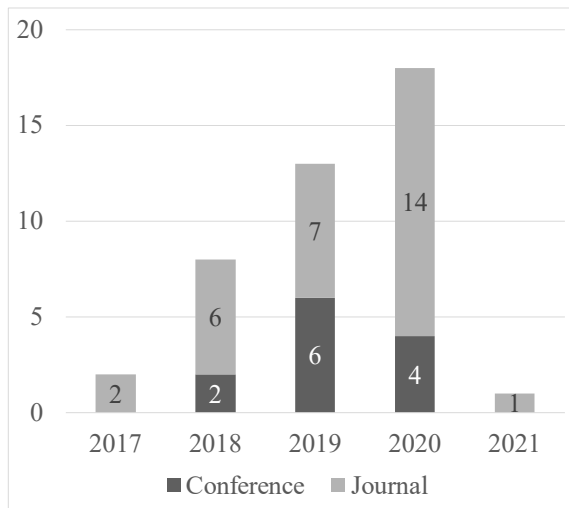


Figure 15. Articles by year & outlet type

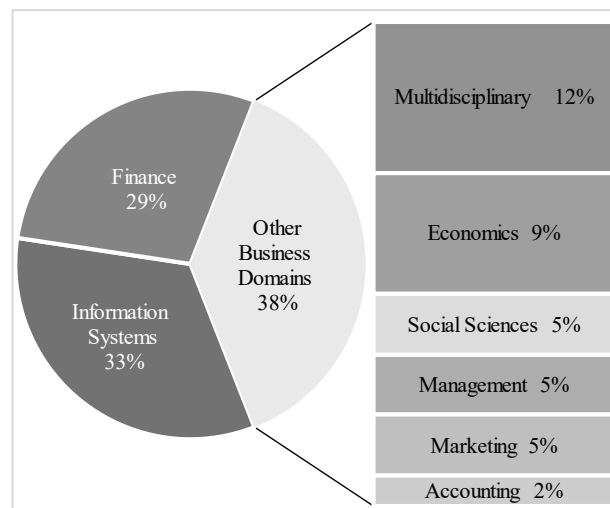


Figure 16. Articles by subject domain

Table 5 also displays the geographical focus of the analyzed articles. Only one-fifth of the articles have no specific regional focus regarding data collection or RAs regional base. Most articles only have one region in focus. When comparing these regions of focus, Europe is most frequently the focus of the study, where Germany and the UK stand out most often. Compared to these countries, the USA was the most frequently stated one nation of focus, within the second most used focus region North America. The Asia/Pacific region is with approximately 15% less frequently focus of the articles. In our final pool of articles, we did not find studies focusing on South America or Africa, which is in line with the low RA penetration rate in these markets (Statista, 2021).

1.4.2 Organizing Framework for RA Research

Jung et al. (2018) classified RA research into the areas *Behavior* (understanding of the RA process) and *Interface Design* (understanding the RA as an interface to new investors). However, as a result of our literature review, we found that RA research can be distinguished into three main themes: *RA Users*, *RA Service*, and *RA Competition*, as illustrated in Figure 17.

On the left side, the framework shows the **RA Users**, what these have in common and how their behavior regarding RA can be explained or predicted. More specifically, the framework differentiates between *RA User Demographics* (i.e., who uses RA) and *RA User Adoption and Acceptance Factors* (i.e., why using and trusting in RA). In the middle of the framework stands the actual **RA Service**. Our visualization distinguishes between *RA Process Design* (i.e., how RA should be designed in each phase), *RA Overall Design* (i.e., how RA should be designed overall and nudge its users to overcome behavioral biases), and the *RA Provider* (i.e., who develops and offers RA services and how can they be differentiated). Lastly, on the right side, the **RA Competition** is depicted. Within this theme, the framework separates between the

Reactions to and Changes because of RA (i.e., how the competition is reacting to the changing circumstances and disruption through RA) and *Comparisons between RA and Traditional Financial Advice* (i.e., what are differences and similarities between the two).

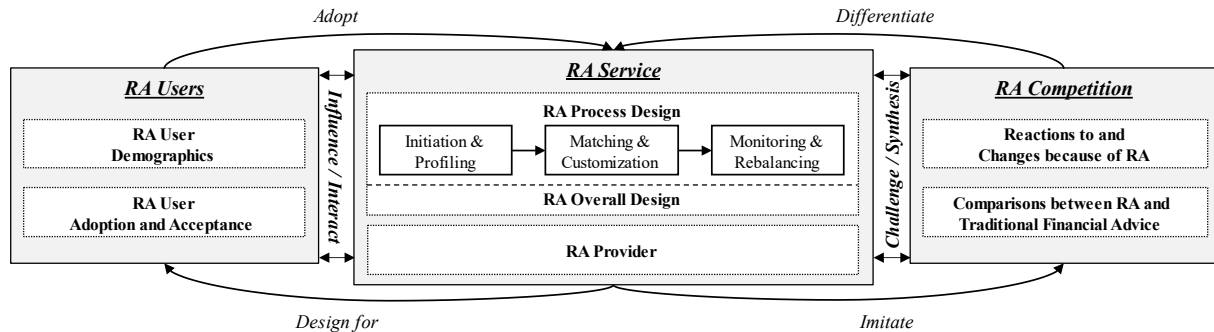


Figure 17. Organizing framework for RA research

The themes thereby relate to each other in various ways: First, a bidirectional relation between RA Users and the RA Service is characterized by mutual ***Influence and Interaction***. On the other side, there is a degree of ***Challenge or Synthesis*** unfolding the bidirectional relation between RA Competition and the RA Service. Additionally, unidirectional links between the main themes moderate these relationships. On the left side, the RA Users *adopt* the RA Service, while the RA Service is *designed for* its specific user groups. On the right side, the framework shows that the RA Service tries to *imitate* its traditional financial services competition. In contrast, the RA Competition aims at *differentiation* from the less comprehensive RA Service.

1.5 RA Users

1.5.1 RA User Demographics

Articles in this research theme investigate the role of certain demographic characteristics of individuals that moderate the likeliness of RA usage. While D’Acunto et al. (2019) found RA users to be similar to RA non-users in terms of overall demographics, most other articles argue that there are significant moderating characteristics for RA usage. RA research thereby found that age, general education, financial expertise, confidence, risk-tolerance, income, and current capital/portfolio values are relevant characteristics moderating RA usage.

Regarding *age*, researchers find that RA users are typically young (e.g., Brenner and Meyll 2020), while only Fan and Chatterjee (2020) describe younger as aged “under 65”. Besides a higher *education* (Lourenço et al., 2020), articles argue that a higher (self-perceived) *financial education or financial literacy* increases the likeness of RA usage (Fan & Chatterjee, 2020; Lourenço et al., 2020). In contrast, Hayes (2019) and Tan (2020) argue that “RAs are actively constructing passive investors by disciplining them through technologies” and thereby “weaken efforts to promote financial literacy and education”. D’Hondt et al. (2020) positively formulate

this circumstance, stating that “people with particular low education and low income, would gain most significantly by using RAs”. In that regard, Reher and Sun (2020) found that investors with low diversified portfolios are more likely to delegate their accounts to an RA. Also, high *confidence*, meaning being less impulsive and more strategic with financial decision-making, leads to RA usage (Fulk et al., 2018; Woodyard & Grable, 2018). Additionally, a higher *risk-tolerance* of individuals was found to increase the likeliness of RA usage (Fan & Chatterjee, 2020). Lastly, economic standing measures suggest that RA users have, in contrast to traditional advice users, *lower incomes* and *lower capital and portfolio values* (Brenner & Meyll, 2020; Fulk et al., 2018). Still, RA users are mostly employed, meaning they have a certain degree of income and net worth (Waliszewski & Warchlewska, 2020). Fulk et al. (2018) found that when a large percentage of their total net worth was inherited, users would prefer traditional financial advice in contrast to RA. This could be explained by the sudden capital increase, without an appropriate increase in financial education or confidence in financial decision-making. Lastly, Waliszewski and Warchlewska (2020) investigated socioeconomic factors moderating RA usage and found differences between *nationalities* (in Europe, USA, and Australia), *gender* (men are more likely to use RAs than women), and *number of people in household* (more people in a household translated into a greater likeliness to use RAs).

Still, the share of RA users compared to investors seeking traditional financial advice is typically very small. For example, Woodyard and Grable (2018) found that only 5% of an US financial capability study were RA users, while the rest of the participants sought traditional financial advice. This is in line with Waliszewski and Warchlewska (2020), who found more than half of the participants of their 15 country surveys declining the idea of delegating investment decisions to RAs. Also, Niszczoła and Kaszás (2020) conclude that an algorithm aversion extends to the financial sector, manifesting a barrier to adopting innovative FinTech solutions.

1.5.2 RA User Adoption and Acceptance

Research in this theme investigates factors that RAs can influence to improve user adoption and acceptance of recommendations. Research found these factors to be the perceived *level of trust*, *transparency*, *ease-of-use*, *usefulness*, and *RAs expertise*.

Trust is the most investigated user adoption factor in RA research and was found to be distinguished in several trust influencing factors, e.g., trust in technologies or trust in RA provider that together moderate trust in RA, enhancing the adoption and acceptance of RA (X. Cheng et al., 2019; F. Guo et al., 2019). While Mesbah et al. (2019) found a noncommittal test of RA services to have a strong influence on trust, they found anthropomorphism, meaning the RA's

humanization, e.g., by giving it an avatar and name, to have a smaller influence on trust. Other articles found the degree of humanization to be a significant increasing factor of trust, especially when the task complexity is perceived as low (e.g., Hodge et al. 2020). Morana et al. (2020) found that a higher humanization degree increases the perceived social presence and trusting beliefs. While the first did not significantly influence the acceptance of RA recommendations, the latter had a significant impact on their likeliness to follow the recommendation (Morana et al., 2020). Also, the usage of conversational RA, utilizing a more human-like communication style, positively affects trust of the RA and its provider, thereby enhancing RA adoption and recommendation acceptance (Hildebrand & Bergner, 2021; Ostern et al., 2020).

When RAs provide more information on how they work, i.e., enhancing their *transparency*, potential users are more inclined to use the RA. Also, Litterscheidt and Streich (2020) suggest, that the provision of financial knowledge can make the potential users understand more of the provided information and therefore enhances user adoption. When the understanding of RA processes and familiarity with AI-based systems is high, it is more likely that users perceive its *usage as easy*, influencing its perceived *usefulness*. Both factors have a significant effect on the attitude toward RAs, which significantly enhances the intention to use them (Belanche et al., 2019). Cheng (2021) found a task-advisor-fit factor, network, and psychological factors to moderate the usefulness that increases the likeliness of RA usage. This is also in line with Hohenberger et al. (2019), who found psychological factors like positive emotions (e.g., joy) and negative emotions (e.g., anxiety) in expected use, increasing respectively decreasing the adoption of RA. Lastly, the perceived *expertise*, e.g., manifesting in the perceived effectiveness of decision making, significantly increases RA adoption (Tauchert & Mesbah, 2019).

1.6 RA Service

1.6.1 RA Process Design

Initiation and Profiling. Due to the absence of human interaction and the importance of trust in financial advisory, RA providers improve the initiation process by giving information about the whole advisory process, products used, and costs associated with the services, enhancing its transparency (Jung et al., 2017; Litterscheidt & Streich, 2020). Belanche et al. (2019) also indicate that RAs should consider the user's familiarity with AI-based systems and provide ad-hoc support, e.g., by employing chatbots (Morana et al., 2020). RAs often utilize simple static online questionnaires to create a user risk profile, which is questioned in literature, suggesting that this profiling method alone is insufficient (e.g., Beketov et al. 2018). Hybrid approaches using human communication should be used to enhance the conversion rate of RAs (Beketov

et al., 2018; Jung & Weinhardt, 2018). In contrast, some RAs try to enhance automated profiling by utilizing metaphors and scenario-based questions with visualizations. RAs thereby balance between the simplicity and sophistication of the questionnaires (D’Acunto et al., 2019). The questions asked by RAs can be differentiated between general information, risk capacity, and risk tolerance of the investor (Tertilt & Scholz, 2018). Tertilt and Scholz (2018) also assess the correlation between questions and risk assessment and find that only approximately 60% of questions impact the risk assessment. They conclude that RA could individualize the profiling further.

Matching and Customization. Since the matching process is usually based on an unpublished algorithm, matching the user profile to a portfolio recommendation is considered a “black box” (D’Acunto et al., 2019; Jung et al., 2018). Since it is beneficial for RAs to provide transparency, Litterscheidt and Streich (2020) suggest opening this “black box” of RA algorithms. Further, Beketov et al. (2018) show that over 80% of RAs base their recommendation on typical portfolio allocation methods, e.g., modern portfolio theory, although more sophisticated portfolio allocation methods attract more affluent users, leading to higher AuM sums for the RAs. By analyzing RAs portfolios for different risk and investment horizon combinations, Torno and Schildmann (2020) found similarities in the used products, often utilizing ETFs and employing mostly passive investment strategies. They also found issues within the recommended portfolios, e.g., a low degree of distinctiveness between different investment horizons and a high amount of equities even in short-term investment horizon portfolios (Torno & Schildmann, 2020).

Monitoring and Rebalancing. Because in RA, the monitoring is mainly delegated to an algorithm, consequences of behavioral biases and irrational human behavior should be reduced (Jung & Weinhardt, 2018). The RAs rebalance portfolios in fixed time intervals, e.g., quarterly or yearly, and after trigger events, e.g., market or user changes (Jung et al., 2019). Concerning the value of the monitoring and rebalancing of RAs, research found that RA portfolios are more diversified, providing the same performance at lower risk-levels compared to self-monitored portfolios of individual investors (D’Acunto et al., 2019; Reher & Sun, 2020). In comparison, Puhle (2019) found that portfolio allocations with similar risk preferences vary greatly between RAs, but that no investigated RA could beat their benchmark index between 2015 and 2018, even before considering fees. Still, D’Hondt et al. (2020) found, by simulating RAs’ investment decision-making, that the 2008 financial crisis would have been surpassed by RAs with fewer losses than their employed passive index strategy.

1.6.2 Overall RA Design

This research theme contains design criteria that are overarching the RA process phases. These include the RA design decisions concerning the *degree of delegation and automation*, the *degree of humanization*, including conversational abilities and *designs to mitigate behavioral biases*.

First, providers design their RAs in a certain way *delegating and automating* different processes to different degrees. Rühr et al. (2019a) thereby distinguish for each RA process phase between seven characteristics, that are each a joint product of automation and delegation: Human advice, Self-management, Hybrid advice, Algorithmic advice, Delegation to human, Delegation to hybrid system, Delegation to algorithm. They find, for example, that processes requiring constant attention and immediate action, such as rebalancing, tend to be highly automated and delegated. In contrast, profiling tends to be only partially delegated, often supported by humans, to mitigate potential errors (Rühr et al., 2019a). In an experiment, Rühr et al. (2019b) also found that a higher degree of automation increases performance expectancy, but decreases user control, which thereby increases perceived risk.

RAs are often designed with a certain degree of *humanization*, which was found to impact RA adoption and recommendation acceptance. For example, Hodge et al. (2020) found that even a low degree of humanization, only naming the RA, could increase its adoption. Research also investigated RA designs with more human characteristics employed, e.g., showing an avatar or providing chatbot functionality with social cues, e.g., having a dynamic response time (Morana et al., 2020). Research thereby found RA adoption as well as recommendation acceptance and invested capital amount to be increased (Adam et al., 2019; Morana et al., 2020). For even higher degrees of humanization, RAs need to understand and process speech, imitating face-to-face conversations in traditional financial advice, to improve customer-advisor interactions. For example, Ostern et al. (2020) provided a design for *conversational RAs* that can understand and process sophisticated voice commands, especially for application in the early onboarding phases, overcoming the problem of missing personalization in the RA process. Hildebrand and Bergner (2021) found that in the evaluation of their conversational RA design, the users perceived the RA and its provider as more trustworthy and recorded greater recommendation acceptance as well as an increase in invested capital in comparison to a non-conversational RA.

RAs also aim to *reduce behavioral biases* of its users by employing certain designs. For example, Jung and Weinhardt (2018) designed two digital nudges, namely default values and warning messages to reduce decision inertia, which is the unwillingness to use new information in

decision making. Portfolios managed by RAs were also found to decrease the rank effect (tendency to sell extreme winning and losing positions), the disposition effect (tendency to realize gains more often than losses), and to a small degree trend chasing (tendency to buy position after its price increases) (D’Acunto et al., 2019). While investors demand a certain degree of control over their portfolios, they tend to lean into their biases when uncontrolled (Rühr, 2020). This “Performance-Control Dilemma” should be mitigated by RA design by maximizing the user perception of control while limiting its actual deviation possibilities from recommendations, for example, with personalized anchors (Adam et al., 2019; Rühr, 2020). This is especially relevant for investors with low financial literacy, often first-time investors. For these often risk-averse, low-budget users, RAs need to be designed in an easy-to-use and understandable way, providing financial advice efficiently and transparently (Jung et al., 2017).

1.6.3 RA Provider

This theme summarizes investigations on the RA providers and specifies differentiating characteristics of them. Firstly, RAs are deployed by different firm types, for example, FinTech startups, e.g., “Betterment” and “Wealthfront,” from established investment companies, e.g., “Vanguard” and “BlackRock” or incumbent banks like “Bank of America” or “Deutsche Bank” (F. Guo et al., 2019; Phoon & Koh, 2018). The adoption of and satisfaction with RAs relies significantly on its provider's trust, moderated by its reputation, integrity, and firm type. While Guo et al. (2019) found a higher reflection of expertise for established financial companies in contrast to startups, Lourenço et al. (2020) also distinguished between firm types and found that profit-oriented firms need to provide more arguments for trust-building and expertise than non-profit oriented firms and, product-provider firms are perceived as more trustworthy and competent than advisor-only firms. Still, especially in the years after the financial crisis 2008, a rebranding of financial service providers took place, and users were sympathizing with startups instead of the incumbent financial service providers that were regarded as responsible for the crisis (Wexler & Oberlander, 2021).

The RA provider business model can be divided into business-to-consumer (B2C) or business-to-business (B2B). While B2C RA providers deliver their services directly to end-customers, B2B RA providers develop “white label” IS, that can be used, e.g., by traditional financial advisors or banks to provide RA services (Phoon & Koh, 2018). Because of different financial market regulations, the RA providers deploy their RAs separately for each national market (Phoon & Koh, 2018). In contrast to traditional advice, RA's business value is based on the widening of the client base giving basic financial advice at affordable prices (Wexler & Oberlander, 2021). While traditional financial advice tends to have very high minimum

investment amounts, RA providers lower this minimum required capital amount further. For example, Reher and Sun (2020) found that a reduction in minimum account size of 90% led to a substantial increase in new account creations while also increasing the total deposit flow, despite the reduction of per-portfolio balances.

1.7 RA Competition

1.7.1 Reactions to and Changes because of RA

Research in this theme provides first insights into the reactions of RA competitors to the RA phenomenon. First, changes in the education and training of human financial advisors take place, emphasizing the usage of RA technologies as decision support tools for the human advisors (Britton & Atkinson, 2017). These slightly automated advice forms align with the trend to utilize algorithmic authority by AI to illustrate objectivity and precision (Wexler & Oberlander, 2021). The blending of RA and human advice is often referred to as “hybrid advice” (Jung et al., 2019). Thereby, the balance between human and algorithmic parts could range from complete technology-driven services to full human-driven services, but research suggests that full automation may not be the preferred option because of its creative and social limits (Coombs & Redman, 2018; Rühr et al., 2019a). Therefore, RAs rather augment than substitute human financial advisors (Coombs & Redman, 2018; Jung et al., 2019).

1.7.2 Comparisons between RA and Traditional Financial Advice

Research comparing RA and traditional financial advice found various advantages and disadvantages of RA. Key advantages of RAs are the possibility of making passive investments at low consulting costs and low minimum investment amounts (Jung et al., 2019; Warchlewska & Waliszewski, 2020). RA also delivers less emotional decision-making and convenient service delivery with instant satisfaction of informational needs (Jung et al., 2019; Mesbah et al., 2019). Still, Niszczoła and Kaszás (2020) found a general aversion against RA, especially when moral recommendations are sought, e.g., in the case of environmental, social, and governance (ESG) friendly portfolio allocations. This is in contrast to the findings of Warchlewska and Waliszewski (2020), which found RA users perceiving RAs mostly as more ethical or at least equally ethical compared to human advisors. Also, RA users often worry about being victimized by investment fraud or are concerned about potential conflicts of interest appearing in the context of human financial advice (Brenner & Meyll, 2020; Woodyard & Grable, 2018).

In contrast to traditional financial advice, RA can only provide a limited range of financial planning services and lack the full adjustment to the user's individual needs (Jung et al., 2019; Warchlewska & Waliszewski, 2020). RAs ask fewer questions of lower quality than its

traditional human competition, which leads to less individualized and sophisticated financial advice or even failing fulfilling its fiduciary duties (Jung et al., 2019; Tertilt & Scholz, 2018). In that regard, a simulated contest of portfolio performance also showed the inflexibility of RAs algorithms for relatively equal risk profile users, which is a crucial human financial advisors advantage, especially in recent turbulent financial market conditions (Harrison & Samaddar, 2020).

1.8 Agenda for Future Research

To synthesize an agenda for future research, we analyzed the limitations and further research opportunities stated by the articles of our literature review. We summarize these insights in selected open research questions for each RA research theme and present them in Table 6. By presenting these most pressing open questions within existing research, we offer directions for future research on RA.

Themes	Selected Open Research Questions
<i>RA Users</i>	Which further user demographics and individual traits influence the utilization of RA?
	How do behavioral biases affect the adoption and acceptance of RA?
	What characteristics distinguish RA users from non-investors?
	How can non-investors be motivated to adopt RA services?
<i>RA Service</i>	How can the user experience and recommendations of RAs reach a more individualized level?
	How does a dynamic adaptation to individual users affect the demand for RA and its competition?
	How can ethical considerations and fiduciary duties be ensured in RA designs?
	Which humanizing characteristics of RAs can influence investor decisions and how?
<i>RA Competition</i>	Where within the distinct phases of financial advisory do humans and automation have their strengths?
	How can worthwhile hybrid RA models be designed?
	How can RAs encompass more comprehensive financial planning services?
	How does RA shape financial advice practices and financial literacy of its users?

Table 6. Selected open research questions

Research on individual characteristics of potential *RA Users* already suggests certain factors that might lead to the utilization of RAs. Still, further studies could investigate the adoption and acceptance of other factors, e.g., influence of experiences with human advice, technology readiness, the necessity for social interaction, and impacts of behavioral biases on the adoption and acceptance of RA. Besides the frequently investigated potential RA users and investors, more research on actual RA users and non-investors could bring valuable insights for their conversion to RA users.

Research has outlined single aspects of *RA Service* design, shedding light on catering to specific user groups or utilizing single technologies. Still, research lacks design principles for more sophisticated RAs aiming to dynamically adapt to individual users, increasing the individualization of the customer experience and recommendations. Additionally, RA designs emphasizing ethical consideration and RAs fiduciary duties could be valuable for research and practice. Since we found a lack of data and opinions directly from RA providers and traditional financial advisors, we suggest conducting interviews with RA providers and its competition to find motives for their design decisions.

Within the research theme *RA Competition*, articles shed light on the competition between RA and traditional human advice. Future research should investigate the synthesis between RA and traditional human advice. In that regard, examining where and how within the process phases humans and automation have their strengths, should be a starting point for valuable hybrid RA designs. Since RA is often lacking more complex advice, research should investigate how RA can encompass more financial advice competencies, imitating traditional financial planning. Lastly, future research should investigate the opportunity of RAs to shape traditional advice practices and the financial literacy of its users.

1.9 Discussion

Many articles state that RA literature is still scarce and in its infancy. Compared to more established research topics in the domain, such as virtual assistance or FinTech, this might be true. However, our results show that scientific RA literature provides first answers within the themes *RA Users*, *RA Service*, and *RA Competition*. Thereby, we present the current state-of-the-art of RA research, how the knowledge can be categorized and open research questions, which can guide future RA research.

Besides its cautious execution, our paper is subject to limitations that can drive further research. We excluded the judicial viewpoints because we wanted to provide a comprehensive scientific analysis of IS and business-related research on RA. Still, the judicial perspective is essential for RA and its users since the regulations on financial advice are complex and manifold. Additionally, it is discussable whether RAs provide sound advice in terms of fiduciary standards, acting in the best interest of investors (Ji, 2017). Relevant law articles could be used to analyze the RA literature from a regulatory perspective, which could be integrated into our research framework as an additional theme. Furthermore, we recognize limitations based on our research design, particularly concerning the searched databases, the used search strings, and inclusion

criteria, which narrowed our pool of relevant literature. Lastly, we acknowledge the exploratory nature of our literature review, with a certain degree of subjectivity within its content analysis.

1.10 Conclusions

While still a novel phenomenon in the FinTech domain, an increased number of RA publications, especially in the last two years, show a high interest of research in this subject. However, no comprehensive state-of-the-art nor a set of future research directions regarding RA is available. We, therefore, conducted a systematic literature review, analyzing 42 peer-reviewed articles focusing on RA. To answer RQ1, we first provided descriptive statistics concerning publication time, outlet type and domain, research types and methods and regional focuses. We then presented and explained our *Organizing Framework for RA Research*, in which we classified the RA literature into three main themes: *RA Users*, *RA Service*, and *RA Competition*. By showing important insights for each theme, subthemes, and interrelations between the themes, we analyzed and summarized the current scientific knowledge about RA. For answering RQ2, we presented a future research agenda for RA with worthwhile open research questions derived from the relevant literature for each RA main theme.

2 More than Mobile Banking – A Taxonomy-based Analysis of Mobile Personal Finance Applications

<i>Authors & Contributions</i>	Albert Torno, albert.torno@uni-goettingen.de	Idea, data acquisition, data analysis, cluster calculations and interpretation, visualization, writing, text revision
	Oliver Werth, werth@iwi.uni-hannover.de	Idea concretization, data acquisition, data analysis, cluster interpretation, writing, text revision
	Robert C. Nickerson, RNick@sfsu.edu	Idea concretization, structural improvements, text revision
	Michael H. Breitner, breitner@iwi.uni-hannover.de	Structural improvements, text revision
	Jan Muntermann, muntermann@wiwi.uni-goettingen.de	Structural improvements, text revision
<i>Citation</i>	(Torno, Werth, et al., 2021): Torno, A., Werth, O., Nickerson, R. C., Breitner, M. H., and Muntermann, J. 2021. “More than Mobile Banking – A Taxonomy-Based Analysis of Mobile Personal Finance Applications,” in <i>Proceedings of the 25th Pacific Asia Conference on Information Systems (PACIS)</i> , Dubai, VAE.	
<i>Abstract</i>	Mobile personal finance applications cannot only assist users in daily personal finance activities, e.g., mobile banking, but can also guide users to optimize long-term financial decisions. Still, research lacks a rigorous classification of this critical mobile commerce domain. We provide insights by developing a taxonomy and conducting a cluster analysis of mobile personal finance applications. We classify 170 mobile personal finance applications into twelve dimensions, combining a technical artifact perspective with a financial services perspective. Additionally, we empirically identify ten distinct clusters of archetypical application configurations. While we classify the field and give inclinations for future research, financial service providers and application developers can understand their competitors and use our insights to improve their applications. Potential users of these applications can use our findings to select mobile applications to optimize their personal finance endeavors.	
<i>Keywords</i>	Personal Finance, Mobile Applications, Mobile Finance, Mobile Commerce, Taxonomy Development, Cluster Analysis, Archetypes	

Table 7. Fact sheet of paper 2

2.1 Introduction

“Finance is not merely about making money. It’s about achieving our deep goals and protecting the fruits of our labor. It’s about stewardship and, therefore, about achieving the good society.”

Robert J. Shiller (Nobel Prize Winner for Economics in 2013)

While it is always important for individuals and households to make “good” financial decisions, it is especially crucial in the current turmoil times, where the future consequences of the Covid-19-pandemic on the economy cannot be calculated (e.g., Garman & Forgue, 2018; Lusardi & Mitchell, 2014; Zhang et al., 2020). To make reasonable financial decisions, individuals and households need to have a decent amount of knowledge in finance, often referred to as *financial literacy*, as well as their own financial goals planned and financial information tracked (Lusardi & Mitchell, 2014; van Rooij et al., 2011). Therefore, budgeting, and financial transaction tracking should be part of the daily life of individuals and households. Having one’s own personal finance under control is relevant for everyone and can be life-changing, e.g., when highly in debt. Still, surveys and literature about personal finance, e.g., concerning budgeting, transaction tracking, credit behavior, and stock market participation, suggest a lack of coherent and sophisticated financial literacy in many societies (Huston, 2010; Lusardi, 2019; van Rooij et al., 2011). Digital tools and services, especially in the form of and delivered through mobile applications (“apps”), help to plan financial goals, track financial information, and in general, nudge users into more robust and long-term thinking financial-related behaviors (Bunnell et al., 2020; Ky et al., 2021). With personal mobile finance apps, users interact with their chosen financial service providers, capture their spending, save for bigger purchases, invest for retirement, or transfer money fast and easily between each other. Since these mobile apps can be used without time- and place restrictions, they are often the preferred way for users to manage their money and finances and interact with financial institutions (Han et al., 2016; Sharma & Sharma, 2019). Therefore, mobile apps are receiving an ongoing interest in the context of “m-commerce” (Sarkar et al., 2020) and especially within the financial services sector from both consumers and financial services providers (Malaquias & Hwang, 2019).

While there is a wide range of research concerning the acceptance and adoption of specific mobile finance apps, e.g., to deliver mobile banking services (Arcand et al., 2017; Kim et al., 2009; Shaikh & Karjaluo, 2015) or mobile payment services (e.g., Dahlberg et al., 2008; Schierz et al., 2010), only Huebner et al. (2018) describe, as an aside, how differing financial services delivered through mobile apps can be distinguished from each other. Still, rigorous research to structure the domain integrating technical mobile app elements and underlying

personal finance service elements currently does not exist. Also, empirically validated archetypes of mobile personal finance apps are missing. To address these research gaps, this paper aims at answering the following research questions (RQs):

RQ1: How can mobile personal finance applications be classified within a taxonomy?

RQ2: Which archetypes of mobile personal finance applications can be deduced empirically with this classification?

Our RQs' objectives are to provide a rigorous structure of the field and classify mobile personal finance apps in empirically validated archetypes. Therefore, we develop a taxonomy according to Nickerson et al. (2013) utilizing literature of the domain of interest and a sample of popular real-world mobile personal finance apps as objects to classify (RQ1). Based on our taxonomy, we conduct a cluster analysis aiming to classify objects into groups, minimizing differences within a group and maximizing differences between groups (Kaufman & Rousseeuw, 1990). We derive, interpret, and explain these distinct mobile personal finance app groups or clusters to identify archetypical mobile app configurations (RQ2).

Mobile app developers and financial service providers can benefit from our taxonomy and derived archetypes to classify their apps, observe what the competition is doing, and use our insights to support app development, e.g., by combining less frequent combinations of characteristics. Finally, regular users of mobile personal finance apps can use the taxonomy and archetypes as decision support for selecting mobile apps enhancing their personal finance endeavors. Also, people who have no experience with financial services on their mobile phones can grasp what is possible on a mobile platform.

First, we explain the term “personal finance” and summarize existing research concerning mobile personal finance applications. Afterwards, we introduce our methodological approach for the taxonomy development, present our iterative development and final taxonomy. Subsequently, we perform our cluster analysis and deduce specifics for each identified mobile personal finance app archetype. We discuss our results and findings, implications, and recommendations, as well as limitations and future research directions. Conclusions summarize our most important insights answering our RQs.

2.2 Mobile Personal Finance Applications

Personal finance is characterized as the management of money of individuals and households and includes activities like budgeting money, transfer of money, lending, investing, or retirement planning (Garman & Forgue, 2018). However, people first need to acknowledge the

importance of such matters, need to be educated about financial instruments and backgrounds, and, in the end, need to be able to manage their personal finance problems. This knowledge and application dimension, known as financial literacy, is important, since people with a lower financial literacy are less likely to invest and make positive long-term financial decisions (Huston, 2010; Lusardi & Mitchell, 2014; van Rooij et al., 2011). This leads to less financial freedom of the individual associated with more dependence on state benefits and reduced retirement wealth (Lusardi & Mitchell, 2014).

Mobile personal finance apps assist and support users concerning their financial needs. They can educate and assist users with user-centric information, making the user more financially literate (Angel, 2018; French et al., 2020). In general, mobile apps are defined as “an [information technology] (IT) software artifact that is specifically developed for mobile operating systems installed on handheld devices, such as smartphones or tablet computers.” (Hoehle & Venkatesh, 2015: 437). Both big app markets, Apple’s App Store and Google’s Play Store (“app stores”) categorize mobile apps within different categories. The App Store, for example, defines apps in the “finance” category as “apps that perform financial transactions or assist the user with business or personal financial matters”(Apple, 2021). We combine both these explanations and define mobile personal finance apps as *IT software artifacts developed for mobile operating systems and installed on smartphones that assist the user with personal financial matters*. Later, we use this working definition as a theoretical background for the inclusion and exclusion of mobile personal finance apps in our sample.

Financial services providers face ongoing challenges forced by the digital transformation, e.g., changing customer demands or new competitors, for example, BigTechs or FinTechs (Puschmann, 2017). Given tighter regulations of the financial services market, low interest rates, and high cost pressure, many banks face critical challenges (Gomber et al., 2017). While smaller businesses develop and publish mobile apps often more quickly due to, for example, agile working environments, incumbents need to react to this new threat in an appropriate manner (Vasiljeva & Lukanova, 2016). As a result, the market must develop or advance mobile apps according to customer demands and must consider mobile apps domain-specific aspects, e.g., data usage or privacy concerns of the users (Malaquias & Hwang, 2019). Han et al. (2016) reveal that personal finance apps have the lowest usability and one of the shortest time usages per week compared to other app categories. This is crucial since the app provider must deliver an appropriate service through well-designed mobile apps to fulfill customers’ needs in a short usage time. Plus, the services delivered through these apps are a success factor for the long-term persistence of customer relationships, since users can easily switch from one app to

another (Arcand et al., 2017). Furthermore, mobile personal finance apps can handle financial matters quickly from wherever and whenever (Malaquias & Hwang, 2019; Sharma & Sharma, 2019).

Past research on mobile apps in the financial services sector is mainly concerned with acceptance and adoption factors (e.g., Schierz et al., 2010; Shaikh & Karjaluoto, 2015), especially with regards to trust (e.g., Kim et al., 2009; Sharma & Sharma, 2019) or security aspects of these apps (e.g., Khalilzadeh et al., 2017). Other researchers examined mobile apps focusing on financial inclusion, specifically for developing countries (e.g., Ky et al., 2021) or financial literacy, but did not examine the overall functions of the market of financial apps in detail (French et al., 2020). Another study investigates the impact of user ratings for mobile finance apps with a quantitative approach across different sub-categories (Huebner et al., 2018). While this study uses a rudimentary taxonomic approach to find the service-based sub-categories of “finance” apps, it does not focus on the more specific “personal” trait of finance apps and does not provide insights by combining a technical and financial service perspective on apps. Thus, a well-structured and comprehensive classification of personal finance apps in the form of a taxonomy and an empirically validated clustering, with the integration of technical and underlying financial services perspectives, is missing.

2.3 Methodological Approach of the Taxonomy Development

Taxonomies play an important role in research, e.g., to structure and organize a domain of interest. A taxonomy is suitable for analyzing complex domains and building more in-depth knowledge about the objects in a domain (Glass & Vessey, 1995; Nickerson et al., 2013). As Nickerson et al. (2013: 1) mentioned “a fundamental problem in many disciplines is the classification of objects of interest into taxonomies.” A taxonomy as a structure-giving artifact is used to understand, grasp and analyze complex issues (Hevner et al., 2004; Szopinski et al., 2019). Therefore, by proposing a taxonomy to understand the dimensions and characteristics of mobile personal finance apps and their interrelated connections in the form of archetypes, we analyze the domain. By using the methodology for taxonomy development by Nickerson et al. (2013), we follow the “most prominent and widely used approach in the field” (Schöbel et al., 2020: 647) After the determination of one *meta-characteristic* and objective and subjective *ending conditions*, iteratively either a *Conceptual-to-Empirical (C2E)* or an *Empirical-to-Conceptual (E2C)* is undergone to develop the taxonomy further. At the end of each approach, the taxonomy is *checked*, thus continuing the development with a C2E- or E2C-approach, when the ending conditions are not met or terminating the development when the ending conditions are

met. In the following, we describe our adapted research design for each step of the taxonomy development.

2.3.1 Meta-Characteristic

The meta-characteristic is defined as the most comprehensive characteristic that serves as the basis for all dimensions and characteristics that follow (Nickerson et al., 2013). To be useful, the meta-characteristic must reflect the expected users and purpose of the taxonomy (Nickerson et al., 2013). We decided that the perspective of the activity with the mobile personal finance app by the user will lead to the most insights. It becomes apparent that for mobile personal finance apps, there is a distinction between what is being delivered (*financial service*) and how it is delivered through the mobile app (*technical artifact*). Thus, we perceive the usage of an app in the domain of interest from two viewpoints: The *technical artifact perspective*, including all mobile app related elements and the *financial services perspective*, including all elements of the underlying personal finance service the app provides. The taxonomy aims to determine and present the interplay between these perspectives on mobile personal financial app usage. Therefore, we define the meta-characteristic for this taxonomy as *technical functionalities of and financial services delivered through mobile applications in the area of personal finance from the perspective of its users*.

2.3.2 Ending Conditions

Nickerson et al. (2013) describe, besides the two defining factors of a taxonomy, namely its *mutual exclusivity* and *collective exhaustiveness*, seven objective and five subjective ending conditions, that must be met to terminate the taxonomy development procedure. We aim at meeting all ending conditions in our final taxonomy. Table 8 shows which defining factors and ending conditions were met at the end of each iteration of our taxonomy development.

2.3.3 Conceptual-to-Empirical (C2E) approaches

In C2E-approaches, existing knowledge within the domain of interest gets reviewed, including identifying main concepts from literature (Eickhoff et al., 2017). Based on that knowledge and the taxonomy's key intention in the form of the meta-characteristic, the researchers deduce relevant dimensions and characteristics (Nickerson et al., 2013).

2.3.4 Empirical-to-Conceptual (E2C) approaches

In E2C-approaches, real-world objects within the domain of interest are categorized, thereby modifying, merging, adding, and deleting dimensions and characteristics of the taxonomy (Nickerson et al., 2013). The objects we classify are native mobile apps found in the corresponding "finance" sections in both Apple App Store and Google Play Store offered in

Germany. The selected app stores are the only respectively biggest channels for delivering mobile apps to the most popular mobile operating systems, iOS and Android (e.g., Lee & Raghu, 2014). Germany has one of the largest smartphone userbases worldwide. The domestic app stores provide a wide range of different apps in the finance category due to its competitive and highly digitally advanced financial services market (e.g., Jünger & Mietzner, 2020). Also, it was the most pragmatic app region for us to use, since we could download and use the apps, to its full potential. However, to obtain a relevant and workable sample of apps, we needed to restrict the objects to the most relevant. For that, we choose to use the apps that are highest ranked in each app store. The app stores sort apps into three classes: free, paid, and grossing, e.g., by in-app purchases. We captured the top-ranked apps for each app store and class by using the databases Similarweb and Appbrain, which accumulate this data. We found that both platforms' apps have sufficiently similar technical functionalities and support of the underlying services. Therefore, we just included one app in our sample, if both iOS and Android apps were within the top-ranked apps. All apps were selected based on the ranking of January 10th, 2021.

To ensure a decent quality of our app sample, we only included apps whose download count was at least 5000+ and that were updated within the last two years. We also needed to exclude apps that, even though listed in the finance category, do not meet our personal finance definition. Therefore, we excluded apps for small businesses, e.g., to write invoices, apps for earning money by playing games with ads, and apps, which only purpose is to support the identification as a person. In contrast, apps that legitimize financial transactions, e.g., “Pushtan” or “Photo-Tan,” are included in our sample. We excluded password and pin managers, mobile data usage trackers, national debt trackers, and calculators without a clear focus on personal finance matters. In contrast we included, e.g., currency, car tax and pension calculators. Lastly, we excluded apps that are exclusively distributed for tablets.

To analyze the final pool of 170 apps, we first read the description given in both app stores, if applicable. Of our final pool, 19 apps are exclusively on iOS, 24 apps are exclusively on Android, and 127 apps are available on both mobile platforms. For more complex apps or less expressive descriptions in the app stores, we also considered the app provider's website. If characteristics could not be determined by store description or internet search, we downloaded the app and tried the functionalities in detail. All decisions concerning modifying, merging, adding, and deleting dimensions and characteristics were conducted based on discussions within the author team.

2.4 Towards a Taxonomy of Mobile Personal Finance Applications

To address RQ1, we describe the taxonomy development of mobile personal finance apps by detailing each of the six iterations and visualizing the dimensions' progression in Figure 18. Table 8 shows which defining factors and ending conditions were met at the end of each iteration. Lastly, we present the final taxonomy in Table 9. We defined all final dimensions and characteristics in Appendix Table 3.

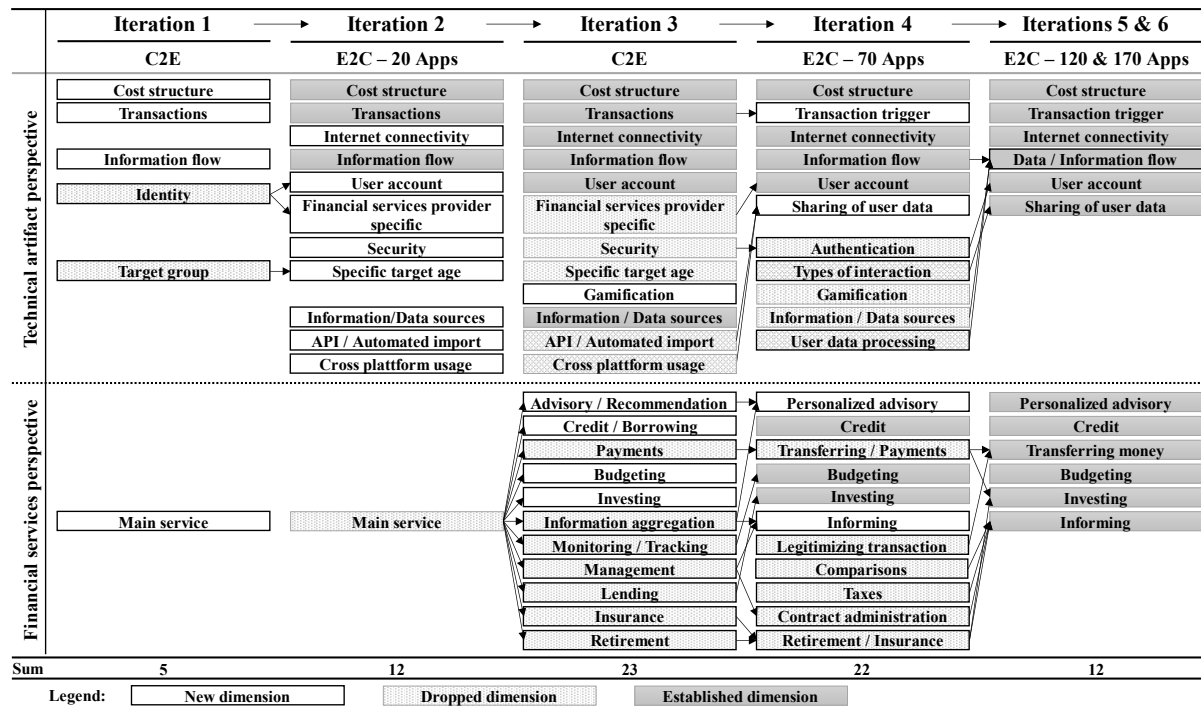


Figure 18. Dimensions in each Iteration of the Taxonomy Development Process

2.4.1 Iteration 1 – C2E

In the first iteration, utilizing the C2E-approach, we used the theoretical background regarding personal finance and related aspects of mobile apps in this domain to construct a preliminary taxonomy with first dimensions and characteristics. Following our definition of personal finance, we constructed the dimension *Main service* with characteristics of more traditional financial services, e.g., “Money management,” “Budgeting,” “Investing” or “Credit” (e.g., Garman & Forgue, 2018), and more recent Digital Finance services, e.g., “Peer-to-Peer (P2P)-lending,” “Crowd funding” or “Digital payments” (e.g., Gomber et al., 2017). Concerning the *technical artifact perspective*, we established a *Cost structure* dimension. Cost structures of apps delivered through App Stores are denominated as app-level attributes, that are a necessary technical condition, i.e., app-specific properties, to use the app and the underlying services (e.g., Lee & Raghu, 2014). The characteristics “Free,” “One-time payment,” “Subscription,” and “Transaction dependent” are derived from the app classification in the app stores. The other dimensions *Transactions* (“No tracking”; “Manual tracking”; “Automated tracking”; “Scan”),

Information flow (“Unidirectional to user”; “Unidirectional from user”; “Bidirectional”), *Identity* (“Identity-based”; “Non-identity-based”) and *Target group* (“Individual”; “Group”) originated from the mobile apps taxonomy of Nickerson et al. (2013). This first preliminary taxonomy did not meet the defining factors of a taxonomy, thus necessitating the continuation of our development.

Ending Conditions		Iterations I1 I2 I3 I4 I5 I6					
Def.	Mutually exclusive: No object has two different characteristics in a dimension			•	•	•	•
	Collectively exhaustive: Objects have at least one characteristic in each dimension		•			•	•
Objective	All objects (or a representative sample) were analyzed					•	•
	No objects were merged or split		•	•	•	•	•
	At least one object assigned to each characteristic		•			•	•
	No new dimensions or characteristics were added in the last iteration						•
	No dimensions or characteristics were merged or split in the last iteration						•
	Every dimension and every characteristic within their dimension are unique			•	•	•	•
	Every combination of characteristics is unique			•	•	•	•
	Concise: Dimensions and characteristics are limited	•	•			•	•
Subjective	Robust: Sufficient number of dimensions and characteristics			•	•	•	•
	Comprehensive: Identification of all (relevant) dimensions of an object				•	•	•
	Extendable: Possibility to easily add dimensions and characteristics in the future	•		•	•	•	•
	Explanatory: Dimensions and characteristics sufficiently explain the object				•	•	•

Table 8. Defining factors and ending conditions met in each iteration of the taxonomy development

2.4.2 Iteration 2 – E2C

Within the second iteration, we classified a randomly selected first set of 20 apps, picked from our pool, into our preliminary taxonomy. Many new functionalities surfaced, and we needed to derive new dimensions or modify existing ones. We refined the *Cost structure* dimension with new characteristics, namely “For free,” “Freemium [in-app purchase],” “Freemium [subscription],” “Freemium [transaction dependent],” and “Premium.” Within the *Transaction* dimension, we merged the “Automated” and “Scan” characteristics to “Assisted manual + automated.” *Target group* was further refined to *Specific target age* with the characteristics “None,” “Child,” “Young adult,” and “Elderly.” We split the dimension *Identity* into more specific dimensions, *User account* (“Mandatory”; “Not mandatory”) and *Financial service provider specific* (“Customer account required”; “No customer account required”). Also, new dimensions and characteristics emerged within the *technical artifact perspective*, namely: *Internet connectivity* (“Yes”; “Partially”; “No”), *Security* (“No password”; “Password / Biometric”; “Password

/ Biometric + 2-Factor”), *Information / Data sources* (“Internal”; “Bank”; “External partners”; “Hybrid”), *API / Automated import* (“Yes”; “No”) and *Cross platform usage* (“Not possible”; “Automated”; “Web service”). Having classified a small set of apps and not fulfilling all defining factors, we continued the taxonomy development.

2.4.3 Iteration 3 – C2E

Approaching the third iteration, we faced difficulties, especially with the dimension *Main service*: We were hindering a more *comprehensive* and *explanatory* taxonomy with too many characteristics in one dimension. Also, our taxonomy did not fulfill the defining *mutual exclusiveness*. Therefore, we choose to step back and conduct a second C2E-approach. To showcase more diverse app characteristic combinations and thus to comply with the *extendibility* of the taxonomy, we broke up the *Main service* dimension into an array of distinct service-related dimensions within the *financial services perspective*. These had often binary characteristics “Yes” or “No” when the mentioned service or value is supported respectively not supported by the app. Of these dimensions, four comprised of *Advisory / Recommendation*, *Information aggregation*, *Monitoring / Tracking*, and *Management*, determining the more abstract received value for the user (Eickhoff et al., 2017). The other five consisted of *Credit / Borrowing* and *Lending* (with each “Traditional” and “P2P” characteristics replacing “Yes”), *Payments* (with “Traditional,” “Digital” and “Crypto” characteristics replacing “Yes”) and *Budgeting*, *Investing*, *Retirement* and *Insurance* summarizing the underlying personal finance services of the apps (Garman & Fogue, 2018; Gomber et al., 2017). Within the functional perspective, we introduced *Gamification* (“Yes”; “No”), based on its nudging power, especially in the mobile apps domain (Schöbel et al., 2020). While finally meeting the *mutually exclusivity*, we did not meet the *collective exclusiveness* factor that necessitated further taxonomy development.

2.4.4 Iteration 4 – E2C

Intending to broaden the now conceptually more rigid taxonomy, we classified 50 more apps of our app pool. To strengthen the distinctiveness between both perspectives and since the monitoring of transactions is described within the dimension *Budgeting*, we changed *Transaction* to *Transaction trigger* (“Manual + Assisted manual”; “Manual”; “None”). *Financial services provider specific* merged into *User account*, since the corresponding characteristics correlated frequently and therefore did not provide more explanatory power to the taxonomy. Both just established dimensions, *API / Automated import*, and *Cross platform usage* from the third iteration, are merged into the new dimension *Sharing of user data* (“App provider only”; “[Other] banks”; “Third parties”; “Banks + Third parties”). We changed *Security* to *Authentication* (“No factor [know/have/are]”; “One factor”; “Two factor”), approaching a more explicit

categorization of security factors. Additionally, we introduced the dimensions *Types of interaction* (“No interaction with others”; “Business-to-Customer/Business-to-Government”; “Peer-to-Peer”; “Business-to-Customer/Business-to-Government + Peer-to-Peer”) and *User data / information processing* (“No processing”; “Aggregation for presentation”; “Aggregation + Further processing”), to broaden the functional perspective even more. Since we could not find enough variations in the sample of apps concerning *Specific target age*, we dropped the dimension.

Within the financial services perspective, we merged all received value dimensions established in the third iteration into the financial services dimension, thus merging *Advisory / Recommendation* and *Information aggregation* in the new formed *Personalized advisory* (“Hybrid”; “Automated”; “Human advice through app”; “None”). While *Monitoring / Tracking* merged into *Budgeting* (“Manual”; “Automated”; “Manual + Automated + Prediction”; “None”), *Management* merged into the new dimension *Contract administration* (“Yes”; “No”) and the new dimension *Informing* (“News and pricing”; “Educational content”; “Multiple information offerings”; “None”), which also incorporates parts of the *Information aggregation* dimension. We merged the dimensions *Retirement* and *Insurance*, because of its common services provided to users, to *Retirement / Insurance* (“Offering”; “Mediating”; “Monitoring”; “None”). Since *Lending* merged into *Investing*, which now incorporated the new characteristic “P2P-Lending”, we could also rename *Credit / Borrowing* into the more concise *Credit* dimension. To account for the transfer of financial assets, we modified the *Payments* dimension to *Transferring / Payments* (“Money [bank transfer]”; “Money [retail]”; “Crypto currency”; “Hybrid”; “None”). Finally, we introduced the following new dimensions: *Legitimizing transactions* (“Yes”; “No”) and *Taxes* (“Yes”; “No”). We continued the taxonomy development, since we found that the defining factor *collective exhaustiveness* and the *conciseness* ending condition were still violated.

2.4.5 Iteration 5 – E2C

Due to the taxonomy's high complexity, with 22 dimensions and 87 characteristics, we mitigated the *explanatory* nature of the taxonomy, discovering interrelated connections between dimensions and characteristics especially hard. We approached the goal to reduce the taxonomy complexity by discussing the following questions within the researchers' team: “Which dimensions are the most important?” - “Which dimensions add the most to the taxonomy?” - “Which dimensions will users find most useful?”. First, the dimension *Information flow* was modified to *Data / Information flow* and incorporated much of the explanatory power of both dimensions *Information / Data sources* and *User data processing*. *Types of interaction* merged into *Sharing of user data*, which was established within the last iteration. While *Authentication* correlated

often with the *User account* dimension, the reason for deleting *Gamification* was that only five apps in our sample provided any gamification elements. Therefore, the dimension did not provide enough data to explain the interrelated connections between the apps of interest. Lastly, we added a characteristic “Hybrid” to the *Cost structure*.

Within the financial services perspective, we changed the characteristics in the *Credit* dimension to accompany, what the app supports concerning credit, instead of where the borrowed money comes from (“Offering / Mediating”; “Monitoring”; “None”). Within *Transferring / Payments*, we moved the characteristic “Crypto currency” to the *Investing* dimension. Thus, the new dimension *Transferring money* (“Money [bank transfer]”; “Money [retail]”; “Hybrid”; “Legitimizing transactions only”; “None”) emerged, which also integrated the *Legitimizing transaction* dimension. *Investing* was, like the dimension *Credit*, changed to account for the service provided through the app, but simultaneously distinguishes between traditional and non-traditional financial assets to invest in. Because of its frequently low usage, we also merged *Retirement / Insurance* into *Investing* (“Traditional financial assets”; “Non-traditional financial assets”; “Hybrid”; “Monitoring”; “None”). Finally, we changed the *Informing* dimension to incorporate the previously established dimensions *Comparisons*, *Taxes*, and *Contract administration*. For that, we developed the more abstract distinction between “non-individualized” information offerings, e.g., news or pricing, and “individualized” information, e.g., on personal contract administration or taxation. Finally, we almost halved the number of dimensions, thus meeting the *conciseness* and *robustness* ending conditions. By classifying 50 more apps of our pool, we also verified that we preserved most of the descriptive and *comprehensive* power of the taxonomy by meeting both defining factors of a taxonomy *collective exhaustiveness* and *mutual exclusivity* simultaneously. Still, we did not meet both objective ending conditions concerning adding, splitting, and merging dimensions and characteristics, and therefore continued the taxonomy development.

2.4.6 Iteration 6 – E2C

Finally, we evaluated the stability of our taxonomy by classifying the last 50 apps of our pool. Since we did not need to further modify the taxonomy dimensions and characteristics to capture the technical functionalities and underlying financial services, we found that the taxonomy is stable. Thus, we terminated the taxonomy development after the sixth iteration. In Table 9. Final taxonomy (with number of occurrences for each characteristic), n=170 apps, we present our final taxonomy with twelve dimensions and 46 characteristics, including the number of occurrences for each characteristic. We also present all 170 apps classified in the final taxonomy in Appendix Table 4.

Dimension		Characteristics							
Technical artifact perspective	Cost structure	For free (57)	Freemium [in-app purchases] (30)	Freemium [sub-scrip-tion] (17)	Freemium [transac-tion dependent] (31)	Premium (27)	Hybrid (8)		
	Transaction trigger	None (98)		Manual (41)		Manual + Assisted manual (31)			
	Internet connectivity	Mandatory (122)		Periodically online (32)		Offline (16)			
	Data / Infor-mation flow	Unidirectional to user (34)		Unidirectional from user (44)		Bidirectional (92)			
	User account	Mandatory (115)			Not mandatory (55)				
	Sharing of user data	App provider only (112)		[Other] banks (18)		Third parties (25)		Banks + Third parties (15)	
Financial services perspective	Personalized advisory	Hybrid (6)		Automated (18)		Human advice through app (8)		None (138)	
	Credit	Offering or mediating (18)		Monitoring (26)		None (126)			
	Transferring money	Money [bank transfer] (21)	Money [retail] (5)	Hybrid (14)		Legitimizing transactions only (12)	None (118)		
	Budgeting	Manual (31)		Automated (19)		Manual + Automated + Pre-diction (17)		None (103)	
	Investing	Traditional finan-cial assets (14)	Non-tradi-tional finan-cial assets (20)	Hybrid (7)		Monitoring (30)		None (99)	
	Informing	Non-individual-ized (65)		Individualized (18)		Hybrid + Education (23)		None (64)	

Table 9. Final taxonomy (with number of occurrences for each characteristic), n=170 apps

2.5 Cluster Analysis and Archetypes of Mobile Personal Finance Applications

To address RQ2, we conducted a cluster analysis, based on our taxonomy, to empirically identify typical patterns (archetypes) of personal finance apps. A cluster analysis aims to find groups of classified objects (personal finance apps) that minimize differences within a group and maximize differences between groups (Kaufman & Rousseeuw, 1990). For this study, we choose the k-means clustering technique, one of the most used unsupervised machine learning algorithms to partition a data set to k groups or clusters. The k-means clustering thereby minimizes the variance within each cluster [total within-cluster sum of square (WSS)] by moving the objects iteratively to the nearest clusters centroid (Punj & Stewart, 1983).

Before performing a k-means clustering, one must first decide on the number of clusters the data set should be classified into. Many approaches exist to find the optimal number of clusters based on the data set, e.g., by calculating the average silhouette width in the “silhouette” method or by minimizing the WSS for different k clusters in the “Elbow method.” In our case, while the *silhouette* method suggested that the data should be categorized into eight clusters, the *Elbow-method* implied eight or ten clusters. Therefore, we conducted the cluster analysis with eight and ten groups using R-Studio with the *kmeans* function and the argument *nstart* set to 25, setting all other arguments to their defaults. We found that the ten-cluster results provided more distinction between the clusters and more potential for interpretation. The resulting cluster analysis in Table 10 shows percentages for each characteristic within a cluster and shading between 100% (dark) and 0% (light). For example, 26% of all apps in cluster 1 require a user account, whereas 74% do not require a user account.

	Dimension	Characteristic	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10
			23 Apps	7 Apps	31 Apps	26 Apps	13 Apps	18 Apps	17 Apps	14 Apps	8 Apps	13 Apps
Technical artifact perspective	Cost structure	For free	17%	0%	3%	4%	100%	72%	41%	29%	25%	92%
		Freemium [in-app purchases]	26%	14%	13%	46%	0%	6%	35%	0%	0%	0%
		Freemium [subscription]	35%	29%	3%	4%	0%	0%	12%	0%	38%	0%
		Freemium [investment / transaction dependent]	0%	0%	81%	0%	0%	6%	6%	0%	38%	8%
		Premium	22%	14%	0%	38%	0%	17%	6%	50%	0%	0%
	Transaction trigger	Hybrid	0%	43%	0%	8%	0%	0%	0%	21%	0%	0%
		Manual + Assisted manual	0%	14%	6%	0%	8%	44%	0%	0%	75%	0%
	Internet connectivity	Manual	0%	0%	90%	0%	0%	50%	12%	0%	25%	0%
		None	100%	86%	3%	100%	92%	6%	88%	100%	0%	0%
		Mandatory	100%	0%	100%	31%	100%	72%	47%	36%	100%	100%
	Data / Information flow	Periodically online	0%	100%	0%	31%	0%	28%	53%	21%	0%	0%
		Offline	0%	0%	0%	38%	0%	0%	0%	43%	0%	0%
		Unidirectional to user	74%	0%	0%	0%	92%	17%	6%	36%	13%	0%
Financial services perspective	User account	Unidirectional from user	9%	43%	0%	100%	0%	6%	18%	57%	0%	8%
		Bi-directional	17%	57%	100%	0%	8%	78%	76%	7%	88%	92%
	Sharing of user data	Mandatory	26%	29%	97%	35%	100%	100%	94%	0%	100%	100%
		Not mandatory	74%	71%	3%	65%	0%	0%	6%	100%	0%	0%
	Personalized advisory	App provider only	83%	0%	55%	100%	92%	50%	65%	100%	13%	23%
		[Other] banks	0%	71%	10%	0%	0%	6%	0%	0%	38%	46%
		Third parties	17%	0%	32%	0%	0%	17%	24%	0%	25%	15%
		Banks + Third parties	0%	29%	3%	0%	8%	28%	12%	0%	25%	15%
	Credit	Hybrid	0%	0%	0%	0%	0%	6%	18%	0%	25%	0%
		Automated	0%	43%	10%	0%	0%	0%	35%	0%	63%	8%
		Human advice through app	22%	0%	0%	0%	0%	0%	0%	0%	13%	15%
	Transferring money	None	78%	57%	90%	100%	100%	94%	47%	100%	0%	77%
		Offering / Mediating	0%	14%	6%	0%	0%	50%	6%	0%	25%	23%
		Monitoring	0%	86%	0%	23%	0%	22%	12%	14%	0%	46%
		None	100%	0%	94%	77%	100%	28%	82%	86%	75%	31%
	Budgeting	Money (bank transfer)	0%	14%	16%	0%	0%	50%	6%	0%	25%	23%
		Money (retail)	0%	0%	0%	0%	8%	22%	0%	0%	0%	0%
		Hybrid	0%	0%	6%	0%	0%	11%	0%	0%	0%	77%
		Legitimizing transactions only	0%	0%	0%	0%	77%	11%	0%	0%	0%	0%
	Investing	None	100%	86%	77%	100%	15%	6%	94%	100%	75%	0%
		Manual	0%	0%	3%	92%	0%	11%	18%	7%	0%	0%
		Automated	0%	0%	10%	0%	0%	44%	6%	0%	0%	54%
		Manual + Automated + Prediction	0%	100%	0%	8%	0%	17%	6%	0%	25%	15%
	Informing	None	100%	0%	87%	0%	100%	28%	71%	93%	75%	31%
		Traditional financial assets	0%	0%	10%	0%	0%	0%	0%	0%	63%	46%
		Non-traditional financial assets	0%	0%	61%	0%	0%	0%	0%	0%	13%	0%
		Hybrid	0%	0%	16%	0%	0%	0%	0%	0%	25%	0%
	Informing	Monitoring	100%	14%	0%	4%	0%	0%	18%	0%	0%	15%
		None	0%	86%	13%	96%	100%	100%	82%	100%	0%	38%
		Non-individualized	52%	14%	90%	8%	0%	0%	0%	86%	25%	62%
		Individualized	9%	0%	0%	4%	0%	0%	82%	7%	0%	0%
	Informing	Hybrid + Education	39%	29%	10%	0%	0%	0%	12%	7%	75%	0%
		None	0%	57%	0%	88%	100%	100%	6%	0%	0%	38%

Table 10. Results of the cluster analysis

In the following, we elaborate on these ten clusters and describe the archetypical technical functionalities and financial services provided, including exemplary apps of each cluster. Additionally, a list of all apps categorized in the clusters can be found in Appendix Table 5.

2.5.1 Cluster 1 – App Provider Specific Financial News and Analysis

Apps in this relatively big cluster provide non-individualized information about financial assets and monitor portfolios of traditional and non-traditional assets e.g., cryptocurrencies without the possibility to trigger transactions. Most apps do not provide other services, except apps like “Seeking Alpha,” that provide financial analysis from human experts, e.g., in the form of forum posts or educational content. Because being informed means having up-to-date information, the apps require a constant internet connection to deliver their service. Although most apps are usable without an account, a user account and additional in-app purchases or subscriptions can provide features, e.g., more sophisticated financial analysis tools, more profound expert advice, or an ad-free experience.

2.5.2 Cluster 2 – Advanced Budgeting

Within this cluster, seven apps provide advanced budgeting services, including future predictions based on personal transactions. These personal transactions can be synced automatically and periodically from the user’s bank accounts, credit cards, and depots through bank APIs or web crawling (e.g., Banking4). Most apps do not require a user account but provide more services with an account and in-app-purchases, subscriptions, or both, e.g., more in-depth budget analyses and advice on cheaper insurances, automatically analyzing financial transactions.

2.5.3 Cluster 3 – Transaction Remunerated Trading and International Money Transfer

Apps within this biggest cluster of our sample provide international transfer of money (e.g., MoneyGram International) and assets (trading), in general, without advising the user. While a minority of apps provide traditional asset trading (e.g., Trade Republic), most apps are specialized in cryptocurrency and other non-traditional asset trading (e.g., Coinbase). To perform trading and money transfers, thus triggering financial transactions, the apps need to be online. Being online is required to process the orders and to update non-individualized information on the pricing of assets or conversion rates in international money transfers. Users also need to have an account, often personally legitimated. User data is often shared with brokers, in the case of traditional assets, with banks, in the case of money transfers, and with third parties in case of cryptocurrency orders. Users are paying for the service by fees on the transaction or investment amounts.

2.5.4 Cluster 4 – Manual Budgeting without Data Sharing

The second biggest cluster in our sample incorporates less advanced, manual budgeting apps. Apps like “1Money” do not sync data with banks. Therefore, users need to manually track financial transactions in the app to control their budgets. Except for credit monitoring, these apps do not provide any additional services. Because of its rudimentary service provision, manual budgeting apps do not often require user accounts or internet connections, except when backing up user data. Therefore, user data is not shared with other entities, and the apps can be used offline. The apps often deliver rudimentary functions in a free version and provide more customization or in-depth analysis when users pay in advance (premium) or through in-app-purchases.

2.5.5 Cluster 5 – Transaction Authorization

This cluster consists of apps that can authorize financial transactions, e.g., transferring money or buying assets. The apps are often supplementary to their financial service provider, e.g., the “Commerzbank photoTAN” app for the Commerzbank, and therefore free to the user. Because of their limited functionality, only legitimizing transactions, the information flow is just unidirectional to the user. Also, because of their security purpose, apps do not share their user data with other entities.

2.5.6 Cluster 6 – Credit Card and Retail Payment

Apps within this cluster provide monitoring of credit cards (e.g., Amazon.de VISA Card) and function as retail payment methods (e.g., Google Pay). Because the apps can trigger manual transactions in retail or provide sensible personal credit information, users need to have an account. These apps are often supplementary to bank accounts or credit cards, therefore free for users. Apps in this cluster do not offer advisory or investing services but money transfer, credit services, and automated budgeting through the record of transactions.

2.5.7 Cluster 7 – User-Account-based Individualized Informing

In this cluster, apps provide individualized information services to users. On the one hand, the cluster consists of tax advisor apps (e.g., Taxfix) or insurance / energy contract comparison platforms (e.g., Check24) that take the individual preferences and life circumstances of the user into account and provide contract monitoring services (e.g., Clark). On the other hand, apps in this cluster let groups of users collaborate on budgets, e.g., by splitting transactions or sharing money pools (e.g., Splitwise). Consequently, a user account and at least a periodical internet connection are often necessary. These apps also have in common that no actual transactions are triggered, except when buying specialized insurance manually through the app (e.g., Getsafe).

Furthermore, information flows bidirectionally to and from users, and data is shared frequently with other entities to provide the underlying service. Most of the apps are free to use or provide further services, e.g., tax declaration submissions through the app, by in-app-purchases.

2.5.8 Cluster 8 – Non-Individualized Informing

In contrast to cluster 7, apps in this cluster provide mainly non-individualized information. For example, apps in this cluster convert currencies (e.g., Exchange rate converter) or calculate net salaries. Information within these apps flows unidirectional to or from the user, never bidirectional. User accounts are not necessary, and an internet connection is not always required to provide the service to users. Therefore, the user data remains at the app provider only. Since the apps are not connected to other entities or services, they often need to be paid for in advance.

2.5.9 Cluster 9 – Investing with Advice

Apps in this relatively small cluster offer investing services in conjunction with personalized advice. Compared to the apps in cluster 3, these apps provide not only information about the pricing of the assets of interest but educate the user about investing or provide automated or even hybrid personalized advice on portfolio decisions. Traditional financial assets as well as investing in cryptocurrencies is possible (e.g., eToro). Triggers to invest are mainly manual but can also be assisted through the app, depending on the user's investment behavior and the degree of decision-making delegation to the service, for example, full automation in the case of Robo-Advisors (e.g., Scalable Capital). Despite its freemium nature, users must pay for the service depending on the transaction value or investment amount. Consequently, apps in this cluster require a legitimized user account, an internet connection, and information flows bidirectionally to and from the user.

2.5.10 Cluster 10 – Full-Featured Mobile Banking

Mobile apps in this cluster provide many traditional mobile banking services (e.g., Deutsche Bank Mobile). Generally, they are free to download, but users must have an account from the financial service provider to get access to the services. Internet connectivity is mandatory, and transactions can be triggered manually or assisted by mobile device functions, e.g., photographing bills. Based on the included services provided, e.g., transferring money, credit offerings, and monitoring, as well as investing in mainly traditional assets, the transfer of user data is manifold. App providers also offer non-individualized information to broaden their services, but without providing educational content. Still, these apps only rarely offer advisory services to their users.

2.6 Discussion, Implications, and Recommendations

The final taxonomy provides relevant dimensions and characteristics to structure the field of mobile personal finance apps with the widely used approach by Nickerson et al. (2013). Therefore, our study can serve as a systematic discussion platform among academics and practitioners about the status quo of the personal finance app domain. Moreover, the expandable nature of our taxonomy allows researchers and practitioners to modify, merge, add and delete characteristics and dimensions.

Our cluster analysis derived ten distinct clusters, which indicates mobile personal finance apps' versatility, and that the domain delivers more than just mobile banking. This study is thereby the first to our knowledge that combines and discusses technical functionalities as well as the underlying delivered personal finance services. In that regard, financial service providers and developers can compare their apps with the competition on an objective scale and gain insights into common archetypical configurations of characteristics. Based on these insights, they could add new technical features and services, focus marketing activities on their unique feature set or find innovative combinations of characteristics not yet present on the market. While we found that our target age group dimension did not provide enough explanatory power to be part of our final taxonomy, developers could build apps specifically for less often addressed but relevant, segmented customer groups. For example, apps could target children, teenagers, or elderly since these demographics have distinctly different needs for technical app features and financial services compared to adults (e.g., Xue et al. 2020). Also, policy makers can use our taxonomy and cluster analysis to identify service providers of relevance and thereby focus their regulation activities and monitoring especially regarding new market entrants. Lastly, researchers could use our taxonomy for theory development, e.g., for explaining app success.

Interpreting the app sample from the *technical artifact perspective*, we can state that most personal finance apps need a mandatory internet connection and a user's account to deliver their services. Only two archetypes, *manual budgeting without data sharing* and *non-individualized informing* provide any offline functionality. This can be explained by mobile internet connections becoming less expensive, and user accounts becoming more ubiquitous due to social media and other personalized internet offerings. While the information and data flows are more frequently bidirectional in comparison to unidirectional, the user data sharing with other entities is not that common. This could be interpreted as a data security measurement or as a less feature-rich app configuration pattern.

Concerning the *cost structure*, we found a shift from less featured apps that are mostly premium, or freemium-based, to more innovative or feature-rich apps with either subscription- or transaction-based revenue models or are free to the user. In the first case, to be up to date on functionality and security, developers need to work on their apps iteratively and therefore need to finance their constant advancement (e.g., Lee & Raghu, 2014). In the second case, developers have a smaller demand to produce revenue since new apps rely more on backing through venture capitalists, and the goal is often to build a big userbase first (e.g., Gomber et al., 2018).

Within the *financial services perspective*, it is noticeable that personal finance apps frequently do not provide more than one service to the user. Except for apps within *cluster 10 – full featured mobile banking*, most apps specialize in one service and mostly differ in their technical functionalities. That said, personal advisory seems not very common in mobile banking despite its large-scale service provision. Furthermore, we only found two clusters that deliver educational content of personal finance at all, almost always concerning investment decisions. This seems like a missed chance for financial services providers since financial education can play a significant role for users, not only in their investment behavior. Delivering more educational content to the user can raise the trust in the financial services provider and cause higher engagement with the app. This can lead to higher investment amounts, thus increase the revenue of the app provider (e.g., van Rooij et al., 2011).

2.7 Limitations and Future Research Directions

Our following limitations can guide future research on mobile personal finance apps. Firstly, we classified a sample of 170 apps from the German app stores to develop our taxonomy. While the German app market is big and diverse, it can be criticized that the results are not generalizable to other app market regions. In that regard, we examined a sample of the top mobile personal finance apps from the US app stores and found that the sample could be sufficiently described and categorized using our taxonomy and archetypes. Still, future research should evaluate the applicability of our taxonomy and archetypes to app markets in other regions and with a larger sample size.

While we performed a sixth iteration within the taxonomy development to show our taxonomy's stability, we did not evaluate our results by third parties. Evaluation is an important step for taxonomy development to support its usefulness and correctness (Szopinski et al., 2019). Therefore, future research could evaluate our taxonomy, e.g., by conducting interviews with financial services providers or other app developers. Also, our cluster analysis could be evaluated e.g., by using other clustering methods or discriminant analysis.

Based on the taxonomy and clustering, a higher-order predictive theory that allows researchers to better design and evaluate mobile personal finance apps could be valuable (Gregor, 2006). In that regard, a possible research direction could be the measurement of mobile finance apps' success, e.g., with the IS success model of DeLone & McLean (2004). We found that download numbers, review counts, and ratings differ between the apps within the archetypes. These possible IS success measurements could be further analyzed, e.g., regarding the archetypes, to find principles for successful mobile personal finance app designs.

Lastly, it seems promising to develop innovative IT-artifacts using a design science research approach. For example, based on one or a combination of multiple of our archetypes, researchers could integrate emerging concepts, for example, gamification elements. These, we only found rarely and rudimentary, e.g., in the form of awards for saving money within the app "Finanzguru." When used more robustly, gamification elements can enhance user engagement with the app and could thereby positively influence personal finance activities of the user (e.g., Schöbel et al., 2020).

2.8 Conclusions

Mobile personal finance applications can not only assist users in daily personal finance activities, for example, mobile banking but can guide users, e.g., to optimize long-term financial decisions. To shed light on this important and diverse mobile commerce domain, we developed a taxonomy and classified 170 mobile personal finance apps (RQ1). We identified twelve dimensions and 46 characteristics, combining a technical perspective and a financial services perspective. In addition, we examined archetypes of these mobile apps based on a cluster analysis, which we derived from the taxonomy (RQ2). We empirically identified ten application archetypes, namely, financial news and analysis, advanced or manual budgeting, transaction authorizing, credit card and retail payments, mobile banking, individualized or non-individualized information, and investments with or without advice.

Besides providing a rigorous classification that can be a starting point for further research, financial service providers and mobile app developers can benefit from our insights when comparing with competitors. Furthermore, we support them to advance their applications with new technical functions or services. Potential users of mobile personal finance applications can use our taxonomy and archetypes to support the selection of mobile apps that optimize their personal finance endeavors.

Research Area II. Analysis and Design of Robo-Advice

The second research area sheds light on more focused analyses of certain RA components and gives recommendations for RA design. The first analysis focuses on the BM of RAs, providing a rigorous understanding of the distinct BM elements of RAs and finding major similarities and differences between RA-providers BMs. [Paper 3](#) (Metzler et al., 2022) provides answers to the following research question:

RQ II.1: How can RA business models be characterized and what are major similarities and differences?

The second analysis focus is on the recommendations that RAs provide, with the aim to understand how the recommended portfolios differ, especially regarding their structure and selected products as well as performance and risk. [Paper 4](#) (Torno & Schildmann, 2020) provides answers to the following research question:

RQ II.2: Which similarities and differences do the portfolios recommended by RA have, regarding portfolio structure and selected products, performance, and risk?

The third focus of this research area is to derive MRs and develop DPs for RA, addressing the problem of unethical behavior that can decrease trust and the adoption of RA. [Paper 5](#) (Torno et al., 2022) provides answers to the following research question:

RQ II.3: What are relevant design principles to establish ethical considerations in RA design and increase its trustworthiness?

3 The Digitization of Investment Management – An Analysis of Robo-Advisor Business Models

<i>Authors & Contributions</i>	Dennis Renee Metzler, dennis.metzler@uni-goettingen.de	Idea, data acquisition, data analysis, visualization, writing, text revision
	Nicole Neuss, nicole.neuss@uni-goettingen.de	Data acquisition, data analysis, writing, text revision
	Albert Torno, albert.torno@uni-goettingen.de	Ideation of analysis structure, text revision
<i>Citation</i>	(Metzler et al., 2022): Metzler, D. R., Neuss, N., and Torno, A. 2022. "The Digitization of Investment Management – An Analysis of Robo-Advisor Business Models," in <i>Proceedings of the 17th International Conference on Wirtschaftsinformatik (WI), Nürnberg, Germany, (Best paper award nominee)</i> .	
<i>Abstract</i>	The emergence of so-called Robo-Advisors (RAs) is disrupting the financial services industry. RAs are algorithm-based systems that digitize and automate the investment advisory process including portfolio recommendation, risk diversification, portfolio rebalancing, and portfolio monitoring. Scientific research in this field is still in its infancy and lacks a comprehensive understanding of the underlying business model (BM) of RAs to comprehensively understand the RA business and to further identify their potential to disrupt the financial services industry. Therefore, in this article, we conduct a multiple case study across the fifteen biggest US-based RAs to explain the basic characteristics and special features of RA BMs. Thereby, we distinguish between pure algorithm-based RAs and hybrid RAs with dedicated human oversight. Through an in-depth analysis of publicly available qualitative data, we contribute to the existing research by unleashing significant elements that underline the power of RAs to disrupt the financial services industry.	
<i>Keywords</i>	Robo-Advisory, FinTech, Business Model Analysis, Digitalization, Qualitative Research	

Table 11. Fact sheet of paper 3

3.1 Introduction

The financial services industry is changing. Especially an ongoing digitalization leads to a shift in this traditional industry. Increasing technological developments and an increasing digitalized society, lead to a need for more digital and innovative solutions within the financial services industry (Gomber et al., 2017). This disruption particularly concerns the wealth and asset management sector. Customers increasingly demand more cost-efficient, easy-to-use, and continuously available services (Blaschke & Kriebel, 2021; Mačijauskaitė, 2018). As a reaction to these changing requirements, financial services firms introduce Robo-Advisors (RAs), which are defined as “*automated investment platforms that use quantitative algorithms to manage investors’ portfolios and are accessible to customers online*” (Beketov et al., 2018). Thereby, a RA is a digital investment advisor that takes over the role of a human investment advisor or amplifies the service through a hybrid human-machine cooperation. The RA replaces manual processes, such as customer profile identification, asset allocation, and portfolio rebalancing, with algorithms (Beketov et al., 2018; Jung et al., 2017). Existing research on RAs primarily deals with the underlying processes (e.g., Jung et al., 2017), the differences between human advisors and RAs (e.g., Britton & Atkinson, 2017; Gold & Kursh, 2017), the design of RAs (e.g., Brenner & Meyll, 2020; Jung et al., 2017), and the performance of RAs (e.g., Puhle, 2019; Torno & Schildmann, 2020). Thereby, literature only partially refers to the underlying business model (BM) of RAs and, in most cases, only refers to the value proposition or the key activities of these businesses (Coombs & Redman, 2018; Jung et al., 2017). Consequently, there is a lack of research regarding a comprehensive understanding of the underlying BM of RAs, including basic characteristics and special features. This paper aims to address this research gap by analyzing the BM of large US-based RAs. The underlying research question is as follows:

How can Robo-Advisor business models be characterized and what are major similarities and differences?

To answer this research question, we conducted a multiple case study across various US-based RA providers and analyzed their underlying BMs. Our main database comprises the RAs’ websites, whitepapers, and ADV forms. The data was analyzed rigorously by a qualitative content analysis approach. In our results, we differentiate between the BM of hybrid and pure RAs and discuss their similarities and differences.

This paper is structured as follows: Starting with the theoretical foundations, we introduce RAs and BMs as the main theoretical concepts for our study. Second, we explain the methodological foundation of our study. Third, we present our findings about RA BMs. Fourth, in the context

of a discussion, limitations of the study as well as implications for research and practice are presented. Finally, the conclusion summarizes the most important findings of our study.

3.2 Theoretical Foundations

The financial services industry undergoes a substantial disruption triggered by the emergence of FinTechs. The term FinTech describes the technology-based design and delivery of products and services within the financial services industry (Gomber et al., 2017; Puschmann, 2017). FinTechs are usually relatively new firms with innovative products and services operating at the intersection of financial products and services and IT (Eickhoff et al., 2017). With innovative BMs, FinTechs try to close the gap between outdated offerings of traditional financial services firms and new customer demands (Vasiljeva & Lukanova, 2016). Eickhoff et al. (2017) found that nine different archetypes of FinTech BMs exist – one of these is represented by RAs. In contrast to general research on FinTechs, research on RAs in specific is still in its infancy and literature in this field is relatively rare.

A RA is defined as an “automated investment platform that uses quantitative algorithms to manage investors’ portfolios and is accessible to customers online” (Beketov et al., 2018, p. 364). Beketov et al. (2018) identified five main processes carried out by RAs: (1) investor profile identification, (2) asset allocation, (3) implementation of investment strategies, (4) portfolio rebalancing, and (5) performance review and reporting. Further, Beketov et al. (2018) highlight several competitive advantages of RAs compared to traditional human portfolio management: (1) lower costs, (2) better customization opportunities, (3) a more transparent workflow, and (4) lower minimum investment sums.

Research on RAs increasingly distinguishes between pure RAs and hybrid RAs. The pure RA is characterized by a fully automated investment advisory process based on algorithms without any human interaction for the user. On the other hand, the hybrid RA combines these automated methods with additional human oversight in varying degrees of severity (Abraham et al., 2019; D’Acunto & Rossi, 2020; Sironi, 2016; Strzelczyk, 2017). Hybrid RAs, therefore, allow additional human interaction in the financial advisory process, which is mostly limited to a certain number of contacts and/or limited to interaction via internet or phone (Abraham et al., 2019). For example, this human interaction can be used to additionally discuss personal preferences with human advisors who have the authorization to override the algorithm-based portfolio allocation (D’Acunto & Rossi, 2020). Whereas D’Acunto and Rossi (2020) recommend pure RAs for the “millennial” generation and hybrid RAs for wealthier and older clients, Jung et al. (2017) highlight a need for a human interaction component in RAs in general. According to Jung et al.

(2017), most investors have the need to have an additional human advisor and, therefore, argue for the implementation of hybrid RAs (Sironi, 2016).

Since the delimitation between pure and hybrid RAs is not quite clear, in this study, we classify a RA as hybrid if the financial advisory process for every single account (i.e., for standard and premium accounts) is enriched with the possibility of making use of additional human advice or if the RA offers premium accounts with additional human advice as their main value proposition. General, non-portfolio-specific advisory, however, is not a reason for classifying a RA as hybrid. Also, the human-based compilation of portfolios that the algorithm can choose from after assessing the customer's preferences is not a reason for classifying a RA as hybrid.

Other existing research on RAs focusses on the underlying investment strategies and advantages and disadvantages. For example, D'Acunto et al. (2019) investigated the effect of RA use on investor performance and trading behavior and indicate that investors with under-diversified portfolios increased their diversification through the use of RAs. Further, RA-supported investors realized a higher portfolio performance concerning market-adjusted trade returns and portfolio returns. However, investors with an already greatly diversified portfolio did not change their diversification through using RAs. Despite more trading activities, these investors did not realize a better performance. Finally, other research on RAs focuses on performance (e.g., Torno & Schildmann, 2020), design principles for the user interface (e.g., Jung et al., 2017), user interaction (e.g., Rühr et al., 2019), and personalization issues (e.g., Faloon & Scherer, 2017).

The BM of a RA can be described as a digital BM. A BM, in general, can be defined as a blueprint that describes the basic principles of how an organization creates value and how this value is transferred to stakeholders (Osterwalder & Pigneur, 2010). In contrast, a digital BM is defined as “*a conceptual extension of business models and are delimited by the explicit use of digital technologies, data, and, in general, the extraction of potentials from digitization for business conduct*” (Guggenberger et al., 2020). A variety of frameworks explain the different elements of a BM. For example, Osterwalder and Pigneur (2010) introduced the Business Model Canvas (BMC) dividing a BM into four BM pillars comprising nine BM elements: (1) value propositions (value propositions of products and/or services), (2) customer interface (customer relationships, customer segments, and channels), (3) infrastructure management (key activities, key resources, and key partners), and (4) financial aspects (cost structure and revenue streams). Since the BMC is an all-encompassing tool describing the business of firms, it is a well-accepted analytical framework appropriate to analyze the BM of RAs in this setting.

Overall, existing research agrees that RAs represent an important FinTech BM with increasing disruptive potential. However, existing literature lacks an in-depth analysis of RA BMs, including specific characteristics of each BM element.

3.3 Methodology

To shed light on the structure and design of RA BMs, we conducted an exploratory case study across a variety of US-based RA providers. Since this study deals with a contemporary phenomenon in a real-life context, where no control over behavioral events is required, the case study is an appropriate research method [24].

3.3.1 Data Collection

To get a comprehensive overview and to consider a large industry share, our analysis focuses on the 15 biggest US-based RAs with a minimum of one billion USD assets under management (AuM). The USA was chosen as geographical region since the biggest and most well-known RAs are located here. In all cases, AuM are limited to funds managed through RA programs. To find relevant RAs, we considered industry reports (e.g., BackendBenchmarking, 2021; Zavalova, 2021) and online-based statistics (Statista, 2021). For each case, we checked the RA's website and other credible sources to validate our inclusion criteria and to decide whether it really is a RA. Further, according to the definitions in our theoretical background, for each RA we decided whether it is a pure or hybrid RA. In that regard, we classified a RA as hybrid if the financial advisory process for every single account (i.e., for standard and premium accounts) is enriched with the possibility of making use of additional human advice or if the RA offers premium accounts with additional human advice as their main value proposition. The final sample of RA providers can be obtained from Table 12.

In some cases, the parent companies are large US investment management companies (e.g., RA1; RA4; RA6; RA13). The remaining RAs are either subsidiaries of smaller companies with a focus on RA (e.g., RA7; RA8; RA12; RA10) or are completely independent (e.g., RA5; RA15). Whereas seven RAs can be classified as pure RAs, the other eight are hybrid RAs.

We used publicly available information of documents provided by the RA providers themselves. This includes the official websites, published whitepapers, annual reports, and ADV forms. We chose these data sources as they represent the main communication channels of all analyzed RAs.

<i>RA</i>	Type	Robo-Advisor Provider	Parent Company	AuM in bn. USD	Clients in k
<i>RA1</i>	Hybrid	Vanguard Advisers	Vanguard Group	> 270.00	> 1,000.00
<i>RA2</i>	Hybrid	Edelman Online	Edelman Financial Engines	> 250.00	> 1,000.00
<i>RA3</i>	Hybrid	Merril Edge Guided Investing	Merrill Lynch	> 200.00	> 2,500.00
<i>RA4</i>	Pure	Schwab Intelligent Portfolios	Charles Schwab & Co.	> 60.00	> 400.00
<i>RA5</i>	Pure	Betterment	-	> 25.00	> 616.00
<i>RA6</i>	Pure	TD Ameritrade Essential Portfolios	TD Ameritrade Holding	> 20.00	Unknown
<i>RA7</i>	Pure	Wealthfront Advisers	Wealthfront	> 15.00	> 278.00
<i>RA8</i>	Hybrid	Personal Capital Advisors	Personal Capital Corp.	> 15.00	> 27.00
<i>RA9</i>	Pure	Bloom	-	> 5.00	> 24.00
<i>RA10</i>	Hybrid	E*Trade Adaptive Portfolio	E*Trade Bank	> 4.00	Unknown
<i>RA11</i>	Pure	M1 Finance	-	> 3.00	> 500.00
<i>RA12</i>	Pure	Acorns Advisers	Acorns Grow	> 3.00	> 5,400.00
<i>RA13</i>	Hybrid	FutureAdvisor	BlackRock	> 1.70	> 24.00
<i>RA14</i>	Hybrid	SigFig Wealth Management	Nvest	> 1.40	> 26.00
<i>RA15</i>	Hybrid	Ellevest	-	> 1.00	> 80.00

Table 12. Overview of analyzed RA providers (sorted by AuM)

3.3.2 Data Analysis

We analyzed the collected data with a qualitative content analysis approach by Mayring (2014). We chose deductive category application to categorize and organize the collected data. Therefore, the categorization of the collected data is driven by an external concept – in our case the BMC introduced by Osterwalder and Pigneur (2010). After implementing the categorization, we analyzed the collected data in two major steps. First, for every RA, we highlighted every statement within the dataset associated with its BM and linked each statement to at least one suitable BM element. This resulted in the illustration of the BM for each RA. Within the next step, the results of each RA were compared to all other RAs. This helped to get a cross-case overview and to strengthen our findings regarding replication logic.

Whereas the characteristics of most BM elements are nearly similar across all RAs, we found that some major differences exist between pure and hybrid RAs. Therefore, in our results we distinguish between the BM of pure RAs and hybrid RAs. Using a dual coder approach, the first researcher coded all available documents. Afterward, another researcher verified all codes by checking all documents and the associated codes. As proposed by Mayring (2014), we questioned and revised the categorization after coding half of the data. Lastly, we finalized the coding based on discussions within the author team. During the whole coding process, we used the criteria construct validity, internal validity, external validity, and reliability to ensure the rigor of our study (Campbell, 1975).

3.4 Findings

In the following, we present the main findings of our study. First, in Figure 19, we present the four BM pillars including its nine elements separately for hybrid and pure RAs. The illustrated BMs represent cross-case results. The italicized and underlined bullet points in the BM elements represent special features of pure resp. hybrid RAs. Afterward, we present the most relevant cross-case results, as well as outstanding case-specific findings and differences between pure and hybrid RAs, divided into the different elements of the BMC. Finally, we also present some rather subordinated findings which are not shown in Figure 19.

Pure RA				Hybrid RA			
Key Resources		•digital platforms •algorithms •financial knowledge		Key Resources		•digital platforms •algorithms •financial knowledge	
Key Activities		•platform provision and maintenance •portfolio compilation and rebalancing •quality assurance •marketing activities		Key Activities		•platform provision and maintenance •portfolio compilation and rebalancing •quality assurance •marketing activities	
Key Partners		•parent companies •third-party broker firms •external agencies		Key Partners		•parent companies •third-party broker firms •external agencies	
Cost Structure		•transaction costs •marketing costs •operational expenses • <u>very low</u> staff payment		Cost Structure		•transaction costs •marketing costs •operational expenses • <u>low</u> staff payment	
Revenue Streams		•AuM-based fees •subscription fees •cash sweep activities •third-party compensation		Revenue Streams		•AuM-based fees •subscription fees •cash sweep activities •third-party compensation	
Channels		Customer Segments		Channels		Customer Segments	
•website •mobile apps •social media and ads		•retail investors with limited capital amount •access limited to residents in headquarter’s state • <u>mostly no capital minimum</u>		•website •mobile apps •social media and ads • <u>phone</u>		•retail investors with limited capital amount •access limited to residents in headquarter’s state • <u>mostly high capital minimum</u>	
Customer Relationships		• <u>only</u> automated and digital communication		Customer Relationships		• <u>mostly</u> automated and digital communication • <u>additional personal communication</u>	

Figure 19. Business model elements for pure and hybrid RAs

3.4.1 Value Propositions

RAs provide automated digital investment management services that can be offered solely automatically via investment algorithms (i.e., pure RA) or as a hybrid service (i.e., hybrid RA). In contrast to pure RAs, hybrid RAs rely on a digital infrastructure and investment algorithms but offer additional human-based services across the whole investment advisory process (e.g., RA3; RA1; RA8). Especially hybrid RAs often offer premium subscriptions including permanent access to an additional human advisory network – mostly via chat or phone, which provides

in-depth financial planning services, as well as additional advisory services (e.g., retirement planning or debt management) (RA3; RA14; RA15).

The investment management services of RAs primarily comprise portfolio management, permanent monitoring of accounts, trade execution, and periodic rebalancing (generally either monthly or quarterly). The periodic rebalancing at all RAs relies on algorithms to monitor the asset class weightings of the customer's portfolio and executes security transactions in case of deviations. All RAs provide dashboards (accessible via web or native mobile apps) displaying the current portfolio performance and forecasts. All RAs follow a passive portfolio management approach, primarily focusing on achieving the financial goal(s) set by the customer. Through detailed questionnaires identifying the customers' profiles, appropriate portfolios can be individualized to match the customer-specific risk tolerance and investment goal(s) (e.g., RA8, RA11), even more through additional human advice in hybrid RAs (RA15).

Most RAs focus on cost-efficient passive investing strategies through concentrating on low-cost index funds. By focusing on algorithms instead of human advisors, RAs can offer their services at a lower price than traditional investment advisors which increases the customers return after costs (e.g., RA1; RA4; RA5). Many RAs further address the increasing demand for sustainable investment solutions (e.g., RA5; RA6; RA8; RA15). If required, RAs prioritize securities of companies that perform well under environmental, social, and governance criteria. For example, most RAs reduce exposure to firms or entire industries with bad environmental or social impacts (e.g., tobacco or petrol industry) by default, but at the same time sustaining the required liquidity and diversification of the portfolio.

Most RAs support tax loss harvesting, a method to reduce the taxable capital gains at the end of a financial year, by selling assets, which generated losses in the past (e.g., RA5, RA 8). Furthermore, some RAs aim to reduce the customer's capital gains taxes through allocating assets across differently taxed accounts (RA1; RA5; RA8; RA13).

Finally, some RAs pursue the goal of additionally improving the customers' financial education, i.e., their capability to understand financial phrases and interrelations, by providing glossaries and explanations of terms via digital channels (RA3; R10; RA12).

3.4.2 Key Partners

Most RAs, both hybrid and pure, do not have the capabilities to provide their whole service portfolio by themselves. Therefore, these RAs establish partnerships with internal and external partners. In some RAs, the parent firms act as an internal partner providing crucial infrastructure, such as offices, financial knowledge, and digital services (e.g., RA1; RA4; RA5).

Additionally, RAs primarily recommend assets issues by their parent firms to set up their customers' portfolios.

RAs partner with internal or external brokers to buy and sell securities. These brokers are company's affiliates (e.g., RA1; RA5; RA7; RA12), parent companies (e.g., RA4; RA6's), or external brokerage firms (e.g., RA8; RA13; RA14; RA15). Some RAs also partner with external banks that manage deposits and provide supporting services, such as debit cards or digital infrastructure (e.g., RA8; RA15). Finally, some RAs rely on external investment knowledge, which provides capital market assumptions, portfolio allocation recommendations, and due diligence execution (e.g., RA6; RA15). For example, RA15 collaborates with Morningstar Investment Management LLC to benefit from their risk and return prediction assessments to offer customers their tailored proposals.

To provide personal advisory services, a few RAs additionally cooperate with external financial agencies such as certified financial planners (e.g., RA5) or other agencies to work together on marketing campaigns, portfolio development, or research and development activities (e.g., RA5; RA8; RA15).

3.4.3 Key Activities

All RAs provide a digital platform, including ongoing maintenance and development activities. Especially for pure RAs, this platform serves as a main source to obtain relevant information from customers and to recommend and compile suitable portfolios. RAs compile low-risk portfolios as well as high-risk portfolios, depending on the customer's need. The portfolios comprise of different asset classes that can be categorized into company stocks, bonds, and alternative asset classes (e.g., real estate). RAs minimize risk through portfolio diversification across multiple asset classes. Each RA divides stock and bond categories into different subclasses and aims to achieve the appropriate weighting for every sub-asset class in accordance with the customer's financial goals and risk aversion. As ETFs are the investment vehicle of choice, another important activity is to ensure the ETFs' quality and compliance. RAs rank multiple ETFs regarding their performance related to a specific benchmark index (e.g., RA5). Since the main difference between the ETFs' performance and the benchmark index' performance are expenses associated with trading and managing the fund, RA5 chooses ETFs with the lowest "total annual cost of ownership" (i.e., the sum of the funds trading expenses). Additionally, most of the RAs also state that they are ensuring that the exchange trading fund (ETF) exhibits sufficient liquidity (e.g., RA4).

Another key activity is the rebalancing process. To maintain the desired asset allocation over time, a continuous adaption of asset class weightings is needed. RAs therefore set limits within which a portfolio is allowed to deviate from the target asset allocation and are permanently monitoring for violations of such limits. If the algorithm (or investment personnel) realizes such a violation, it initiates the necessary transactions to rebalance the portfolio. These deviation limits may vary between different RAs. For example, RA1 rebalances a portfolio if it deviates more than 5% from the target allocation in any asset class, while RA5 sets the limit at 3%. We also found differences between rebalancing approaches in the frequency of reviewing the portfolio. While all pure RAs and the hybrid RA8 use automated algorithms to run the rebalancing mechanism, monitoring, and transactions at RA1 are carried out by humans. This more time-consuming process at RA1 leads to a relatively low quarterly monitoring frequency, compared to RA4 and RA5, which monitor their customer's portfolio daily.

As part of the portfolio management process, most RAs undertake tax harvesting activities to reduce the customer's taxable capital gains and therefore tax bill (e.g., RA4; RA5; RA7). This includes tax loss harvesting activities (e.g., RA4; RA5; RA7) and the provision of other additional tax benefits through efficient asset allocation (e.g., RA1; RA5; RA8; RA13). In that regard, most RAs developed algorithms which monitor and rebalance automatically (e.g., RA5; RA7; RA13). Only some hybrid RAs use human labour for these tasks (e.g., RA3).

Another activity of the RA providers consists of marketing activities, usually carried out through different digital channels – without significant differences between pure and hybrid RAs. The specific channels used are discussed in the corresponding section “channels” below. Finally, although all RAs offer non-advisory-related customer support, this is a rather subordinated activity across all considered RAs.

3.4.4 Key Resources

One of the most important key resources for all RAs are their digital platforms and investment management algorithms. These algorithms analyze the customer's financial situation, develop customized financial plans, and recommend asset allocation. In addition, algorithms in many RAs carry out portfolio rebalancing and tax loss harvesting processes (e.g., RA4; RA5; RA7).

Both, pure and hybrid RAs embed financial knowledge, such as in-depth capital market knowledge, integrate well-known theories, such as modern portfolio theory (Markowitz, 1952), and use established simulation methods, such as Monte Carlo simulations (Hertz, 1979) (e.g., RA7; RA14). This financial knowledge is reflected in intelligent investment management algorithms as well as in well-educated personnel. Whereas in pure RAs, personnel is not directly

involved in the service delivery to customers and therefore plays a rather subordinated role, hybrid RAs offer additional human investment advisory and asset allocation services. Therefore, human labour is more important in hybrid RAs (e.g., RA1; RA8). This also applies to pure RAs offering human advisory via premium subscriptions (e.g., RA4; RA5).

3.4.5 Customer Relationships

The relationship between customers and RAs differs significantly between pure and hybrid RAs. While pure RAs do not provide any additional human advisory services or only for premium customers that are paying higher service fees or invest a higher amount of capital (e.g., RA5), hybrid RAs provide this service for all customers (e.g., RA1; RA3). For example, the hybrid RA1 provides one constant personal advisor for customers with a very high amount of invested capital, whereas customers with less capital invested have changing personal advisors (e.g., RA1). Other hybrid RAs provide customer service independent of the amount of invested capital, either with a constant personal advisor or changing personal advisors (e.g., RA8).

Ensuring the customer's financial plan being up to date in the long run, RAs contact their customers once a year (e.g., RA1; RA4; RA5; RA6; RA14) or more frequently, e.g., once a quarter (e.g., RA6). This process is generally carried out by asking the client to fill out the initial online questionnaire again. For hybrid RAs, this process can also be carried out personally through the RA's staff.

To strengthen customer relationship and to attract new customers, some RAs have established referral programs offering discounts and remunerations to customers or third parties for attracting new customers (e.g., RA5, RA15).

3.4.6 Channels

All analyzed RAs aim at minimizing personnel effort in communication and sales channels and primarily use digital, mostly automated, communication channels. For pure RAs this includes websites, mobile apps, or social media (e.g., RA4; RA5; RA9). Hybrid RAs that offer human advisory services, also use telephone, e-mail, or video chats as additional, non-automated, channels (e.g., RA1; RA8; RA14; RA15).

As part of their marketing campaigns, RAs use several, mostly digital, communication channels to attract new customers. For example, RAs run paid blogger marketing campaigns (e.g., RA7), place ads through platforms like Google or Instagram (e.g., RA13), or have promotion programs with selected partners (RA15).

3.4.7 Customer Segments

All RAs primarily address retail investors with limited capital amount. Pure RAs primarily address individual retail investors with relatively low amounts of investment capital. This can be derived from a minimum required capital amount for individuals to open a portfolio, which usually ranges from \$0 to \$5,000 (e.g., RA9; RA11; RA12). On the other hand, especially hybrid RAs (but also some pure RAs, such as RA6) primarily focus on high-net-worth individuals and companies and require a high minimum amount of \$10,000 or more for opening a managed portfolio (e.g., RA6; RA8; RA13).

Some RAs also offer their services to employer-sponsored retirement plans, such as 401(k) accounts (e.g., RA1; RA5). Other RAs, in addition to their main business, act as sub-advisors for financial institutions. Thereby, they offer their own investment advisory services to their customers but use a third party for supplying the necessary infrastructure (e.g., RA14). RA14 defines its addressed customer segment as financial institutions, investment advisers, banks, or broker-dealers. Some providers focus on specific segments, e.g., lifespan-adjusted retirement plans directed to women or options to create multiple accounts for kids' savings (RA12; RA15). Due to all analyzed RAs being based in the US, their offer is generally limited to US citizens with a US social security number (e.g., RA1; RA4; RA5).

3.4.8 Revenue Streams

RAs primarily generate revenue through a yearly (usually fixed) percentage fee of the daily average of the customer's AuM. This fee is charged monthly (RA7; RA8; RA12; RA14; RA15), quarterly (RA1; RA5; RA6), or depending on the customers' wish (RA13). The charged percentages vary across the different RAs. Furthermore, some RAs charge a fixed subscription fee for their services regardless of the AuM (RA5; RA6; RA7; RA13; RA14; RA15). Rather seldom is a one-time opening fee. For example, RA1 charges a one-time opening fee of \$1,000 for customers with AuM below \$50,000 and \$250 for customers with AuM above \$50,000. In general, it can be observed that pure RAs have lower fees than hybrid RAs, even though exceptions exist (e.g., RA6). Some RAs don't charge fees for their standard accounts and only generate revenue through premium accounts and other revenue streams (e.g., RA8; RA11).

Some RAs generate additional revenue through cash sweep methods. Thereby, the RAs transfer the free cash of their customer's portfolio to a partner bank that afterwards invests the received cash. The partner bank pays an interest rate to the RA and the RA gives a portion of this interest rate to the customer (e.g., RA4; RA5; RA8).

Finally, RAs generate revenue through third-party compensations. This, for example, includes remunerations for promotional campaigns (e.g., RA15; RA14) and the offering of administrative services to partners like individual financial advisors (e.g., RA5; RA13; RA14). Furthermore, RA5 and RA15 generate income for their partners through funds deposited in debit accounts and associated debit card fees for transactions and withdrawals. In the first case, these payments increase the profit of its affiliate and will therefore not be renumbered, while RA15 receives compensations from their partner for offering their debit card services to the RAs customers.

3.4.9 Cost Structure

In some RAs, transaction costs through buying and selling securities, charged by brokerage firms, are directly forwarded to customers (e.g., RA1; RA13; RA14). However, other RAs include the brokerage commissions in their wrap fee, meaning it is directly diminishing their final profit. Other high impact costs are marketing costs, primarily including referral compensations and marketing budgets (e.g., RA1; RA4; RA5). Other factors influencing the cost structure include, but are not limited to, operational expenses, such as renting buildings, maintaining digital infrastructure, general administration, and legal advice (e.g., RA4; RA6). Salary and bonus payments to staff accounts make another large share of the cost structure (e.g., RA5). However, through the high degree of automation in the advisory process, the personnel costs in all RAs are rather low compared to traditional human investment advisory. Since the pure RAs do not offer any additional human advise, the personnel costs in pure RAs are even lower (e.g., RA9; RA12) than in hybrid RAs.

3.5 Implications, Limitations, and Future Research

Our paper provides several important implications for research and practice. First, our paper offers a well-funded analysis of pure and hybrid RA BMs, extending the existing understanding of the RA phenomenon. Further, this analysis enables researchers to track future developments by comparing new BM-related findings with the results of this study. Such continuous re-evaluations are especially important in early developing businesses, as in the RA business. Since existing RAs are usually relatively young, their current success might only be temporary and not necessarily sustainable in the long run.

With our study, we can confirm existing research on RAs regarding the main processes carried out by RAs. Like Beketov et al. (2018), we found that the main processes are investor profile identification, asset allocation, implementation of investment strategies, portfolio rebalancing, and performance review and reporting.

Whereas most BM elements are highly similar across different RAs, we found some major differences between pure and hybrid RAs. Concerning the BM element customer segments, pure RAs mostly do not have an account minimum, whereas hybrid RAs often have a relatively high minimum (e.g., 25,000 USD or even more), which confirms the statement of D'Acunto and Rossi (2020) who recommend pure RAs for millennials and hybrid RAs for wealthier and older clients. Further, in contrast to hybrid RAs, the value proposition of pure RAs does not comprise additional human portfolio advice and human advisory networks. The customer relationships of pure RAs also do not include personal communication. On the other hand, this leads to a relatively lower amount of staff payments at pure RAs. Future research could build on these insights by diving deeper into BM differences of RAs by developing a taxonomy.

As stated by Jung et al. (2017), investment banks are downsizing their services for retail customers because of too high administrative expenses for low investment amounts, which creates a vacuum in this customer field. Our analysis shows that RAs aim to penetrate especially this customer segment through offering advisory solutions, including a low minimum investment amount, convenient online interfaces, a goal-based approach, and several additional offers at a low price. A declining offering of conventional services and an increasing awareness towards financial technology on the demand-side poses significant future opportunities for RAs in the retail investor segment. In addition, RAs adapt quickly to industry developments, such as the trend towards passive portfolio management and sustainable investments (Beketov et al., 2018).

Although customers increasingly prefer passive portfolio management instead of active portfolio management, human interaction is still important for customers (Jung et al., 2017). Our analysis shows that some RAs lack behind in this field. Solely relying on algorithms and online questionnaires to identify customers' profiles and create financial plans can lead to portfolios that do not sufficiently reflect the customers' risk aversion and financial need. This can lead to unsatisfactory results in the long run. Jung et al. (2017) proposed the solution of RAs, which still rely on human interactions in core processes. Our analysis shows that this solution has been adopted by hybrid RAs combining the efficiency of digital investment algorithms and the advantages of human advisors, for example, in the customer attraction and profiling stage. However, pure RAs still solely rely on investment algorithms and minimize human interactions.

Our results indicate that the features of RAs have the potential to lead to a strong increase in the use of digital and automated solutions in investment advice in the upcoming years. However, some competitive advantages of RAs are based on the fact that they are subsidiaries of large investment firms or banks. Established firms might therefore presumably continue to

dominate this market, making it difficult for smaller RA providers or startups to enter the market. It can therefore be assumed that RA providers, that already are major players in the financial services industry, are using RAs as an additional channel to increase distribution of their own investment products.

Despite the careful design of our study, this paper is subject to some limitations. First, our sample of analyzed RAs is limited to the biggest US-based RAs. Our results can therefore only be generalized to large RAs in the USA. Future research could extend the research scope to other geographical regions, such as Europe and Asia, and/or to smaller RAs, e.g., from less established FinTech firms. The number of RAs can also be increased as part of future research. We only include publicly available documents of the RAs themselves, instead of additionally evaluating external data. This could result in biased findings. Therefore, future research could extend the database with external RA information, e.g., from industry reports. Further, because of our limited database, for some statements we cannot answer the “why” question. For example, although we can state that some RAs have a high account minimum which delimits their potential customer segments, we cannot answer why some RAs decide to do so. Since this is important for understanding their underlying BM, future research should also elaborate on this by expanding the database or even conduct interviews with experts in the field of RA. Since financial information is not available for all analyzed RAs, we also cannot give a statement regarding the financial profitability of RA BMs. Finally, we encourage scholars for future research concerning a detailed comparison of RA BMs and BMs of traditional asset and wealth management services as well as investment advisory services to gain further insights on the success of RA BMs now and in the future.

3.6 Conclusion

This paper aimed to evaluate the potential of RA BMs to disrupt the financial services industry. To approach this goal, we conducted an exploratory case study across the fifteen largest US-based RAs. Our in-depth analysis of publicly available documents of these RAs resulted in the illustration of exemplary BMs for pure and hybrid RAs. Further, we presented the most important similarities and differences between these BMs. Our results indicate that RAs with their digital BMs have the potential to change the landscape of traditional investment advisory. The provision of customized services at a relatively low price leads to an increasing competitive advantage against traditional wealth and asset management. However, our results also indicate that solely relying on algorithms instead of additionally draw on human-based services, does not fully comply with existing customer needs. Further, as many competitive advantages of

most RAs are based on a strong partnership with the parent company, it is especially hard for pure RA start-ups to gain foothold in this market.

4 What do Robo-Advisors Recommend? – An Analysis of Portfolio Structure, Performance and Risk

<i>Authors & Contributions</i>	Albert Torno, albert.torno@uni-goettingen.de	Idea, data analysis, calculations and interpretation, visualization, writing, text revision
	Sören Schildmann, soeren.schildmann@stud.uni-goettingen.de	Idea concretization, data acquisition, preliminary data analysis and calculations, text revision
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<i>Abstract</i>	Robo-Advisors guide investors through an automated investment advisory process, recommend personalized portfolio assignments based on their individual risk-affinity as well as investment goals and rebalance the portfolio automatically over time. Giving basic investment advice to customers, it can provide a useful way to reduce risk by diversifying and mitigating biases, while keeping a certain degree of performance at low costs. To verify these claims we conduct a sophisticated analysis of recommended portfolios of 36 Robo-Advisors, based on six distinct model customers with different risk-affinities and investment horizons, resulting in 216 recommended portfolios. We find that the analyzed Robo-Advisors provide distinct recommended portfolios for the different risk/investment horizon combinations, while sharing similarities in used products for portfolio allocation. We also find issues within the recommended portfolios, e.g., a low degree of distinctiveness between different investment horizons and a high amount of equities even in the short-term investment horizon.	
<i>Keywords</i>	Robo-Advisor, FinTech, Portfolio Analysis, Performance and Risk Analysis	

Table 13. Fact sheet of paper 4

4.1 Introduction

The Digital Transformation of industries lead to enhancements of operational process as well as changes in customer experiences and business models. Within the financial industry incumbent financial firms, as well as new start-ups, so called FinTechs, are competing in digitalization and automatization efforts to provide new ways of customer service, for example in wealth and asset management (Alt & Puschmann, 2016). Traditionally, wealth and asset management are based on human interactions and trust between a financial advisor and the customer, which is a time consuming and costly process. This business model requires high capital investments to be profitable for financial advisors. Therefore, financial advisors mostly offer these services to high-net-worth individuals (Jung et al., 2018). To provide financial advisory services to a wider range of customers and reduce costs, the Digital Transformation lead to the development of so called Robo-Advisors (RA) (Gomber et al., 2018; Sironi, 2016). A RA is an information system (IS), which guides investors through an automated investment advisory process, recommend personalized investment portfolio assignments, based on their individual risk-affinity as well as investment goals and rebalances the portfolio automatically over time (Jung et al., 2018; Sironi, 2016). Low interest rates, as well as new und cost effective financial products like Exchange Traded Funds (ETFs) are the basis of an upcoming customer interest in the financial markets, even with low amounts of invested capital (Sironi, 2016). RA providers claim to simplify investment decisions and financial planning, but the advice provided is considerably less comprehensive than that of a human financial advisor (D’Acunto et al., 2019). Nevertheless, especially first-time investors can benefit from basic investment advice to mitigate basic portfolio mistakes, like low diversification, home bias or other human tendencies researched within the domain behavioral finance (Jung & Weinhardt, 2018).

While research on RA portfolio structures is still rare, lacking the analysis of a sufficient sample of portfolio structures as well as risks and performances, RA comparison websites emerged, e.g. (Brokervergleich 2019. Statistiken und Daten. <https://www.brokervergleich.de/>. Zugriff am 10. November 2019, 2019; Robo-Advisor, 2020), that try to provide recommendation for the best RA to potential customers. However, these websites only consider and track one portfolio per RA and are just focusing on performance, without the relation or analysis of the associated risks. Also, the websites do not disclose which underlying methods or customer characteristics are used within the RA recommendation procedures. This paper contributes to a better understanding of RAs by systematically capturing and analyzing these recommended portfolios and thus answers the following research question:

Which similarities and differences do the portfolios recommended by RA have, regarding portfolio structure and selected products, performance, and risk?

We examine 36 RAs and analyze a sample of 216 distinct portfolio recommendations, based on six distinct model customers with low, medium, and high risk-affinities, as well as different investment horizons of 3 and 15 years. Based on our analysis using various performance and risk indicators, we provide novel insights on recommended portfolio structures of RA for research and practice.

To answer the RQ the remainder of this paper is structured as follows: Starting with the theoretical foundations we describe the key characteristics and process phases of RA, as well as present existing research on RA portfolio structures. Secondly, we describe the methodology by explaining the analysis approach as well as analysis measures and statistical test procedures. Thirdly, we present the findings of our analysis, followed by a discussion including implications for practice and research as well as providing limitations and future research directions. Finally, the conclusion summarizes the most important findings and implications.

4.2 Foundations and Related Research on Robo-Advisors

4.2.1 Robo-Advisor Definition and Process

The term *Robo-Advisor* is comprised of two components: “*Robo*” as an abbreviation of *robot* meaning “a machine controlled by a computer that is used to perform jobs automatically” and “*Advisor*” meaning “someone whose job is to give advice about a subject” (Cambridge English Dictionary, 2020). A RA in the field of asset management can therefore be defined as an automated system, which undertakes the role of a financial advisor. Therefore, the RA providers’ aim is to digitize and automate the entire traditional financial advisory and asset management process (Jung et al., 2018). Instead of a human financial advisor analyzing the financial situation of a customer, a typical RA uses algorithms to combine customer information with a suitable portfolio recommendation (Beketov et al., 2018). As input, the RA uses the characteristics entered by the customer regarding her person, goals and risk-affinity (Faloon & Scherer, 2017). Based on this information RAs recommend a personalized investment portfolio to the customer and rebalance it over time. The RA process can be divided into four phases: *Initiation*, *RAP*, *Matching* and *Maintenance* (Jung et al., 2018).

Initiation. In the first phase of the process, information asymmetries between providers and customers are dismantled (Jung et al., 2018). Due to the absence of human interaction and the importance of trust in financial advisory, RA providers aim at enhancing transparency by giving information about the whole advice process, the products used, and the costs associated with

the services. This transparency not only has a positive effect on the attitude of the customers to the RA provider, but also increases the customers willingness to accept costs (Nussbaumer et al., 2012). In this phase, providers also make a pre-selection of products (mostly ETFs) from which their recommended portfolios are compiled. Besides the preselection of funds by the RA provider, the customer often is asked for her investment objective, which may have an influence on the following phases.

Risk Assessment Process (RAP). The formulation of an investment goal leads into the RAP. In this phase, the risk profile of the customer is created, which is the basis of the portfolio recommendation. In an online questionnaire the customer goes through an self-assessment of her risk-affinity and investment characteristics (Tertilt & Scholz, 2018). The questions asked can be divided into three types: *(I)* General information, *(II)* Risk capacity and *(III)* Risk tolerance (Tertilt & Scholz, 2018). It could be shown that RAs ask an average of ten questions, six of which have an impact on the risk profile (Tertilt & Scholz, 2018). Creating a risk profile using a mostly static online questionnaire is a rather simple procedure, in comparison to traditional financial advice. It implies that clients have only one single and static risk preference. The literature in this area questions, whether the actual risk affinity of the client can be derived with this method alone (Beketov et al., 2018; Jung et al., 2018). RAs increasingly use more sophisticated methods to create a risk assessment e.g., by utilizing metaphors and scenario-based questions. RA thereby aiming at a balance between simplicity and sophistication of the risk profile (D’Acunto et al., 2019).

Matching. Within the matching phase an algorithm transfers the answers provided into a risk profile of the customer and recommends a corresponding portfolio from the investment product space of the RA provider. Since matching is usually based on an unpublished algorithm, the exact way of how a risk profile is matched to a portfolio is considered a black box (D’Acunto et al., 2019; Jung et al., 2018). However, an investigation of 219 RAs showed that over 80% of RA providers base their recommendation according to their own statements on three methods: *(I)* Modern portfolio theory according to Markowitz, *(II)* Model portfolios and *(III)* Portfolios with constant weightings (Beketov et al., 2018). Thereby, it was found that more sound methods of portfolio creation also lead to a higher total Assets under Management (AuM) sum of the RA providers (Beketov et al., 2018). When presenting the recommended portfolio structure to the customer, some RAs provide the option to modify her risk class and/or modify the portfolio structure in various ways. Logical risk verifications are run to ensure, that the customer does not change too much from the associated risk profile. (Jung et al., 2018). Typically, the end of

the matching phase is marked by an offer. If not already done to this point, the personal data of the customer is now required, and an account opening is initiated.

Maintenance. In the last phase of the process, rebalancing and reporting takes place. By means of automated rebalancing, the RA maintains the portfolio weights of the individual asset classes and thus ensures that the risk of the entire portfolio remains stable. By maintaining a desired portfolio risk, both over- or underperforming individual products, as well as reactions to external effects can lead to changes in the portfolio structure (Jung et al., 2019). Each RA provider pursues an individual strategy, thereby using fixed time intervals (e.g., quarterly, yearly) and/or trigger events (market changes, customer changes) for starting a rebalancing action. Because the maintenance is delegated from a human financial advisor to an algorithm, consequences of behavioral finance e.g. irrational human behavior in financial markets and biases should be reduced (Jung & Weinhardt, 2018). Lastly, within the maintenance phase RA do reporting. Besides the permanent available online access, the RA providers offer their customers in differing intervals reporting functionality as well as financial news and occasionally educational content.

4.2.2 Research on Robo-Advisor Portfolio Structures

Research on RA portfolio structures is still in its infancy and often based on small samples of internal data provided by one RA provider or uses external data, with often non-transparent data capturing procedures and analysis methods.

Using internal data provided by one RA, D’Acunto et al. (2019) analyze the aspects of behavioral biases like return chasing and the disposition effect and find a significant increase of diversification in RA portfolios compared to portfolios managed by the investor themselves. Also based on internal data of one RA, Reher & Sun (2020) conclude that a reduction of the minimum account size led to a net increase in total deposit inflows and an increase of new accounts by less-wealthy investors.

Using external accumulated data, Beketov et al. (2018) investigate portfolio recommendations in form of quantitative methods used inside the RA, by studying RA websites and white papers. This qualitative research was based on 219 existing RAs (reduced to 28 for the actual analysis), and shows a high usage of classic Modern Portfolio Theory within RA algorithms. Scherer (2017) investigates which data about an investor should have a high influence on recommended portfolios and conclude that information about the ability to take risks (e.g., net wealth) and the willingness to take risks (e.g., risk aversion) should have the biggest impact. The panel study, while helpful for RA providers, didn’t analyze how or what RA actually recommend within

their portfolios. Faloon & Scherer (2017) conclude, that RA while asking many questions, do not use all information adequately to model recommended portfolios, thus concluding that “most RA provide generic and poorly individualized advice”. Huxley & Kim (2016) evaluate the investment performance of four RA for four investment horizons (1-3, 4-6, 7-15 and 16-40 years), but without capturing distinct portfolios with varying risks per RA.

4.3 Methodology

4.3.1 Analysis Approach

To answer the research questions, we started by developing distinct model customers, to ensure a neutral, transparent, and replicable analysis procedure. Firstly, we considered, which characteristics of a customer are highly impactful for the RA portfolio recommendation. Based on a first sample of five RAs and various combinations of differing response patterns and the work of Scherer (2017), we choose three distinct risk and two distinct investment horizons for differentiation between recommended portfolios, thus representing the six distinct model customers shown in Table 14. These dynamic characteristics had the biggest impact on the differing recommendations of RA portfolios. While we already described the risk associated to a customer in our RA foundations chapter, we want to briefly state our rationale for the chosen investment horizon timeframes. In research and practice, short- and long-term investment horizons stand for differing investment behaviors and asset holding patterns (Amadi & Amadi, 2019; Warren, 2014). How many years of an investment horizon classifies as short-term or long-term is, to our knowledge, not defined in literature. We chose the short-term investment horizon to be three years, since e.g., a two-year investment horizon is too short for some RA to recommend a portfolio at all. We choose 15-years as the long-term investment horizon, because it is well above the three-year timeframe and therefore distinctly different to the short-term investment horizon.

(Lo3): Low risk / investment horizon 3 years	(Lo15): Low risk / investment horizon 15 years
(Me3): Medium risk / investment horizon 3 years	(Me15): Medium risk / investment horizon 15 years
(Hi3): High risk / investment horizon 3 years	(Hi15): High risk / investment horizon 15 years

Table 14. Risk/investment horizon combinations of model customers

Besides the dynamic characteristics, we choose static characteristics, that have not changed during the various RAP runs (e.g., age, sex, investable capital, savings ratio), to reduce complexity and ensure a manageable execution of RAP and subsequent analysis of the portfolios. All static characteristics had a low or none impact on the portfolio recommendation. The rationale behind each value of the static characteristic of the model customer, as well as

exemplary questions and answers to model the static and dynamic characteristics are presented in Appendix Table 6 and Appendix Table 7.

After defining the model customers, we needed to find suitable RA to derive portfolio recommendations. The selection of RAs was based on literature references and an explorative internet research (Beketov et al., 2018; Brokervergleich 2019. Statistiken und Daten. <https://www.brokervergleich.de/>. Zugriff am 10. November 2019, 2019). Only if the RAP phase led to a portfolio recommendation without registering with personal data (e.g., social security number), the RA could be considered for our analysis. We thus obtained the following three categories of data availability of the RAs portfolio recommendations:

- (*Category A*): Fully transparent portfolio structure, including weightings per asset class as well as associated products.
- (*Category B*): Semi-transparent portfolio structure with weightings per asset class, but no associated products.
- (*Category C*): No transparency concerning portfolio structure.

RAs of category A provide the best data basis and allow a comprehensive analysis not only of the structure but also for risk and performance measures of the recommended portfolios, since our data analysis is based on historical prices of the products in the portfolios. These could only be gathered, if the names of the portfolio products could be obtained and matched with its International Securities Identification Number (ISIN). For these products historical daily closing prices in U.S. dollars between October 23rd, 2009 and October 25th, 2019 were retrieved from Thomson Reuters via DataStream. Based on that data, we could calculate annual averages of various performance and risk measures to simulate how the recommended portfolios would have performed in the given timeframe backwards from 2019 to 2009. RAs of category B allow at least the analysis of the portfolio structure, since they present a portfolio allocation at the end of the matching phase which can be used as a risk indicator (Tertilt & Scholz, 2018).

A first descriptive analysis shows that 40% of the RAs present a transparent portfolio structure, including the used products. While 26% show at least the portfolio structure with asset classes but without products, 34% do not provide any information on where the capital will be invested before registration. As a result, we collected data from 20 RA providers of category A (ten from Germany, seven from the USA, two from the UK, one from Singapore). Two of these RA providers offer additionally topic-specific portfolio recommendations on sustainability (climate neutral investments) and gender diversity. These topic-specific portfolio recommendations were handled as separate RA in our analysis, as they were clearly distinguishable from the main

RA recommended portfolios. In addition, we found and analyzed 13 RAs of category B (seven from Germany, four from the USA, one from Switzerland and the UK). Lastly, we found 16 RAs which fit to category C and are therefore not considered within our analysis. Appendix Table 8 provides an overview of the analyzed RA per category and country of residence.

For each of the considered 36 RAs in categories A and B, the RAP was passed through six times, matching the distinct risk/investment horizon combinations of our defined model customers. Each corresponding portfolio recommendations was captured in our database. Since the data collection took place at a certain time period (September 01st, 2019 until October 10th, 2019), the RA portfolio recommendations are a snapshot and may not be identical in other periods. Figure 20 summarizes our described analysis approach.

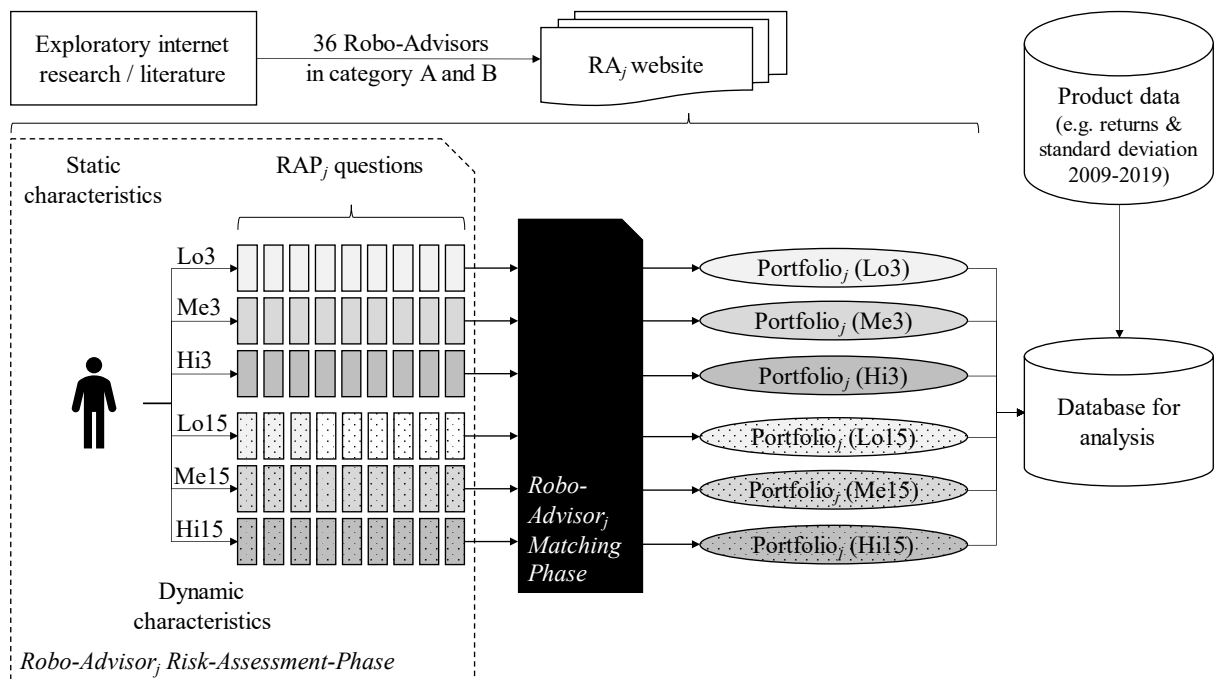


Figure 20. Analysis approach with risk-assessment and RA recommended portfolio capture

4.3.2 Analysis Measures and Statistical Test Procedures

Performance measures. The historical returns of the RA recommended portfolios are serving as our main performance measure for the analysis. Therefore, based on the daily closing prices, steady daily returns of the products were calculated for available data points (Steiner et al., 2017). Afterwards, the simple return rate of the total period could be calculated per product. The average annual return on a product was calculated using the geometric return for the available period. This ensures, that compared to the arithmetic mean, the intra-year interest on simple returns is considered (Mondello, 2018). By adding up the N products within the RA recommended portfolios, weighted according to their portfolio share, the average historical portfolio return per year could be obtained (Berk & Demarzo, 2019).

Risk measures. Within our analysis we used two indicators as a measure of risk: The standard deviation per year (volatility) and the Value at Risk (VaR). Firstly, to calculate the average annual standard deviation of a product, the daily standard deviation of the continuous daily returns was calculated for each product and afterwards annualized (Mondello, 2018). To calculate the standard deviation of an entire portfolio, a correlation matrix of daily returns of all considered products was created. Based on that matrix, we calculated the correlation coefficients of the individual assets contained in a portfolio (Berk & Demarzo, 2019). These correlation coefficients are used to calculate the mean portfolio variance, as well as the mean portfolio standard deviation p.a. In addition to volatility, the annual VaR serves as another highly established risk indicator for our analysis. The VaR can be understood as the total loss of an investment position, which with a certain probability, will not be exceeded in a certain period of time (Mondello, 2018). The VaR p.a. was calculated for confidence levels of 95% and 99% using the variance-covariance method. Thereby, the normally distributed annual standard deviations of the portfolios serve as the basis for calculation.

Sharpe Ratio. The Sharpe Ratio (SR) is a key figure that relates performance to risk. Based on Markowitz (Markowitz, 1952) and Tobin's findings on efficient portfolios, the SR is suitable to describe the best portfolio on an “Efficiency Line” using only one key figure (Sharpe, 1966). In our analysis, the SR was calculated for both products and portfolios and shows the excess return over the risk-free interest rate per unit of standard deviation (Sharpe, 1994). The excess return can be calculated by subtracting the risk-free interest rate from the mean annual portfolio return and dividing by the mean standard deviation p.a.

Statistical test procedures. Because most of our variables do not meet the normal distribution requirement for parametric tests, two nonparametric Signed-Rank tests were used for our analysis. The *Mann-Whitney-U-Test* was used to investigate the relationship between two unrelated samples. It is the non-parametric alternative to the t-test and checks the distinction between the mean values of the distributions of groups (Janssen & Laatz, 2017). The null hypothesis supports the equal distribution of the variable in the groups. Therefore, rejecting the null hypothesis significantly describes a non-random relation of the groups. The direction can be determined by the middle rank (Janssen & Laatz, 2017).

For k independent samples (groups) the *Kruskal-Wallis-H-Test* was used in conjunction with the *Dunn-Bonferroni-Test*. This corresponds to the single factor variance analysis for parametric data. Here, too, the correlations were tested for a statistically significant difference in the ranks of the groups formed in the 95% confidence interval. The first test shows whether the

groups differ significantly from each other. If they differ, those groups between which the difference exists are determined by pairwise comparisons. The preservation of the significance level α in repeated pairwise comparisons is ensured by the Bonferroni method (Janssen & Laatz, 2017). The effect strength r of the tests used can be approximated from the z value in SPSS, where $0 < r \leq 0.3$ describes a small, $0.3 < r \leq 0.5$ a medium and $r > 0.5$ a strong effect (Field, 2017).

4.4 Findings

4.4.1 Portfolio products and allocation

A total of $N=214$ different products are utilized by the analyzed RA in category A for their portfolio allocations, consisting of 143 ETFs ($\sim 2/3$) and 71 ($\sim 1/3$) mutual funds. The largest issuers of products are iShares by Blackrock with 25%, Vanguard Group with 11% and Xtrackers with 9%. The most frequently recommended products in the portfolios, measured by AuM, are Vanguard emerging markets ETF (VWO), the Vanguard FTSE developed markets ETF (VEA) and the iShares Core S&P 500 ETF (IVV). Figure 21 shows the return and risk (in form of standard deviation) box plots of all products, that are used within the RA recommended portfolios.

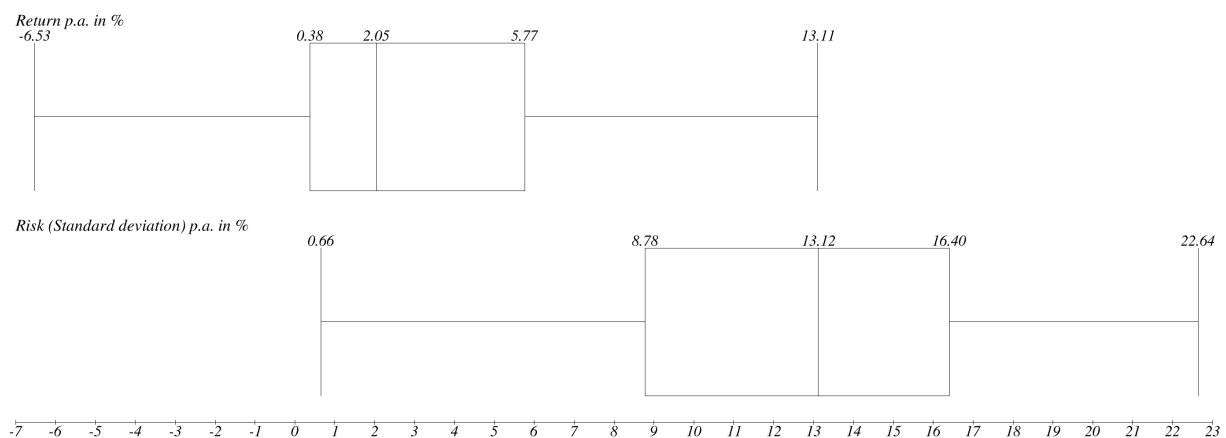


Figure 21. Return and risk (standard deviation) box plots of all RA used products

After analyzing the products used by the RA in isolation, we investigated the portfolio allocations of all 216 RA recommended portfolios (RAs of category A and B). Table 15 shows the average, minimum and maximum weightings of the asset classes within the RA recommended portfolios in percent. The asset weights do not sum up to 100% since some asset classes with low weights are left out.

	Lo3			Me3			Hi3		
<i>Asset class</i>	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
<i>Equities</i>	21.27	0	51	46.40	11	76	69.89	13	100
<i>Cash</i>	5.6	0	48	2.83	0	42	1.84	0	35
<i>Gold</i>	0.76	0	5	0.39	0	5	0.33	0	5
<i>Commodities</i>	0.65	0	7.5	1.3	0	6.1	1.45	0	12.5
<i>Government Bonds</i>	45.27	0	89	30.06	0	60	15.93	0	55
<i>Corporate Bonds</i>	25.38	0	80	17.36	0	36	8.94	0	30
	Lo15			Me15			Hi15		
<i>Asset class</i>	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
<i>Equities</i>	25.01	0	79	53.14	30	84	80.84	39.59	100
<i>Cash</i>	4.33	0	48	1.55	0	10	0.82	0	6
<i>Gold</i>	0.76	0	5	0.39	0	6	0.33	0	5
<i>Commodities</i>	1.38	0	7.5	1.5	0	11	1.31	0	10
<i>Government Bonds</i>	42.79	0	89	25.33	0	60	7.68	0	33
<i>Corporate Bonds</i>	24.91	0	80	16.33	0	35	7.24	0	32

Table 15. Portfolio allocation in % for each model customer

Since equity funds have a higher risk/return profile compared to the other asset classes, their portfolio weighting is often used as a risk-return indicator. We find that across all RA providers, the risk class determined in the RAP has a high impact on the recommendation of the RA. As the customer's risk affinity increases, the equity quota in the portfolio rises and the quotas of less volatile products, like government and corporate bonds, fall. With the change from the risk class low to medium, the equity ratio in the average portfolio increases by 100% for both investment horizons. When choosing a medium-risk instead of a high-risk profile, the result is an increase in the equity quota by 50%. The proportion of bonds decreases with the change from low-risk to medium-risk by about 30-40% and from medium-risk to high-risk by 50-70%. On average, the pairing of risk-affinity and portfolio recommendation regarding the asset class can be considered as working.

However, in terms of investment horizons, the three risk classes and their asset class ratios barely differ from each other: Major differences in the group averages are only noticeable between Hi3 and Hi15. The equity quota is 15% higher for the long-term portfolios, while the government bond quota is twice as high on average in the short-term portfolios at 15.90% vs. 7.68%.

The minima and maxima displayed in Table 3 show how different the RA recommended portfolios are. Especially, the Hi3 portfolios seem to vary highly between different RAs: For example, the equity ratios range between 13% and 100%. With an average annual VaR (95%) of 26%, equities have the highest volatility of the asset classes and therefore risk associated to

them. In this context, e.g. UBS recommends an investment horizon of at least five years for its equity funds. Nevertheless, for a high-risk/performance portfolio, the recommendation of a high ratio of equities can probably be justified for a short-term investment horizon. However, recommending a maximum equity allocation of 51% (79% for 15 years) for a low-risk/performance class and an investment horizon of three years seems questionable. The big differences between RA recommended portfolios show that there is little consensus between the RA on what the best investment strategies and therefore portfolio allocations are.

4.4.2 Portfolio Performance and Risk

In the following we present our findings regarding portfolio performance and risk. As stated in the methodology, this in-depth portfolio analysis could only be done with the recommended portfolios the 23 category A RAs. Figure 22 presents the μ - σ -chart for the $N=138$ portfolios of these RAs, with averages given for the six distinct model customers. To put the RA portfolios into relation, we also present three benchmark indices, that represent the asset classes equities (MSCI World), corporate bonds (Bloomberg Barclays Global Aggregate Corporate Bond) and government bonds (Bloomberg Barclays Global Treasury).

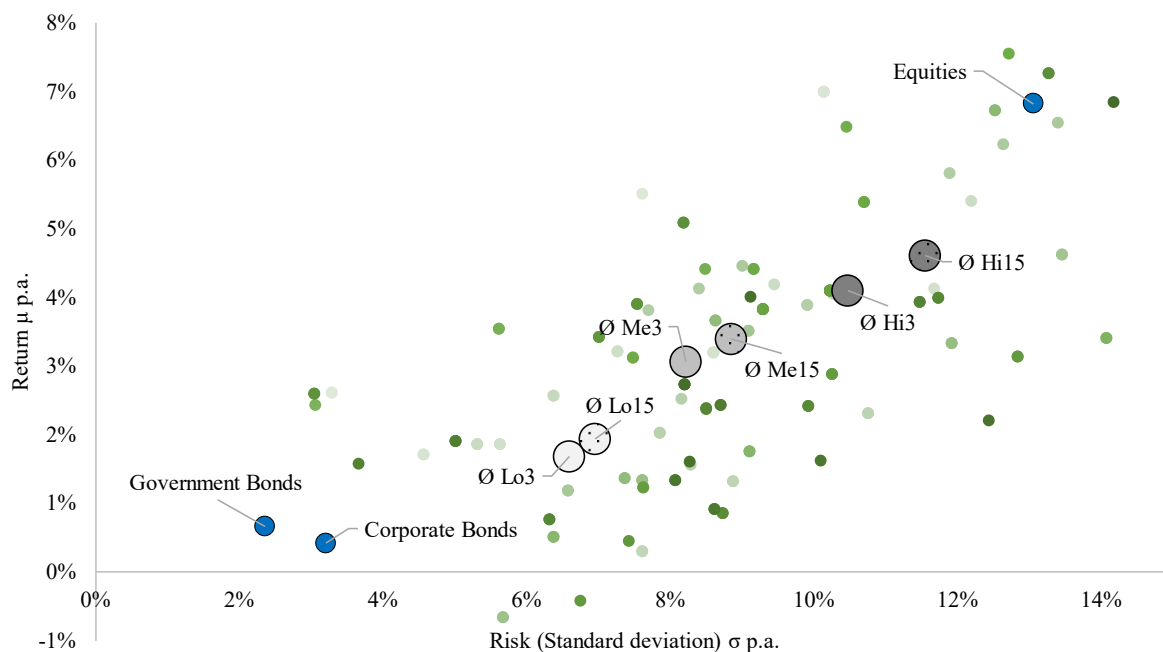


Figure 22. RA recommended portfolios of category A in the μ - σ -chart with benchmark indices (October 2009 to October 2019)

It is noticeable, that there are major differences between the RA portfolio recommendations. Many portfolios exist that dominate others with the same risk and higher returns p.a. or vice versa. However, these differences can't be significantly grouped by the investment horizon of portfolios. On average, portfolios recommended for a term of three years have an annual return of 2.95% and a standard deviation p.a. of 8.43%. Portfolios with an investment horizon of 15

years have an annual return of 3.3% and a standard deviation p.a. of 9.1%. The statistical analysis of these two groups using the Mann-Whitney-U-test does not show significant differences for the variables return p.a., standard deviation p.a., VaR p.a. (95%) and SR p.a. Therefore, it can be stated, that investment horizons play a minor role in RA portfolio recommendations.

In contrast to the investment horizon groups Table 16 shows by utilizing the Kruskal-Wallis-H-Test, that the portfolio recommendations differ significantly for each risk class regarding their return p.a., standard deviation p.a. and partly SR p.a. As expected, the greatest difference can be observed in the risk/return combination from the lowest to the highest risk class. We also found a positive correlation between the mean values of the risk classes, which implies that a higher return is associated with a higher risk within the portfolio. Lastly, the group of the risk class “low” has significantly lower returns per unit of risk (measured by the SR p.a.), than the other two risk classes.

Summarizing our findings, it can be stated that a higher risk-affinity entered in the RAP does lead to the recommendation of a higher risk/performance portfolio. In contrast, a lower risk-affinity leads to significantly lower risk/performance portfolio recommended by the RAs. The RAP and matching phase of the analyzed RA therefore work as intended.

<i>Kruskal-Wallis-H-Test</i>	Risk class/ Product	N	Mean values (left) & middle rank (right) for each variable					
			Return p.a.		Standard deviation p.a.		Sharpe-Ratio p.a.	
<i>RA Portfolios</i>	Low	46	1.70%	38.52	6.35%	37.52	0.22	46.93
	Medium	46	3.22%	73.11	8.48%	65.63	0.35	77.63
	High	46	4.38%	96.87	11.08%	105.35	0.37	83.93
	Total	138						
<i>Pairwise comparisons</i>			Corr.Sig. by Bonferroni (2-sided) (95%)			Effect strength r		
<i>Return p.a.</i>	Lo-Me		$\rho < 0.001^*$			0.433		
	Lo-Hi		$\rho < 0.001^*$			0.730		
	Me-Hi		0.013*			0.297		
<i>Standard deviation p.a.</i>	Lo-Me		0.002*			0.352		
	Lo-Hi		$\rho < 0.001^*$			0.848		
	Me-Hi		$\rho < 0.001^*$			0.497		
<i>Sharpe-Ratio p.a.</i>	Lo-Me		$\rho < 0.001^*$			0.384		
	Lo-Hi		$\rho < 0.001^*$			0.463		
	Me-Hi		1.000			-		

Table 16. Portfolio analysis concerning risk classes

4.5 Discussion

4.5.1 Implications

The results of our study provide several important implications for practice and research. Our analysis shows that interested investors should not trust their preferred RA blindly. Especially when considering shorter investment horizons, investors should be aware that RA, despite of their high volatility, often use large shares of equities in their recommended portfolios. This may be due to the need of RA to offer clients a high return, but it also has the disadvantage, that if a crisis occurs and the investment horizon is exceeding, a loss must be realized.

RAs intend to offer solutions for their risk-averse investors with short-term investment horizons but providing such solutions within the current low-interest market can be complicated, and therefore too complex for RAs. The volatility of equities and bonds makes it at least questionable to invest in short-term time horizons using trading algorithms based on passive investments and diversification strategies, that are often used within RAs (Jung et al., 2018; Sironi, 2016). To provide a more sophisticated financial advisory service, RAs need to consider more financial products with lower volatility for short-term investments like savings accounts. An alternative approach is to neglect short-term investment horizons entirely like Scalable Capital does, thus refusing to provide a portfolio recommendation for short-term investment horizons. This seems to be, when no other options provided, the best advice a RA could give to a short-term investor. Finally, our analysis indicates, that the analyzed RA do not include the captured data sufficiently into their recommendation process, or a high amount of information does not change the recommended portfolio structure. Thus, we agree with Faloon & Scherer (2017) and state, that RA provider should use the data captured within the RAP for more individualized portfolio recommendations or improve the RAP in a way, that RAs just ask for information, that is actually used within their recommendations.

4.5.2 Limitations and Future Research

Despite the careful design of our study, this paper is subject to several limitations. Firstly, since our data collection took place at a certain time period between September and October 2019, the recommendations of the RAs are only a snapshot and may not be identical with recommendations from other periods. Within our analysis we did not capture the maintenance phase of the RA. Therefore, we cannot provide insights on how often and to which degree the different RA are rebalancing their recommended portfolios. By analyzing the portfolios of the RA at various times, the changes within the portfolio recommendations could be observed and

analyzed. Also, it can be of interest, how the RA approach the more volatile financial markets after the financial crash due to the Coronavirus-pandemic.

Another limitation regarding our analysis can be seen in the data collection from the perspective of six distinct customer models, having different risk-affinities and investment horizons. While carefully modelling the dynamic characteristics of our model customers and rigidly going through the RAPs, it is possible, that occasionally questions couldn't be answered with confidence according to the risk-affinity of the model customer. Also, more granular portfolio changes through more differentiating individual customer profiles, e.g., by varying our static characteristics, could be helpful to collect more varying RA recommended portfolios. This can lead to a broader understanding of the relationship between the RAP and RA recommended portfolios.

Lastly, the different monetary policies of the US Federal Reserve System (FED) and the European Central Bank (ECB) lead to separate market conditions in the country groups, which made comparisons difficult. This problem could be solved by considering different interest rates at least for the calculation of the SR p.a. Due to the lack of appropriate conditions for parametric tests, the non-parametric alternatives were used. These characterize in a lower test strength but are considered more robust. The results of the tests were clear and plausible, so there is no reason to assume, that the type of statistical test mislead our results.

4.6 Conclusion

Previous research on Robo-Advisors imply, that they provide basic investment advice and management. This paper aimed at providing new insights on the question of how RA recommended portfolios are structured, especially concerning performance and risk. Therefore, we analyzed a sample of 36 RA and 216 distinct recommended portfolios for six defined model customers, between September and October 2019.

The results of our study state several important implications for practice as well as for research. Firstly, we show that the basic investment advice of RA functions sufficiently, providing appropriate investment advice, at least for higher risk-affinities and long-term investment horizons. The recommendations of the various providers however vary greatly, especially for customers with a short-term investment horizon and high risk-affinity. When the investment horizon is getting into mid- or short-term territory, RA recommend on average very risky portfolio allocations for passively managed investment portfolios. Furthermore, we show that investment horizons play a subordinate role in the recommendation of a RA portfolio, despite its impact on the long-term return of especially volatile asset classes like equities.

5 Taming the Next Wolf of Wall Street – Design Principles for Ethical Robo-Advice

<i>Authors & Contributions</i>	Albert Torno, albert.torno@uni-goettingen.de	Idea, data analysis and structuring, interviewing, interpretation, visualization, writing, text revision
	Siska Bähnsch, s.baehnsch@stud.uni-goettingen.de	Idea concretization, data acquisition, preliminary data analysis, text revision
	Moritz Dreyer, moritz.dreyer01@stud.uni-goettingen.de	Idea concretization, data acquisition, preliminary data analysis, text revision
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<i>Abstract</i>	Automated investing in form of Robo-Advice (RA) has promising qualities, e.g., mitigating personal biases through algorithms and enable financial advice for less wealthy clients. However, RA is criticized for its rudimentary personalization ability questioning its fiduciary duties, nontransparent recommendations and violations of data privacy and security. These ethical issues pose significant risks, especially for the less financially educated targeted clients, who could be exploited by RA as illustrated in the movie “Wolf of Wall Street”. Yet, a distinct ethical perspective on RA design is missing in literature. Based on scientific literature on RA and international standards and guidelines of ethical financial advice we derive eight meta-requirements and develop 15 design principles, that can guide more ethical and trustworthy RA design. We further evaluated and enhanced the design artifact through interviews with domain experts from science and practice. With our study we provide design knowledge that enables more ethical RA outcomes.	
<i>Keywords</i>	Robo-Advice, Ethical Financial Advice, Design Principles	

Table 17. Fact sheet of paper 5

5.1 Introduction

Investing is becoming increasingly digital and automated enabled through disruptive financial technology (FinTech) (Gomber et al., 2018; Sironi, 2016). One novel business model within the FinTech sector is Robo-Advice (RA) (Eickhoff et al., 2017; Gomber et al., 2017). Robo-advisors (RAs) guide investors through an automated financial advice process, recommend personalized portfolio assignments based on their risk-affinity and financial goals, and monitor as well as rebalance their portfolios automatically over time (Jung et al., 2018; Sironi, 2016). Hence, RAs take on the role of traditional financial advisors and have promising attributes, e.g., accessibility independent of time and location, less costs, lower minimum investment amounts and a consistent decision making process decreasing psychological pitfalls (Beketov et al., 2018; Jung et al., 2019). However, RA also encompasses problems. For example, fast-evolving technologies are often criticized for unintended negative consequences such as algorithmic bias or discrimination (e.g., Müller & Kerényi, 2019; Veale & Binns, 2017). Respectively, RAs can be seen as “black-boxes” of algorithms with a high scalability of possible bad advice, violating client and stakeholder interests (Baker & Dellaert, 2018; Ji, 2017). Due to the RA’s rudimentary personalization ability, RA’s compliance with fiduciary duties has also been questioned (Tertilt & Scholz, 2018). Furthermore, violations of privacy and security have been reported (e.g., Scalable Capital, 2021) that can diminish customer trust. These ethical problems could give rise to RAs that are not acting in the best interests of its clients and even exploit them. The movie “Wolf of Wall Street” illustrated into which direction such non-ethical financial advice can lead in the context of traditional financial planning.

Unethical behavior that manifests itself in scandals or ombudsman decisions is decreasing customer trust in the advisory service (Richards et al., 2021). Trust was found to be a strong pre-requisite for RA adoption (e.g., Cheng et al. 2019; Guo 2020). Laws regulating the financial sector have the objective to enhance trust between market participants and especially protect investors by directing advisors to act ethically (Maume, 2019). While guidelines on ethical traditional financial advice exist, it is not clear, what exactly these directives mean for RA and how RAs should be designed to ensure these goals are met. A recent RA literature review found that existing research on RA design concentrated on the degree of delegation and automation (e.g., Rühr et al., 2019), the degree of humanization, including conversational abilities (Morana et al., 2020; Ostern et al., 2020), and mitigation of behavioral biases of investors (e.g., Adam et al., 2019; Jung et al., 2017), while neglecting ethical considerations (Torno, Metzler, et al., 2021). Therefore, we address this research gap by proposing the following research question (RQ):

What are relevant design principles to establish ethical considerations in RA design and increase its trustworthiness?

To answer the RQ, we derive meta-requirements (MR) and develop design principles (DP) based on scientific literature on RA, as well as standards and guidelines for ethical financial advice. We thereby contribute to research by providing a blueprint for ethical considerations in RA. This should enable designers to develop RAs that are more ethical and trustworthy, increasing the financial well-being of not only clients but also stakeholders and society.

In the following, we provide the theoretical background of this study and introduce our design science research (DSR) approach. We then present Design Dimensions (DD), Meta-Requirements (MR) and corresponding Design Principles (DP) for more ethical RA. Afterwards, we present the evaluation of the MRs and DPs through expert interviews. Subsequently, we discuss our findings as well as the implications and limitations of our study. Our conclusion summarizes the most important insights.

5.2 Theoretical Background

RAs can be defined as Information Systems (IS) that guide private investors through an automated financial advisory process, recommend personalized portfolio assignments based on their individual risk-affinity and financial goals, and monitor as well as rebalance their portfolios automatically over time (Jung et al., 2018; Sironi, 2016). Instead of a human financial advisor, RAs subsequently analyze and quantify information about the financial situation of clients by using automated algorithms and risk models, which are built upon financial theories before recommending and implementing a suitable portfolio allocation (Beketov et al., 2018; D'Acunto et al., 2019). Thereby, RA can be seen as a substitute for human financial advice eliminating almost all human interaction between the client and RAs (Beketov et al., 2018).

Despite its benefits, RA adoption falls short of expectations (D'Acunto et al., 2019). While the most critical adoption factor for RA is the perceived trust in the service (e.g., Cheng et al. 2019), ethical issues that reduce trust become gradually latent but not resolved (D'Acunto et al., 2019; Fein, 2015; Jung et al., 2019). Conflicts of interest might occur due to RA clients being exposed to information asymmetries, typical for principal-agent relationships, resulting in the advisor recommending products that are not in the best interest of their clients (Eisenhardt, 1989a; Nussbaumer et al., 2012). RA conflicts, thereby, may have an even larger and more certain impact than conflicts of traditional human advice. While some human advisors may be influenced by outside motivations or tempted by kickbacks or bonus incentives, biased RA will certainly impact all clients and their investment performance (Ji, 2017).

To mitigate conflicts of interest, further ensure the quality of advice and increase trustworthiness, ethical considerations are critical not only in the regulation of financial advice (Boatright, 2010; Müller & Kerényi, 2019) but also in the adoption of RA (X. Cheng et al., 2019; L. Guo, 2020). While ethics in general is defined as “the study of what is morally right and wrong” (Cambridge Dictionary, 2022), ethics in finance is concerned with moral issues arising from economic transactions among individuals and organizations. Ethics is thereby questioning what is believed to be “fair” in the financial markets and which rights and obligations market participants have (Boatright, 2010). Therefore, internationally recognized organizations have developed standards and guidelines for traditional financial advisors to ensure ethical behavior in their service provisioning (CFA Institute, 2014; CFP Board, 2018; IMA, 2017; International Organization for Standardization, 2005). The most cited ethical characteristics are integrity, objectivity, competence, fairness, confidentiality, credibility, professionalism, and diligence (Boatright, 2010; International Organization for Standardization, 2005). Although, these standards and guidelines provide a general perspective on how traditional financial advisors should behave ethically, they fall short on providing applicable design guidelines for ethical RA.

Besides ethics in finance, research in different subdisciplines of computer ethics and DSR emerged recently. Thereby, the relevance of ethical considerations and its practical implementation becomes more elaborated in recent studies (e.g., Benke et al., 2020; Myers & Venable, 2014). Mason (1986) firstly addressed ethical issues of the information age such as privacy, accuracy, property, and accessibility. More recent studies have reviewed existing ethical AI Principles and found that the missing considerations of ethics in IS are mainly due to the impaired linkage between the abstract ethical principles and the technical implementation (Hagendorff, 2020) as well as the overall lack of implementation strategies (Jobin et al., 2019). Some studies have discussed the topic of ethical AI regarding systemic risks (e.g., Crawford & Calo, 2016) or unintended negative consequences such as algorithmic bias or discrimination (e.g., Veale & Binns, 2017). Although scientific literature is evolving, most recognized publications are issued by private organizations, e.g., Google (2021) and Microsoft (2021) that rely on AI for their business purpose, and international organizations, e.g., the European Commission (2019) which are concerned with the societal well-being (Jobin et al., 2019). However, since it is not evident that contemporary RAs are using AI for their automated recommendations (e.g., Bianchi and Briere 2021), the guidelines and considerations by the AI ethics literature are not directly applicable for the design of ethical RA.

We define ethical RA as treating clients fairly, without harming them or society by encompassing commonly in literature agreed upon ethical attributes such as competence, confidentiality,

integrity, and credibility (e.g., IMA, 2017). Including ethical considerations in RA design thereby ensures that the RA meets its fiduciary duties and acts in the best interests of clients by increasing its transparency and trustworthiness.

5.3 Design Science Research Approach

To answer our RQ, we follow the DSR approach according to Hevner (2007). This allows us to not only generate knowledge and improve the understanding of the problem of designing ethical RA but also helps to solve relevant issues for society, organizations, and individuals (Gregor & Hevner, 2013). DSR describes an iterative process that links existing knowledge with the practical environment, divided into three respective research cycles: The relevance cycle establishes the initial context, determines the requirements for the design artifact, and defines the criteria that characterize the artifact as useful. The rigor cycle provides the scientific grounding and includes the communication of the design knowledge gained. The design cycle represents the core of the structured research process and is used to develop and evaluate the design artifact, including the before-mentioned insights from the environment and knowledge base (Hevner, 2007; Hevner et al., 2004). An overview of our DSR approach is shown in Figure 23.

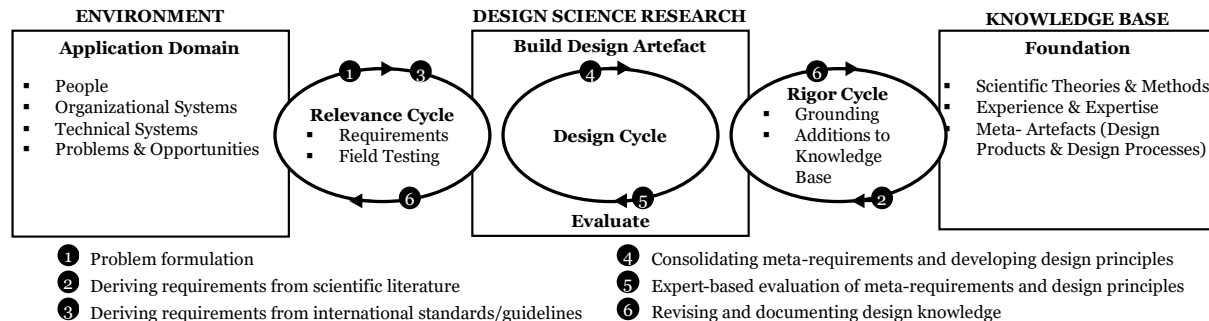


Figure 23. Visualization of our design science research approach

The first step of the DSR method consists of the problem formulation whereby the relevance for more ethical RA has already been described in the introduction and theoretical background of this paper. In the second and third step we derived requirements from scientific knowledge and respectively international standards and guidelines. A visual representation with details of the performed systematic literature review and search for relevant standards and guidelines can be obtained from Figure 24.

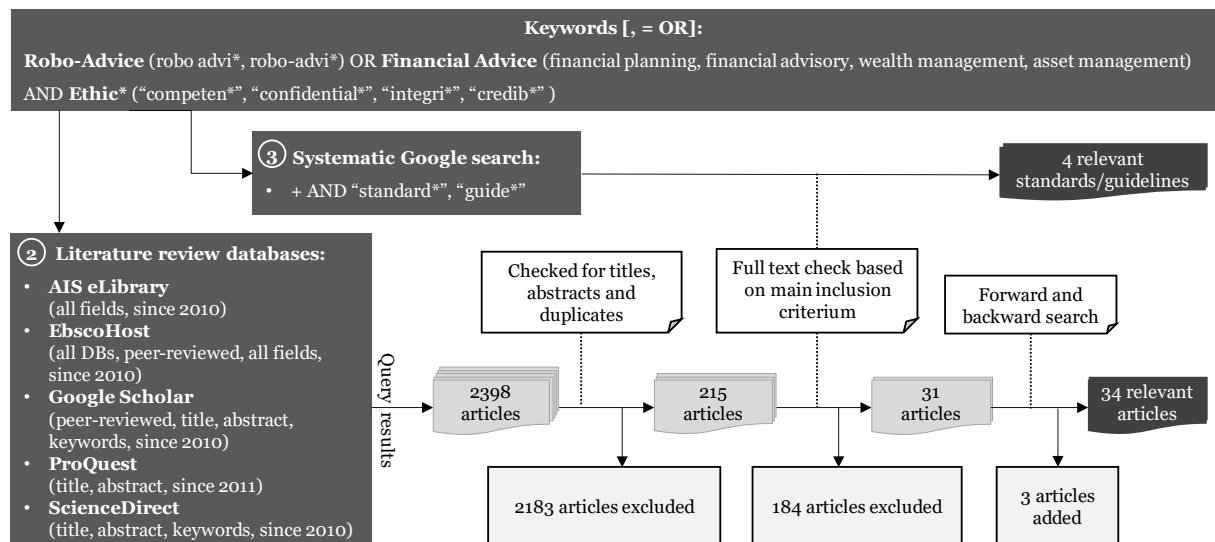


Figure 24. Process of the systematic literature review and search for relevant standards and guidelines (DSR approach steps 2 and 3)

Firstly, we conducted a systematic literature review using the method by Webster and Watson (2002) since it is the most used approach in IS research and well documented (Brendel et al. 2020). We searched five databases for scientific publications containing keywords of the domains “Robo-Advice” and “Financial Advice” in conjunction with “Ethic” and previously mentioned ethical values such as “competence”, “confidentiality”, “integrity” and “credibility”. Thereby, we chose to limit the search to articles published after 2009 to comply with the actual state of technology. Afterwards, we checked the found articles for titles and abstracts and excluded duplicates. Besides checking for topic relevancy, we thereby esp. used quality criteria to include only completed published scientific studies with comprehensible results. Further, we thoroughly reviewed the resulting long list of articles and checked for relevance using the following main inclusion criterium: Articles must allude to descriptions of ethical issues in the robo-advice domain and/or provide ideas for their solution. Lastly, we performed a forward and backward search for these articles, resulting in our final pool of 34 relevant scientific articles.

For the third step, we extended this knowledge pool by deriving requirements from international standards and guidelines for ethical financial advice. As mentioned in the background section, we do not consider current RA as AI-based, and therefore did not incorporate AI ethics standards/guidelines for our analysis. To find relevant standards and guidelines that meet our main inclusion criterium, we performed a systematic Google search: We used the parameters from the systematic literature review (financial advice OR robo-advice AND ethics) and extended the search terms “standard*” or “guide*”. To provide an international perspective, we excluded national standards e.g., from the German BaFIN or the American Institute of CPAs. A list of the relevant international standards and guidelines are presented in Table 18.

Standard/Guideline	Issuer	Year
ISO 22222 –Requirements for personal financial planners	International Organization for Standardization (ISO)	2005
Codes of ethics and standards of professional conduct	Chartered Financial Analyst Institute (CFA)	2014
Statement of ethical professional practice	Institute of Management Accountants (IMA)	2017
Code of ethics and standards of conduct	Certified Financial Planner Board (CFP)	2018

Table 18. Relevant international standards and guidelines for ethical RA

We read the final pool of articles and standards/guidelines extensively and employed the qualitative content analysis approach by Mayring (2014) coding the articles and standards/guidelines inductively to extract requirements and possible solutions for ethical RA. Thereby, the categorization of collected data results from the material itself, not from theoretical considerations, mitigating possible biases owing to preconceptions of the researchers (Mayring, 2014). In our approach, the first two researchers coded half of the relevant documents openly, creating two separate category systems. As proposed by Mayring (2014), these categorizations were questioned and revised in the entire author team after coding half of the data. We agreed on and verified a unified category system and used it to analyze all documents for ethical RA requirements and possible solutions. In the fourth step, we consolidated the identified requirements into MRs to express the goals of the ethical RA design. Based on these MRs, and our systematized knowledge base, we developed DPs that should benefit these goals and guide ethical RA design. We finalized the coding procedure as well as MR and DP formulation based on discussions within the entire author team.

In step five, we performed an expert-based evaluation by conducting semi-structured interviews in line with Venable et al. (2016) to evaluate our MRs and DPs. Lastly, in step six we revised our design artifact based on the experts' insights and present it in form of new design knowledge in this study.

5.4 Meta-Requirements and Design Principles for Ethical RA

Our fundamental assumption is, that if a human advisor acts ethically when adhering to the principles for ethical financial advice, then IS, in this case RAs, should also act ethically when adhering to these principles. Therefore, we structured the MRs and DPs for ethical RA into four Design Domains (DDs) based on four main values of ethical financial advice: Competence, confidentiality, integrity, and credibility. We identified a set of eight MRs and subsequently developed 15 DPs for ethical RA. While the MRs express the goals that ethical RA should achieve, the DPs are formulated as possibilities that benefit the attainment of these goals

(Diederich et al., 2020). We thereby employ the DPs notation scheme from Chandra et al. (2015), who propose that DPs should incorporate actions (or activities of users), material properties (in terms of form and function) and boundary conditions (user group’s characteristics or implementation settings) (Chandra et al., 2015). In the next four subsections we present and provide the rationale for the MRs and DPs for more ethical RA. An overview of our design artifact can be obtained from Table 19.

<i>Design Domain (DD)</i>	<i>Meta-Requirement (MR)</i>	Design Principle (DP)
<i>DD I Competence</i>	<i>MR I Expertise</i>	DP 1: Maintain, improve, and act in accordance with knowledge in financial markets and products, financial models, and algorithms as well as rules and regulation of financial advice to provide objectively correct and high-quality advice.
		DP 2: Explain the RA reasoning process to make its expertise objectively assessable and enroll in certification processes and consumer tests to signal trustworthiness.
	<i>MR II Professionalism</i>	DP 3: Provide agreed upon services while reducing information asymmetries by offering sufficient information about the entire advice process, asset handling and service costs to achieve transparency, so clients can make informed judgments.
		DP 4: Understand and validate client’s financial situation, needs and goals objectively and make only suitable recommendations in the client’s best interest.
<i>DD II Confidentiality</i>	<i>MR III Privacy</i>	DP 5: Inform transparently about information handling and usage and establish robust processes to safeguard the right of clients to their data while maintaining regulatory duties to signal the safety and reliability of the RA.
	<i>MR IV Security</i>	DP 6: Provide secure internal infrastructures and enable secure data, money and asset transfers encouraged by internal policies and audited regularly through external experts so clients feel protected against any cyber harm.
<i>DD III Integrity</i>	<i>MR V Independence</i>	DP 7: Avoid conflicts of interest and if a conflict of interest is suspected, disclose it promptly to signal RAs independence.
		DP 8: Always prioritize client's interests and act accordingly to prevent misconducted advice.
	<i>MR VI Fairness</i>	DP 9: Serve targeted clients equally without discrimination and ensure that the recommendations provided are understandable and effective for the specific client enhancing perceived fairness.
		DP 10: Educate clients to better understand financial information and advice, and thereby improve financial inclusion.

<i>DD IV</i> <i>Credibility</i>	<i>MR VII</i> <i>Responsibility</i>	DP 11: Be honest and make only true statements about RA capabilities as well as limitations and disclose responsibilities to signal transparency.
		DP 12: Regularly evaluate used financial products and inform transparently about portfolio composition so that clients understand in what industry sectors and companies they invest.
		DP 13: Update clients proactively, regularly to their liking and provide context and recommendations to the given information.
	<i>MR VIII</i> <i>Guidance</i>	DP 14: Provide easily accessible guidance following proven design practices while informing the client clearly and concisely about process steps and portfolio performance.
		DP 15: Increase social presence and provide human assistance when needed to improve client's confidence in using the RA.

Table 19. Design dimensions (DDs), meta-requirements (MRs), and design principles (DPs) for ethical RA

5.5 Design Domain I – Competence

Competence is defined as having the ability and skills to do its job (Cambridge Dictionary 2022). Ethical RAs therefore need to be equipped with sufficient expertise and professionalism guaranteeing a high quality of the advisory process while ensuring its fiduciary duty.

5.5.1 MR I – Expertise

RAs shall have the necessary financial knowledge to provide competent advice (Boatright, 2010) while understanding the nature and scope of the engagement (International Organization for Standardization, 2005). For that, RAs should maintain and improve their knowledge about all relevant financial products available on the market (CFA Institute, 2014). Also, RAs should not specialize on certain asset classes, since this could lead to biases towards these asset classes (Boreiko & Massarotti, 2020). Expertise in the RA domain also means knowing how to model the financial knowledge into automated algorithms. For that, experts need to develop, govern and supervise the algorithms at all times (L. Guo, 2020). RAs should also have knowledge of all relevant processes, rules and regulations related to personal financial planning (International Organization for Standardization, 2005). Finally, RAs need to act in accordance with that knowledge.

DP 1: Maintain, improve, and act in accordance with knowledge in financial markets and products, financial models, and algorithms as well as rules and regulation of financial advice to provide objectively correct and high-quality advice.

Since clients need to assess the expertise of RAs, ethical RA design includes providing sufficient information about its expertise (Ji, 2017). The information provided by the RA must be of high quality, sufficient quantity and up-to-date (Ruf et al., 2015). RA providers should thereby explain the models and data on which the financial models are based on, the outcomes

that the algorithms are seeking, and provide evidence that the algorithms perform in the way they are designed (Baker & Dellaert, 2018). Explaining the RA's reasoning process was found to improve the perceived competence and goodwill directly (M. Wu & Gao, 2021). Additionally, providing information about previous activities and results, e.g., in form of key performance indicators of the RAs (Tauchert & Mesbah, 2019) and how long the RAs have been active on the market may show their experience which can be perceived as expertise (Mesbah et al., 2019). Certifications issued by recognized institutions can also improve perceived expertise. Since RAs cannot be certified like human financial advisors (L. Guo, 2020), they can voluntarily certify their processes through financial institutions and enroll in consumer tests, which objectively compare their service to that of their competitors. Finally, RAs should inform to which national and international laws they are obliged to and which institutions are monitoring them (Wambsganss et al., 2021).

DP 2: Explain the RA reasoning process to make its expertise objectively assessable and enroll in certification processes and consumer tests to signal trustworthiness.

5.5.2 MR II – Professionalism

RAs shall perform the financial services with care, diligence and reliability, which can be subsumed as having a professional attitude (Boatright, 2010). Firstly, professionalism involves that RAs should provide all services that have been agreed upon in the engagement sufficiently (International Organization for Standardization, 2005). To deliver better comprehensible services and reduce the information asymmetry between client and advisor, RAs need to provide transparency regarding the advisory process and cost structure (Bai, 2021; Rühr, 2020; M. Wu & Gao, 2021). For that, RAs need to provide necessary information and explanations on their inner workings at every step of the process (Rühr, 2020; M. Wu & Gao, 2021). To help clients understand better what the RAs activities and objectives are, they should explain how the client information provided relates to their recommendations (Mesbah et al., 2019). Process transparency could therefore even imply opening the “black-box” of RA algorithms to clients, describing how the matching of risk profile to portfolio recommendation actually works (Litterscheidt & Streich, 2020). Concerning clients' assets, RAs should inform, e.g., about restrictions that could limit client's access to their funds, and the disinvestment process, including withdrawal conditions and fees (Fein, 2015; M. Wu & Gao, 2021). Furthermore, the general cost structure should be presented transparently to give the client an overview of the separate costs incurred (Jung et al., 2017; Nussbaumer et al., 2012). Cost transparency could be further improved by providing interactive cost calculators, based on the projected individual client's investment amount (Jung & Weinhardt, 2018).

DP 3: Provide agreed upon services while reducing information asymmetries by offering sufficient information about the entire advice process, asset handling and service costs to achieve transparency, so clients can make informed judgments.

A competent RA should only recommend suitable products to the individual client (Baker & Dellaert, 2018). RAs should thereby base their recommendations objectively on fact-based information regarding the client's situation and needs to mitigate personal judgments and biases (Baker & Dellaert, 2018; Boatright, 2010; International Organization for Standardization, 2005). It has been stated that RAs often lack sufficient analysis of the clients overall financial situation, leading into the problem of not fulfilling their fiduciary duty (Strzelczyk, 2017; Tertilt & Scholz, 2018). Ethical RAs should understand the entire financial situation, needs and goals of the client and act in accordance with that knowledge. Therefore, RAs need to generate a full financial needs analysis of the client's current and projected situation, in the context of confirmed goals of the client (Chuck, 2019). Presenting openly the interpretation of the situation by the RA could allow the client to explore the validity of their answers and gives them the opportunity to correct possible misinterpretations (Chuck, 2019; Kilic et al., 2017; Scholz, 2021). RAs should thereby allow clients to modify their recommendations (M. Wu & Gao, 2021).

DP 4: Understand and validate client's financial situation, needs and goals objectively and make only suitable recommendations in the client's best interest.

5.6 Design Domain II – Confidentiality

Confidentiality is defined as keeping private information secret (Cambridge Dictionary 2022). Ethical RA therefore needs to safeguard the privacy of clients and their data and protect the data against inside and outside security threats.

5.6.1 MR III – Privacy

RAs shall respect and safeguard privacy and mitigate concerns to build trust with the client (Ruf et al., 2015). Firstly, RA should be clear and honest about their data collection and usage (Wambsganss et al., 2021). RAs should be transparent about what information is collected, processed and shared (Ruf et al., 2015; M. Wu & Gao, 2021). The ePrivacy Regulation by the European Commission only allows to process data if it is necessary to provide the service or meet the pursued quality, to maintain or restore the security of the service or detect technical faults, for billing or other financial or auditory purposes and if the users have given their explicit consent to do so (European Commission, 2019; Ostern et al., 2020). So, ethical RAs should give clients the ability to monitor which personal information is used for which purpose, how

the data is relevant for RA decisions to facilitate clients stated objectives and why certain data points are needed for service provision (Chuck, 2019; Jung et al., 2017; Rühr, 2020). RAs could also allow clients not passing on certain private information, even when this could lead to decreased advisory precision (M. Wu & Gao, 2021). Secondly, RAs have the obligation to keep private information confidential and to protect it (Boatright, 2010; CFP Board, 2018). This includes not only the information of present clients, but also former clients and all involved stakeholders (Myers & Venable, 2014). Thereby, the regulatory duties, i.e., identity checks that mitigate money laundering or terrorist financing and the business interests of RAs, i.e., sharing client profiles, may conflict with privacy rights of clients (International Organization for Standardization, 2005; Maume, 2019). While the GDPR provides individuals the right to have their personal data erased immediately, MiFID II requires financial firms to maintain a record of clients' information for at least five years with as much detail as possible (J. Lee, 2020). Therefore, RAs need to establish robust data privacy policies and processes to ensure the individual's right to their data and the societal safety in form of market integrity (J. Lee, 2020; Ostern et al., 2020). RAs can increase the robustness of these processes by assigning compliance roles and responsibilities for internal monitoring and raise awareness for privacy concerns through dedicated training. Also, the internal controls and collected information could be regularly reviewed by third parties, e.g., regulatory authorities and external experts (Ostern et al., 2020).

DP 5: Inform transparently about information handling and usage, and establish robust processes to safeguard the right of clients to their data while maintaining regulatory duties to signal the safety and reliability of the RA.

5.6.2 MR IV – Security

RAs shall secure sensible data and its algorithms from inside and outside attacks. Firstly, a reliable information technology infrastructure needs to be in place (Baker & Dellaert, 2018; L. Guo, 2020). The RA should therefore implement and maintain recent security standards and processes. To mitigate the possibility of third parties compromising the data transfer as well as money and asset transaction processes, RAs should use recent security standards and processes to prevent and detect cyber security threats. Security measures can take the form of encrypted data transmission, server and client certificates, two-factor authentication, and firewalls (Ruf et al., 2015; Scholz, 2021). To mitigate internal data leakages security arrangements should prevent unauthorized access to the internal data and algorithms and enable RAs to control and monitor all modifications (L. Guo, 2020; Ostern et al., 2020). For both internal and external cyber-crime prevention, regular security checks and periodic testing should be performed to

ensure that the data security is always considered and up-to-date (Strzelczyk, 2017; Wambsganss et al., 2021). The RA design should further signal the protection of client data so that the client feels protected from any misuse or harm (Wambsganss et al., 2021). For example, awareness campaigns and advertisements can highlight the adherence to mechanisms that protect client data (Gan et al., 2021). Additionally, certifications or regular independent external audits can verify the RA provider's compliance to recent security standards (Scholz, 2021). Lastly, to control the severity of potential compromised security, insurances obtained to cover leaks and sufficient plans for incident management and business continuity in case of cyber-attacks should be established (Ostern et al., 2020; Strzelczyk, 2017).

DP 6: Provide secure internal infrastructures and enable secure data, money and asset transfers encouraged by internal policies and audited regularly through external experts so clients feel protected against any cyber harm.

5.7 Design Domain III – Integrity

Integrity is defined as having strong moral principles that are not changed (Cambridge Dictionary 2022). Ethical RA therefore needs to act independently and responsible in the best interest of their clients.

5.7.1 MR V – Independence

RAs shall be independent from biased, self-centered goals as well as goals by third parties. Thereby, RAs should avoid any conflicts of interest and if a conflict of interest is suspected, to disclose it promptly (International Organization for Standardization, 2005). RAs often use affiliated brokers, custodian banks or other firms to provide their services (Ji, 2017). Thereby, RAs may receive compensation, e.g., for order flow in exchanges, for routing trades to a clearing firm or use deposits of an affiliated bank for cash sweep allocations (Fein, 2015). Own investment products are often used as well, ones sponsored by affiliates or from which they and/or their affiliates receive fees (Fein, 2015). To avoid conflicts of interest affecting the underlying financial products of recommended portfolios, the RAs should transparently disclose at the beginning of the advisory process which brokers are worked with and which companies issue the used financial products (Jung et al., 2019). Moreover, an RA should disclose any compensation or other arrangements that have potential to bias the advice adverse to the clients' interests (Baker & Dellaert, 2018). Furthermore, RAs should provide sufficiently specific facts and explanations, so that the client is able to understand the conflicts of interest and can give informed consent or reject the advice (Ji, 2017).

DP 7: Avoid conflicts of interest and if a conflict of interest is suspected, disclose it promptly to signal RAs independence.

Besides avoiding and disclosing conflicts of interest, the RAs should always place the client's interests above their own and act in the best interest of the clients and their current situation (CFA Institute, 2014; CFP Board, 2018). Thereby, the usage of algorithms within RAs provides the opportunity to mitigate biases since the advice is independent from personal views of one individual human financial advisor (Bai, 2021). Yet, stating RA algorithms to be unbiased is problematic because RA could be designed to prioritize in the interest of the RA provider, e.g., by only recommending products that are most profitable for the RA provider (Ji, 2017; Tauchert & Mesbah, 2019). Even when done unintentionally, the humans who design RAs may be influenced by firm incentives which can lead to subconsciously biased algorithms (Ji, 2017). These biases and not acting in the best interests of clients can be explained by the principal-agent theory. This theory suggests that financial advisors may act in their own interests, when there is an information asymmetry between the principal (client investor) and agent (financial advisor) (Bai, 2021; Eisenhardt, 1989a). RA clients mostly lack the knowledge necessary to verify if the RA provided meets their needs and if the RA acts in their best interest (Bai, 2021). Resolving these principal-agent conflicts often consist of reducing the information asymmetry between client and advisor as well as providing sufficient incentives for the advisor to act in the best interest of the client (Eisenhardt, 1989a).

DP 8: Always prioritize client's interests and act accordingly to prevent misconducted advice.

5.7.2 MR VI – Fairness

RAs shall act accordingly to the principle of fairness, treating individuals equally or in a way that is right or reasonable (Cambridge Dictionary 2022). Fairness can be achieved by ensuring representativeness, e.g., by having enough personalization options and risk profiles to associate to individual clients. Thereby the client should not be concerned about being negatively judged because of certain criteria (e.g., gender, age, religion) that do not need be relevant for the RA outcome (Wambsganss et al., 2021). This implies that any deviation, resulting in different treatment of certain groups, requires a binding explanation (Boatright, 2010). Treating individuals rightful and reasonable means providing all information user-specifically, so that clients, despite high information content, can maintain a sufficient understanding of the advisory process (Ruf et al., 2015). RAs should thereby provide clients the tools and information available to themselves, e.g., when simulating portfolio changes (Ruf et al., 2015). Furthermore, the information and recommendations from the RA need to be communicated in an understandable,

effective, and constructive manner (International Organization for Standardization, 2005). Clients should thereby receive contextually relevant additional information when needed (Wambsganss et al., 2021). For example, by assessing the financial education of the client at the beginning of the advisory process, information can be specifically adjusted to be understandable on different levels of comprehension and financial literacy. Using an adequate language can thereby lead to a higher perceived capability and trust in the RA (Wambsganss et al., 2021).

DP 9: Serve targeted clients equally without discrimination and ensure that the recommendations provided are understandable and effective for the specific client enhancing perceived fairness.

RAs should not only make financial recommendations but also educate the clients to become more financially literate. Since investors often hold on to suboptimal investment decisions, RA should give warning signals to protect the client from making bad financial decisions and provide the rationale behind their recommendation (Jung et al., 2018). Besides educating while giving advice, distinct educational content could be provided by RAs, e.g., through podcasts or blog posts, that empower clients and engage them with financial topics (Microsoft, 2021). Thereby, educating can not only benefit clients, but also the RA providers. For example, more financially literate clients understand the information and recommendations provided more clearly which can lead to more trust and acceptance of the service (Litterscheidt & Streich, 2020; Rühr, 2020). It could also increase user binding to RA services (Belanche et al., 2019).

DP 10: Educate clients to better understand financial information and advice, and thereby improve financial inclusion.

5.8 Design Domain IV – Credibility

Credibility is defined as the fact that someone can be believed or trusted (Cambridge Dictionary 2022). Ethical RAs therefore need to act responsibly while providing understandable guidance.

5.8.1 MR VII – Responsibility

RAs shall act responsibly by communicating honestly, transparently, and proactively. Thereby, honesty encompasses making only true statements about the advice process, used financial products, estimated gains and any intermediary's compensations (Baker & Dellaert, 2018). In addition, RAs need to be particularly honest about its limitations, e.g., what is considered within the RA and what not (International Organization for Standardization, 2005). For example, RAs often do not provide a comprehensive, all factors considering financial plan (Fein, 2015). They thereby only give advice on one distinct segment of the client's portfolio (Ji, 2017).

Additionally, even though RAs can automatically rebalance portfolios, they often only conduct limited, non-periodic reviews of client portfolios (Fein, 2015; Lightbourne, 2017). The exact responsibilities of the RA and the client therefore need to be addressed honestly, e.g., by disclosing the responsibility for updating the information and therefore instruct and remind the client to update their information periodically (Ji, 2017). In addition, the client should be made aware of all potential risks and rights associated with the RA (Myers & Venable, 2014). This should enable the client to actively participate in the advisory process and taking responsibility for the investments.

DP 11: Be honest and make only true statements about RA capabilities as well as limitations and disclose responsibilities to signal transparency.

To act responsible, the financial products used in the portfolio allocation should be regularly tested and evaluated by the RAs (Scholz, 2021). Furthermore, since RA has a responsibility towards the public to not harm it, a balance between the interests of clients and the public needs to be maintained (Myers & Venable, 2014). Thereby, it could be argued that it is more ethical to invest in firms that act according to Environmental, Social or Governance (ESG) attributes, instead of investing in all possible firms, including ones, that arguably harm the society (Brunen & Laubach, 2021). Therefore, RAs should provide information about the industry sectors and companies the client invests in when the recommended portfolio gets implemented. To make this better understandable for clients, RA could showcase prominent examples of companies they would invest or would not invest in. We acknowledge, that the client could be nudged in a certain direction, which in turn can be interpreted as manipulation and therefore non-ethical advice. Responsibility therefore means being as transparent as possible about this topic, providing sufficient options and to act in the interest of the clients, when they make their choice.

DP 12: Regularly evaluate used financial products and inform transparently about portfolio composition so that clients understand in what industry sectors and companies they invest.

Ethical RA involves regularly and proactively giving updates to the client. RAs should summarize the past performance of the portfolio regularly, but customizable to the liking of the clients, e.g., weekly, monthly, or quarterly. The rebalancing of the portfolios due to market or client changes should be communicated as quickly and openly as possible. Therefore, if a portfolio is adjusted, the client should be informed proactively and reasons for the modifications should be given (Ruf et al., 2015; M. Wu & Gao, 2021). Also, proactive alerts should be triggered when the performance deviates substantially from client goals (Chuck, 2019). Lastly, while RAs are in general legally bind to inform about data leakages, they should also inform timely and

transparently about other changes, e.g., regarding company restructuring or modifications of products and services.

DP 13: Update clients proactively, regularly to their liking and provide context and recommendations to the given information.

5.8.2 MR VIII – Guidance

RAs shall guide clients understandably and with sufficient human and social presence. Thereby, the RA should be accessible at all times as well as user-friendly to ensure problem-free interaction (Boreiko & Massarotti, 2020; Wambsganss et al., 2021). The first interaction of the client with the RA is on its website. Clients could question the competence, integrity and credibility of the service, when the design of the website is not perceived as professional and responsive (Jung et al., 2017). RA providers should therefore follow proven practices in web design, especially during the advice process, e.g., by displaying the current and next steps to provide a transparent experience, visual predictions of future returns and corresponding probabilities when users decide among candidate portfolios (M. Wu & Gao, 2021). To make the process even more transparent and reduce concerns and risks associated with the implementation of a portfolio, clients could be allowed to test the RA with a dummy portfolio. This could further confirm the RAs competence and integrity which ultimately increase trust in RA (Mesbah et al., 2019). When the recommendations have been implemented, RAs provide clients with a dashboard to examine the past portfolio performance, preferably in the form of graphs (M. Wu & Gao, 2021). This holistic view on the client portfolio should be customizable, incorporate transparent, auditable data points and should include an analysis of the performance relative to the client's goals (Chuck, 2019). Furthermore, the client should be given the opportunity to make subsequent changes to their settings and preferences concerning investments (Ruf et al., 2015).

DP 14: Provide easily accessible guidance following proven design practices while informing the client clearly and concisely about process steps and portfolio performance.

While RA is in essence an automated IS, users often prefer human over machine interactions and therefore aim for a certain degree of humanization (Hildebrand & Bergner, 2021). Also, a higher level of social presence of RA is thereby perceived as more transparent and trustworthy (Morana et al., 2020). Especially during the first interactions with an RA, social presence and thereby initial trust could be increased by adding videos and photos of the RA development team (Jung & Weinhardt, 2018; Scholz, 2021). Furthermore, RAs should convey the feeling that the customer has always access to the expert network ensuring the availability of competent

advice (Ruf et al., 2015). RAs should consider providing not only automated help through FAQs or contextually through chatbots, but by providing additional human assistance (Jung et al., 2017). This blending of RA and human advice is often referred to as “hybrid advice” (Jung et al., 2019). Humans are thereby better suited in tasks that require creativity and social skills, e.g., recording and incorporating individual needs within the risk assessment process or in providing answers to uncommon or specific questions (Jung et al., 2019; Rühr et al., 2019a).

DP 15: Increase social presence and provide human assistance when needed to improve client’s confidence in using the RA.

5.9 Expert-based Evaluation through Interviews

After deriving the MRs and developing the DPs in the design cycle, we evaluated our design artefact with the help of experts from research and practice. We conducted semi-structured expert interviews to receive answers to selected predetermined questions concerning our MRs and DPs and to clarify the reasoning behind the answers (Yin, 2014). Thereby, each interview was separated into three parts. In the first part we talked about the current state of ethics in RA and ensured a common understanding of the topic by providing our definition of ethical financial advice. Exemplary questions in the first part were: “What do you understand by the term ethics in the field of RA?” or “How important are ethical issues in RA design decisions in research/your company?”. In the second part, we sequentially asked the interviewees to state their opinions on our preliminary MRs and DPs for more ethical RA design. We thereby illustrated the MRs with examples that are present in the DP elaborations and asked questions about their importance, reasonableness, and applicability, e.g., “How important / reasonable / implementable is this MR / DP for the ethical design of RA and why?”. Furthermore, we asked the interviewees if considerations for each DD or MR of ethical RA were missing. The third section closed the interview with general opinions concerning our MRs and DPs and the possibility to report related thoughts, which might be useful for the design of more ethical RA. Exemplary questions were: “What are the most important, meaningful points?”, “Which points need the most attention?” or “What are main implementation threats and difficulties?”.

In total, we interviewed five experts whereby two are researchers in the RA domain (I1 and I2) and three practitioners of large RAs operating in Germany (I3-I5). To prepare the interviewees and get more thought-out opinions on our design artifact, we provided the preliminary MRs and DPs one week before the respective interview took place. The interviews were held in German language and lasted between 46 and 73 minutes, with an average of 57 minutes and were digitally recorded, transcribed, and imported into the qualitative data analysis software MAXQDA.

Afterwards, the interviews were qualitatively analyzed employing the qualitative content analysis approach by Mayring (2014), but this time using a deductive approach based on our previously developed coding system for ethical RA. We thereby coded the given answers, e.g., regarding a certain MR or DP and categorized comparable and related statements. This enabled us to not only analyze the similarities and differences of statements regarding one MR or DP but to find similarities across design dimensional statements. The coding was performed separately by two researchers and unified and finalized in a discussion of the entire author team.

In general, the evaluation confirmed the importance, reasonableness as well as applicability of our MRs and DPs which were perceived mostly positive. To begin with, there was a common understanding of the definition of ethics in financial advice with all interviewees. However, while we defined ethical attributes and thereby ethical RA in total as being continually improvable, some interviewees had a differing view. Their main goal for ethical RA is to meet a minimum of ethical requirements since being more ethical may not be in the best interest of the company. Still, ethical improvements to RA design were found to be widespread in the industry. Yet, this is often not the case because of intrinsic motives regarding the welfare of stakeholders and the society, but because of regulatory directives or to gain trust with clients. In part 2 of the interview, we evaluated the relevance, robustness, usefulness and applicability of our MRs and DPs for more ethical RA. Exemplary, in English translated quotes from the experts are presented in Table 20.

Concerning DD I, we found that RAs face challenges to enhance their perceived competence with possible solutions of better storytelling, providing information about the people behind the RAs or asking clients questions about their life circumstances regularly. But this is also in conflict with the aim to be simple, as illustrated by I5: *“You have to ask yourself the question: Am I confusing the customer and asking too many questions which then in turn tend to trigger a blockade and the user not buying?”* Regarding DD II, the experts considered confidentiality to be a hygiene factor, which nevertheless was acknowledged as an integral part of building customer trust. Therefore, investments in factors that enhance data privacy and improve security measures were highlighted. Still, it was mentioned, e.g., by I4, that with increasing confidentiality, there is likely to be a tradeoff in terms of user experience: *“Every increase in security is accompanied by a reduction in convenience. The more secure a thing becomes, the more complicated it becomes, also in relation to the customer.”* Considering our MRs and DPs of DD III, the experts had differing viewpoints about the positive and negative effects of RAs being independent from other companies. Consensus was reached about educating customers, which was viewed as a positive approach for RAs, which they support by offering e.g., newsletters,

podcasts and webinars. The experts thereby mentioned that integrity could lead to the exclusion of some investors conflicting with MR VI “Fairness”, e.g., I5: *“With some factors, you simply must be biased: If a customer doesn't have the free capital to invest, then it makes sense that the risk assessment doesn't go any further.”* Addressing fairness on the note of some clients requiring higher levels of human support than others, it was emphasized that contemporary RAs should be hybrid models providing human assistance when necessary. Lastly, concerning DD IV, the experts highlighted, that RAs are built for long-term wealth creation, not for trading. Thereby, providing data more transparently and regularly could increase nervousness and therefore decrease chances of fulfilling long-term financial goals. Furthermore, the experts implied that ethical considerations should be incorporated into the financial products offered, e.g., I5: *“Where you really invest in - the customer should know about that. (...) It's quite shocking where you invest in if you don't have an ESG portfolio. I don't think the client is aware of that.”* These insights are reflected by our modified and enhanced DPs concerning MR VII.

While splitting the individual requirements has been criticized as being partly artificial, the importance of a holistic view of the DDs rather than strict adherence to individual MRs was highlighted. It was also mentioned that the DDs, MRs, and DPs converge on the theme of trust, which is in line with our goal and research question. However, some of the MRs and DPs were found to be less specific to ethical RA (e.g., competence). Also, it has been stated, that “transparency” could be an individual MR, but we found transparency to be a natural requirement for ethical advice that increases trust, and it is therefore incorporated in multiple MRs and DPs. Still, following our DPs for ethical RA was considered to provide overall „good“ advice to clients.

DDs	Quotes
DD I <i>Competence</i>	<p>“The question is how to illustrate competence and underpin it with a good story. Storytelling is helpful, for adequately capturing customer needs. (...) Customers want to know who the people behind the RA are.” (I4)</p> <p>“Compared to traditional financial advice, the RA advertises simplicity, and its client group is different: Clients with less expertise in personal financial planning and those who are less comfortable with abstract ways of thinking. As a result, capturing true needs is difficult.” (I3)</p> <p>“You could have questionnaires filled out again and again at regular intervals (...) to understand and adjust customer needs over time.” (I1)</p>
DD II <i>Confidentiality</i>	<p>“I take this design dimension for granted because it is a given framework through the regulatory framework in each region. It is nevertheless an integral part of building customer trust.” (I2)</p> <p>“Confidentiality is a hygiene factor. It's something that customers take for granted and are rightly very sensitive about. Where all RAs also invest a lot, which doesn't mean that it always succeeds 100%.” (I4)</p> <p>“Regular audits for data protection and security are important - as a customer, I would feel more comfortable if I knew that they were taking place.” (I5)</p>

DD III <i>Integrity</i>	<p>“(Independence) is a unique selling point of many non-bank RAs and a reason why investors go there: They want to be sure that they are not sold anything that has not been selected according to objective criteria.” (I4)</p> <p>“For a while now, we have been more explicitly stating that we are a subsidiary of (larger financial institution), because the user then has more trust - because there is a financial service provider behind it, which has been around for longer than 5 years.” (I3)</p> <p>“Fairness is an important issue. It is important to break down barriers and facilitate easy access. (...) Webinars are helpful for improving financial literacy.” (I4).</p> <p>“A lot of emphasis is placed on providing customers more knowledge via newsletters or podcasts, because this is often their entry point into the investment world. This was well received with good click rates.” (I5)</p> <p>“The RAs don't talk about themselves in the "we're not so good at that" way. But they offer premium services (...) for additional costs, which often have to do with the fact that a human consultant is also involved.” (I1)</p>
DD IV <i>Credibility</i>	<p>“Many customers have wished to have their performance displayed on a per-minute basis, which is difficult, because it speaks against the concept of the RA and how it works. It is simply not day trading. In the best way you should invest the money and then delete the app for seven years.” (I5)</p> <p>“We want to offer a product for long-term wealth creation - not a product for trading. (...) We want to be transparent, but we also don't want to increase nervousness. To be successful as an investor in the long term, you should be patient. We try to educate in this respect. (...) Anyone can get their info, but we don't want to incentivize to go in a suboptimal direction. We do this with detailed quarterly reporting.” (I4)</p> <p>“When it comes to onboarding, the human factor is important, especially for older customers, but this is difficult to implement as a RA - which is probably another reason why the market for this is so small and has grown so little. (...) Perhaps hybrid models are the future.” (I5)</p>
Overall	<p>“Ethics play a greater role in traditional financial advice and is used specifically as a marketing tool. Within RAs, ethical aspects can only be found between the lines in the business model. This raises the question why it is neglected in comparison, although many people have great skepticism regarding new technologies.” (I2)</p> <p>“The four dimensions converge at the theme of trust. So, they are all dimensions that pay into that.” (I4)</p>

Table 20. Exemplary evaluation quotes from experts

5.10 Discussion, Implications and Limitations

We conclude that our DDs, MRs, and DPs are of high relevance, interrelated with each other and can therefore be seen as a holistic framework for ethical RA design. However, it remains questionable whether all requirements are individually of high relevance for clients. All requirements initially imply an additional effort for clients resulting in a more complex decision-making process. For example, clients will have to decide how often proactive updates will be sent, in which industry sectors to invest and will have to deal with more of detailed information about their portfolio allocation and data handling. This adds complexity to the RA which can be problematic, since fundamental benefits of RAs are convenience and ease of use (Beketov et al., 2018; Jung et al., 2019). The short-term adoption rate, especially for the inexperienced or low financially literate target audience of RA could decrease, due to the increased effort in answering more questions and getting more information. There seems to be a fine line between

adoption and non-adoption of RA based on a trade-off between more ethics and ease-of-use. The question arises to what extent ethical considerations and therefore concrete ethical DPs should be implemented in RA. Presumably, only a certain degree of ethical considerations need to be established to provide sufficiently ethical RA to clients. Implementing ethical attributes beyond this “minimum hurdle” would be in the long-term interest of clients and society but would also require resources from RA providers that they do not see enough value in. Therefore, RA providers are likely to maximize profits and considering ethics secondly. This implies that a more binding regulation is needed if RA should provide more ethical financial advice.

Our study provides interesting insights for RA researchers, practitioners, and regulators. Firstly, we contribute to research by consolidating current literature in the areas of ethical financial advice and ethical RA. Further we follow recent suggestions to implement ethical considerations not only in IS (Benke et al., 2020) but also in DSR (Myers & Venable, 2014). Thereby, our study contributes to research by providing a blueprint for ethical considerations in RA. Because of its abstract nature, our MRs could also be applied in other FinTech contexts and could thereby be used to structure ethical DPs for other FinTech business models to increase trustworthiness. For RA developers and practitioners, we provide applicable DPs to help them ensure ethical considerations in their RA designs are met. By implementing our DPs, RA providers can, e.g., increase the quality of services and trust in their RA. This might help RA providers to understand client needs better and increase RA adoption. Additionally, regulators can use our DPs as a discussion base on whether to incorporate a stricter regulation upon RA-providers that would enhance their moral aspects and force them to go beyond a minimum of ethical considerations.

Despite its careful design, our study is subject to limitations. While the classification of requirements into DDs and MRs can be described as subjective, they were discussed in the author team until a consensus was reached. Additionally, the evaluation resulted in an agreement with our DDs, MRs and DPs and concluded that no further requirements were missing. Second, although practical insights from international guidelines and standards of financial advice were incorporated into the DDs and MRs, the DPs were predominantly derived from RA literature. We therefore recommend for further research to broaden this perspective and to include different design literature streams, e.g., from ethical IS design and AI design, considering the fast-evolving technological advances in RA. Third, the requirements analysis was initiated from a scientific and practitioners’ perspective. Hence, the users’ perspective on ethical RA design is missing. Therefore, users and respectively important stakeholders should be involved in future studies for the design of ethical RA. Fourth, a quantitative evaluation of our MRs and DPs could

provide insights into their individual contribution to more ethical RA. Fifth, adhering to our DPs for improving RA could be hard to measure and could be differing depending on the targeted client preferences. Sixth, since we did not instantiate our DPs in a prototype, we encourage future research to develop, demonstrate and evaluate ethical RA prototypes based on our DPs. Lastly, our evaluation is mainly based on the expertise of RAs operating in Germany. Therefore, future research could analyze larger and cross-regional samples of RAs to gain more comprehensive insights.

5.11 Conclusion

While investing is becoming increasingly digital and automated through RA, ethical issues pose significant risks. Providing more ethical RA could benefit clients, RAs, and the society. However, a distinct ethical perspective on RA design is missing in literature. Therefore, following a DSR approach, we firstly classified ethics in RA into four DDs: Competence, confidentiality, integrity, and credibility. Based on RA literature as well as international guidelines for ethical financial advice and computer ethics, we derived eight MRs that express the attributes of ethical RA: Expertise, professionalism, privacy, security, independence, fairness, responsibility, and guidance. We then developed 15 applicable DPs, that can benefit these attributes and therefore guide to more ethical RA design increasing their trustworthiness. The expert-based evaluation confirmed the importance, reasonableness as well as applicability of our MRs and DPs which were perceived mostly positively. Still, the evaluation revealed, that the implementation of ethical considerations not only challenges RAs but could also come with trade-offs regarding customer adoption. Our study provides researchers a baseline to investigate more deeply how RA can become more ethical, while practitioners can use our DPs directly to ensure more ethical outcomes of their RA. We encourage researchers and RA provider to implement our design principles in RA instantiations to mitigate ethical problems, increase their trustworthiness and enhance the experience of their clients.

C Contributions

The papers of this dissertation contribute to the ongoing research on the digitalization and automation of financial advice in form of RA. This third part of this dissertation contains the main contributions of the two research areas “Positioning of RA in science and practice” as well as “RA analysis and design”. Firstly, I present a summary of the most important findings of the papers by relating them to their respective research questions and synthesizing interrelated insights. Afterwards, I discuss theoretical and practical implications of these insights. Lastly, limitations and future research directions are formulated in the overall context of both research areas.

1 Summary of Findings

In this section, I summarize the findings of the two research areas and synthesize interrelated insights. For that I restate the respective RQs of the papers and present answers by summarizing important results.

1.1 Research Area I. Positioning of Robo-Advice in Science and Practice

The first research area addresses the positioning of RA in science and practice. As previously stated, the main goal is to provide a structure for more in-depth analyses of RA. Firstly, we provide insights on RA from a scientific perspective in [paper 1](#) (Torno, Metzler, et al., 2021). Therefore, we conducted a systematic literature review based on the method by Webster & Watson (2002) to analyze 42 relevant peer-reviewed articles that focus on the digitalization and automation of financial advice in form of RA, answering the following RQ:

RQ I.1: How can research on RA be systematized and what are worthwhile future research directions regarding RA?

The first results comprise descriptive statistics of the relevant articles concerning publication time, outlet type and domain, research approaches and regional focuses. We found that an increasing number of RA publications, especially in the last years, show a high interest of research in this topic. We also found that scientific literature about RA is diverse, with many business domains interested in different aspects of RA. While most of the IS domain articles were published at conferences, the other business domains, published articles exclusively in journals with an increased focus on higher rated outlets in the last two years. Concerning research approaches of the articles, we found almost two-thirds of the articles use quantitative methods (e.g., surveys, experiments, portfolio analyses, and simulations), one-fourth use qualitative methods (e.g., interviews, literature-based studies, and qualitative content analyses, e.g., of RA websites), and approx. 10% mixed-method approaches (design science and case study research using various datasets). Lastly, concerning the geographical focus of the analyzed articles we found that most articles focus on only one region. Thereby, the USA and the European countries Germany and the UK stand out as the most frequently used regional focuses of the studies. While the Asia/Pacific region is less frequently investigated we could neither find any relevant articles focusing on South America nor Africa.

We then presented and explained an *Organizing Framework for RA Research*, visualized in Figure 11, in which we classified the RA literature into three main themes: *RA Users*, *RA Service*, and *RA Competition*. Firstly, we found that the literature about *RA User Demographics*

suggests that users are mostly financially literate, confident in financial decision making and have a higher-than-average risk-affinity. As expected, RA users are less wealthy than people seeking traditional financial advice. Still, only approx. 5% of people seeking for financial advice use RA. The most important factor leading to *RA User Adoption and Acceptance* is a high level of trust in the RA-provider and the underlying technologies. Further adoption and acceptance factors include a high level of transparency, ease-of-use, usefulness, and the perceived expertise of RAs.

Secondly, within the subtheme *RA Process Design*, we found that RAs use mostly simple static online questionnaires with approx. 40% of questions not impacting the risk assessment in the *Initiation & Profiling* phase. This may lead to a non-sufficient profiling of clients. Studies also found that the *Matching & Customizing* phase is considered mostly a “black box”. The recommended portfolios have thereby similarities in its products, using ETFs and passive investment strategies. Literature concerning the *Monitoring & Rebalancing* phase found that the delegation of investment decisions to an algorithm reduces behavioral biases and irrational human behavior, leading to more diversified RA-portfolios compared to self-monitored portfolios. Still, the financial performance against benchmark indices is disputed. Studies on the *Overall RA Design* discuss designs to mitigate behavioral biases as well as decisions regarding the degree of delegation and automation, and the degree of humanization and conversational abilities. The scientific community also discusses the different *RA Providers*, e.g., in the context of their maturity (FinTechs vs. investment companies and incumbent banks) and their BMs (B2C and/or B2B).

Thirdly, concerning the *RA Competition* we found that the emergence of RA led to changes in the education of human financial advisors, who use decision support systems more frequently to increase the objectivity and precision of their advice. Also, a blending of RA and human advice to “hybrid advice” was discussed and suggested that RA rather augments than substitutes traditional human advice. Lastly, advantages and disadvantages of RA are discussed in literature. It is mostly agreed on that RA can provide a convenient financial advice service with less emotional decision-making at low costs and minimum investment amounts. However, RA is thereby less individualized and sophisticated compared to traditional financial advice.

To answer the second part of RQ I.1, we presented a future research agenda for RA with worthwhile open RQs for each RA main theme. Thereby, future research on *RA Users* could examine, e.g., the adoption and acceptance factors concerning the influence of experiences with human advice, the necessity for social interaction, technology readiness, and impacts of behavioral biases. Studies should thereby focus on actual RA users, instead of already investigated

potential RA users. Research on the *RA Service* could develop design principles for more sophisticated RAs aiming at dynamically adapting to individual users, which could increase the individualization of the customer experience and recommendations. Further, it could be valuable to use data and opinions from RA-providers and traditional financial advisors to find motives for their design decisions. We also found that future research on *RA Competition* should investigate on the synthesis between RA and traditional human advice. Research on hybrid RA could thereby examine where and how within the RA process phases humans and automation have their strengths, designing even better hybrid RA models. Since RA is often lacking more complex advice, research could also explore how RA can encompass more financial advice competencies, delivering even more WM services. Lastly, future research should investigate on the opportunity of RAs to shape traditional advice practices and the financial literacy of its users.

The *Organizing Framework for RA Research* developed in paper 1 (Torno, Metzler, et al., 2021) is also used to structure the other research papers that are part of this dissertation. For research area I we added the overall context of the DT of the financial sector to this framework. Thus, the second focus of research area I is on the practical positioning of RA in the broader landscape of FinTech services. By utilizing the relevant customer requirements of ease-of-use and ubiquitous availability, this practical positioning of RA is approached in the context of mobile personal finance applications. Thereby, paper 2 (Torno, Werth, et al., 2021) provides answers to the following RQ:

RQ I.2: How can mobile personal finance applications be classified and what archetypes can be distinguished?

To answer the first part of RQ I.2, we developed a taxonomy by classifying 170 mobile personal finance apps in two C2E- and four E2C-iterations. We identified twelve dimensions and 46 characteristics, combining a technical perspective and a financial services perspective. The final taxonomy with respective numbers of occurrences for each characteristic can be obtained in Table 9. Interpreting the app sample from the *technical artifact perspective*, we can state that most personal finance apps need an internet connection and user accounts to deliver their services. Further, the information and data flows are more frequently bidirectional in comparison to unidirectional and the user data sharing with other entities is not common. We noticed in the *financial services perspective* that most personal finance apps specialize in delivering only one service to users and mostly differ in their technical functionalities. An exception are full-featured mobile banking apps, which provide various services but are neglecting personal advice despite its large-scale service provision.

For the second part of RQ I.2, we examined archetypes of personal mobile finance apps within a cluster analysis based on the beforementioned taxonomy. We thereby empirically identified ten application archetypes, based on a clustering that groups objects (personal finance apps) to minimize differences with-in a group and maximize differences between groups (Kaufman & Rousseeuw, 1990). The archetypes comprise financial news and analysis, advanced or manual budgeting, transaction authorizing, credit card and retail payments, mobile banking, individualized or non-individualized information, and investments with or without advice (see Table 10). Especially cluster 9 - “Investing with Advice” encompasses a relevant archetype for this dissertation, since the apps in this cluster offer investing services in conjunction with personalized advice. These apps not only inform about the pricing of the assets but educate users about investing and provide automated or hybrid personalized advice on portfolio decisions. Investments were found to be mainly manually triggered but could also be assisted through the apps. This depends on the user's investment behavior and the degree of decision-making delegation to the service, for example, full automation in the case of some RA apps. Thereby, these apps support trading of traditional financial assets as well as investing in cryptocurrencies. Despite its freemium nature, users must pay for the services depending on the transaction value or investment amount. Consequently, apps in this cluster require a legitimized user account, an internet connection, and information flows bidirectionally between the app and user.

Overall, the papers in this research area provide the baseline understanding for automated and digitized financial advice in form of RA, its current scientific knowledge, and a practical classification of the RA phenomenon in the DT of the financial sector. We thereby show how the current scientific knowledge about RA can be structured, summarize important insights for each emerged theme and derive worthwhile directions for future research. Further, we extend this by investigating how certain changes associated with the DT of the financial sector (i.e., changes in financial markets, changes in customer requirements and changes in technology) led to the present mobile personal finance application landscape, providing insights on real-world RAs characteristics.

1.2 Research Area II. Analysis and Design of Robo-Advice

The second research area sheds light on more focused analyses of certain RA components and gives recommendations for RA design. The first study focuses on the BM of RA, aiming at understanding the distinct BM elements of RA and finding major similarities and differences between RA providers BMs. Thereby, [paper 3](#) (Metzler et al., 2022) provides answers to the following RQ:

RQ II.1: How can RA business models be characterized and what are major similarities and differences?

To answer RQ II.1, we conducted an exploratory case study across the fifteen largest US-based RAs. An in-depth analysis of publicly available documents of these RAs resulted in an illustration of exemplary BMs based on the BMC by Osterwalder & Pigneur (2010). Whereas the characteristics of most BM elements are nearly similar across all RAs, we found that major differences exist between pure and hybrid RAs (see Figure 19). Thereby, pure and hybrid RAs differentiate, e.g., in their cost structure (very low vs. low staff payment), their customer segments (mostly no capital minimum vs. mostly high capital minimum) and their customer relationship (only automated and digital communication vs. mostly automated and digital communication with additional personal communication, e.g., via phone). Furthermore, concerning their value proposition, hybrid RAs provide, compared to pure RAs, higher degrees of customized and individualized portfolios with additional human portfolio advice while supporting clients through human advisory networks.

The focus of the second paper in research area II is on the recommendations that RAs provide. The goal of this study is to understand how these recommended portfolios differ, especially regarding their structure and selected products as well as performance and risk. Thereby, paper 4 (Torno & Schildmann, 2020) provides answers to the following RQ:

RQ II.2: Which similarities and differences do the portfolios recommended by RA have, regarding portfolio structure and selected products, performance, and risk?

To answer RQ II.2, we analyzed a sample of 36 RAs and 216 distinct recommended portfolios for six defined model customers with differing investment horizons and risk-affinities. Firstly, we found a total of 214 different products utilized by the analyzed RAs that provided this information, consisting of approx. 66% ETFs and 33% mutual funds. Further, we showed that the basic investment advice of RAs functions sufficiently: Across all RA providers, the determined risk class has a high impact on the recommendation of the RA. As the customer's risk affinity increases, the equity quota in the portfolio rises and the quotas of less volatile products, like government and corporate bonds, fall. However, the recommendations of the RAs vary greatly, especially for customers with a short-term investment horizon and high risk-affinity. When the investment horizon is getting into mid- or short-term regions, RAs recommend on average risky portfolio allocations for passively managed investment portfolios. Furthermore, we showed that investment horizons play a subordinate role in the recommendation of a RA portfolio, despite its impact on the long-term returns of especially volatile asset classes like equities.

The third focus of this research area is to derive MRs and develop DPs for RA, addressing the problem of unethical behavior that can decrease trust and the adoption of RA. Thereby, [paper 5](#) (Torno et al., 2022) provides answers to the following RQ:

RQ II.3: What are relevant design principles to establish ethical considerations in RA design and increase its trustworthiness?

To answer EQ II.3, we followed a modified DSR approach by Hevner (2007). Thereby our fundamental assumption is, that if a human advisor acts ethically when adhering to the principles for ethical financial advice, then IS, in this case RAs, should also act ethically when adhering to these principles. Based on scientific literature on ethical RA as well as international standards and guidelines for ethical financial advice, we firstly structured ethical RA into four DDs based on four main values of ethical financial advice: Competence, confidentiality, integrity, and credibility. We then identified a set of eight MRs that express the goals that ethical RA should achieve, namely: Expertise, professionalism, privacy, security, independence, fairness, responsibility, and guidance. Subsequently, we developed 15 applicable DPs, that can benefit these goals and therefore guide more ethical RA designs, increasing their trustworthiness. An overview of the design artifact can be obtained from Table 19. An expert-based evaluation confirmed the importance, reasonableness as well as applicability of the MRs and DPs, which were perceived mostly positively. The experts also agreed that the DDs, MRs, and DPs converge on the theme of trust which is in line with our goal and RQ. Following our DPs for ethical RA was considered to provide overall „good“ advice to clients. Still, the evaluation revealed that the implementation of ethical considerations not only challenges RAs but could also come with trade-offs regarding customer adoption, e.g., when additional efforts for clients result in more complex decision-making processes.

1.3 Interrelated Insights

All insights of this dissertation can be classified in the *Organizing Framework for RA Research* developed and presented in paper 1 (Torno, Metzler, et al., 2021). For example paper 3 (Metzler et al., 2022) provides insights on the overall *RA Service* configuration. By using data of 15 real-world RAs, we also analyzed the *RA Competition*, comparing RA with traditional financial advice and describing similarities and differences. We could thereby provide evidence for the relationship, also described in the framework between the *RA Competition* and the *RA Service*. The *Synthesis* between automated RA and traditional financial advice in form of hybrid RA not only *Imitates* parts of the traditional financial advice but also *Challenges* their practices, leading to more *Differentiation* between the differing RA BMs hybrid and pure RA.

Paper 4 (Torno & Schildmann, 2020) provides insights on the *RA Service* theme, especially on the *RA Process Design* of the first two phases *Initiation & Profiling* as well as *Matching & Customization*. We thereby found that the RAs have different levels of information transparency and customization ability. Additionally, the different recommended and analyzed RA portfolios were based on preferences of model *RA Users* with realistic investment horizon and risk-affinity characteristics. The insights of this paper reveal the bidirectional relation between RA Users and the RA Service, illustrated in the framework, that is characterized by mutual *Influence and Interaction*. Additionally, unidirectional links between the main themes RA Users and RA Service moderate this relationship. The RA Users *Adopt* the RA Service, while the RA Service is *Designed for* its specific user groups. This is also reflected in paper 5 (Torno et al., 2022) which provides insights on the *Overall RA Design*, focusing on solving ethical issues in RA and increasing its trustworthiness. Thereby, the ethical RA design moderates its adoption from RA Users. Similarly, paper 3 (Metzler et al., 2022) found that the distinct RA BM configurations (hybrid/pure) can lead to differing designs of the RA, which consequently appeal to differing RA Users adopting the RA Service.

Further, some of the research gaps found in paper 1 (Torno, Metzler, et al., 2021) were addressed by the subsequent papers of this dissertation. For example, the research gap to investigate the synthesis of RA and traditional human advice is addressed by paper 3 (Metzler et al., 2022) in the investigation of RA BMs and the main distinction between pure and hybrid RA. Additionally, paper 3 (Metzler et al., 2022) and paper 4 (Torno & Schildmann, 2020) use data that RA-providers publish themselves, which addresses another worthwhile research direction. Paper 5 (Torno et al., 2022) contributes to the found research gaps by including opinions from RA-providers to find motives for their design decisions and by providing design knowledge emphasizing on ethical considerations and RAs fiduciary duties. Additionally, this study consolidated current literature in the areas of ethical financial advice and ethical RA following the recent suggestions to implement ethical considerations not only in IS (Benke et al., 2020) but also in DSR (Myers & Venable, 2014).

2 Implications

The papers of this dissertation provide valuable insights that lead to important implications. In this section, I present the most important implications for both research areas.

2.1 Research Area I. Positioning of Robo-Advice in Science and Practice

While still a novel phenomenon in the FinTech domain, an increased number of RA publications, show a high interest of research in this subject. This contradicts the widespread opinion that RA literature is still scarce and in its infancy. Paper 1 (Torno, Metzler, et al., 2021) showed that scientific literature on RA provides first answers within the themes *RA Users*, *RA Service*, and *RA Competition*. Thereby, we present the current state-of-the-art of RA research and how the knowledge can be categorized. This categorization is not only used to structure this dissertation but could also be a viable structure for future research in the RA domain. Further, we derive open RQs from the relevant literature, which can imply important directions for future RA research.

The second focus in research area I is on the practical positioning of RA in the broader landscape of FinTech services. Thereby, the taxonomy developed in paper 2 (Torno, Werth, et al., 2021) provides relevant dimensions and characteristics to structure the field of mobile personal finance apps with the widely used approach by Nickerson et al. (2013). Additionally, the cluster analysis performed in this paper derived ten distinct clusters, which indicate the versatility of mobile personal finance apps. This study is thereby the first that combines and discusses technical functionalities as well as the underlying delivered personal finance services.

Interpreting the app sample in the taxonomic context shows that an internet connection and user accounts are often mandatory to deliver their services. This can be explained by mobile internet connections becoming less expensive, and user accounts becoming more ubiquitous due to social media and other personalized internet offerings. The renunciation of user data sharing with other entities could be interpreted as a data security measurement or as a less feature-rich app configuration pattern. Furthermore, we only found two app clusters that deliver educational content of personal finance at all, almost always concerning investment decisions. This seems to be a missed chance for financial services providers since financial education can play a significant role for users, not only in their investment behavior. Delivering more educational content to the user can raise trust in the financial services provider and cause higher engagement with the app. This can lead to higher investment amounts, thus increasing the revenue of the app provider (e.g., van Rooij et al., 2011). Additionally, we found a shift from less featured apps that are mostly premium, or freemium-based, to more innovative or feature-rich apps with

either subscription- or transaction-based revenue models or are even free to the user. In the first case, to be up-to-date on functionality and security, developers need to work on their apps iteratively and therefore need to finance their constant advancement (e.g., Lee & Raghu, 2014). In the second case, developers have a smaller demand to produce revenue since new apps rely more on backing through venture capitalists, and the goal is often to build a big userbase first (e.g., Gomber et al., 2018). Lastly, while only a small number of apps provided the distinct services that are associated with RA, this study showed, that despite its novelty, RAs already exist in the highest ranked personal finance apps.

This study can serve as a systematic discussion platform among academics and practitioners about the status quo of the personal finance app domain and FinTech in general. In that regard, financial service providers and developers can compare their apps with the competition on an objective scale and gain insights on common archetypical configurations of characteristics. Based on these insights, they could add new technical features and services, focus marketing activities on their unique feature set or find innovative combinations of characteristics not yet present on the market. While we found that a target age group dimension did not provide enough explanatory power to be part of the final taxonomy, developers could build apps specifically for less often addressed but relevant, segmented customer groups. For example, apps could target children, teenagers, or elderly since these demographics have distinctly different needs for technical app features and financial services, compared to adults (e.g., Xue et al. 2020). Lastly, policy makers can use our taxonomy and cluster analysis to identify service providers of relevance and thereby focus their regulation activities and monitoring, especially regarding new market entrants.

2.2 Research Area II. Analysis and Design of Robo-Advice

The results of paper 3 (Metzler et al., 2022) indicate that RAs with their digital BMs have the potential to change the landscape of traditional investment advisory. As stated by Jung et al. (2017), investment banks are downsizing their services for retail customers because of too high administrative expenses for low investment amounts, which creates a vacuum in this customer field. The analysis shows that RAs aim at penetrating especially this customer segment through offering advisory solutions, including a low minimum investment amount, convenient online interfaces, a goal-based approach, and several additional offers at a low price. Additionally, RAs adapt quickly to industry developments, such as the trend towards passive portfolio management and sustainable investments (Beketov et al., 2018).

However, the results of paper 3 (Metzler et al., 2022) also indicate that solely relying on algorithms instead of additionally drawing on human-based services, does not fully comply with existing customer needs. Although customers increasingly prefer passive portfolio management instead of active portfolio management, human interaction is still important for customers (Jung et al., 2017). Exclusively relying on algorithms and online questionnaires to identify customers' profiles and create financial plans can lead to portfolios that do not sufficiently reflect the customers' risk aversion and financial needs and can lead to unsatisfactory results in the long run. Therefore, Jung et al. (2017) proposed that RAs should still rely on human interactions in some core processes. Our analysis shows that this solution has been adopted by hybrid RAs, combining the efficiency of digital investment algorithms and the advantages of human advisors. Still, the distinct BM configurations of pure and hybrid RA can serve different user groups as stated by D'Acunto and Rossi (2020) who recommend pure RAs for millennials and hybrid RAs for wealthier and older clients. These user groups differ in their investable capital amounts, their adoption rate to new technology, their complexity of financial situations, and therefore their need for more individual human support.

Since many competitive advantages of most RAs are based on a strong partnership with their parent company, it is especially hard for pure RA start-ups to gain a foothold in the market. It can therefore be assumed, that established firms in the financial services industry continue to dominate the market, using RAs as an additional channel to increase the distribution of their own investment products and penetrate the retail customer market.

Lastly, the results of paper 3 (Metzler et al., 2022) confirm existing research on RAs regarding their main processes. In line with Beketov et al. (2018) and Jung et al. (2018), we found that the main processes are investor profile identification, asset allocation, implementation of investment strategies, portfolio rebalancing, and performance review and reporting. This was also revealed, while collecting the data for the analysis of RAs portfolio recommendations in paper 4 (Torno & Schildmann, 2020).

The analysis of RA portfolio recommendations indicates that interested investors should not trust their preferred RAs blindly. Especially, when considering shorter investment horizons, investors should be aware that RAs, despite of their high volatility, often use large shares of equities in their recommended portfolios. This may be due to the need of RAs to offer clients high returns which has the disadvantage, that if a crisis occurs and the investment horizon is exceeding, a loss must be realized. Thereby, RAs intend to offer solutions for their risk-averse investors with short-term investment horizons but providing such solutions within the current

low-interest market can be complicated, and therefore too complex for RAs. The volatility of equities and bonds makes it at least questionable to invest in short-term time horizons using trading algorithms based on passive investments and diversification strategies that are often used within RAs (Jung et al., 2018; Sironi, 2016). To provide more sophisticated financial advice, RAs need to consider more financial products with lower volatility for short-term investments like savings accounts. An alternative approach is to neglect short-term investment horizons entirely, refusing to provide a portfolio recommendation for short-term investment horizons. This seems to be, when no other options are provided, a good advice that RA could give to a short-term investor.

Finally, the analysis of paper 4 (Torno & Schildmann, 2020) implies that the analyzed RA do not include all profiling data sufficiently into their recommendation process, or at least a high amount of information does not change the recommended portfolio structure. Thus, we agree with Faloon & Scherer (2017) and recommend RA providers to use the data captured within the profiling to its full extend for more individualized portfolio recommendations. An alternative is to improve the profiling in a way that RAs just ask for information, that is actually used within their recommendations. This can also improve the ease-of-use of RA services and ultimately customer adoption. The trade-off between asking potential clients more questions and its ease-of-use was also discussed in the evaluation of the DDs, MRs and DPs for ethical and trustworthy RA within paper 5 (Torno et al., 2022).

Thereby, all discussed MRs and DPs involve an additional effort for clients resulting in a more complex decision-making process. When adhering to the DPs, clients would have to decide how frequently proactive updates would be sent, in which industry sectors to invest and would have to deal with more detailed information about their portfolio allocation. This adds complexity to the RA which can be problematic, since their fundamental benefits are convenience and ease-of-use (Beketov et al., 2018; Jung et al., 2019). The short-term adoption rate, especially for the inexperienced or low financially literate target audience of RA could decrease due to the increased effort in answering more questions and getting more information. The question arises to what extent ethical considerations and therefore concrete ethical DPs should be implemented in RA. Presumably, only a certain degree of ethical considerations need to be established to provide sufficiently ethical RA to clients. Implementing ethical attributes beyond this “minimum hurdle” would be in the long-term interest of clients and society but would also require resources from RA providers that they do not see enough value in. Therefore, RA-providers are likely to maximize profits and considering ethics secondly. This implies that a more binding regulation is needed if RAs should provide more ethical financial advice. Regulators

can therefore use our DPs as a discussion base on whether to incorporate a stricter regulation upon RA-providers that would enhance their moral aspects and force them to go beyond a minimum of ethical considerations.

Further, this study provides researchers a baseline to investigate how RA can become more ethical, while practitioners can use our DPs directly to ensure more ethical outcomes of their RA. We encourage RA provider to implement our DPs in RA instantiations to mitigate ethical problems, increase their trustworthiness and enhance the experience of their clients. Additionally, this might help RA providers to understand client needs better and increase RA adoption.

3 Limitations

Besides their careful design and execution, each study of this cumulative thesis is subject to limitations. In the following, I present the major limitations grouped into the two research areas.

3.1 Research Area I. Positioning of Robo-Advice in Science and Practice

In paper 1 (Torno, Metzler, et al., 2021) we excluded the judicial viewpoints, because we wanted to provide a comprehensive scientific analysis of IS and business-related research on RA. Still, the judicial perspective on RA can be valuable since the regulations on financial advice are complex and manifold. For example, it is discussable whether RAs provide sound advice in terms of fiduciary standards, acting in the best interest of investors (Ji, 2017). Furthermore, we recognize limitations based on our research design, particularly concerning the searched databases, the used search strings, and inclusion criteria, which narrowed our pool of relevant literature. Lastly, we acknowledge the exploratory nature of the literature review, with a certain degree of subjectivity within its content analysis.

As a first limitation of paper 2 (Torno, Werth, et al., 2021) we classified a sample of 170 apps from the regional German app stores to develop the taxonomy. While the German app market is big and diverse, it can be criticized that the results are not generalizable to other app market regions. Countering this objection, we examined a sample of the top mobile personal finance apps from the US app stores and found that the sample could be sufficiently described and categorized using our taxonomy and archetypes. A second limitation can be seen in not performing an evaluation of our results by third parties. While we performed a sixth iteration within the taxonomy development to show our taxonomy's stability, an evaluation could support its usefulness and correctness (Szopinski et al., 2019).

3.2 Research Area II. Analysis and Design of Robo-Advice

The first limitation of paper 3 (Metzler et al., 2022) comprises the sample of analyzed RAs that is limited to the biggest US-based RAs, which makes generalizations to other regions or types of firms problematic. Secondly, we only included publicly available documents of the RAs themselves which could result in biased findings. Further, we cannot answer why RAs decided on their respective BM configuration. For example, although we can state that some RAs have a high account minimum which delimits their potential customer segments, we can only guess why these RAs decide to do so. Lastly, since financial information was not available for all analyzed RAs, we could not analyze the financial profitability of RA BMs.

Also paper 4 (Torno & Schildmann, 2020) is subject to several limitations. Firstly, since the data collection took place at a certain time period, the recommendations of the RAs are only a snapshot, and their analysis may reveal different insights in other periods. Secondly, we did not capture the maintenance phase of the RAs. Therefore, we cannot state how often and to which degree the different RA are rebalancing their recommended portfolios. Another limitation can be seen in the data collection from the perspective of six distinct customer models, having different risk-affinities and investment horizons. While carefully modelling the dynamic characteristics of the model customers and rigidly going through the Initiation & Profiling phases, it is possible, that occasionally questions could not be answered with confidence. Additionally, the different monetary policies of the FED and the ECB led to separate market conditions in the country groups which made comparisons difficult. Due to the lack of appropriate conditions for parametric tests, the non-parametric alternatives were used in these cases. While these the non-parametric test are characterized by a lower test strength, they are considered to be more robust. Since the test results were clear and plausible, we have no reason to assume that the type of statistical test misled the insights.

The limitations of paper 5 (Torno et al., 2022) start with the classification of requirements into DDs and MRs, which can be described as subjective. This was mitigated by using the qualitative content analysis approach by Mayring (2014) and discussions in the author team until a consensus was reached. Additionally, the evaluation resulted in an agreement with our DDs, MRs and DPs and concluded that no further requirements were missing. Secondly, although practical insights from international guidelines and standards of financial advice were incorporated into the DDs and MRs, the DPs were predominantly derived from RA literature. Thirdly, the requirements analysis was initiated from a scientific and practitioners' perspective. Hence, a users' perspective on ethical RA design is missing in the design artifact. Fourth, adhering to our DPs for improving RA could be hard to measure and could be differing depending on the targeted client preferences. Finally, our evaluation is mainly based on the expertise of RAs operating in Germany, neglecting perspectives from other regions.

4 Future Research

The limitations presented in the section above can also guide future research. In the following, I present worthwhile directions for future research in RA grouped into the two research areas.

4.1 Research Area I. Positioning of Robo-Advice in Science and Practice

One of the goals of paper 1 (Torno, Metzler, et al., 2021) was to derive open RQs in the RA domain. We therefore encourage interested researchers to consider these questions when designing RA studies. Still, there could be more open RQs in future scientific publications. Therefore, we suggested to not only continue the systematic literature review approach based on our study, but to enhance it. For example, relevant law articles could be used to analyze the RA literature from a regulatory perspective, which could be integrated into our research framework as an additional theme.

The limitations of paper 2 (Torno, Werth, et al., 2021) can also provide worthwhile future research directions. Thereby, future research should evaluate the applicability of our taxonomy and archetypes to app markets in other regions than Germany and with a larger sample size. Furthermore, future research could evaluate our taxonomy, e.g., by conducting interviews with financial services providers or other app developers. Also, our cluster analysis could be evaluated e.g., by using other clustering methods or discriminant analysis. Thereby, the expandable nature of the taxonomy allows researchers to modify, merge, add and delete characteristics and dimensions and therefore adapt the taxonomy to possible new innovations.

Based on the taxonomy and clustering, a higher-order predictive theory could be developed that allows researchers to better design and evaluate mobile personal finance apps (Gregor, 2006). In that regard, a possible research direction could be the measurement of mobile finance apps' success, e.g., with the information systems success model of DeLone & McLean (2004). We found that download numbers, review counts, and ratings differ between the apps within the archetypes. These success measurements could be further analyzed, e.g., regarding the archetypes, to find principles for successful mobile personal finance app designs.

Lastly, it seems promising to develop innovative IT-artifacts using a DSR approach. Based on one or a combination of multiple identified archetypes, researchers could integrate emerging concepts, e.g., gamification elements. These were only found rarely and rudimentary in mobile personal finance apps, e.g., in form of awards for saving money. When used more robustly, gamification elements can enhance user engagement with the app and could thereby positively influence personal finance activities of the user (e.g., Schöbel et al., 2020).

4.2 Research Area II. Analysis and Design of Robo-Advice

The results of paper 3 (Metzler et al., 2022) were based on the 15 biggest RAs in the USA and can therefore only be generalized to large RAs in this region. Future research could extend the research scope to other geographical regions, such as Europe and Asia, and/or to smaller RAs, e.g., from less established FinTech firms. Thereby, the number of analyzed RAs could also be increased. Additionally, future research could extend the database with external RA information, e.g., from industry reports. Since it is important to understand which factors led to RAs BM configurations, future research should elaborate on this, e.g., by conducting interviews with RA experts from practice.

Since existing RAs are usually relatively young and modifications to their BMs common, the main differentiation between pure and hybrid RA could be a subject of change. Therefore, we suggest tracking future developments by comparing new BM-related findings with the results of this study. Such continuous re-evaluations are especially important in early developing businesses, as in the RA business. Lastly, we encourage researchers to compare RA BMs and BMs of traditional asset and WM services to gain further insights on the success of RA BMs now and in the future.

The limitations of paper 4 (Torno & Schildmann, 2020) provide worthy directions for future research. By analyzing the portfolios of the RA at various times, the changes within the portfolio recommendations could be observed and analyzed. Thereby, it can be of special interest how the RAs approach more volatile financial markets, e.g., after the financial crash due to the Coronavirus-pandemic. Also, more granular portfolio changes through more differentiating individual customer profiles, e.g., by adding more dynamic characteristics or changing the static characteristics, could be helpful to collect more varying recommended portfolios of RAs. This can lead to a broader understanding of the relationship between the Initiation & Profiling phase and the recommended portfolios.

Paper 5 (Torno et al., 2022) contributes to research by providing a blueprint for ethical considerations in RA. Because of its abstract nature, the derived MRs could also be applied in other FinTech contexts and could thereby be used to structure ethical DPs for other FinTech BMs to increase trustworthiness. To tackle the limitations of this study, future research could analyze larger and cross-regional samples of RAs and involve users and important stakeholders to gain more comprehensive insights. We also recommend broadening the database by including additional design literature streams, e.g., from ethical IS design and AI design, considering the fast-evolving technological advances in RA, eventually including AI technology and concepts.

Furthermore, a quantitative evaluation of our MRs and DPs could provide insights into their individual contribution to more ethical RA. Finally, since we did not instantiate our DPs in a prototype, we encourage future research to develop, demonstrate and evaluate ethical RA prototypes based on the presented DPs.

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Appendix

	#	Paper (Citation)	Author(s)	Contribution
Included in this dissertation	Research Area I. Positioning of Robo-Advice in Science and Practice	1 Torno, A., Metzler, D. R., and Torno, V. 2021. “Robo-What?, Robo-Why?, Robo-How? – A Systematic Literature Review of Robo-Advice,” in <i>Proceedings of the 25th Pacific Asia Conference on Information Systems (PACIS)</i> , Dubai, VAE.	Torno, A. Metzler, D. R. Torno, V.	80% 10% 10%
		2 Torno, A., Werth, O., Nickerson, R. C., Breitner, M. H., and Muntermann, J. 2021. “More than Mobile Banking – A Taxonomy-Based Analysis of Mobile Personal Finance Applications,” in <i>Proceedings of the 25th Pacific Asia Conference on Information Systems (PACIS)</i> , Dubai, VAE.	Torno, A. Werth, O. Nickerson, R. C. Breitner, M. H. Muntermann, J.	50% 30% 10% 5% 5%
	Research Area II. Analysis and Design of Robo-Advice	3 Metzler, D. R., Neuss, N., and Torno, A. 2022. “The Digitization of Investment Management – An Analysis of Robo-Advisor Business Models,” in <i>Proceedings of the 17th International Conference on Wirtschaftsinformatik (WI)</i> , Nürnberg, Germany, (Best paper award nominee).	Metzler, D. R. Neuss, N. Torno, A.	50% 40% 10%
		4 Torno, A., Schildmann, S. 2020. “What Do Robo-Advisors Recommend? - An Analysis of Portfolio Structure, Performance and Risk,” in <i>Clapham B. and Koch J.-A. (eds) Enterprise Applications, Markets and Services in the Finance Industry. FinanceCom 2020. Lecture Notes in Business Information Processing (LNBIP)</i> (401), 92–108.	Torno, A. Schildmann, S.	85% 15%
		5 Torno, A., Bähnsch, S., and Dreyer, M. 2022. “Taming the Next Wolf of Wall Street – Design Principles for Ethical Robo-Advice,” in <i>Proceedings of the 26th Pacific Asia Conference on Information Systems (PACIS)</i> , Taipei/Sydney.	Torno, A. Bähnsch, S. Dreyer, M.	70% 15% 15%
Not included in this dissertation	6	Metzler, D. R. and Torno, A. 2021. “How Incumbent Financial Firms Approach their Digital Transformation – An Analysis of Digitalization Initiatives of Traditional Banks,” in <i>Banking and Information Technology</i> (22:1), 11-20.	Metzler, D. R. Torno, A.	50% 50%
	7	Rodríguez Cardona, D., Werth, O., Torno, A., Breitner, M. H., Muntermann, J. 2022. “What Determines FinTech Success? – A Taxonomy-based Analysis of FinTech Success Factors,” in <i>Electronic Markets</i> (under review).	Rodríguez Cardona, D. Werth, O. Torno, A. Breitner, M. H. Muntermann, J.	

Appendix Table 1. Overview of papers and approx. author contribution ratios

Appendix of Paper 1: Robo-What?, Robo-Why?, Robo-How? – A Systematic Literature Review of Robo-Advice

Exclusion criteria	Exemplary excluded articles
<i>Studies outside the IS, finance, or other business literature domains, e.g., law</i>	(Baker and Dellaert 2018; Bayón and Vega 2018; Fein 2017; Guo 2020; Lee 2020; Lightbourne 2017; Maume 2019; Strzelczyk 2017)
<i>Studies not focusing on RA or the digitalization and automation of traditional financial advice</i>	(Ahn et al. 2020; Baek et al. 2020; Bunnell et al. 2021; Eickhoff et al. 2017; Engin and Treleaven 2019; Gomber et al. 2017, 2018; Haberly et al. 2019; Kilic et al. 2017; Kim et al. 2020; Lewis 2018; Łyczkowska-Hanćkowiak 2020; Musto et al. 2015; Nueesch et al. 2016; Puschmann 2017; Scherer 2017; Semko 2019; Sensenig et al. 2020; Tharp 2020; Vasiljeva and Lukanova 2016; Xue, Liu, et al. 2018; Xue, Zhu, et al. 2018)
<i>Not peer-reviewed studies and studies without rigorous research method such as whitepapers, market analyses, commentaries, research-in-progress articles, or books</i>	(Beltramini 2018; Beyer 2017; Bruckes et al. 2019; D’Acunto and Rossi 2020; Faloon and Scherer 2017; Fisch et al. 2019; Jung et al. 2018; Kaya 2017; Puhle 2017; Salam-pasis 2017; Shanmuganathan 2020; Sironi 2016; Tokic 2018; Viceira et al. 2018; Wang 2020)

Appendix Table 2. Exclusion criteria with exemplary excluded articles

References of Excluded Articles

- Ahn, W., Lee, H. S., Ryou, H., and Oh, K. J. 2020. “Asset Allocation Model for a Robo-Advisor Using the Financial Market Instability Index and Genetic Algorithms,” *Sustainability* (12:3), Article 849.
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Appendix of Paper 2: More than Mobile Banking – A Taxonomy-based Analysis of Mobile Personal Finance Applications

<i>Dimension /</i> Characteristic	Definition
<i>Cost structure</i>	Whether and how the user pays a fee for the offered service or mobile app
For free	Completely free usage of app and service
Freemium [in-app purchases]	The app is free to download and provides additional features as in-app purchases
Freemium [subscription]	The app is free to download and provides additional features when subscribing to the service with a fee
Freemium [transaction dependent]	The app is free to download but to use certain services, a percentage of the investment or transaction amount needs to be paid as a fee
Premium	The app has a certain price that needs to be paid in advance to use the app
Hybrid	The app has a certain price that needs to be paid in advance to use the app and provides additional features when subscribing to the service with a fee and/or through in-app purchases
<i>Transaction trigger</i>	Whether and how the mobile app provides a way to trigger financial transactions, e.g., bank transfers, investment buying orders, or contactless payment
Manual + Assisted manual	Financial transactions can be manually or assisted manually triggered by the user through the app, e.g., by using additional smartphone functions
Manual	The user must manually trigger financial transactions through the app
None	The user cannot trigger financial transactions through the app
<i>Internet connectivity</i>	Whether and how an internet connection is necessary to deliver the service through the mobile app
Mandatory	To use the service, the app needs to have an internet connection
Periodically online	To use the service, the app needs to have an internet connection periodically, e.g., to sync the newest financial transactions
Offline	To use the service, the app does not need an internet connection
<i>Data / Information flow</i>	In which direction the information between user and mobile app provider flows
Unidirectional to user	Information and data generally flow from the mobile app to the user
Unidirectional from user	Information and data generally flow from the user to the mobile app
Bidirectional	Information and data flow in both directions between user and mobile app
<i>User account</i>	Whether a user account is mandatory to use the mobile app and service
Mandatory	A user account is mandatory to use the app and service
Not mandatory	No user account is mandatory to use the app and service

<i>Dimension /</i> Characteristic		Definition
<i>Sharing of user data</i>		Whether and how the data/information of users is transferred to others through the mobile app
	App provider only	The app has no connection for data/information transfer to other apps, services, or companies
	[Other] banks	The app connects to (other) banks, e.g., to provide automated import of financial transactions
	Third parties	The app connects to other third parties, e.g., to provide automated import of insurance contracts
	Banks + Third parties	The app connects to multiple third parties
<i>Personalized advisory</i>		Whether and how the mobile app delivers an advisory or recommendation service to the user
	Hybrid	The app provides both automated personalized advisory services and a channel for human advice
	Automated	The app provides automated personalized advisory services without human advice
	Human advice through app	App provides a channel for human advice
	None	The app does not provide any personalized advisory service
<i>Credit</i>		Whether and how the mobile app provides the user with a way to borrow money
	Offering / Mediating	User can borrow money from the underlying financial service provider or other financial institutions mediated through the app
	Monitoring	User can monitor current credit scores and/or accounts in the app
	None	The app does not provide a way to borrow money or monitor credit
<i>Transferring money</i>		Whether and how the mobile app provides a way for the user to pay with money or cryptocurrency
	Money (bank transfer)	The app provides a way to transfer money via bank transfer
	Money (retail)	The app provides a way to transfer money in retail, e.g., contactless payment
	Hybrid	The app provides different ways to transfer money
	Legitimizing transactions only	The app provides only a way to legitimate transactions of the user
	None	The app does not provide a way to transfer money or cryptocurrencies

<i>Dimension /</i> Characteristic		Definition
<i>Budgeting</i>		Whether and how the mobile app provides the user a way to budget his/her money
	Manual	The app provides a manual categorization of transactions and budgeting
	Automated	The app provides automated transaction categorization
	Manual + Auto-mated + Prediction	The app provides automated recommendations for transaction categorization, budgeting, and future predictions of budget over-/underspending
	None	The app does not provide budgeting functionality or categorization of transactions
<i>Investing</i>		Whether and how the mobile app provides a way for the user to invest in financial assets
	Traditional financial assets	The app provides a way to invest in traditional financial assets, e.g., stocks, bonds, and funds
	Non-traditional financial assets	The app provides a way to invest in other investment vehicles, e.g., CFDs or cryptocurrencies
	Hybrid	The app provides a way to invest in traditional financial assets and other investment vehicles
	Monitoring	The app provides a way to monitor portfolios of financial assets or other investment vehicles
	None	The app does not provide a way to invest in investment vehicles or monitor portfolios
<i>Informing</i>		Whether and how the mobile app provides information offerings to the user
	Non-individualized	App provides non-individualized information offerings like news, pricing, and conversion rates
	Individualized	App provides individualized information offerings, e.g., on personal contract administration or personal taxation
	Hybrid + Education	App provides multiple (individualized or non-individualized) information offerings and educational content
	None	The app does not provide information offerings

Appendix Table 3. Definitions of dimensions and characteristics

	Technical artifact perspective														Financial services perspective																																						
	Cost structure					Transaction trigger	Internet connectivity	Data / Information flow		User account		Sharing of user data			Personalized advisory		Credit		Transferring money			Budgeting		Investing			Informing																										
	For free	Freemium [in-app purchases]	Freemium [subscription]	Freemium [transaction dependent]	Premium	Hybrid	None	Manual	Manual + Assisted manual	Mandatory	Periodically online	Offline	Unidirectional to user	Unidirectional from user	Bidirectional	Mandatory	Not mandatory	App provider only	[Other] banks	Third parties	Banks + Third parties	Hybrid	Automated	Human advice through app	None	Offering / Mediating	Monitoring	None	Money [bank transfer]	Money [retail]	Hybrid	Legitimizing transactions only	None	Manual	Automated	Manual + Automated + Prediction	None	Traditional financial assets	Non-traditional financial assets	Hybrid	Monitoring	None	Non-individualized	Individualized	Hybrid + Education	None							
Mobile personal finance app																																																					
Cryptocurrency Exchange Rates				x		x				x			x				x	x			x				x					x							x				x												
CryptoPort - Coin portfolio tracker		x					x			x					x	x				x				x						x											x												
Daily Budget Original Pro					x																		x																														
Daily Expenses License / Daily Expenses 3						x	x				x			x			x	x							x		x																										
Delta Investment Portfolio Tracker			x				x			x					x	x				x					x																												
Deutsche Bank Mobile	x								x	x					x	x				x					x	x																											
Deutsche Bank photoTAN	x						x			x			x					x							x																												
Digifox: Finance for Everyone		x						x		x					x	x				x					x																												
Digitale Karten	x								x		x														x																												
divTimer - dividend manager			x				x				x														x																												
DKB-Banking	x								x	x				x											x	x																											
DKB-TAN2go	x						x			x			x												x																												
Drakdo: Bitcoin & Forex Price Action	x						x			x							x	x							x																												
Driverslog Pro	x						x				x		x				x	x							x																												
Easy Currency Converter Pro						x					x		x				x	x							x																												
ElsterSmart	x						x			x				x			x	x							x																												
eToro - Smart crypto trading made easy				x					x	x					x	x		x							x																												
Exchange rate converter				x			x					x			x			x							x																												
Exodus: Crypto Bitcoin Wallet				x				x		x							x	x							x																												
ExpensesTracker MyMicroBalance		x					x				x			x			x	x							x																												
Family Budget Finance Tracking		x									x			x			x	x							x																												
Fast Budget - Expense & Money Manager		x									x			x			x	x							x																												
Finanzen100 - Börse, Aktien & Finanznachrichten				x			x			x							x	x							x																												
Finanzguru			x				x				x			x			x				x																																
Finimize: Finance Simplified			x							x			x				x	x																																			
flatex next				x				x					x		x		x	x								x																											
FOCUS-MONEY						x	x				x			x			x	x								x																											
Freedom24 by Freedom Finance				x				x			x				x	x				x						x																											
FXStreet - Forex News, Economic Calendar & Rates			x				x				x						x									x																											
Getsafe	x							x		x					x	x		x																																			
Google Pay	x								x		x						x	x																																			
Guidants – Stocks & News			x					x		x					x	x																																					
Hanseatic Bank Secure	x							x					x				x								x																												
HomeBudget with Sync					x									x																																							
Household Account Book : Saving for Simple-tons			x					x				x					x	x																																			
Hypothekenrechner HypoPlaner					x		x				x			x			x	x									x																										
iCurrency Pad					x			x			x						x	x										x																									
iFinance 4					x			x			x			x			x				x																																
ING Banking to go – Banking einfach und sicher	x								x	x					x	x		x							x																												
Invest with Peaks				x					x		x		x						x																																		
Investing.com: Stocks, Finance, Markets & News				x				x		x							x	x																																			
Investment portfolio, stocks, etf, forex, crypto		x					x			x							x	x																																			

[illegible]

	Technical artifact perspective																		Financial services perspective																															
	Cost structure					Transaction trigger		Internet connectivity		Data / Information flow		User account		Sharing of user data				Personalized advisory			Credit			Transferring money				Budgeting			Investing				Informing															
	For free	Freemium [in-app purchases]	Freemium [subscription]	Freemium [transaction dependent]	Premium	Hybrid	None	Manual	Manual + Assisted manual	Mandatory	Periodically online	Offline	Unidirectional to user	Unidirectional from user	Bidirectional	Mandatory	Not mandatory	App provider only	[Other] banks	Third parties	Banks + Third parties	Hybrid	Automated	Human advice through app	None	Offering / Mediating	Monitoring	None	Money [bank transfer]	Money [retail]	Hybrid	Legitimizing transactions only	None	Manual	Automated	Manual + Automated + Prediction	None	Traditional financial assets	Non-traditional financial assets	Hybrid	Monitoring	None	Non-individualized	Individualized	Hybrid + Education	None				
Mobile personal finance app																																																		
Pro Credit Card Reader NFC					x		x					x	x			x	x	x	x			Hybrid		Automated			x							x																
ProfitTrading For Binance - Trade much faster				x				x			x					x	x			x						x								x				x												
Remitly: Send Money & Track International Funds				x				x			x					x	x				x																													
Revolut - Get more from your money			x						x	x						x	x				x						x									x														
S-ID-Check	x						x						x								x															x														
S-Invest - Wertpapiere und Börse	x							x			x					x	x																																	
S-pushTAN	x							x			x					x		x																																
Santander Banking	x							x			x					x	x																																	
SantanderSign	x							x					x					x																																
SayMoney - Your finances		x						x			x					x		x																																
Scalable Capital: Broker Trading & Robo Advisor					x				x							x				x																														
Seeking Alpha: Stock Market News & Analysis			x					x			x					x		x	x																															
Simple Cashbook						x			x									x	x																															
SpardaSecureApp	x										x							x																																
Sparkasse Ihre mobile Filiale	x								x	x						x	x																																	
Spend Stack: Budget Tracker						x			x							x																																		
Spendee - Budget and Expense Tracker & Planner			x															x																																
Splicd - Split group bills	x								x								x																																	
Splittr - Expense Splitting		x							x								x																																	
Splitwise			x														x																																	
StarMoney - Banking + Kontenübersicht	x								x		x						x																																	
Steuerbot: Free German Tax Return incl. ELSTER		x							x							x	x																																	
Stocks & Markets - ARIVA.DE									x									x	x																															
StormGain: Bitcoin Wallet & Crypto Exchange App					x				x							x	x																																	
Stoxy PRO - Stocks, Indices, Futures						x																																												
TabTrader Buy Bitcoin and Ethereum on exchanges		x							x								x																																	
TARGOBANK Mobile Banking	x								x	x							x																																	
Taxfix - Simple German tax declaration via app						x											x																																	
Toshl Finance - Personal Budget & Expense Tracker		x							x																																									
Trade Republic: Mobile Broker									x		x																																							
Trading 212 - Stocks, ETFs, Forex, Gold						x			x								x																																	
Trading Room - Forex signals and analytics									x								x																																	
TradingView - Stock charts, Forex & Bitcoin price									x																																									
TransferWise Money Transfer									x	x							x																																	
Tricount - Split bills & manage group expenses		x							x								x																																	
TronLink Pro - The Best TRON Wallet									x								x																																	
Trust: Crypto & Bitcoin Wallet									x								x																																	
VR Banking Classic		x							x	x							x																																	
VR SecureGo plus (Kreditkarte)		x							x								x																																	
VR-SecureGo		x							x								x																																	
Wallet: Personal Finance, Budget & Expense Tracker									x								x																																	
Western Union® App: Send Money Abroad									x	x							x																																	
WISO Steuer - Steuererklärung einfach gemacht.									x								x																																	
Zoya: Instantly find halal stocks									x								x																																	
Sum	66	33	20	34	30	11	104	44	34	128	35	19	45	47	90	121	58	118	21	28	18	15	21	11	141	24	29	129	27	8	17	15	121	37	22	20	106	20	23	10	33	102	71	21	26	67				

Appendix Table 4. Taxonomy with all classified 170 apps

Cluster 1 - App Provider Specific Financial News and Analysis	Cluster 2 - Advanced Budgeting	Cluster 3 - Transaction Remunerated Trading and International Money Transfer	Cluster 4 - Manual Budgeting without Data Sharing	Cluster 5 - Transaction Authorization
23 Apps	7 Apps	31 Apps	26 Apps	13 Apps
Bitcoin Crypto Prices Alerts Portfolio Widget News Biticker Pro - Bitcoin Price, Ripple, Ethereum Bitstat - Crypto Tracker Börse & Aktien - BörsennewsApp Börse & Aktien - finanzen.net Börse, Aktien & Finanzen CoinMarketCap - Crypto Price Charts & Market Data Crypto Tracker & Bitcoin Price - Coin Stats Cryptocurrency Exchange Rates CryptoPort - Coin portfolio tracker Finanzen100 - Börse, Aktien & Finanznachrichten Finimize: Finance Simplified FXStreet - Forex News, Economic Calendar & Rates Investing.com: Stocks, Finance, Markets & News Investment portfolio, stocks, etf, forex, crypto My Stocks Portfolio & Widget onvista - Musterdepot, Aktien, Finanzen, Derivate Portfolio Trader-Stock Tracker Seeking Alpha: Stock Market News & Analysis Stocks & Markets - ARIVA.DE Stoxy PRO - Stocks, Indices, Futures Trading Room - Forex signals and analytics TradingView - Stock charts, Forex & Bitcoin price	Banking4 Finanzguru Money Pro: Personal Finance AR MoneyStats - Expense Tracker Spendee - Budget and Expense Tracker & Planner Toshl Finance - Personal Budget & Expense Tracker Wallet: Personal Finance, Budget & Expense Tracker	Binance: Bitcoin Marketplace & Crypto Wallet BISON - Buy Bitcoin & Co Bitcoin trading - Capital.com Bitcoin.de Bitpanda: Buy Bitcoin Bitwala: Crypto Banking Blockchain.com Wallet - Buy Bitcoin, ETH, & Crypto Coinbase - Buy & Sell Bitcoin. Crypto Wallet Crypto App - Widgets, Alerts, News, Bitcoin Prices Crypto.com - Buy Bitcoin Now Delta Investment Portfolio Tracker Digifox: Finance for Everyone Exodus: Crypto Bitcoin Wallet flatex next Freedom24 by Freedom Finance Kraken Pro: Advanced Bitcoin & Crypto Trading Libertex: Trade in Stocks, Forex, Indices & Crypto Money Transfer App Paysend MoneyGram International NetDania Stock & Forex Trader nextmarkets Plus500: CFD Online Trading on Forex and Stocks ProfitTrading For Binance - Trade much faster Remitly: Send Money & Track International Funds StormGain: Bitcoin Wallet & Crypto Exchange App TabTrader Buy Bitcoin and Ethereum on exchanges Trade Republic: Mobile Broker Trading 212 - Stocks, ETFs, Forex, Gold TronLink Pro - The Best TRON Wallet Trust: Crypto & Bitcoin Wallet Western Union® App: Send Money Abroad	1Money - Expense Tracker, Money Manager, Budget Bluecoins Finance: Budget, Money & Expenses Car Costs Complete Daily Expenses License / Daily Expenses 3 Driverslog Pro ExpensesTracker MyMicroBalance Family Budget Finance Tracking Fast Budget - Expense & Money Manager HomeBudget with Sync Household Account Book : Saving for Simpletons Mina utgifter Mobills Budget Planner and Track your Finances Moneyfy Pro - Budget Manager and Expense Tracker Moneon — personal budget planner, finance tracker Money Lover: Expense Manager & Budget Tracker Money Manager Expense & Budget MoneyBook - finance with flair MoneyControl Spending Tracker My Budget Book My Expenses Next for iPhone Our Budget Book Pro Pennies – Budget and Expenses SayMoney - Your finances Simple Cashbook Spend Stack: Budget Tracker	Bernecker comdirect photoTAN App Commerzbank photoTAN Consorsbank SecurePlus Deutsche Bank photoTAN DKB-TAN2go Hanseatic Bank Secure Postbank BestSign S-ID-Check S-pushTAN SantanderSign SpardaSecureApp VR-SecureGo
Cluster 6 - Credit Card and Retail Payment	Cluster 7 - User-Account-based Individualized Informing	Cluster 8 - Non-Individualized Informing	Cluster 9 - Investing with Advice	Cluster 10 - Full-Featured Mobile Banking
18 Apps	17 Apps	14 Apps	8 Apps	13 Apps
Advanzia Amazon.de VISA Karte Amex Deutschland Bank X Mobile 4 BankingZV Barclaycard Deutschland Consors Finanz Mobile Banking Digitale Karten Google Pay iFinance 4 Mobiles Bezahlen - Ihre digitale Geldbörse MoneyWiz 3 - Personal Finance N26 Mobile Banking PayPal Mobile Cash: Send and Request Money Fast paysafecard – pay cash online Santander Banking StarMoney - Banking + Kontenübersicht VR SecureGo plus (Kreditkarte)	Best Brokers: Stock Simulator Capital Magazin CHECK24 Vergleiche CLARK - Versicherungen einfach managen Daily Budget Original Pro divTimer - dividend manager ElsterSmart Getsafe Meine Allianz meine SIGNAL IDUNA Splid – Split group bills Splitt - Expense Splitting Splitwise Steuerbot: Free German Tax Return incl. ELSTER Taxfix – Simple German tax declaration via app Tricount - Split bills & manage group expenses WISO Steuer – Steuererklärung einfach gemacht.	Bitcoin Ticker Widget Bruno Pro - Brutto Netto Rechner 2021 Drakdoo: Bitcoin & Forex Price Action Easy Currency Converter Pro Exchange rate converter FOCUS-MONEY Hypothekenrechner HypoPlaner iCurrency Pad KfzSteuer+ Mobile HitBTC Money manager, expense tracker, budget, wallet My Currency PRO: Exchange Rate Pro Credit Card Reader NFC Zoya: Instantly find halal stocks	eToro - Smart crypto trading made easy Guidants – Stocks & News Invest with Peaks Numbrs – Mobile Banking Own360 Revolut - Get more from your money S-Invest - Wertpapiere und Börse Scalable Capital: Broker Trading & Robo Advisor	comdirect Commerzbank Banking - The app at your side Consorsbank Deutsche Bank Mobile DKB-Banking ING Banking to go – Banking einfach und sicher o2 Money & o2 Banking: Finanz- und Banking-App paydirekt Postbank Finanzassistent Sparkasse Ihre mobile Filiale TARGOBANK Mobile Banking TransferWise Money Transfer VR Banking Classic

Appendix Table 5. List of apps in each cluster

Appendix of Paper 4: What do Robo-Advisors Recommend? – An Analysis of Portfolio Structure, Performance and Risk

<i>Exemplary Questions</i>	Static Characteristics	Rationale
<i>Gender and age</i>	Male, 30	Target group of RA: Young, digital native and professionally successful individuals, without financial affinity and time to take care of finances themselves (Jung et al., 2019; Sironi, 2016).
<i>Occupation</i>	Employee	
<i>Annual income</i>	50,000 – 100,000 €	
<i>Savings rate</i>	7%	Corresponds to the average savings rate of households in 18 European countries, as well as the USA and Canada between 2016 and 2018 (Statista, 2018b).
<i>What amount would you like to invest?</i>	42,500 €	Corresponds to the average AuM per user for RAs in the USA (approx. 81,000 €) (Statista, 2020b) and Germany (approx. 4,000 €) (Statista, 2020a) in 2019.
<i>What is your total wealth?</i>	50,000 – 180,000 €	Corresponds to the net private financial assets per capita in Germany and the USA in 2018 (Statista, 2018a).

Appendix Table 6. Exemplary static characteristics of model customers

<i>Exemplary questions</i>	Dynamic characteristics		
	Short-term investment	Long-term investment	
<i>Investment horizon?</i>	3 years	15 years	
	Low Risk (Lo)	Medium Risk (Me)	High Risk (Hi)
<i>Have you ever lost 25% or more of your investment within a year?</i>	no	no	yes
<i>What would you do if your portfolio loses 20% in value within one year?</i>	Sell immediately	Do nothing	Buy more assets

Appendix Table 7. Exemplary questions regarding dynamic characteristics of model customers

<i>RA of category A (Portfolio structure & used products)</i>	<i>Country</i>	<i>RA of category B (Portfolio struc- ture only)</i>	<i>Country</i>	<i>RA of category C (No portfolio structure)</i>	<i>Country</i>
<i>Acorns</i>	USA	<i>Bevestor</i>	DEU	<i>Ameritrade TD</i>	USA
<i>Ally Invest Managed Portfolios</i>	USA	<i>comdirect - cominvest</i>	DEU	<i>Axos</i>	USA
<i>Asset-Builder</i>	USA	<i>Deutsche Bank - ROBIN</i>	DEU	<i>Hedgeable</i>	USA
<i>Autowealth</i>	SGP	<i>ELVIA e-invest</i>	CHE	<i>Minveo</i>	DEU
<i>Baloise Monviso</i>	DEU	<i>E*Trade Core Portfolios</i>	USA	<i>Personal Capital</i>	USA
<i>Easyfolio</i>	DEU	<i>FutureAdvisor</i>	USA	<i>Quirion</i>	DEU
<i>E-Base</i>	DEU	<i>Investify</i>	DEU	<i>Smavesto</i>	DEU
<i>Ellevest</i>	USA	<i>Moneyfarm</i>	GBR	<i>Tradeking (Merged with Ally)</i>	USA
<i>Evestor</i>	GBR	<i>Schwab Intelligent Portfolios</i>	USA	<i>truevest</i>	DEU
<i>Fairr.de</i>	DEU	<i>SigFig</i>	USA	<i>Vaamo (Merged with Moneyfarm)</i>	GBR
<i>Fintego</i>	DEU	<i>Visualvest</i>	DEU	<i>Wealthfront</i>	USA
<i>Ginmon</i>	DEU	<i>Warburg Naviga- tor</i>	DEU	<i>WiseBanyan (Merged with Axos)</i>	USA
<i>Growney</i>	DEU	<i>Whitebox</i>	DEU	<i>WMD Capital</i>	DEU
<i>JPMorgan Chase</i>	USA			<i>Zeedin Hauck- Aufhäuser</i>	DEU
<i>LIQID</i>	GBR				
<i>LIQID: Sustainabil- ity</i>	DEU				
<i>Merrill Guided In- vesting</i>	USA				
<i>Morgan Stanley</i>	USA				
<i>Morgan Stanley: Climate</i>	USA				
<i>Morgan Stanley: Gender Diversity</i>	USA				
<i>Nutmeg</i>	GBR				
<i>Scalable Capital</i>	DEU				
<i>Wüstenrot</i>	DEU				

Appendix Table 8. Analyzed RAs

Versicherung bei Zulassung zur Promotionsprüfung

Ich versichere,

1. dass ich die eingereichte Dissertation „Robo-Advice: The Digitalization and Automation of Financial Advice“ selbstständig angefertigt habe und nicht die Hilfe Dritter in einer dem Prüfungsrecht und wissenschaftlicher Redlichkeit widersprechenden Weise in Anspruch genommen habe,
2. dass ich das Prüfungsrecht einschließlich der wissenschaftlichen Redlichkeit – hierzu gehört die strikte Beachtung des Zitiergebots, so dass die Übernahme fremden Gedankenguts in der Dissertation deutlich gekennzeichnet ist – beachtet habe,
3. dass beim vorliegenden Promotionsverfahren kein Vermittler gegen Entgelt eingeschaltet worden ist sowie im Zusammenhang mit dem Promotionsverfahren und seiner Vorbereitung
 - kein Entgelt gezahlt oder entgeltgleiche Leistungen erbracht worden sind
 - keine Dienste unentgeltlich in Anspruch genommen wurden, die dem Sinn und Zweck eines Prüfungsverfahrens widersprechen
4. dass ich eine entsprechende Promotion nicht anderweitig beantragt und hierbei die eingereichte Dissertation oder Teile daraus vorgelegt habe.

Mir ist bekannt, dass Unwahrheiten hinsichtlich der vorstehenden Versicherung die Zulassung zur Promotionsprüfung ausschließen und im Falle eines späteren Bekanntwerdens die Promotionsprüfung für ungültig erklärt werden oder der Doktorgrad aberkannt werden kann.

Göttingen, Juni 2022

Albert Torno