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UNDERSTANDING USER PERCEPTIONS AND PREFERENCES FOR MASS-MARKET INFORMATION SYSTEMS – LEVERAGING MARKET RESEARCH TECHNIQUES AND EXAMPLES IN PRIVACY-AWARE DESIGN

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FACULTÉ DES HAUTES ÉTUDES COMMERCIALES

DÉPARTEMENT DES SYSTÈMES D'INFORMATION

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THÈSE DE DOCTORAT

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pour l'obtention du grade de
Docteure ès Sciences en systèmes d'information

par

Dana NAOUS

Directrice de thèse
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Jury

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Lausanne, le 8 octobre 2020

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and have found it to meet the requirements for a doctoral thesis.
All revisions that I or committee members
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Doctoral Thesis

UNDERSTANDING USER PERCEPTIONS AND PREFERENCES FOR MASS-MARKET INFORMATION SYSTEMS – LEVERAGING MARKET RESEARCH TECHNIQUES AND EXAMPLES IN PRIVACY-AWARE DESIGN

Dana Naous

Department of Information Systems,
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Lausanne, 2020

"If I have seen further, it is by standing on the shoulders of giants."

– Sir Isaac Newton

Abstract (*English version*)

With cloud and mobile computing, a new category of software products emerges as mass-market information systems (IS) that addresses distributed and heterogeneous end-users. Understanding user requirements and the factors that drive user adoption are crucial for successful design of such systems. IS research has suggested several theories and models to explain user adoption and intentions to use, among them the IS Success Model and the Technology Acceptance Model (TAM). Although these approaches contribute to theoretical understanding of the adoption and use of IS in mass-markets, they are criticized for not being able to drive actionable insights on IS design as they consider the IT artifact as a black-box (i.e., they do not sufficiently address the system internal characteristics). We argue that IS needs to embrace market research techniques to understand and empirically assess user preferences and perceptions in order to integrate the "voice of the customer" in a mass-market scenario. More specifically, conjoint analysis (CA), from market research, can add user preference measurements for designing high-utility IS. CA has gained popularity in IS research, however little guidance is provided for its application in the domain. We aim at supporting the design of mass-market IS by establishing a reliable understanding of consumer's preferences for multiple factors combing functional, non-functional and economic aspects. The results include a "Framework for Conjoint Analysis Studies in IS" and methodological guidance for applying CA. We apply our findings to the privacy-aware design of mass-market IS and evaluate their implications on user adoption. We contribute to both academia and practice. For academia, we contribute to a more nuanced conceptualization of the IT artifact (i.e., system) through a feature-oriented lens and a preference-based approach. We provide methodological guidelines that support researchers in studying user perceptions and preferences for design variations and extending that to adoption. Moreover, the empirical studies for privacy-aware design contribute to a better understanding of the domain specific applications of CA for IS design and evaluation with a nuanced assessment of user preferences for privacy-preserving features. For practice, we propose guidelines for integrating the voice of the customer for successful IS design.

Abstract (*Version française*)

Les technologies cloud et mobiles ont fait émerger une nouvelle catégorie de produits informatiques qui s'adressent à des utilisateurs hétérogènes par le biais de systèmes d'information (SI) distribués. Les termes "SI de masse" sont employés pour désigner ces nouveaux systèmes. Une conception réussie de ceux-ci passe par une phase essentielle de compréhension des besoins et des facteurs d'adoption des utilisateurs. Pour ce faire, la recherche en SI suggère plusieurs théories et modèles tels que le "IS Success Model" et le "Technology Acceptance Model". Bien que ces approches contribuent à la compréhension théorique de l'adoption et de l'utilisation des SI de masse, elles sont critiquées pour ne pas être en mesure de fournir des informations exploitables sur la conception de SI car elles considèrent l'artefact informatique comme une boîte noire. En d'autres termes, ces approches ne traitent pas suffisamment des caractéristiques internes du système. Nous soutenons que la recherche en SI doit adopter des techniques d'étude de marché afin de mieux intégrer les exigences du client ("Voice of Customer") dans un scénario de marché de masse. Plus précisément, l'analyse conjointe (AC), issue de la recherche sur les consommateurs, peut contribuer au développement de système SI à forte valeur d'usage. Si l'AC a gagné en popularité au sein de la recherche en SI, des recommandations quant à son utilisation dans ce domaine restent rares. Nous entendons soutenir la conception de SI de masse en facilitant une identification fiable des préférences des consommateurs sur de multiples facteurs combinant des aspects fonctionnels, non-fonctionnels et économiques. Les résultats comprennent un "Cadre de référence pour les études d'analyse conjointe en SI" et des recommandations méthodologiques pour l'application de l'AC. Nous avons utilisé ces contributions pour concevoir un SI de masse particulièrement sensible au respect de la vie privée des utilisateurs et nous avons évalué l'impact de nos recherches sur l'adoption de ce système par ses utilisateurs. Ainsi, notre travail contribue tant à la théorie qu'à la pratique des SI. Pour le monde universitaire, nous contribuons en proposant une conceptualisation plus nuancée de l'artefact informatique (c'est-à-dire du système) à travers le prisme des fonctionnalités et par une approche basée sur les préférences utilisateurs. Par ailleurs, les chercheurs peuvent également s'appuyer sur nos directives méthodologiques pour étudier les perceptions et les préférences des utilisateurs pour différentes variations de conception et étendre cela à l'adoption. De plus, nos études empiriques sur la conception d'un SI de masse sensible au respect de la vie privée des utilisateurs contribuent à une meilleure compréhension de l'application des techniques CA dans ce domaine spécifique. Nos études incluent notamment une évaluation nuancée des préférences des utilisateurs sur des fonctionnalités de protection de la vie privée. Pour les praticiens, nous proposons des lignes directrices qui permettent d'intégrer les exigences des clients afin de concevoir un SI réussi.

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Introductory Paper on

Understanding User Perceptions and Preferences for Mass-Market Information Systems – Leveraging Market Research Techniques and Examples in Privacy-Aware Design

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1 Introduction

In light of technological advances and changes in organizational environment, the software landscape has evolved to span mass-market information systems (IS) targeting distributed and heterogeneous end users. For the IT industry, this means a shift from customer-specific software systems in enterprises to a market where software as a standard product is commercialized with mobile and cloud technologies (Van De Weerd et al. 2006). With the increased number of offerings and global competition, software providers need to be more responsive to customers. Understanding user requirements and the factors that drive user adoption are crucial for IS design (Bano and Zowghi 2015; Harris and Weistroffer 2009). Thus, user involvement is considered "common wisdom" for IS success (Ives and Olson 1984).

Several theories and models have been suggested in IS research to study user adoption and intentions to use technology. Among those is the IS success model (DeLone and McLean 1992, 2003), which is employed to understand users' intentions to use a system and their satisfaction through quality perceptions. A majority of studies rely on the Technology Acceptance Model (TAM) (Davis 1989) and its extensions to understand users' attitudes and perceptions about system's usefulness and ease of use as precursor to intentions. While those studies assess users' attitudes and perceptions, they disregard system features or implementation options that shape the system and can be adoption drivers or barriers. IS research has been criticized for not sufficiently treating the IT artifact where it is mostly "absent, black-boxed, abstracted from social life, or reduced to surrogate measures" (Orlikowski and Iacono 2001). Several extensions to the existing theories have been suggested based on consumer behaviour literature taking into account an enjoyment factor for utilitarian and hedonic products, which are important for individual users adoption (Thong et al. 2006). Moreover, Venkatesh et al. (2012) have added a cost-price ratio to the Unified Theory of Acceptance and Use of Technology (UTAUT) to account for the new settings of consumer IS.

Although these studies and models contribute to theoretical understanding of the adoption and use of mass-market IS, they are criticized for not being able to drive actionable insights in terms of IS design (Wortmann et al. 2019). Thus, a fine-grained approach that takes into account system characteristics is needed for studying user adoption and providing an understanding of preferred system design. With the proliferation of cloud and mobile services in a mass-market scenario, this approach should extend beyond functional features and include non-functional and economic aspects. In fact, users are confronted with multiple offerings from which they need to select based on criteria related to the system implementation features as well as overarching business model elements.

In commercial settings, consumer research has shown a strong link between user's preferences and a product's success (Cooper and Kleinschmidt 1987; Gruner and Homburg 2000; Chuang et al. 2001). Market research techniques allow studying users' preferences and analyzing users' trade-offs in the selection of products and services based on an evaluation of product features by consumers (Green and Srinivasan 1990; Merino-Castello 2003). This serves as input for successful product design that conforms to users' needs. Market research techniques have proved to be helpful in the design of commercial products, and can be applied in the development of mass-market IS in a comparable scenario. We argue that estimating users' preference structures can extend IS theories and models on user adoption in a mass-market context. This extension takes into account product features (i.e., implementation options) and external factors surrounding it to study other acceptance variables than perceptions and attitudes. Thus, providing a nuanced assessment of the main drivers of user adoption and also providing input to IS design.

The aim of this dissertation is to add to the body of knowledge in IS design and adoption through integrating concepts from consumer research and empirical insights. This dissertation is based on foundations from two research streams that inform the users' perspective in the design of mass-market IS.

- Research stream 1 studies how consumer research techniques can inform mass-market IS design through the study of users' preferences. Conjoint analysis (CA), from market research, is a promising approach to support the user-oriented design of IS through the preference lens. It provides "a practical set of methods for predicting consumer preferences for multi-attribute options in a wide variety of product and service contexts" (Green and Srinivasan 1978). IS researchers started employing CA to study adoption decisions and preference structures for different IS categories (e.g., Abramova et al. 2017; Burda and Teuteberg 2015; Giessmann and Stanoevska 2012; Krasnova et al. 2009; Mikusz 2018; Zibuschka et al. 2019) and the number of CA studies in the IS domain has risen over the past few years. However, no cumulative research patterns have been observed regarding the application of CA in IS research. This research stream provides a state-of-the-art review of CA status in IS research along a framework for its applications and illustrations on its use. Based on that, we build and demonstrate a preference-based approach for incorporating the "voice of the customer" in mass-market IS design that takes into account specific system design and implementation options in addition to other external or contextual aspects.

- Research stream 2 addresses users' perspectives on security and privacy in the design and adoption of mass-market IS, since the latter present strong barriers for users' adoption in the digital age (Li and Chang 2012). It comprises empirical studies investigating user perceptions and preferences for privacy-aware IS design of context-aware services, specifically location-based services and contact tracing apps. We apply CA to study user preferences in light of privacy concerns, and compare results to the study of user perceptions based on the privacy calculus (Dinev and Hart 2006) that is commonly applied to understand adoption in a privacy context based on users' trade-offs of risks and benefits.

This introductory paper provides an overview of the dissertation and explains how each research stream contributes to improving our understanding of user adoption and intentions to use in mass-market scenarios. The remainder of this paper is structured as follows: Section 2 provides foundational background and theoretical underpinnings for this dissertation. Section 3 highlights existing gaps and discusses research opportunities. Section 4 provides an overview of the dissertation structure and research streams. Then, the research streams are presented with background, research questions, research method, contributions, as well as limitations, implications, and outlook. In the last section, theoretical and practical implications of findings are discussed with directions for future research.

2 Prior Research

2.1 Understanding User Adoption and Drivers for IS use

To produce commercially successful systems, it is crucial to understand users' needs. For that purpose, prior research in IS has studied user adoption and the determinant factors for intentions to use for different types of systems (Table 1). This is mainly reflected in Rogers' (1983) Diffusion of Innovation (DOI) theory that is used in IS adoption studies to assess the effect of system related factors on the use of new technologies. Moreover, IS studies in the adoption domain rely on the Theory of Planned Behaviour (TPB) (Ajzen 1985, 1989) and the Technology Acceptance Model (TAM) (Davis 1989) to understand users' attitudes towards the system which leads to usage intentions and acceptance behaviour. These attitudes are based on technological factors (as in TAM) and social or contextual factors (as in TPB). In addition, the IS success model (DeLone and McLean 1992, 2003) was developed to measure users' satisfaction and intention to use as precursor of system use based on assessment of quality aspects: system, information and service.

Theory	Measure	System Predictors	External Predictors
Diffusion of Innovation (Rogers 1983)	Intention to use/ Decision-making	• Relative advantage • Complexity • Compatibility • Trialability • Observability	-
Theory of planned behaviour (Ajzen 1985, 1989)	Intention to use	Attitude towards system (general)	Subjective norms Perceived behavioural control
Technology acceptance model (Davis 1989)	Intention to use	Attitude towards system: • Perceived usefulness • Perceived ease-of-use	-
IS success model (DeLone and McLean 1992, 2003)	Intention to use/ User satisfaction	• System quality • Information quality • Service quality	-
Unified Theory of Acceptance and Use of Technology (Venkatesh et al. 2003, 2012)	Intention to use	• Performance expectancy • Effort expectancy • Facilitating conditions • Hedonic motivation • Price value	• Social influence • Personal moderating factors (age, gender, experience, voluntariness of use) • Habit

Table 1. Foundational IS Theories on User Acceptance and Adoption

Several extensions to these models have been discussed to improve their explanatory power, combining different perspectives on IS success and adoption. Most prominently, the TAM model has been extended in three primary modes (cf. Wixom and Todd 2005; Wortmann et al. 2019). In a first approach, extensions from existing models such as subjective norms and perceived behavioural control based on the TPB model have been discussed to the perceived usefulness (PU) and perceived ease-of-use constructs (PEOU) (e.g., Hartwick and Barki 1994; Mathieson et al. 2001). The second approach introduces additional belief factors related to the system view as portrayed in the DOI theory. The third approach adds external factors to the system evaluation that influence ease of use and usefulness within the TAM, such as personal and demographic characteristics (Venkatesh and Davis 2000). Venkatesh et al. (2003) introduced the UTAUT based on empirical evaluation of eight models. This is a commonly used model after TAM that identifies four key factors that predict intentions to use based on system perceptions as a result of performance expectancy, effort expectancy, social influence, and facilitating conditions. It also incorporates four moderators related to personal characteristics. The UTAUT2 model (Venkatesh et al. 2012) incorporates new constructs to adapt to the new nature of IS targeting individual consumers rather than organizational context. These extensions include hedonic motivation embracing the perceived enjoyment factor suggested by Thong et al. (2006). In addition, it takes into consideration price value given the economic requirements of such systems, as well as habits governing individual use.

In their effort to explain system use, IS researchers mainly focus in the existing theories on measuring user satisfaction through users' evaluation of a variety of factors (including system perceptions and external contextual factors). Those theories rely on individual attitudes and perceptions of system and social factors to predict intentions to use. Accordingly, adoption studies in IS relate to the proxy view of the technology (Orlikowski and Iacono 2001). They have been criticized for only lacking a comprehensive assessment of the IT artifact and disregarding the specific system design choices in their evaluation (Orlikowski and Iacono 2001; Weber 2003; Benbasat and Zmud 2003). This focus on perceptions results with a fractioned view of the IT artifact, which can lead to inadequate understanding of the system elements that drive use. As a result, having restricted implications for system design. Therefore, a more granular or fine-grained assessment of the IT artifact on multiple aspects is required.

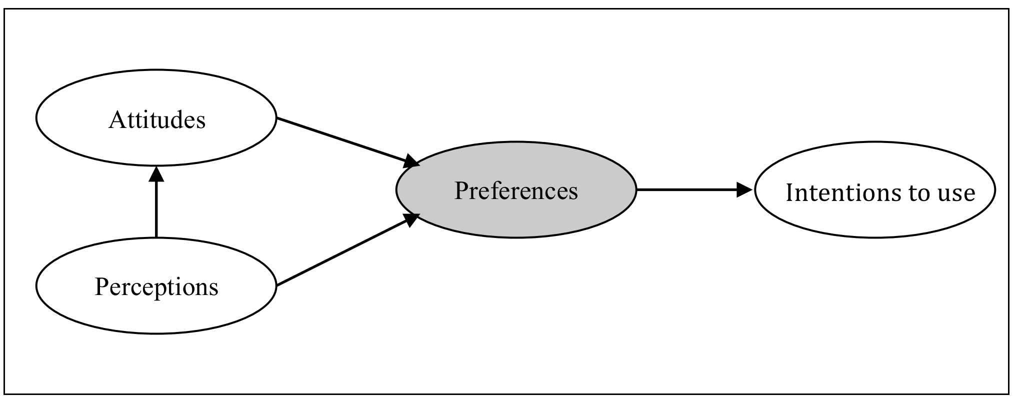

Figure 1. Preferences as a Predictor of Intentions to Use

Economics research has proven that generalized attitudes and perceptions together determine preferences, which in turn, translate into behavioural intentions (McFadden 1986; Chuang et al. 2001). McFadden (1986) explains that market behaviour is generated by maximization of consumer preferences. These preferences comprise a multi-dimensional psychological construct determined by perceptive, affective, and behavioural dimensions (Chuang et al. 2001). In fact, the design of successful and high-utility products rely on a detailed understanding of consumer preferences along these dimensions (Baxter 1995; Swift 1997). As such, measuring the preference structure can help predict intentions to use in IS (Figure 1) based on inputs from system attributes, personal experiences, social and economic factors that shape perceptions and attitudes. To elicit and measure user preferences, several methods have been suggested. Particularly, conjoint analysis and discrete choice experiments (Merino-Castello 2003). These methods aim at modeling the decision-making process and the cognitive mechanism that govern behaviour through evaluation of product characteristics via an experimental design. This enables the mapping between the consumer behaviour and a utility function that describes the user's preference structure (Mark and Swait 2004). Accordingly, this structure can serve as a reference model for product design.

2.2 Designing Mass-Market IS

For the software industry, the shift from customer-specific to market-driven systems with cloud, mobile and Internet of Things (IoT) elicits a need for more thoroughly defined products including delivery and pricing models as well as privacy options in addition to core functional and non-functional requirements (Cusumano 2010; Jarke et al. 2011). Thus, product management plays an important role and is an essential area to handle the interplay among the different system features and guarantee market success and the greatest value for businesses (Bekkers et al. 2010). At the core of software product management (Van De Weerd et al. 2006) is requirements management, i.e., gathering, identifying and organizing requirements. Requirements management links portfolio management and product road-mapping to release planning. By translating product roadmaps into detailed product requirements lists, requirements management informs prioritization and selection of requirements in the release planning (Figure 2).
Requirements management and release planning are part of requirements engineering (RE), which can be described as "a cooperative, iterative, and incremental process, which aims at ensuring that (1) all relevant requirements are explicitly known and understood at the required level of detail, (2) a sufficient agreement about the system requirements is achieved between the stakeholders involved, as well as [ensuring that] (3) all requirements are documented and specified in compliance with the relevant documentation formats and rules" (Pohl 2010). Software products offered to an open market with many customers, impose special challenges on the RE process as the requirements are coming from a larger base of heterogeneous and distributed users with different needs. In general, requirements are collected from representatives of market segments or invented by developers to come up with new system design (Dahlstedt et al. 2003), then new requirements are collected by current user experience after the first release. This serves as an input to plan further incremental releases where an additional set of requirements is implemented. The main activity is to manage new and changing requirements (Carlshamre and Regnell 2000) which imposes a challenge for release planning. Prioritization is a central activity that supports decisions regarding product releases. It results in implementing

preferential requirements of stakeholders. To prioritize requirements, stakeholders have to compare requirements to determine their relative weights of importance in the implementation of a software product. However, with the increasing number of requirements and stakeholders, due to technology advances with cloud and mobile applications, this process becomes more and more complex (Achimugu et al. 2014). As a result, in mass-market scenarios, product managers lack methodological guidance for systematically eliciting and quantifying user requirements in order to avoid biases and to ensure consensus and customer acceptance. The need to integrate the voice of the customer calls for new approaches in IS design to ensure the widest customer reach and acceptance and to capture different user perceptions instead of relying on user representatives only for well-defined products and service bundles. More specifically, this calls for a data-driven approach that enables obtaining empirical data from a large set of users to validate both market and requirements.

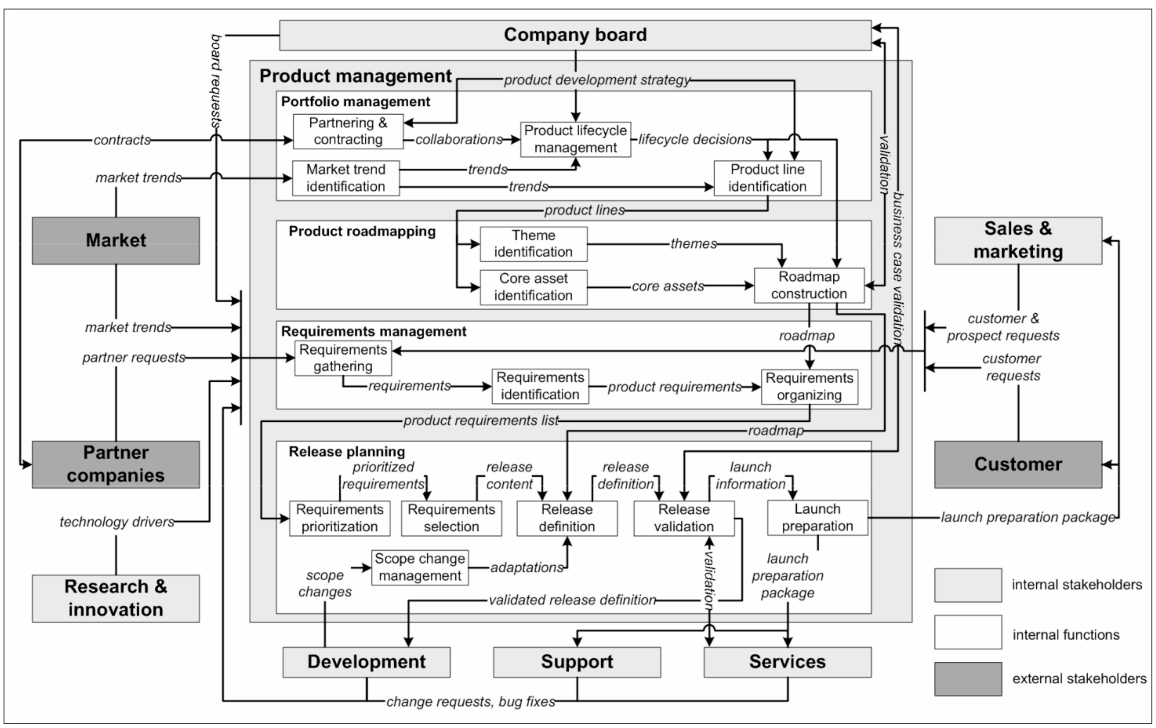

Figure 2. Software Product Management Framework (Van De Weerd et al. 2006)

2.3 Research Gap & Opportunities

System design and adoption are two complementary domains that inform each other and are critical for mass-market software design. System design focuses on identifying and implementing system features that fit users' needs, while adoption studies aim to understand the user's perception and attitudes with regards to a whole system view as a precursor to system use. We argue that evaluating a system requires the evaluation of the sum of its parts. Thus, an evaluation of system features in addition to the holistic view is required. While Orlikowski and Iacono (2001) highlight that the IT artifact black-boxed or mostly absent in IS research, we aim to contribute to a more complete conceptualization of the IT artifact for understanding user acceptance and adoption, which can then inform system design. We argue that IS adoption requires understanding user preferences together with perceptions based on empirical data from users for effective use.

The preference measure can add a detailed valuation of the accepted system features and characteristics resulting with user intention to use. Adding this preference component can support adoption and decision-making studies to highlight relatively important features of a given system. Thus, giving a nuanced assessment of the main drivers of user adoption and also providing input to IS design. Following a reverse-engineering path, we see that measures of preference for system factors or attributes can provide insights and support RE for mass-market systems. We aim to extend IS theories and models on user adoption by taking into account product attributes, and the external factors surrounding it, to study acceptance variables other than perceptions and attitudes.

Marketing and consumer research has proven to provide insights into users' preferences for successful commercial design. This can also be applicable to technical product design in a similar mass-market context. While the IS discipline originally falls on the intersection of other reference disciplines, Baskerville and Myers (2004) have fueled the discussion on the necessity of shifting the orientation of the IS discipline to a referring and reference discipline itself. As a result, IS research has moved from being a purely applied discipline to a discipline that provides foundation of further IS research as well as other fields. We therefore aim to contribute to the IS body of knowledge on adoption and design in mass-markets through a concept and method adapted from the consumer research and marketing domains.

3 Dissertation Structure & Research Streams

In light of the existing gaps, this research attempts to answer the following question: ***How can the user's perspective be systematically integrated in mass-market IS design?*** The aim is to support mass-market IS design through incorporating users' preference measurement from market research techniques to the existing IS methods. More specifically, the objective is to develop methodological guidance for eliciting and analyzing user preferences to inform mass-market IS design and adoption.

Accordingly, this thesis is based on foundations from two research streams that foster the systematic integration of the users' perspective. The first stream aims to lay foundation for future research in IS through highlighting application areas for CA, as a preference-based approach from market research, and developing a method component for mass-market IS design that elucidates users' preferences for multiple aspects corresponding to system implementation options. The second stream provides empirical insights on privacy-aware design, comparing the user preference approach to existing methods for measuring user adoption (i.e., privacy calculus). Each research stream has sub-questions to be investigated to inform the general thesis question (Table 2).

Research Stream	Essay	Research Question	Research Method	Key Contributions	Publication Status
I. CA – State-of-the-art & Methodological Guidelines	Essay 1.1: Leveraging Market Research Techniques in IS – A Review of Conjoint Analysis in IS Research	• What is the current state of conjoint analysis applications in IS? • What are guidelines for future IS studies applying conjoint analysis?	Literature review in line with Webster and Watson (2002) and vom Brocke et al. (2015)	State of the art: Review of 46 previous conjoint studies in the IS design from 1999 to 2016, and development of a first version framework for its application	Proceedings of the *International Conference on Information Systems (ICIS) (2017)* Nominated for *Best Theory Development Paper*
	Essay 1.2: Leveraging Market Research Techniques in IS – A Review and Framework of Conjoint Analysis Studies in the IS Discipline			21 years of CA in IS: Updated review of 70 CA studies that were published between 1999 and 2019 in the IS field "Framework for Conjoint Analysis Studies in IS" that outlines 6 distinct CA applications	Journal manuscript *(Follow-up of previous conference paper)*: Accepted with minor revisions in the *Communications of the AIS*
	Essay 1.3: Incorporating the Voice of the Customer into Mass-Market Software Product Management	How can product managers leverage market research techniques for the design of mass-market software systems?	Method-engineering guidelines (Brinkkemper 1996), combining an inductive approach building on field research, and a deductive approach	A method component that refines CA for the use in mass-market software product management	Proceedings of the *ACM/SIGAPP Symposium on Applied Computing (2020)*

	Essay 1.4: Incorporating the Voice of the Customer: A Preference-based Approach to Mass-Market Software Product Design		based on literature for the method construction	Design of a preference-based approach to mass-market IS design Expert evaluation of the method component in the RE of mass-market IS	Journal Manuscript (*Follow-up of previous conference paper)*: Invited from *ACM/SIGAPP Symposium on Applied Computing* for submission to the *Applied Computing Review*
	Essay 1.5: Understanding Users' Preferences for Privacy & Security Features – A Conjoint Analysis of Cloud Storage Services	How do users value privacy and security features in personal cloud storage services?	Adaptive choice-based conjoint analysis	Demonstration of the CA method for mass-market IS design Empirical insights on users' preferences of privacy and security features in cloud storage services	Proceedings of the *International Conference on Business Information Systems Workshops (2019)*
II. User Preferences and Perceptions for Privacy-aware Design	Essay 2.1: Information Disclosure in Location-based Services: An Extended Privacy Calculus Model	How can the privacy-calculus model for location-information disclosure be revisited in light of (1) co-located/interdependent data, (2) increased privacy controls due to government regulations, and (3) monetary incentives for location sharing?	Privacy Calculus (Dinev and Hart 2006)	Extended privacy calculus model for a nuanced conceptualization of disclosure Empirical insights on the adoption of location-based services under privacy trade-offs	Proceedings of the *International Conference on Information Systems (ICIS) (2019)*

	Essay 2.2: Understanding User Adoption of Contact Tracing Apps	• What are users' perceptions regarding the use of contact tracing apps? • What are users' preferences for contact tracing app features?	Privacy Calculus (Dinev and Hart 2006) Adaptive choice-based conjoint analysis	Two empirical studies on the users' perceptions and preferences for contact tracing apps Empirical insights on the users' perspective on contact tracing apps under privacy trade-offs	Journal Manuscript: Submission to the *European Journal of Information Systems*

Table 2. Dissertation Structure and Research Streams

4 Research Stream I: CA – State-of-the-art & Methodological Guidelines

4.1 Background

Conjoint analysis is among the most famous methods for estimating user preferences. This method, through its different variants, has the ability to derive a user preference structure through a quantitative measure (utility) (Green and Srinivasan 1978). CA has its roots in the work of Green and Rao (1971), who advocated the use of conjoint measurement in consumer-oriented marketing research. As a concept from mathematical psychology established by Luce and Tukey (1964), conjoint measurement is used to measure "the joint effects of a set of independent variables on the ordering of a dependent variable" (Green and Rao 1971). In a CA study, a product is defined in terms of attributes and attribute levels. Based on a consumer evaluation in a survey setting, a utility function is estimated and translated into a preference structure that reflects the most accepted characteristics in a product. The part-worth utility function is the most commonly used model due to its compatibility with different preference functions corresponding to categorical variables with discrete implementation options or continuous variables such as price (Green and Srinivasan 1978).

CA is a well-suited approach to quantify judgmental data as quantifiable preferences, and can be leveraged in several ways in the context of product design (Green et al. 2001; Green and Srinivasan 1978): (1) relative importance of attributes and levels, price–value relationship measurement by analyzing the consumer trade-off for price and quality of products, and attitude measurement to analyze the trade-offs between several product attributes. This involves analyzing the utility for collections of items to facilitate the combination packaging of certain product types; (2) cost–benefit analysis to study the willingness-to-pay (WTP) for certain attributes and design products accordingly; and (3) clustering or segmentation of customers based on their utility functions. Furthermore, Johnson (1974) referred to another application using (4) market simulation, which is used to estimate the market shares of currently available or new products based on the study sample's predicted consumer preferences.

As an illustration of CA (Figure 3), consider the simplified example of a smartphone, where a user has to evaluate different attributes with multiple levels or product profiles related to screen size, camera resolution and price. Consumer evaluation follows, where the user will be presented with alternative designs of different attributes combinations for which he needs to rank or choose the most acceptable option. Based on this data, the utility function can be estimated to provide scores for each attribute and preferred attributes' levels as input for multiple analysis techniques that support the design process.

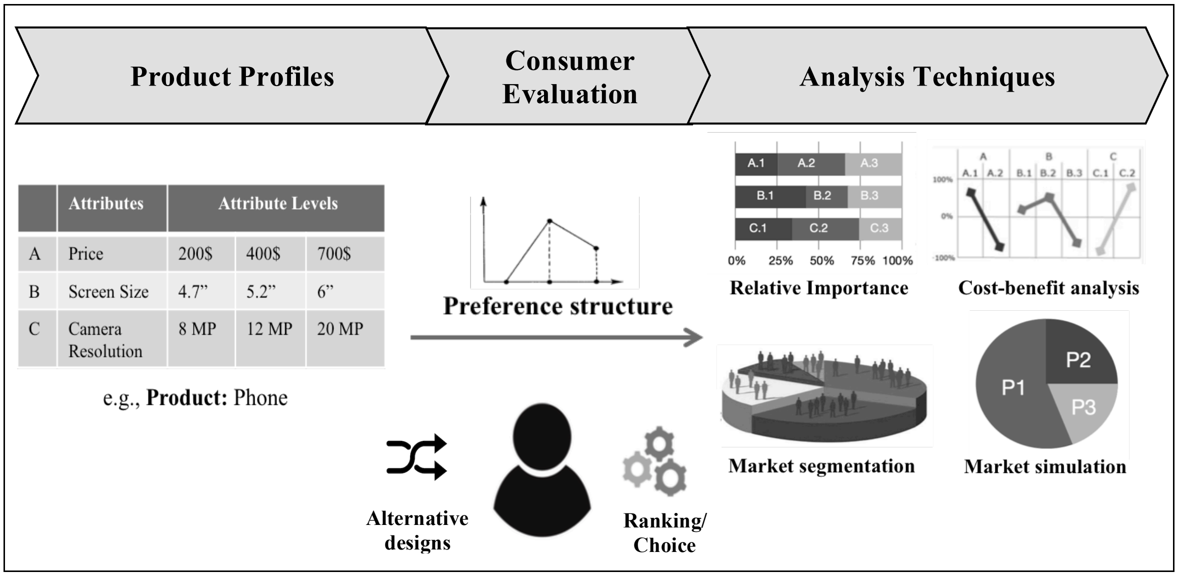

Figure 3. Illustration of CA for Smartphone Design

Marketing research has argued that CA is particularly useful in measuring user trade-offs when evaluating products or services, adding a quantitative measurement that reflects optimal product or service design (Wittink and Cattin 1989). As such, it can be a very well-suited methodology for understanding underlying users' decisions when it comes to IS adoption and design. CA allows for assessing requirements along multiple dimensions, thereby integrating software, operational and business model design. Thus, it provides a complete view of the system, which can serve as input for successful IS design in mass-markets.

In IS research, Bajaj (1999) introduced the CA methodology's for studying user preference structure in the assessment of IS for purchase decisions and adoption. He suggested that CA can bring useful insights into users' decision models when evaluating different product classes of software tools. CA was then applied by various IS researchers to study users' preference structure of system attributes to obtain insights into user trade-offs through applying the well-known CA techniques. These studies target mass-market systems in multiple domain categories, such as mobile applications, online services covering social networks, website design and online banking services, and lately cloud services and internet of things. Relative importance of attributes was used in Bouwman et al. (2008), Brodt and Heitmann (2004), and Zubey et al. (2002) to come up with optimal mobile services or application designs. In the context of cloud services, Burda and Teuteberg (2015) and Koehler et al. (2010) applied CA for exploring user preferences for cloud features. Other studies cover economic features and apply WTP techniques to study the trade-offs among different attributes through variations in a price attribute (Daas et al. 2014; Haaker et al. 2006). Moreover, Koehler et al. (2010) applied segmentation to define customer preferences for different configurations of software as a service. In addition, in the context of privacy design, CA is gaining popularity to study information privacy trade-offs in different types of services (Baum et al. 2019; Ho et al. 2010; Mihale-Wilson et al. 2017).

The few applications of CA in literature bring into discussion a very well-established method in market research to the IS domain, especially in the case of mass-market IS. CA allows users to evaluate product profiles simultaneously and choose the best-fit alternative corresponding to their preference model. Thus, it provides an understanding of the elements or structures widely accepted by users in terms of product success. This method has several advantages if applied in the context of mass-market systems. It provides a data-driven approach to systematically quantify users' preferences for understanding design trade-offs and for feature selection.

4.2 Research Objectives and Methods

Although there exist an increasing number of CA studies in IS research, they remain one-time efforts, and we do not observe a cumulative research tradition among IS researchers applying this method. The CA method has not been used to its full potential and we lack a fundamental discussion on its role and use for understanding user preferences in the IS discipline. The objective of this research stream is to provide a critical assessment concerning its domain-specific applications and to integrate it as a methodology in IS design. We answer the following questions:

- *What is the current state of CA in IS?*
- *What are guidelines for future IS studies applying conjoint analysis?*
- *How can product managers leverage market research techniques for the design of mass-market software systems?*

Essays 1.1. and 1.2 explore the different domains in IS in which CA has been applied, and propose a framework that IS researchers can use to guide their research for employing CA. For that, we opted for a systematic longitudinal literature review of existing CA studies in IS.

Our literature review can be characterized as a combination of descriptive and critical literature review (Paré et al. 2015). As a descriptive review, we analyze the existing CA studies with respect to their study design choices and methodological aspects. We then highlight the main patterns in literature. As a critical review, we provide a critical assessment of the main methodological choices throughout the CA procedure and recommendations for methodological improvements. In Essay 1.1 we review literature from 1999 (the first CA study by Bajaj) to 2016. Essay 1.2 is a follow-up study that extends the review period to 21 years in IS research (from 1999 to 2019), and we develop based on that a framework for CA studies in the IS discipline. The results of our review emphasize that market research techniques, i.e., CA, can be of great benefit if developed as a methodology for IS.

In Essay 1.3 and 1.4, we foster the use of CA for application areas related to IS design (IS concept definition and design iterations). We systematically develop a method component that leverages CA, from consumer research, to complement RE approaches and software product management frameworks (Van De Weerd et al. 2006). We refer to this method component as a "preference-based approach" for mass-market IS design. As method component, we denote "a self-contained part of a systems development method expressing the transformation of one or several artifacts into a defined target artifact and the rationale for such a transformation" (Karlsson and Wistrand 2006). Characterized in the context of situational methods, this method component adapts a base method against the background of a specific development situation (Bucher et al. 2007). Accordingly, it is meant to adapt CA techniques for mass-market IS design.

In constructing the method component, we follow method-engineering, i.e. "the engineering discipline to design, construct and adapt methods, techniques and tools for the development of information systems" (Brinkkemper 1996). We combine an inductive approach building on field research, and a deductive approach based on the literature (Braun et al. 2005). This allows us to integrate practical insights from employing CA in mass-market software design with theoretical foundations from market research and software product management literature. In Essay 1.3, the suggested artifact is documented by two constituent elements (Braun et al. 2005): (1) a meta-model that specifies a conceptual model with main constructs and their relationships; (2) a procedure model that represents a set of ordered activities to achieve the method goals.

In Essay 1.4, we extend Essay 1.3 and provide a practice-oriented evaluation with an illustration of two application scenarios of the method component. Expert evaluations with 3 product managers, 2 business analysts and 1 product analyst allow us to assess the feasibility, usefulness and ease-of-use of the preference-based approach for mass-market IS design. As expert evaluation, a focus group was conducted to asses the utility, ease of use and feasibility of the method component for RE.

Essay 1.5 demonstrates the application of the method component in the context of cloud services and specifically assesses users' preferences for the design of security features of cloud storage services. We evaluate the applicability of this method component for understanding the users' perspective and its effectiveness in providing input for design refinement and requirements prioritization in software product management. Based on a survey of 144 users of personal cloud storage, we use adaptive choice-based CA to identify relative importance of secure and privacy preserving features and segment users. This also serves as an artificial evaluation of the method component with users.

4.3 Research Contributions

Our main contributions in this research stream are represented by a "Framework for CA Studies in the IS Discipline" and a "Preference-based Approach for Mass-market IS Design". Both contributions add to the body of IS knowledge through adapting a method from market research into the IS discipline, specifically IS design and evaluation. Therefore, we aim to engage in a cumulative research tradition that builds on existing studies and reuse of previous applications to inform the body of knowledge in IS and guide future research in our discipline following adopting CA as a research method.

The framework (Figure 4) outlines 6 distinct applications of CA in IS in the initial conceptualization, iterative design and evaluation of IS and respective business models. We thereby accumulate knowledge from previous studies for guiding IS researchers on "how" and "where" to use CA as an established method for future studies.

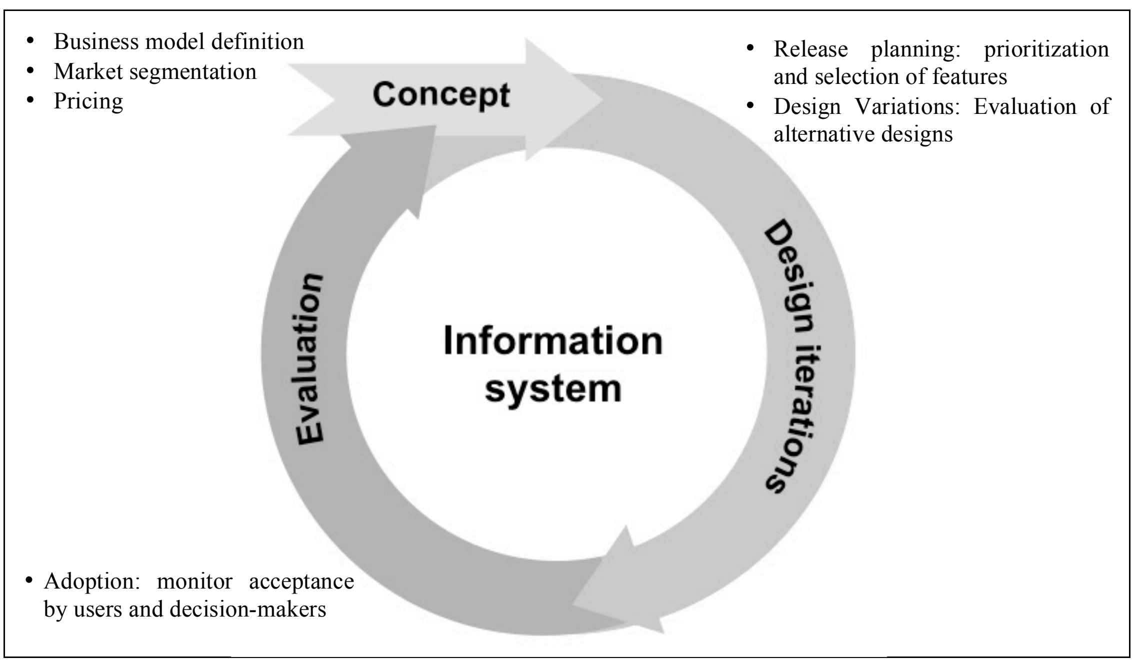

Figure 4. Framework for CA Studies in IS

By analyzing the current state of CA in IS and providing a reference framework for IS studies, our contribution can be considered a Type 1 theory according to Gregor (2006)'s taxonomy of theory types in IS. As "theory for analyzing" it is the most basic theory resulting in classification schema, frameworks, or taxonomies that lay the foundation of future research.

Phase	Role of CA	Applications (A)	CA Supporting Techniques	Sample Studies
IS concept definition	Validation of new IS concepts and business models	*A1.1* – Business model definition	Define business model and value proposition - Relative importance/ Trade-off analysis	Derikx et al 2015; Giessmann and Stanoevska 2012
		A1.2 – Market segmentation	Define target segments - Market segmentation	Giessmann and Stanoevska 2012; Krasnova et al. 2009
		A1.3 – Pricing	Define revenue model and pricing - Willingness-to-pay - Market simulation	Koehler et al. 2010
IS design iteration	Complement existing requirements engineering techniques	*A2.1* – Release planning	Prioritize & select features - Relative importance/ Trade-off analysis - Market segmentation	Bouwman et al. 2008; Naous and Legner 2019
		A2.2 – Design variation	Evaluate alternative designs - Market segmentation - Market simulations - Variation analysis	Giessmann and Legner 2013
IS evaluation	Extend IS success and adoption models	*A3.1* – Willingness-to-accept	Monitor acceptance and adoption by users and decision-makers - Relative importance - Market segmentation	Benlian and Hess 2011; Chen et al. 2010

Table 3. CA Role and Applications in the IS Lifecycle

Since CA has multiple implementation scenarios, we outline the supporting CA techniques in each application area (Table 3). We thereby provide guidance on "how" to leverage more sophisticated CA approaches and techniques, which are not fully exploited in the current state. The suggested framework helps IS researchers to understand how CA complements existing IS methods by providing a data-driven approach for understanding user preferences. It also allows them to position their conjoint studies within one of the application areas suggested.

In addition to supporting IS evaluation studies on user adoption, our review illustrates that CA is a very well-suited methodology for preference elicitation and can support IS design at different levels: "IS concept definition" and "IS design iterations". CA enables the capturing of individual and group preferences via relative importance of features and the application of market segmentations and simulation techniques. Thus, it could be a fundamental method for release planning and selecting relevant features based on user choices. In addition, having design feedback from a large number of users is facilitated via the conjoint surveys, which is also a concern in research on mass-market IS.

This research stream also develops a preference-based approach, as methodological guidance for user-oriented design. We address existing gaps in research related to the user-oriented design of mass-market IS and the lack of quantitative methods that assist software product managers in RE of mass-market IS. We contribute with a preference-based approach for mass-market IS design, via a method component that adapts advanced CA techniques to cope with the specificities of mass-market systems and provides methodological guidance in applying them in the context of requirements management. This method component complements existing software product management frameworks and suggests methodological guidelines: 1) how requirements should be specified and presented, to serve as input for formal consumer research methods; and 2) how these methods can inform requirements elicitation and analysis.

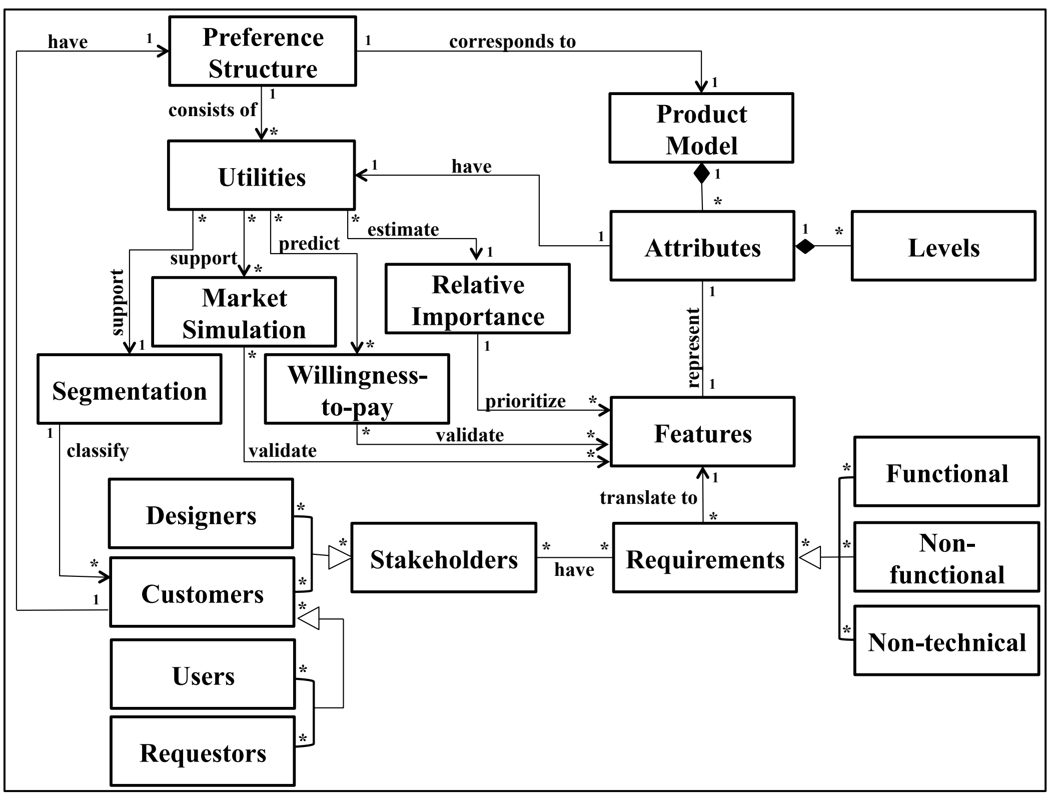

Figure 5. A meta-model of the method component

We represent our method in a meta-model (Figure 5), which defines the main concepts addressed and their relationships (Braun et al. 2005). It evolves around two main constructs, which are requirements and stakeholders and the relationships governing them through the requirements-related activities in product management. We illustrate how the user utilities derived from the CA can support the RE process through the different analysis techniques We also provide a step-by-step procedure for applying CA in the context of mass-market software design. The main phases to be considered in studies of IS design are product modeling, preference elicitation and preference interpretation. We derive a procedure model comprising of main activities, recommendations on methodological choices and outcomes for each phase (Table 4).

Phase 1: Product Modeling	
Main Activities	Analyze design options and transform requirements into attributes and levels using a mixed method approach: • Select attributes based on inputs from requestors • Collect feedback on feasibility of attributes and levels from designers (technical experts) or/and analysis of existing products • Define knock-out criteria, and must have elements during the process
Outcomes	A list of attributes and levels representing the functional, non-functional and non-technical properties for evaluation
Phase 2: Preference Elicitation	
Main Activities	2.1 Construct product profiles and design survey Present clear definitions of attributes and levels to survey respondents to avoid misinterpretations Develop prototypes (or mock-ups) for feature sets when possible to simulate realistic choices 2.2 Select sample of current and potential users 2.3 Execute survey
Outcomes	2.1 Survey with representation of product combinations 2.2 Sample with participants representing customers 2.3 A data set of participants' evaluations with aggregated and individual utilities
Phase 3: Preference Interpretation	
Main Activities	Analyze utilities to answer specific questions in requirements management and prioritization: 3.1 Use relative importance of attributes for getting weights 3.2 Use WTP for measuring trade-offs among attributes and attribute levels 3.3 Use segmentation to define user groups with similar preferences for bundling options 3.4 Use market simulation to facilitate attributes variations for competitive analysis
Outcomes	Depending on the applied technique: 3.1 Preference structure for attributes and trade-offs 3.2 Price premium for specific attributes/ levels 3.3 User segments and their preference structure 3.4 Expected market shares for attributes combinations

Table 4. Method Component - Procedure Model

We demonstrate the use of the method component for understanding user preferences for privacy and security features of personal cloud storage in response to increasing data protection regulations and privacy awareness. We show how the method component can deliver empirical insights on users' preferences and privacy trade-offs which allow service providers to better design or adjust their offerings based on market needs.

4.4 Implications, Limitations, and Outlook

Market research techniques are popular for new product development, but have to date not been fully embraced in IS research. By conducting a systematic longitudinal literature review we have gained detailed insights into CA's applications in IS. We conclude that CA can be adapted to several application areas in IS, and can have advantages in understanding user preferences. Our framework ideally covers the three phases of design and evaluation of IS starting from the core system and involving business model elements. In the design phase, CA can be used for IS concept definition to facilitate the construction of early system features for further prototyping. Through concept definition, customers can assess complete and hypothetical product offerings based on their stated preferences, leading to a design process with initial product preferences. This also includes the evaluation of business model elements, which are as important as the system features for users. In further stages, CA can support IS design iterations in release planning by providing quantitative insights into most valued features. In addition, we discuss how the market simulation techniques advance new propositions to support the refinement of existing systems. We also illustrate how the method allows deriving decision models for user selection and adoption patterns in IS evaluation scenarios. Through the preference model, the conjoint methodology could extend IS theories and models on user adoption to incorporate internal and external factors system factors to provide a comprehensive understanding of the IT artifact rather than perceptions and attitudes only.

For practice, this research has contributions for IT vendors, who currently use ad-hoc approaches (Ebert and Brinkkemper 2014) and invented requirements (Todoran et al. 2013). The suggested approach and method component can support in the RE process at different levels through integrating the voice of the customers. Our methodological guidelines provide support for interpreting preferences to capturing individual and group preferences.. Obtaining empirical data from a large set of users or potential customers is a specific advantage of this method as it helps product managers to avoid bias in design decisions through representative samples. Moreover, the ability to construct utility functions of individual and group preferences allows deriving a decision model that reflects users' behaviour and establishing a prioritized list of attributes each corresponding to defined system requirements agreed upon by different stakeholders. Therefore, this research provides IT vendors and specifically product managers with targeted RE techniques for mass-market software product design, based on actual measurements of user preferences. This will support them in defining high-utility products and in tailoring their offerings to the most promising customer segments.

While no cumulative research tradition has been observed in applying CA, there is a research opportunity to facilitate the implementation of such method in IS research. This is mainly through the creation of validated user preference models. CA's success relies on the choice of right attributes, which can lead to valuable preference models and actionable insights. Besides domain-specificity, the models can be categorized based on application areas to reflect methodological applications of CA. Given the number of CA studies covering different IS domain categories, future research can focus on developing user preference models that represent the relevant attributes from a user perspective, covering functional, non-functional, economic, and operational dimensions. These models would consist of validated catalogues of attributes and attribute levels based on previous studies of CA with additional empirical investigations, increasing the CA method's practicality. This would allow researchers to construct their conjoint studies rapidly and avoid the time-consuming task of constructing attributes and levels from scratch.

In addition, future research should explore how the CA method can be further instantiated and integrated into existing methodologies in the application areas identified in the reference framework. This could be achieved through ex-ante evaluation of the method with domain experts, and through empirical studies for validation. With our research, we propose a preference-based approach based on CA to support the design of mass-market IS. This is a first step in adapting CA techniques to a specific development situation in IS research, which can open up the door for other instantiations. For instance, organizational context is another avenue that is worth investigating building upon the few CA studies done on enterprise systems and organizational decision-making. This can be considered as a specific development situation that involves multiple stakeholders in the design process (including organizations and employees) who have multiple trade-offs to be considered.

We evaluate the method component with product managers and business analysts within the area of mass-market systems and demonstrate it in a specific scenario of cloud storage services. However, we have not been able to apply and evaluate it in commercial product design, which can be considered a limitation of our research. We urge future research to focus on naturalistic evaluations of the method component in realistic organizational settings and in different design phases - concept evaluation and design iterations. It is worthwhile noting that the suggested method component is suitable for the specific application scenarios suggested in the framework, however it is not a replacement to existing methods, but rather complements them. The application of this method in a practical setting could help validating its position and value in software product design. For instance, although it could be very a well-suited method for concept evaluation, certain reservations can arise on its applicability in the design iterations for agile development. While the method component has several benefits if applied systematically in the design process, we acknowledge that CA studies are largely underused in IS and have been criticized. Most prominently cited are the complexity of the study design and the acquisition of suitable study participants. We address these limitations through methodological recommendations that can speed up the setup of the conjoint study (for instance, through user preference models) and increase user reach (through established panels that provide the necessary user base and foster user participation). It is worthwhile noting that the suggested method component is not a replacement to existing methods, but rather complements them. Therefore, it could be used in special instances when introducing new design features.

5 Research Stream II: User Preferences and Perceptions for Privacy-aware Design

5.1 Background

The evolution of the Internet technology allows open access to personal data and creates a medium in which data is available and easily collected and used by different entities. All this positioned information privacy as a core topic for the use of personal ICTs in IS research (Bélanger and Crossler 2011; Smith et al. 2011; Xu et al. 2011). Recent statistics (2020) on Internet users' concerns regarding personal digital data security show that over 90% of global online users have at least one significant concern about data privacy; 47% of respondents are worried about that their personal information would be compromised by a data breach or cyber criminals, and 40% of respondents are concerned about their personal information being sold to third parties without their consent (Statista 2020).

However, there is still a disagreement about the concept of "information privacy" (Pavlou 2011). Perhaps the most frequently used definition of privacy is that of Westin (1967) who defines privacy as "the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others". In that context, thinking of privacy as a human right is intuitive. However, Clarke (1999) has defined it as "an interest that individuals have in sustaining a 'personal space' free from interference by other people and organizations". He suggests various types of privacy defined in four categories: privacy of the person, privacy of personal data, privacy of personal behaviour and privacy of personal communication. In the IS domain, most studies focus on the second category of privacy, which is the privacy of personal data or what we refer to as information privacy.

Information privacy confronts the individual with demanding trade-off decisions (Acquisti and Grossklags 2004). According to the Communications Privacy Management Theory (CPM) (Petronio 2002), disclosure has benefits and risks and involves a complex decision making process about sharing boundaries. These boundaries comprise controlling who has access to personal information and how much (Metzger 2007). The privacy calculus paradigm is used in IS to explain the dynamics underlying the user's sharing behaviour in the light of privacy concerns (Dinev and Hart 2006; Krasnova et al. 2009; Sun et al. 2015), it thus views privacy-related decision-making as a rational process based on a cost-benefit analysis. Privacy calculus has its theoretical underpinnings grounded in the Exchange Theory (Houston and Gassenheimer 1987) which explains individual's information sharing behaviour for an expected outcome, whether hedonic or utilitarian exchange. Privacy calculus studies mainly measure user perceptions as a proxy to intention to use, similar to other approaches on IS adoption (section 2.1). However, as situation-specific assessment of risks and benefits is bounded by several factors (e.g., contextual and vendor-related aspects), the conceptualization of disclosure (or intention to use) as the dependent construct is considered to be fractioned. Bélanger and Crossler (2011) underline that most studies in the IS literature focus on explaining information privacy rather than prescribing designs or actions. Thus, they call for research focusing on the design of tools and technologies that enable the protection and control of information privacy (Pavlou 2011).

An alternative approach is the use of CA to investigate user preferences for privacy and security features (Abramova et al. 2017; Baum et al. 2019; Ho et al. 2010; Hann et al. 2007; Krasnova et al. 2009). It has been occasionally used for understanding the privacy trade-offs in the design of personal ICTs (Mihale-Wilson et al. 2017; Zibuschka et al. 2019), and to assess the user's utility with respect to privacy design trade-offs (for instance with the combination of a game-theoretic framework to study co-location in social networks (Olteanu et al. 2019)). This method provides insights into user preferences allowing for the formation of services that fit users' expectations. Compared to the privacy calculus, CA can result with tangible user insights on privacy and security feature, which has implications for service providers to better design and adjust their offerings and eventually gain more customers and market shares.

5.2 Research Objectives and Methods

Security and privacy are essential components for users in an interconnected world. We therefore aim to revisit existing approaches for studying IS adoption in a privacy related setting and provide empirical evidence of how studying user preferences can contribute to successful privacy-aware designs. We focus in this research stream on context-aware applications, among the widely adopted category of mass-market IS. These types of mobile applications rely on contextual information (i.e., information about the surrounding environment including location and time (Ryan et al. 1998)) to provide adapted and personalized services for the user (Schilit et al. 1994). Context-aware applications rely on positioning technologies such as GPS, Bluetooth-based positioning, WiFi-based positioning or cellular network-based positioning. They span several domains including social networks, navigation, advertising and recommender systems. However, sharing information on such services involves privacy implications (Krumm 2007) as it can give insights on the individual's lifestyle including religious and political affiliation, sexual orientation, financial and health status (Zhong et al. 2015; Riederer et al. 2016; Boutet and Gambs 2019).

The IS community has started to study user adoption of context-aware applications and the rationale behind user's motivation to share location information under privacy concerns (Xu et al. 2009; Sun et al. 2015; Krasnova et al. 2009). These studies employ the privacy calculus to investigate users' privacy perceptions and the resulting disclosure behaviour or intentions to use. However, they lack actionable insights that can inform the privacy-aware design of such applications. Privacy calculus studies consider disclosure as a single dimensional construct, thus not taking into account the nature and extent of the information shared and the context in which it is disclosed. Moreover, discussions arise on considerations for interdependent privacy in context-aware services (Humbert et al. 2019), and implementations of privacy-protective mechanisms or privacy-control settings (Krasnova et al. 2009; Huguenin et al. 2018) promoted by recent regulations, such as EU GDPR. Moreover, recent technology advances, specifically block-chain, create opportunities for data monetization (e.g., *streamr.com, brave.com*) that can incentivize the user's information sharing behaviour.

Our objective is to provide a realistic and nuanced understanding of the user's disclosure behaviour and intentions to use of context-aware applications based on users' perceptions of the system characteristics. We also aim to understand the elements or features within these applications that can foster their adoption. We argue that CA can add an understanding of the user preferences for the specific privacy-preserving features within these applications, which can inform their successful design.

Thus, we study how perceptions and preferences can provide input to privacy-aware design of context-aware applications. We consider two types of applications: location-based services (LBS) and contact tracing apps, and we answer the following questions:

- *How can the privacy-calculus model for location-information disclosure be revisited in light of (1) co-located/interdependent data, (2) increased privacy controls due to government regulations, and (3) monetary incentives for location sharing?*
- *What are users' perceptions regarding the use of contact tracing apps?*
- *What are users' preferences for contact tracing app features?*

In Essay 2.1, we develop an extended privacy calculus model for a nuanced conceptualization of disclosure. The objective is to understand disclosure behaviour as a multi-level decision making process. We represent location-information disclosure as multi-dimensional construct, accounting for the extent of location sharing, sensitivity and the sharing parties, which in turn can reflect design characteristics for LBS. We also take into account the recent technology developments and their effect on users' disclosure behaviour. We test our research model on empirical data collected from more than 1000 respondents in Germany and the US. In line with our findings, we emphasize the need for an extended privacy calculus model that studies disclosure and intentions to use along multiple dimensions that enable prescriptive design.

Along the same lines, in Essay 2.2 we address a concurrent and recent issue related to the worldwide pandemic of COVID-19. Contact tracing apps have been developed in multiple countries as a solution for fighting the pandemic (e.g., TraceTogether in Singapore, SwissCOVID in Switzerland, Corona-Warn-App in Germany and StopCOVID in France) (Legendre et al. 2020). For these applications to be effective, they should be adopted by a large part of the population. It is therefore crucial to investigate the user perspective to understand and foster the adoption of these apps. We follow a multi-method study approach that builds on two empirical studies for understanding adoption intentions of COVID-19 apps. We first apply a privacy calculus approach to study users' intentions to use contact tracing apps. The data is collected from more than 1000 respondents in Germany. We then compare results from a CA, to better understand users' preferences and acceptable application features for increased adoption. We apply Adaptive Choice-Based CA on a sample size of 500 from Germany.

5.3 Research Contributions

Major contributions of this research stream are the extension of the privacy calculus model for understanding LBS use and empirical contribution on IS adoption under privacy trade-offs. The empirical studies improve the understanding of user perceptions and preferences for security and privacy features, willingness to accept as well as market reactions to design variations for a specific category of services (i.e., context-aware services). Following that assumption, we elaborate how our empirical contributions show originality and utility (Agerfalk 2014).

We elaborate that the extensions of the privacy calculus model (Figure 6) are necessary in providing a more nuanced understanding of the disclosure behaviour and intention to use based on different variants in the design of the system under investigation. Our study on LBS illustrates how understanding the multi-dimensional nature of disclosure provides insights into privacy-aware design of IS. It also takes into account interdependent privacy, controls and monetary incentives, which have not been fully covered in previous studies of LBS.

Our empirical results show that disclosure behaviour might vary depending on the extent of sharing (or mechanism), sensitivity of information to the users and the sharing parties involved within the disclosure frame. They also provide insights into users' motivations for location-information disclosure and highlight the importance of transparent privacy control settings in diminishing the effect of privacy risk perceptions for disclosure. Our findings also discuss implications for interdependent privacy risks in an increasingly interconnected ecosystem that brings several inconceivable privacy threats.

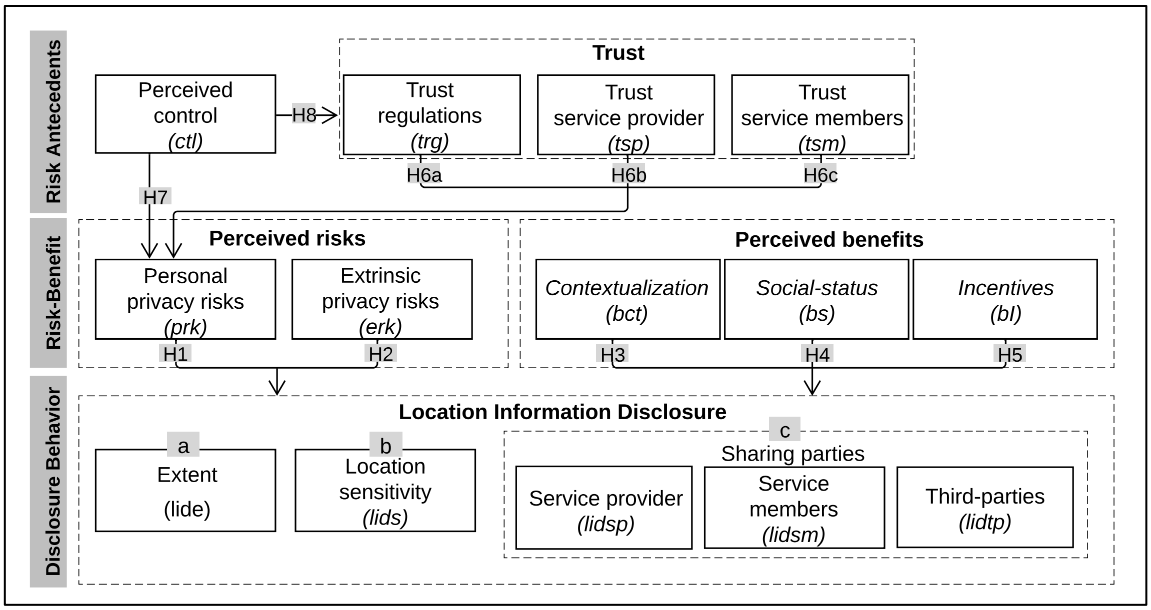

Figure 6. An Extended Privacy Calculus Model for Location-Based Services

While IS research on information privacy is criticized for lacking prescriptive design and actions, we suggest integrating the CA method to this domain for understanding users' preferences and privacy trade-offs. We provide a critical account on current established models (i.e., privacy calculus) for such purposes and promote the use of CA to provide empirical insights on user adoption of IS under privacy concerns. Comparing two approaches in Essay 2.2, we demonstrate how CA can complement existing theories on IS adoption through providing insights on acceptable system features. We emphasize how studying user preferences in addition to perceptions can be useful in having a profound understanding of the user's decision model along multiple perspectives. This is mainly elaborated in a privacy context, thus we contribute to the privacy-aware design of mass-market IS through an adaptation of a method from market research for this purpose.

We provide empirical insights on users' general perceptions about benefits and risks and how they affect adoption of contact tracing apps, which has implications on their design. An important finding from the privacy calculus is the privacy paradoxical behaviour with regards to this category of context-aware applications. Acquisti and Grossklags (2004) explain that users' attitudes can be contradictory with their behaviours, based on how they assess the cost-benefit trade-offs. In a pandemic situation, health benefits can be a main driver for adopting such applications, which explains the paradox. Moreover, our results emphasize the importance of perceived privacy control by users and the transparency of data management within the app. In addition, they show the positive impact of social norms and peer pressure on the intentions to use.

	Cluster 1	**Cluster 2**	**Cluster 3**
Number of participants	76 (26.85%)	92 (32.51%)	115 (40.64%)
Privacy Characterization	Privacy concerned users	Privacy concerned users	Unconcerned users
Value-added services	No additional services	Included	Included
Preferences			
Health information registration	No information is required	No information is required	Health status information
Exposure logging	Contacts (via Bluetooth)	Contacts (via Bluetooth)	Contacts and Location (Bluetooth & GPS)
Test results sharing	User can share positive test results on app only with a validation code by the healthcare provider	User can share positive test results on app only with a validation code by the healthcare provider	Healthcare provider directly shares test results (positive/ negative) with users
Exposure notification	Alert only if you had contact with an infected person	Alert if you had contact with an infected person with risk assessment (low, medium, high)	Alert if you had contact with an infected person with risk assessment (low, medium, high)
Diagnosis services	No in-app diagnosis	Simple diagnosis: Symptoms tracking with checklists	Advanced diagnosis: Using sensors to capture symptoms
Contextual services	No additional services	Maps with indication of safe areas/ infected zones	Maps with indication of safe areas/ infected zones
Dashboard	Detailed dashboard on data logging, updates and sharing	Detailed dashboard on data logging, updates and sharing	Detailed dashboard on data logging, updates and sharing
Data sharing	Restricted to contact tracing	Restricted to contact tracing	Contact tracing, research and specific purposes for safety measures
App Architecture	Decentralized: matching with positive cases done on your phone	Decentralized: matching with positive cases done on your phone	Centralized: matching with positive cases done by a central server
Interoperability	Cross-country integration	Cross-country integration	Cross-country integration

Table 5. Group preferences based on customer segmentation (common preferences are highlighted)

Through our application of CA in the same study we provide insights into concrete system realizations based on an understanding of users preferences for design features. We improve the understanding of group preferences applying segmentation techniques on the CA results (Table 5). In addition to privacy-preserving features, our results emphasize the importance of value-added services in the design of contact tracing apps for increased benefits perceptions. We show that users value the app more if it has augmented or congruent functionalities, for instance providing diagnosis (simple or advanced) and contextual services (safe check-in and infection maps).

With the aim of increasing adoption of such apps, we promote the use of market simulations to provide empirical evidence on successful designs. We illustrate how variation analysis techniques can contribute through reliable quantitative data (estimated market shares) based on user preferences. This was tested on different scenarios for value-added services to assess their importance in driving adoption. Our results confirm the role of goal-congruent features additions in increasing user adoption (Wortmann et al. 2019).

Label	**Reference**	**App 1**	**App 2**	**App 3**	**App 4**	**App 5**
Description	Corona-Warn-App	Simple Diagnosis	Advanced Diagnosis	Check-in Service	Maps	Simple Diagnosis + Maps
Health information registration	No information is required					
Exposure logging	Contacts (via Bluetooth)					
Test results sharing	User can share positive test stsults on app only with a validated code					
Exposure notification	Alert if you had contact with an infected person with risk assessment					
Dashboard	Basic dashboard on data logging					
Data sharing	Restricted to contact tracing					
App Architecture	Decentralized					
Interoperability	No cross-country integration					
Diagnosis services	No in-app diagnosis	Simple diagnosis: Symptoms tracking with checklists	Advanced diagnosis: Using sensors to capture symptoms	No in-app diagnosis	No in-app diagnosis	Simple diagnosis: Symptoms tracking with checklists
Contextual services	No additional services	No additional services	No additional services	Check-in service with QR code in public places for safe entry	Maps with indication of safe areas/ infected zones	Maps with indication of safe areas/ infected zones
Market share		57%	39%	49%	56%	60%

Table 6. Scenarios for variation analysis simulation

5.4 Implications, Limitations, and Outlook

Privacy calculus has been commonly used as a framework to study user adoption in light of privacy concerns. However, this approach narrows down disclosure or intention to use to a uni-dimensional construct without taking into consideration contextual factors that provide a proper conceptualization of the system under study. We extend the privacy calculus to account for the multi-dimensions of disclosure for a better understanding of system characteristics that guarantee privacy-aware design and thus adoption. This extension should be further discussed and instantiated in IS research to provide a structured understanding of adoption drivers or barriers based on system characteristics. Therefore, we suggest an extension to existing IS adoption approaches to better conceptualize the system through examining relevant dimensions that can impact design, rather than general disclosure or use constructs. This contributes to a more nuanced understanding that supports actionable insights in terms of system design. From a practical perspective, our results are relevant for application developers and service providers as well as regulatory bodies and policy makers. Understanding the multi-dimensional nature of information disclosure assists developers and providers to address the privacy by design principle through operationalizing features valued and accepted by users. It also provides input for enforcing regulatory standards compliant with user privacy perceptions.

Although we provide insights into the motivations for users' sharing behaviour, we conclude that no concrete system realizations can be achieved unless an evaluation of system features is also performed. Understanding users' perceptions provide a general picture of wanted elements within the system. However, a more granular approach to system features can help in addressing the design options that can lead to successful system design. Our empirical studies with CA on the specific category of context-aware applications from mass-market systems demonstrate the application of CA and illustrate its feasibility and usefulness in such domain. In the first research stream, we show that CA has been discussed as method for IS adoption. In fact, in this research stream, we demonstrate how CA can be of great value in understanding user adoption especially when it comes to privacy-aware design. The method can highlight which privacy-preserving features are required by users as well as group preferences for increased adoption. It can be also used for market simulations to assess the impact of varying certain design elements and complementing design through value-added services.

Future research can focus on further applications of the CA method for understanding user preferences under privacy constraints. Thereby contributing to a credible explanation of the privacy paradox. Contrasting CA and studies on perceptions allow for showing differences between general attitude and behaviour in specific privacy trade-off situations. A serious discussion on how CA can extend existing methods and frameworks for IS adoption in different contexts (similar to privacy calculus) is an interesting avenue for future research as well. Another stream worth exploring, based on our results, is the role of goal-congruent features addition on user preferences and consequently user adoption of IS for driving system use. These goal-congruent features can be used to enhance the benefit perceptions, which plays a role in the user decision-making.

While the privacy calculus lens has been extensively used to understand the user's risk-benefit trade-offs, we acknowledge the limitation of this approach since it views privacy-related-decision-making as a rational process. In fact, previous research (Acquisti and Grossklags 2004) has highlighted a discrepancy between user's attitudes and behaviour. Thus, resulting with a privacy paradox phenomena that disregards privacy concerns in the disclosure behaviour. It is therefore important to have a clear understanding of the benefit structure triggering the disclosure behaviour to explain the sharing behaviour. Moreover, a focus on promoting privacy-aware design is necessary to cope with this paradoxical situation. It is also worth mentioning that in our research we rely on user's intentions to use and willingness-to-disclose rather than the actual behaviour. While we consider intentions as prerequisites to actual use, an avenue for future research is to study actual behaviour and assess implications for privacy-aware design with real implementation scenarios to better understand users' privacy trade-offs.

6 Conclusion

Mass-market IS emerged as a result to technology advances and address heterogeneous and distributed users. As user involvement is a critical aspect to achieve system success (Bano and Zowghi 2015), several theories and models have been employed in IS research to study user adoption in multiple contexts. Existing approaches have been criticized for not sufficiently treating the IT artifact (i.e., system), but rather providing fractioned views on users' attitudes and perceptions. Thus, they do not allow deriving actionable insights in practice (Wortmann et al. 2019). This dissertation addresses existing gaps in research related to the user-oriented IS design in mass-markets. We suggest adopting market research techniques, specifically CA, in assessing users' preferences in mass-market scenarios. The preference measure is expected to add a detailed valuation of the accepted system features, contributing to a complete view of system characteristics resulting in higher adoption levels and can in turn inform IS design. We therefore contribute to a comprehensive conceptualization of the IT artifact in IS studies targeting mass-market systems. Furthermore, we set the stage for IS adoption studies in the privacy domain, which is a core topic for mass-market IS. We show how empirical evaluations in this special context through CA provide insights into user preferences and privacy trade-offs, which can inform system design.

Analyzing the past to predict the future is a goal for science. By standing on the shoulders of giants, we contribute to IS research through a Type 1 Theory (Gregor 2006). As "theory of analyzing", the main purpose is to lay foundation for IS research by reviewing past applications in the domain. Through a "Framework for Conjoint Studies in the IS Discipline", we contribute to the knowledge in IS by highlighting application areas in IS design and evaluation.

In the area of IS design, research stream 1 contributes through methodological guidelines for using CA in software product management for mass-markets. As an outcome from design science research, we build an artifact that aims at adding the user perspective to existing methods in software product management by providing data-driven insights based on utility function derived from user choices in a CA setup. In response to the call of Baskerville and Myers (2002), we refer to a method from another discipline (marketing) in the aim to inform IS research and add to its body of knowledge. The resulting method component extends existing RE approaches and provides reliable customer feedback for initial concept definition and an iterative design process. This in turn provides a practical contribution for IT vendors that can apply the method for obtaining user preference measurement for system features.

In the area of IS evaluation, research stream 2 shows how empirical insights on user perceptions and user preferences can inform system design. We also illustrate how CA can extend existing IS theories for adoption and intentions to use through comparing CA results in a study of contact tracing apps to privacy calculus in the same context. Our results show that CA can provide a better conceptualization of the system in terms of implementation options to inform privacy-aware IS design. We demonstrate that privacy calculus, as an established IS adoption model, has shortcomings in delivering insights on acceptable design features and should be extended to handle the multi-dimensional aspects corresponding to contextual factors related to system use. Our extension of the privacy calculus model has theoretical implications on the conceptualization of disclosure that serves as input for privacy design. Future research in this domain has two areas for exploration: first, the extended privacy calculus model should be examined with formal operationalization of the disclosure dimensions; second, more instantiations of CA studies for privacy-aware design are required to evaluate the effectiveness and utility of this method, especially in employing market simulation techniques to assess design variations and predict market shares based on estimated utilities.

To summarize, through two research streams we provide theoretical and empirical contributions to IS research in general, and IS design and adoption in mass-markets in specific. We highlight the importance of establishing a solid understanding of the users' preferences for building a successful and reliable system design. We also emphasize the interplay of user's perceptions and preferences as input for understanding drivers and barriers for user adoption, especially in the privacy context. Our focus in this thesis was on conjoint analysis as a method for preference measurement, however it would also be interesting to explore adjacent methods that aim at modeling the user decision-making process to understand the underlying cognitive mechanisms governing the user choice. Future research in the domain can play an important role in promoting the user preference philosophy as a contribution to the body of knowledge in IS.

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Appendix

Essay	Title	Authors	Publication Status
1.1	Leveraging Market Research Techniques in IS – A Review of Conjoint Analysis in IS Research	Dana Naous and Christine Legner	Proceedings of the *International Conference on Information Systems (2017)*
1.2	Leveraging Market Research Techniques in IS – A Review and Framework of Conjoint Analysis Studies in the IS Discipline	Dana Naous and Christine Legner	Accepted with minor revisions in the *Communications of the AIS*
1.3	Incorporating the Voice of the Customer into Mass-Market Software Product Management	Dana Naous, Andrea Giessmann and Christine Legner	Proceedings of the *ACM/SIGAPP Symposium On Applied Computing (2020)*
1.4	Incorporating the Voice of the Customer: A Preference-based Approach to Mass-Market Software Product Design	Dana Naous and Christine Legner	Invited for the *Applied Computing Review*
1.5	Understanding Users' Preferences for Privacy & Security Features – A Conjoint Analysis of Cloud Storage Services	Dana Naous and Christine Legner	Proceedings of the *International Conference on Business Information Systems Workshops (2019)*
2.1	Information Disclosure in Location-based Services: An Extended Privacy Calculus Model	Dana Naous, Vaibhav Kulkarni, Christine Legner and Benoit Garbinato	Proceedings of the *International Conference on Information Systems (ICIS) (2019)*
2.2	Understanding User Adoption of Contact Tracing Apps	Dana Naous, Manus Bonner, Mathias Humbert and Christine Legner	Submission to the *European Journal of Information Systems*

Table 7. List of Publications from the Dissertation

Title	**Authors**	**Publication Status**
User-Oriented Cloud Service Design Based on Market Research Techniques	Andrea Giessmann, Dana Naous and Christine Legner	*Proceedings of the European Conference on Information Systems (2016) – Research-in-progress Paper*
Analytics as a Service: Cloud Computing and the Transformation of Business Analytics Business Models and Ecosystems	Dana Naous, Johannes Schwarz and Christine Legner	*Proceedings of the European Conference on Information Systems (2017)*
Exploring Information Disclosure in Location-based Services: US vs. German Populations	Dana Naous and Christine Legner	*Proceedings of the International Conference on Information Systems (Pre-ICIS) Workshops (2019)*

Table 8. List of Other Publications

Leveraging Market Research Techniques in IS – A Review of Conjoint Analysis in IS Research

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Abstract. With the increasing importance of mass-market information systems (IS), understanding individual user preferences for IS design and adoption is essential. However, this has been a challenging task due to the complexity of balancing functional, non-functional, and economic requirements. Conjoint analysis (CA), from marketing research, estimates user preferences by measuring tradeoffs between products attributes. Although the number of studies applying CA in IS has increased in the past years, we still lack fundamental discussion on its use in our discipline. We review the existing CA studies in IS with regard to the application areas and methodological choices along the CA procedure. Based on this review, we develop a reference framework for application areas in IS that serves as foundation for future studies. We argue that CA can be leveraged in requirements management, business model design, and systems evaluation. As future research opportunities, we see domain-specific adaptations e.g., user preference models.

Keywords: Information systems, design, evaluation, conjoint analysis, user preferences

1 Introduction

Understanding user requirements and the factors that drive user adoption are crucial when designing information systems (IS). However, the user perspective is far from easy to grasp, owing to the complexity of IS solutions and the many tradeoffs between different properties and multiple functional, non-functional, and economic dimensions. In fact, the IS domain has experienced a shift from customer-specific systems in enterprises to a “market in which vendors package ready-to-install products” (Sawyer 2001, p. 97). As a result of technology advances, such as mobile and cloud computing, today’s systems can be described as mass-market IS, which target distributed and heterogeneous end-users. For software vendors, these types of commercial systems create challenges, since they require different bundling and pricing strategies with segmentation of users to fulfill the needs of multiple user profiles. Thus, there is a need to tailor existing development methods to address the specificities of mass-market IS (Fitzgerald et al. 2003; Karlsson and Agerfalk 2004).

Traditionally, user-oriented design of IS was promoted through requirements elicitation. Elicitation techniques collect data from individual or group users via interviews, surveys, focus groups, ethnographic techniques comprising user contextual observations, cognitive techniques, and/or prototyping (Nuseibeh and Easterbrook 2000). Since most of them rely on close interactions with users or their representatives, they are difficult to apply in the context of mass-market IS with individual and dispersed users. Moreover, these techniques critically depend on participant selection, which can bias requirements representation. Thus, the need to integrate the *customer’s voice* calls for new approaches in IS design to ensure the widest customer reach and acceptance (Jarke et al. 2011; Tuunanen et al. 2010) and to capture different user perceptions for well-defined product and service bundles.

Market research techniques, specifically conjoint analysis (CA), are promising approaches to address these goals and to support the user-oriented design of IS. We argue that CA could have a significant impact on IS research (and practice) if it were fully developed and adopted as a methodology in IS. CA has become the most applied market research technique in the past decades and is increasingly used in IS studies. It is “a practical set of methods for predicting consumer preferences for multi-attribute options in a wide variety of product and service contexts” (Green and Srinivasan 1978, p. 103). CA’s popularity is due to its allowing for the measuring of user tradeoffs when evaluating products or services, adding a quantitative measurement that reflects optimal product or service design, which better fit users' needs. Marketing research has argued that the conjoint method is particularly useful in new technical product development (Green et al. 2001; van Kleef et al. 2005). In the IS domain, the CA methodology was first suggested by Bajaj (1999), who emphasizes its usefulness for studying human behavior in the assessment of IS for purchase decisions and adoption. In this context, conjoint methodology could extend the Technology Acceptance Model (TAM) to study other acceptance variables than perceived usefulness (PU) and perceived ease-of-use (PEOU), such as product attributes and external factors. IS researchers started employing CA to study adoption decisions as well as users' preference structures governing IS design based on Bajaj's (1999) CA study procedure guide. Examples of studies applying CA are those by Schaupp and Bélanger (2005) on purchase decisions in e-commerce, Keil and Tiwana (2006) on ERP package evaluation, Bouwman et al. (2008) on the design preferences and adoption of mobile applications for police officers, and Giessmann and Stanoevska (2012) on cloud services. While these studies demonstrate CA's value in the IS domain, they have mostly been one-time efforts, and we still lack a fundamental discussion on its uses in IS. This motivates our research.

We seek to lay the foundation for future studies by analyzing the current state of conjoint method application in the IS domain via a systematic literature review. For this purpose, we provide a comprehensive analysis of the 46 CA studies published between 1999 and 2016 in the IS field. Our contribution is three-fold: First, we critically assess the existing CA studies in IS with regard to the application areas and methodological choices along the CA procedure. Second, based on our review, we develop a reference framework for applying CA as a methodology for IS that may serve as a foundation for future studies. Third, we outline opportunities for future research and the further development of CA in the IS domain.

The remainder of this paper is structured as follows: In Section 2, we review the current state of conjoint analysis and its evolution over time as well as application areas. In Section 3, we present our research methodology, based on Webster and Watson's (2002) guidelines for literature reviews. In Section 4, we summarize the findings of the literature review along the analysis framework. In Section 5, we discuss implications of this research and make recommendations for the domain-specific adaptation of CA. We conclude with a summary of our findings and limitations as well as future research opportunities.

2 Prior Research: Conjoint Analysis

2.1 Foundations of Conjoint Analysis

Conjoint analysis has its foundations in the work of Green and Rao (1971), who advocated the use of conjoint measurement in consumer-oriented marketing research. As a concept from mathematical psychology established by Luce and Tukey in 1964, conjoint measurement is used to measure "the joint effects of a set of independent variables on the ordering of a dependent variable" (Green and Rao 1971, p. 355). Accordingly, it is well suited to problems in marketing as an approach to quantify judgmental data.

The original approach, also called *concept evaluation* or *full-profile*, is based on rank orders of consumers' preferences of product profiles (also called stimuli) composed of several attributes and levels that refer to product characteristics. Thus, part-worth utilities of each attribute are determined by applying an additive composition rule. Besides the *concept evaluation*, Johnson (1974) suggested an alternative approach called the *tradeoff matrix* or *pairwise approach*, in which respondents evaluate a pair of attributes, providing information about the tradeoffs among all product features. This method's strength is its ability to support a large number of attributes, since it can make predictions based on the evaluation of subsets of attribute pairs (Johnson 1974).

A traditional conjoint study would rely on six steps, as suggested by Green and Srinivasan (1978); we highlight the key aspects:

1. **Preference model selection:** As a de-compositional method that allows for the exploration of consumers' tradeoffs, the part-worth utility function is the most attractive model, owing to its flexibility in presenting attributes preferences.
2. **Data collection method:** This involves selecting a conjoint method approach. The full-profile approach is most frequently used, since it provides a more realistic description of the stimuli. However, as mentioned, the pairwise approach has an advantage when the attribute number is large.
3. **Stimulus set construction:** Depending on the number of attributes in a conjoint study, the number of stimuli could be very high, which burdens the participants. Thus, researchers tend to reduce the number of stimuli to facilitate participants' evaluation task. This is mainly based on fractional factorial orthogonal design, assuming no interaction effects among the selected attributes.

4. **Stimulus presentation:** Several variations exist, such as verbal description, paragraph description, or pictorial representation. The choice of the presentation depends on the product type and can be a combination of methods. Further, when applying CA in some product categories, such as packaged goods, prototypes, or actual products could be used to provide more realistic stimuli.
5. **Measurement scale:** Scales depend on the study purpose and on the data collection method. While both methods (the full-profile and the pairwise approach) can use ranking to capture preferences or purchasing intentions, the full-profile approach could also use ratings of the different presented profiles.
6. **Estimation method:** It is selected based on the dependent variable type resulting from the measurement scale. While an ordinal-scaled variable could use MONANOVA, an interval-scaled variable can for instance use an ordinary least squares (OLS) regression. In addition, LOGIT or PROBIT models can be used when a choice-probability model is applied for data.

Attributes	***Attribute levels***		
Price	$200	$400	$700
Screen size	4.7 inches	5.2 inches	6 inches
Camera resolution	8 MP	12 MP	20 MP

Table 1. Example for Attributes and Attribute Levels of a Conjoint Analysis

To illustrate the CA procedure, take the simplified example of a smartphone. In Table 1, we introduce attributes and attribute levels of the product class selected based on existing product specifications in the market. For the conjoint method, we selected a part-worth function model (Step 1) in a full-profile approach (Step 2). The stimulus set of three attributes with three levels would lead to 27 (=3^3) product concepts. Fractional-factorial design (Step 3) would be employed to arrive at a reduced design, in this case with nine stimuli. In our smartphone example, the stimulus presentation (Step 4) can benefit from a combination of verbal description and pictorial representation (or the de facto prototype, if available) to help participants see the differences between screen sizes. This would enable them to rank (Step 5) the stimuli based on their preferences. Multiple regression analysis could be employed to estimate the part-worth utilities (Step 6). The utilities are then calculated by adding individuals' part-worth utilities, i.e., following the use function $u = \sum_{i=1}^{k} u_i + e$. Finally, the part-worth utilities are standardized, to ensure that all utilities use the same unit of scale.

2.2 Developments and Extensions of the CA Method

Owing to the prevalence of CA, the methods for applying it have been further developed and improved (see Table 2). During the 1980s, two additional CA approaches were introduced to address the data collection step in terms of evaluation methods: adaptive conjoint analysis (ACA), and choice-based conjoint analysis (CBCA) (Green et al. 2001). Adaptive conjoint analysis, which was developed by Sawtooth Software to solve the number of attributes issue faced in the traditional full-profile CA, is based on a hybrid technique that combines self-explicated tasks with an evaluation of partial-profile descriptions (Green 1984; Johnson 1987). The self-explicated task allows respondents to rate attributes individually and to exclude unacceptable attribute levels from the evaluation task (Johnson 1987).

Choice-based conjoint analysis can be considered as a replacement of ranking-based or rating-based conjoint methods. It simulates the process of purchasing a product; participants are asked to make hypothetical choices in a scenario similar to a competitive marketplace, and their individual-level utility function is estimated using Hierarchical Bayes (HB) (Johnson et al. 2003). The main concern with this approach is that participants need to evaluate a large number of purchase scenarios; however, it has the advantage of being able to deal with the complexity of choosing among competitive profiles, which makes it a mixed blessing (Green et al. 2001).

As a combination of the two approaches, adaptive choice-based conjoint analysis (ACBCA) is able to estimate part-worth utilities from a small sample size with less than 100 participants (Johnson et al. 2003). ACBCA asks participants to choose among a set of stimuli to select the most relevant attributes and levels, simulating purchase behaviors similar to the CBCA after participants perform a self-explicated task (which is performed in an ACA).

Further developments to the presented CA methods have been discussed by several researchers (Netzer et al. 2008; Rao 2008); they mainly targeted technique and application issues. Given the variety of approaches, the decision on the CA method becomes more complex, but would be based on several criteria, including product and study-related factors. Orme (2009) has thoroughly discussed this matter by demonstrating advantages and limitations of each CA type and then building a recommendation guide for selecting the appropriate method. He proposes the following main selection criteria: the number of attributes, the mode of interviewing, the sample size, the interview time, and the inclusion of pricing research in a study. Generally, adaptive methods are more favored when the number of attributes is large or the sample size is small. Choice-based methods are preferred for pricing studies.

CA steps	Alternative methods to CA	
	Traditional conjoint analysis *(proposed by Green and Srinivasan 1978)*	**Developments and extensions**
1. Selection of the preference model	Vector model, ideal-point model, part-worth function model, mixed	
2. Data collection method	Two-factor-at-a-time (tradeoff analysis), full-profile (concept evaluation)	ACA, CBCA, adaptive CBCA
3. Stimulus set construction	Fractional factorial design, random sampling from multimethod variate distribution	Partial profiles, self-explicated method
4. Stimulus presentation	Verbal description (multiple cue, stimulus card), paragraph description, pictorial or three-dimensional model representation	Actual products, prototypes
5. Measurement scale	Paired comparisons, rank order, rating scales, constant-sum paired comparisons, category assignment	
6. Estimation method	MONANOVA, PREFMAP, LINMAP, Johnson's non-metric tradeoff algorithm, multiple regression, LOGIT, PROBIT	Hierarchical Bayes

Table 2. CA Steps Based on Green and Srinivasan (1978)

2.3 Applications in Marketing Research

After the introduction of conjoint methodology by Green and Rao (1971), its application became widely popular in consumer research and was extended into applied psychology, decision theory, and economics (Green and Srinivasan 1978). CA is used to measure consumer tradeoffs between product attributes and to derive user preferences or intentions to buy. It is "marketers' favorite methodology for finding out how buyers make tradeoffs among competing products and suppliers" (Green et al. 2001, p. S56).

Previous research has exposed the different application areas for CA in marketing based on different techniques. Green and Rao (1971) have paved the way for different suggestions: 1) **vendor evaluation** by developing criteria for vendor rating, 2) **price-value relationship** by measuring consumer tradeoffs for price and quality of products, 3) **attitude measurement** to analyze the tradeoffs between several product attributes and to derive the importance of functional vs. symbolic characteristics such as brand image, or to analyze utility for collections of items to facilitate combination packaging of certain product types, 4) **cost-benefit analysis** to study the willingness-to-pay (WTP) for certain attributes and to design products accordingly, and 5) **clustering or segmentation of customers** based on their utility functions. Further, Johnson (1974) has referred to another application using **market simulation**, which is used to estimate market shares of currently available or new products based on predicted consumer preferences of the study sample.

In the practical domain, there were two comprehensive surveys on the commercial use of CA in the 1980s to explore applications of this method in marketing research. The first (Cattin and Wittink 1982) showed that the method is mainly applied for concept or product design, whether a development of a new product or a modification of an existing one based on feature (attribute) preferences. Pricing was also among the most important objectives for using this approach. Other domains for application have also been presented, such as market segmentation, advertising, and distribution. In an update to this survey (Wittink and Cattin 1989), competitive analysis was ranked among the top objectives for using CA in marketing research via the application of a market simulation, with the help of computer software (e.g., Sawtooth Software).

Marketing research has proved that conjoint methodology is a useful tool in providing insights into consumer preferences and predicting consumer behaviors in purchasing decisions and intentions to buy (Wittink and Cattin 1989). Beyond marketing, the strategy literature has adopted CA as a decision support tool, for instance to evaluate decision policies by top managers (Priem 1992). Green et al. (2001) have also foreseen the future of the CA method in other application domains, extending other fields such as telecommunications and banking services, also extending consumer bases to involve stakeholder groups, suppliers, and employees.

3 Research Methodology

The objective of this research is to summarize the current state of conjoint studies in IS and to provide a critical assessment concerning its domain-specific applications and methodological aspects. We explore the different domains in IS in which CA has been applied, and propose application areas, following Bajaj's (1999) suggestion. We develop a framework that IS researchers can use to guide their research, employing CA as their methodology. We follow the recommendations of Webster and Watson (2002) on conducting a literature review in the IS field.

3.1 Literature Selection

Seeking to attain completeness and quality in our review, we conducted a comprehensive longitudinal analysis of peer-reviewed publications, starting from Bajaj (1999) until the end of 2016. To identify empirical studies using CA in top IS journals, we relied on the *Senior scholars' basket of journals* from the Association of Information Systems (AIS) including the *European Journal of Information Systems*, *Information Systems Journal*, *Information Systems Research*, *Journal of AIS*, *Journal of Information Technology*, *Journal of MIS*, *Journal of Strategic Information Systems*, and *MIS Quarterly*. We then performed an electronic search in the following databases: AIS Electronic Library (AISe), EBSCOHost, ScienceDirect, Springerlink, and Wiley. This was followed by a Google Scholar search to cover any missing studies. To ensure that we capture all relevant pieces of research, the search criteria was based on the following keywords: *conjoint analysis* OR *consumer preferences*; we used filtering where possible to restrict the search to the title or abstract. In addition, in advanced search, we restricted the research area to IS/IT and business management when the search resulted in many irrelevant articles. We performed backward and forward citation searches to identify prior articles as well as relevant articles that could have been missed by the search criteria (Webster and Watson 2002).

The literature selection phase resulted in 66 publications in proceedings of highly reputable international and regional IS conferences as well as publications from academic journals relating to IS/IT and business research. We then scanned these by carefully reading the abstract to judge their relevance; we eliminated 15 publications, which are not in relevant domains or lack methodological illustrations. The procedure resulted in 52 relevant studies in 51 publications – Bouwman et al. (2008) had two CA studies in the same publication. The final sample comprises 46 studies, since we combined six studies in conference papers with their extended versions published as journal articles.

3.2 Literature Analysis & Classification

Building on the suggestion by Webster and Watson (2002), we developed an analysis framework to synthesize the literature and to provide a guide for future CA studies. We were able to analyze and group the CA studies and the different applications based on a coding scheme that reflects CA techniques and procedures. The resulting coding scheme covers three elements: attribute and level selection, data analysis building on relevant aspects of Green and Srinivasan's (1978) CA steps, and study administration. We also included coding of the ***publication type*** (i.e., conference or journal publications), the specific ***category of IS*** investigated using CA, and the ***study purpose*** to help classify the literature.

3.3 Attribute & Level Selection Coding

The first step in a CA study involves representing the system class with a set of attributes and levels. The coding then involves: ***attributes selection*** (literature review, focus groups, user interviews, questionnaires, expert interviews, or existing products), ***number of attributes***, and ***attribute level type*** (binary, multileveled, or multicriteria).

3.4 Data Analysis Coding

A coding of CA steps is useful to analyze the literature and how the method is used in the IS domain compared to other fields. Based on the CA steps suggested by Green and Srinivasan (1978) (see Table 2), the coding involved: the **preference model**, the **data collection method**, the ***stimuli design*** and ***type of stimuli*** to account for the stimulus set construction and presentation, the **measurement scale** of the dependent variable in the CA, and the **estimation method**.

After the estimation of the utility functions, further techniques in CA can be applied for certain study scenarios. The coding captures ***analysis techniques*** that are frequently performed beyond the relative importance of attributes. These techniques (see Section 2.3) comprise market segmentation (including clustering methods), WTP (based on a defined price attribute), and market simulation (to provide a competitive analysis).

3.5 Study Administration Coding

In terms of ***study setup***, CA surveys can be conducted via face-to-face interviews, experiments, questionnaires, or online surveys. The second code relates to the use of specific software to perform the study. This coding of ***software used*** can help provide suggestions for the designs of future studies. Also, as the CA method targets heterogeneous and distributed users, researchers must decide the representative ***sample size*** for their study, and most importantly, the targeted user base (i.e., ***subjects' backgrounds***).

4 CA Studies in IS Research

4.1 Overview

Based on our systematic literature review, we identified 52 studies from IS research in which CA is applied as a methodology. Table 5 (see Appendix) presents an overview of 26 studies in journal articles and 26 conference proceedings, including bibliographic and meta-information on each article (year, study objective as described in the paper, purpose, domain, CA method type, study sample size, and subjects' backgrounds). The statistics in Table 3 and the following sections refer to the total number of conjoint studies (i.e., 46) that combine the conference proceedings that were further developed into journal articles with the latter (highlighted in Table 5).

Coding item	Coding options	Number of studies	Percentage (%)
IS category	Enterprise systems	8	17.4
	Mobile applications & communication	16	34.8
	E-commerce	6	13
	Online services	9	19.6
	Cloud services	5	10.9
	Internet of Things	2	4.3
Study purpose	Organizational decision-making	6	13
	End-user adoption	13	28.3
	IS design	12	26.1
	Pricing	9	19.6
	Information privacy	5	10.9
	Channel selection	2	4.3
Attributes selection	Literature review	35	76.1
	Existing products	13	28.3
	Expert interviews	11	23.9
	Questionnaires	4	8.7
	User interviews	7	15.2
	Focus groups	6	13
Method type	TCA	28	60.9
	ACA	6	13
	CBCA	11	23.9
	ACBCA	1	2.2
Analysis techniques	WTP	14	30.4
	Segmentation	21	45.7
	Simulation	6	13

Table 3. Summary of Results from the Literature Review of CA Studies in IS

Overall, we found more than 20 types of information systems and applications that were investigated via CA. We classified them into five main categories:

- **Enterprise systems (ES):** This category includes studies on computing architecture, office systems, and enterprise resource planning (ERP) systems.
- **Mobile applications and communications (MC):** Studies in this category mainly covered mobile platforms, mobile applications, and mobile communication infrastructure.
- **E-commerce (EC):** This category relates to online shopping applications.
- **Online (O) services:** Studies cover different type of online services, such as social networks and online banking.
- **Cloud (C) services:** This category relates to services provided on the cloud, such as data storage, Software as a Service (SaaS) and Platform as a Service (PaaS).
- **Internet-of -Things (IoT):** Studies covering connected and smart devices.

We were able to map the study objectives and results to the different applications in marketing research (see Section 2.3) and associate them with one or more CA techniques employed (i.e., relative importance, WTP, segmentation, and simulation). From this mapping, based on identified patterns from the literature coding, we derived six typical purposes for CA in IS:

- **Organizational decision-making (DM):** The purpose is mainly associated to situations involving managerial decisions on adopting information systems in an organizational context. This includes selecting decision criteria for systems evaluation based on the studies attributes' relative importances. These studies are similar to vendor evaluations in marketing research.
- **End-user adoption (A):** The purpose is to understand customer preferences or behaviors in adopting new technologies. While they are similar to decision-making studies, they target user intentions to use rather than the selection or evaluation of a system. This is based on preference predictions derived from utilities estimated from evaluations of product profiles. The study could also employ segmentation to analyze different user groups' preferences. Compared to marketing research, this is part of attitude measurement applications.
- **IS design (D):** The study purpose is to elicit user preferences for designing a new IS as a product, an application (in the context of mobile development), and services. This is based on measuring preferences and tradeoffs among attributes and levels related to systems requirements. This will then reflect the relative importance of each attribute and level from the estimated part-worth utilities to guide the product class' design process. These study types can also include techniques of WTP and user segmentation.
- **Pricing (P):** The purpose is to understand WTP for product or service features. These studies mainly involve cost-benefit analysis, based on an analysis of the price attribute variations' effects on the resulting user preferences and preferences predictions.
- **Information privacy (IP):** The study purpose is to measure tradeoffs between information privacy concerns and monetary values, which could be achieved through tradeoff analysis of information privacy attributes with monetary rewards or by applying WTP analysis for certain information privacy attribute levels.
- **Channel selection (C):** The study seeks to understand user preferences for different information distribution channels by evaluating different profiles and estimating the part-worth utility function, which reflects the selection decision.

4.2 Attribute & Level Selection

Selecting attributes and levels is a key decision in CA study design. Most studies of CA rely on a literature review of a domain-specific topic to select attributes (Table 3). Also, evaluating existing product features is a common method used especially in studies of IS design. More than 50% of these studies followed a multistage selection process. The most common combinations are a literature review with an evaluation of existing products or with expert interviews to gain insights into feasible features. In some cases, a three-stage selection process was performed to get user insights via questionnaires, interviews (Choi et al. 2013), or focus groups (Brodt and Heitmann 2004; Giessmann and Stanoevska 2012; Nikou et al. 2014).

The number of attributes correlates to the selected conjoint method. Most studies followed the pattern suggested by Orme (2002) on attribute selection, where traditional full-profile studies considered up to six attributes; adaptive studies included more. However, there were exceptions, where full-profile CA contained more than six attributes. These cases depend on the study purpose and were mainly in decision-making CA where the attribute levels are limited to binary (low or high) (e.g., Benlian and Hess 2011; Keil and Tiwana 2006) or multilevel (low, medium or high) (e.g., Mahindra and Whitworth 2005) or in service design studies that involved bundling options with binary attributes corresponding to services (included or not included) (e.g., Daas et al. 2014).

4.3 Data Analysis

All the studies were conducted after 2000, which means that the extended developments of conjoint methods already existed. They were all based on a part-worth utility preference model (as pointed out in Section 2.1). Interestingly, the conjoint studies in IS mainly used the traditional approach (60.9%) and did not consider the improvements presented in Section 2.2. Studies in the IS domain relied mostly on traditional full-profile CA, even though studies with a large number of attributes – according to CA guidelines – should better rely on adaptive methods. It must also be noted that none of the methodologies strictly related to the study purpose according to CA literature. For instance, CBCA was applied for pricing, adoption, decision-making, and service design studies, although it is said to mainly support pricing decisions. Also, there was only one application of ACBCA by Giessmann and Stanoevska (2012) for cloud service design. The dominance of the full-profile CA implies that CA studies in IS rely on hypothetical system representations rather than on realistic choices, and are more constrained concerning the number of attributes.

The stimulus set construction depends on the data collection method. Studies of traditional or choice-based CA employed fractional factorial design to reduce the number of stimuli for a large number of attributes or levels. When adaptive methods are used, the self-explicated method helps to reduce the attribute set, to facilitate the study procedure. Most studies employed verbal description in the form of profile cards, and paragraph description as vignettes and scenarios. Interestingly, few studies used visual representation in evaluating website features for online services (Hann et al. 2007; Mahindra and Whitworth 2005), as well as e-commerce (Tamimi and Sebastianelli 2015). In adoption studies of existing products in IS (e.g., for enterprise systems), a de facto product would be of great significance to study participants. Even if it requires more resources for study setup, it should be used in categories such as online services, cloud services, e-commerce, and mobile applications to improve the quality of CA results.

The method for estimating the part-worth utilities of product attributes varies depending on the measurement scales. Ranking and rating were used similarly in the traditional approaches, and OLS is the main estimation method used. In the choice-based studies, a mix of the logit model was used to estimate utilities based on probabilistic assumptions from users' choices, and Hierarchical Bayes to obtain participants' individual utilities.

In addition to the relative importance of attributes based on the part-worth utilities, other data analysis techniques were applied in a CA study. **Market segmentation** is one technique applied by 20 studies to develop market segments based on groupings generated from sample demographics or specific clustering analysis techniques corresponding to the type of the conjoint method (the most commonly used are k-means clustering for full-profile or ACA, and hierarchical agglomerative clustering analysis for CBCA). **Willingness-to-pay** is another technique that was used mainly in the pricing, privacy tradeoff, and decision-making studies where a price attribute is included. Also, a different application of this technique was elaborated in the study by Baek et al. (2004), where the price was the dependent variable that was determined by the study participants for different online games options. Finally, **market simulation** can also be employed in the context of a competitive market analysis. It was employed by five studies in the current list, including Choi et al. (2013), Daas et al. (2014), Fritz et al. (2011), Song et al. (2009), and Weinreich and Schön (2013). Their main purpose was to predict market shares of new products or modified existing products based on preference models, and to evaluate the contribution margin. CA of PaaS by Giessmann and Stanoevska (2012) suggested the simulation method as a tool to design cloud business models.

4.4 Study Administration

Online surveys are the most frequently used research method for applying CA owing to their adaptability to a large sample size and high availability of online resources and survey software. CA could be performed using statistical tools such as R and SPSS with a conjoint package integrated to them, or through the use of specialized commercial software such as Sawtooth Software, the market leader, or Globalpark Software (e.g., Krasnova et al. 2009; Mann et al. 2008). The latter typically administer an online survey and are mainly used in studies that apply adaptive methods.

Marketing research deploys commercial panels to identify target samples whereas, in IS research, no existing panels are present for this methodology type. To date, very few studies have used existing online panels, such as Fritz et al. (2011). Although the sample in most conjoint studies comprises only consumers, the sample background in the IS literature depends on the study purpose. For instance, managers are considered as study samples in research involving organizational decision-making regarding IS/IT purchases or adoption. Other samples concerning users include student populations owing to the convenience of this sample in research. For instance, students performed a decision-making study taking roles as managers in an evaluation situation of corporate browsers (Mahindra and Whitworth 2005). Further, some researchers have applied CA in student-dedicated studies, such as mobile adoption (Head and Ziolkowski 2010) and cloud service adoption (Burda and Teuteberg 2015).

In marketing research, the typical sample size has a median of 300 especially in traditional CA. However, for adaptive methods, the sample size can be less than 100 and can still retain its statistical significance. In IS research, no specific patterns were identified. However, the median determined for the sample literature is 170. It is worth noting that the variance in our case is high owing to large-scale online studies with more than 1,000 respondents and several controlled studies with less than 30 respondents.

5 Synthesis and Discussion

5.1 The Current State of CA in IS and Recommendations

Our review reveals that there are a large variety of scenarios for using CA in IS, as well as a large number of CA variants from market research. While to date CA studies in IS have mostly used the basic techniques, there are many more options for using CA in specific situations. Table 4 provides a synthesis of our findings for the different steps in the CA procedure. It summarizes the current state, as discussed in Section 4.2, and critically assesses it against the CA literature (Sections 5.2 and 5.3). For future CA studies, it provides recommendations (R) to leverage existing CA methods in IS and suggests domain-specific adaptations (A) to enhance methodological support for CA studies in IS. Most importantly, these adaptations should address key challenges in conducting conjoint analysis, mainly in the study preparation: (1) the **choice of the CA variant for specific study objectives**, and (2) the first step of the study procedure, i.e., **user preference modeling** with attribute and level selection. We elaborate on both aspects in Section 5.3.

CA procedure	**Current State**	**Recommendations (R) and domain-specific adaptations (A)**
Attributes and levels Selection	Most studies use mixed methods in a multistage process for attribute selection	**A:** Creation of domain-specific user preference models to support selection
Data collection method	Since traditional CA is dominant, the number of attributes is constrained	**R:** Use of ACA, CBCA, and ACBCA to deal with high attribute numbers
Stimulus set Construction and presentation	Verbal and paragraph descriptions are mostly used; only a few studies relied on pictorial representations for websites	**R:** Development of prototypes and actual products (or mock-ups) to simulate realistic choices
Data analysis	IS studies don't exploit the full set of CA techniques; they mostly analyze relative importance from estimated utilities	**A:** Methodological guidance in selecting the data analysis techniques and applying them in design (ex-ante) and evaluation (ex-post) phases
Sample selection	The sample depends on the study purpose (e.g., students or managers); the sample size largely varies, but is often too small	**R:** Establishment of IS-specific panels to increase sample sizes
Study administration	Online surveys are mostly employed, and the subsequent analysis is based on statistical packages or commercial software	**R:** Exploration of software and packages to combine online data collection and analysis

Table 4. Current State of CA in IS and Guidelines

5.2 A Framework for Using CA in IS

CA provides a number of very useful data analysis techniques, including the ***estimation method*** (part-worth utilities estimation for preferences), ***market segmentation*** or ***clustering***, ***WTP*** (for a price attribute), and ***market simulation*** (to provide a competitive analysis context). These techniques can be used in manifold ways in the IS domain, but have not yet been fully leveraged. Based on our review and the identified purposes of CA studies, we suggest scenarios for applying CA in IS. We grouped them into a framework (Figure 1) that may guide future studies in IS. The framework outlines application areas where CA can have substantial impacts and significant potentials for design and evaluation in IS. The framework depicts that CA can be used in different phases – ex-ante in the design phase and ex-post in the evaluation of existing systems – and address different scopes. The narrowest scope is the core system, in which functional and non-functional requirements can be elicited and analyzed. In the case of online and cloud services, a broader scope is often applied, and business model elements can be evaluated via CA. Specifically, value delivery in terms of channel selection and customer relationships, value capture regarding value propositions and economic aspects (i.e., pricing) of the system linked to the customer segments, and value configuration elements specifically related to partnerships.

IS design: CA is a very well suited methodology for preference elicitation and can support IS design at different levels (e.g., Bouwman et al. 2008; Giessmann and Stanoevska 2012; Kim 2005; Nevo et al. 2012; Zubey et al. 2002). This is established by studying user design preferences for defined attributes relating to functional or non-functional characteristics leading to core system design preferences. CA enables the capturing of individual and group preferences via relative importances of features and the application of user clustering techniques. This analysis type could support requirements management for customer-oriented IS (Kabbedijk et al. 2009). Thus, it could be a fundamental method for release planning and selecting relevant features based on user choices. In addition, having design feedback from a large number of users is facilitated via the conjoint surveys, which is also a concern in research on mass-market IS where wide-base end-users demand new requirement engineering approaches (Jarke et al. 2011; Todoran et al. 2013; Tuunanen et al. 2010).

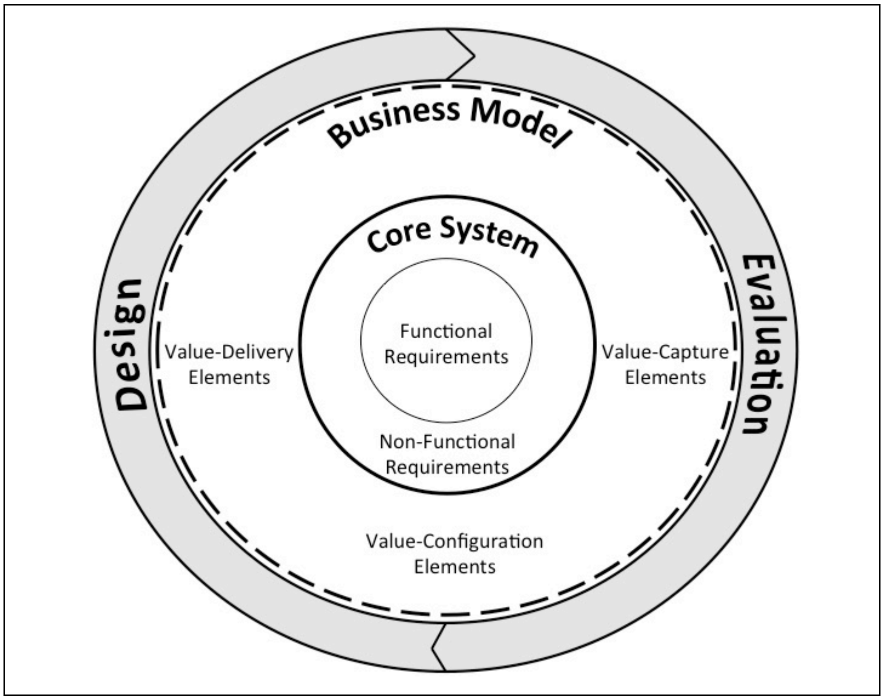

Figure 1. Reference Framework for CA Applications in IS

Business model design: CA allows one to measure design tradeoffs between functional, non-functional, and economic properties, as it is the case for information privacy studies that mainly measure tradeoffs between privacy and monetary values on online channels (Krasnova et al. 2009). Thus, it can be used to evaluate the highly perceived value propositions of specific business models (e.g., IoT systems' value propositions (Derikx et al. 2015). It is also applied to support pricing decisions based on the WTP approach (e.g., Koehler et al. 2010; Mann et al. 2008). In such scenarios, CA serves as an estimation method for consumer utilities for different price levels, which then enables the determination of attractive prices or bundle prices. Pricing can be also done in addition to a channel selection scenario where the consumer decides on the preferred format of information delivery as in the case of e-commerce (Berger et al. 2015). Moreover, CA can be applied to measure preferences for partnership related characteristics; for instance, migration among PaaS providers (Giessmann and Stanoevska 2012). These presented scenarios can be used individually or can be combined to support business model development. CA covers application areas that correspond to elements of the business model canvas (Osterwalder and Pigneur 2010), including value delivery, configuration, and capture aspects. Thus, CA can be used ex-ante to design business model elements based on consumer research for new mass-market IS. For instance, Tesch (2016) suggests CA as a method for scenario planning when designing IoT business models.

IS evaluation: Besides the initial design phase, CA could be useful in the evaluation of current systems. CA has been proven to be useful in decision-making for strategic purchasing of IS in organizations (Benlian and Hess 2010, 2011; Keil and Tiwana 2006). These studies determine factors that drive software system selection in an organizational context at a managerial level. They mainly reflect weights of evaluation criteria governed by attribute tradeoffs to help assess existing systems and their selection or purchasing decisions. This could involve studying typical evaluation criteria of packaged systems (such as functionality, cost, ease of use, implementation, customization, and integration) and extending that to domain-specific and vendor-related criteria. Also, from a user perspective, CA allows one to measure adoption and to predict consumers' intentions to use of IS products (e.g., Chen et al. 2008, 2010; Nikou et al. 2012, 2014; Schaupp and Bélanger 2005). In fact, a review of TAM applications in IS by Lee et al. (2003) indicates that CA is one of the data analysis methods used to measure the acceptance of new IS with the TAM model. This shows the conjoint method's applicability in measuring the adoption of new technologies in organizations, considering product attributes and the external factors that surround them (such as vendor-related aspects) in addition to user perceptions. This could also be based on clustering of user groups to determine target segments.

Business model evaluation: Finally, CA can be used to validate and refine business models of existing products in an ex-post approach. This could be enhanced by market simulations and predictions based on estimated preferences (Giessmann and Legner 2013). The calculated utilities allow one to predict user preferences for different hypothetical attributes combinations. Market simulations based on CA are mainly employed to obtain benchmarks and for competitive analysis. This enables comparing product combinations and their overarching business models with other vendors via the prediction mechanism and to generate virtual market shares for multiple vendors. Further, the ability to perform attribute variation analysis to study the effects of varying attributes on market shares is important in identifying which elements of the business model could be refined or should be changed for better outcomes. Thus, software vendors would be aware of business model elements that can have significant impacts on users' choices.

5.3 The Need for Domain-Specific Adaptation

5.3.1 Methodological Guidance for Applying CA in IS

In view of the large number of variants and application areas, we need domain-specific adaptations and methodological guidance for conducting CA studies in IS. Methodological guidance needs to be developed concerning the following aspects: In a first step, there is a need to support the selection of the appropriate CA variant that fits the IS domain's specificities and the study's objectives. Depending on the scenarios outlined in Section 5.2 and the CA variant type, data collection (e.g., hybrid or adaptive), as well as the econometric and statistical methods to estimate utility functions may vary. In a second step, guidelines would be useful for integrating them into the existing methods for requirement engineering, business model design, and IS evaluation.

5.3.2 User Preference Modeling

CA's success relies on the choice of right attributes, which can lead to valuable preference models and actionable insights. However, "little guidance is given in how to select them, other than to use qualitative research methods (one-on-one interviews, focus groups), and possibly open-ended survey items as a guide" (Bradlow 2005, p. 322). To address this issue for CA studies in IS, researchers could develop **user preference models** that represent the relevant attributes from a user perspective, covering functional, non-functional, economic, and operational dimensions. These models would consist of validated catalogues of attributes and attribute levels based on previous studies of CA with additional empirical investigations, increasing the CA method's practicality. In line with Bradlow (2005), the number of attributes should also be discussed in greater detail. CA has been shown to operate quite well when the number of attributes in a profile is within a moderate range (less than 8) (Backhaus et al. 2010, 2011). However, when describing IS, the number of features may be much higher (15 to 20 or more). Two common practices in such situations are (a) to utilize partial profiles (Green and Krieger 1990) where each profile contains an experimentally designed attributes subset, or (b) self-explicated conjoint (Green and Krieger 1987) in which the importances of attributes and desirability of levels are collected in a self-report, in a one-at-a-time manner (Bradlow 2005). An idea for future research in this area would be the development of partial profile conjoint (Netzer et al. 2008), presuming that not all attributes interact with one another. These results would allow researchers to construct their conjoint studies rapidly and avoid the time-consuming task of constructing attributes and levels from scratch.

Besides domain-specificity, these models could be also categorized based on the study purpose to reflect methodological applications of conjoint analysis. For instance, technology acceptance research can benefit from previous evaluation studies based on TAM (e.g., Mahindra and Whitworth 2005) to develop future reference models.

6 Conclusion and Future Research

Market research techniques are popular for new product development, but have to date not been fully embraced in IS research. By conducting a systematic longitudinal literature review and analyzing 46 studies, we have gained detailed insights into CA's applications in IS. We conclude that CA can be adapted to several application areas in IS, and can have advantages in understanding user preferences. Our findings are of interest for both IS theory and practice. For academics, we make three primary contributions: First, our review assesses methodological setup or method variants from previous CA studies in IS. Second, we provide guidance for future studies by proposing a reference framework for applications of CA in IS. Our framework ideally covers the two phases of design and evaluation of IS starting from the core system and involving business model elements. Third, we suggest domain-specific adaptations of CA that should be addressed in future research. We see empirically validated user preference models as a prerequisite for leveraging CA in the design and evaluation of mass-market IS.

For practitioners, we show that CA could be employed in specific scenarios to support the design of ISs and their business models. The method could serve requirement elicitation and prioritization techniques for integrating user preferences in the development of new systems, applications, and service offerings. Through concept evaluation, customers can assess a complete product offering and can rate it based on their stated preferences, leading a design process with initial product preferences. Further, CA combines human intuition with a systematic approach that quantifies preferences (via a relative importance measure) for further feature selection from a defined set of attributes and attribute levels. Moreover, the method allows for the derivation of decision models for user selection and adoption patterns. We have discussed that the market simulation techniques advance a new proposition that can support the design, evaluation, and refinement of existing systems. This could support the ex-post evaluation of systems and business models.

Future research should explore how the CA method can be further instantiated and integrated into existing methodologies in the areas identified in Section 5.2. This could be achieved through ex-ante evaluation of the method with domain experts, and through empirical studies for validation. Another research opportunity is the methodological contributions for the domain-specific adaptation of CA, for instance through the creation of user preference models for typical categories of IS solutions and domains.

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Appendix

Study	Study objectives (as stated by authors)	Domain	Purpose	Type	Sample	Subjects
Bajaj (2000)	identify the factors that senior IS managers across mid-sized to large organizations would consider when making decisions regarding the adoption of a new architecture for their organization	ES	DM	TCA	23	Managers
Brinton Anderson et al. (2002)	study the relative values of these factors in the decision models of senior IS managers when evaluating software for use by their organization	ES	DM	TCA	24	Managers
Hann et al. (2002, 2007)	explore individuals' tradeoffs between the benefits and costs of providing personal information to websites	O	IP	TCA	184	Students
	estimate an individual's utility for the means to mitigate privacy concerns	O	IP	TCA	268	Students
Zubey et al. (2002)	suggest the VoIP technology attributes that best meet users' needs	MC	D	TCA	254	Customers
Baek et al. (2004)	examining customers' WTP for online games	O	P	TCA	179	Customers
Brodt and Heitmann (2004)	drills down to the importance of service attributes	MC	D	ACA	103	Students
Keen et al. (2004)	investigate the structure for consumer preferences to make product purchases via three available retail formats: store, catalog, and the Internet	EC	C	TCA	290	Customers
Kim (2005)	build descriptions of hypothetical mobile service packages	MC	D	CBCA	1000	Customers
Mahindra and Whitworth (2005)	a conjoint analysis of the contribution of these factors in a proposed corporate software purchase of browser	O	DM	TCA	28	Students
Mueller-Lankenau and Wehmeyer (2005)	gathering first insights into consumer preferences for mobile couponing	MC	D	TCA	125	Students
Schaupp and Bélanger (2005)	examining the roles of several technology, shopping, and product factors on online customer satisfaction	EC	A	TCA	188	Students
Haaker et al. (2006)	assess which combination of services and prices are the most attractive for users	MC	P	TCA	156	Customers
Keil and Tiwana (2006)	first empirical investigation of the relative importance that managers ascribe to various factors that are believed to be important in evaluating packaged software	ES	DM	TCA	126	Managers
Bouwman et al. (2008)	what are the relevant context-related, individual and technological characteristics that play roles in the use of mobile technologies by police officers, and where they conflict with the requirements identified by police stakeholders	MC	D	TCA	23	Stakeholders
Bouwman and van de Wijngaert (2009)			A	TCA	106	Customers
	examines the role and explanatory values of context-, task-, and information-related characteristics vis-a-vis individual characteristics in relation to the adoption of mobile technologies and applications	MC	A	TCA	106	Customers
Chen et al. (2008, 2010)	grasp the relative preference level of each attribute and its corresponding experience level	EC	A	TCA	20000	Students
	understand which factors influence consumer purchase intentions and these factors' relative importances	EC	A	TCA	1567	Students
Mann et al. (2008)	how consumer utility and WTP in one specific channel may be correlated with time of availability	O	P	ACA	489	Customers

Krasnova et al. (2009)	first attempt to assess the value of privacy in monetary terms in this context	O	IP	ACA	168	Students
Schwarz et al. (2009)	provide theoretical rationalizations on the confluence of pertinent attributes when selecting an external source for an application service	ES	DM	TCA	84	Managers
Song et al. (2009)	estimate customer preferences and the relative importances of service factors	MC	D	TCA	-	Students
van de Wijngaert and Bouwman (2009)	obtain insights into the factors that influence the use of wireless grid applications before a given technology is actually introduced on the market	MC	A	TCA	257	Students
Benlian and Hess (2010, 2011)	derive implications on the relative importances IS managers ascribe to evaluation criteria in ERP selection based on the different personality traits of IS managers	ES	DM	ACA	232	Managers
	the first empirical investigation to compare the relative importances of evaluation criteria in proprietary and open-source EAS selection	ES	DM	ACA	358	Managers
Doerr et al. (2010)	examines, from a customer perspective, the importances of the different features of premium offers	C	P	ACA	132	Customers
Head and Ziolkowski (2010)	provides insights into how students value various mobile phone applications and tools	MC	A	ACA	188	Students
Ho et al. (2010)	finds the levels of tradeoffs between monetary rewards provided by e-payment gateways and buyers' protection excess imposed by e-payment gateways	EC	IP	TCA	1795	Customers
Koehler et al. (2010)	analyze customer preferences for cloud services	C	P	CBCA	60	Customers
Fagerstrøm and Ghinea (2011)	expand our understanding of approach/avoidance behaviors by examining the motivating impact of price relative to online recommendation at the point of online purchase	EC	A	TCA	270	Customers
Fritz et al. (2011)	empirically estimate consumers' reactions to the offer of fair use flat rates	MC	P	CBCA	263	Students
Giessmann and Stanoevska (2012)	empirical investigation of the essential and necessary characteristics of PaaS from the perspective of third-party developers	C	D	ACBCA	103	Customers
Hu et al. (2012)	provide a fuller conceptualization of technology design and advance our understanding of the impacts of essential design factors individually and jointly	MC	D	CBCA	105	Students
Nikou et al. (2012, 2014)	an attempt to understand the criteria and expectations of consumers to opt for a specific platform from a device manufacturer or operator	MC	A	TCA	88	Students
	determine the most important characteristics of the mobile platforms	MC	A	TCA	166	Customers
Nevo et al. (2012)	understand the relative importance of meta-memory in the transactive memory processes in order to fit the best technology support for each process	ES	D	TCA	180	Customers
Choi et al. (2013)	assumes a consumer utility function for tablet PCs that reflects the variety of consumer preferences	MC	D	CBCA	389	Customers
Luo et al. (2013)	identify a hierarchy of importance concerning the critical factors influencing the adoption of mobile offices	MC	A	CBCA	101	Customers
Weinreich and Schön (2013)	analyze customer preferences for automation of service processes in the unified communications (UC) industry and derive managerial implications for optimal service design	ES	D	TCA	34	Customers
Burda and Teuteberg (2014, 2015)	what preferences do end-users have in their choice of cloud storage services when employed for the purpose of personal archiving and the relative importances of certain service attributes	C	A	CBCA	340	Students
	uncovering the preference structure and tradeoffs that users make in their choice of storage services when employed for the purpose of archiving	C	A	CBCA	340	Students

Daas et al. (2014)	determine the reservation prices of the services and to assess which price-bundle combinations are most attractive	C	P	TCA	47	Customers
Lee and Rhim (2014)	investigate user preferences for the ISs in order to achieve user satisfaction	ES	A	TCA	55	Customers
Berger et al. (2015)	explore differences in consumer preferences and WTP between offline and online formats	O	C & P	CBCA	506	Customers
Derikx et al. (2016)	studies whether and how privacy concerns for connected car services can be compensated financially	IoT	IP	CBCA	55	Customers
Pu and Grossklags (2015)	quantify the monetary value people place on their friends' personal information in a social app adoption scenario	O	IP	TCA	201	Customers
Tamimi and Sebastianelli (2015)	estimate the effects of selected e-tailer and product-related attributes on a consumer's likelihood of making a particular online purchase	EC	A	TCA	122	Students
Yusuf Dauda and Lee (2015)	analyze the technology adoption pattern regarding consumers' preferences for potential future online banking services in Nigeria's banking industry	O	A	CBCA	1291	Customers
Siegfried et al. (2015)	provide a nuanced analysis of platform and environment signals that drive app installation and contribute to a better understanding of the underlying decision process	MC	A	TCA	121	Customers
Cwaikowski et al. (2016)	measure WTP for legal rather than illegal content as it compares to valuation of other features of the product	O	P	CBCA	228	Customers
Mikusz and Herter (2016)	investigate how consumers evaluate value propositions of connected car services with a high option and/or indirect value-in-context	IoT	D	TCA	84	Customers

Table 5. Overview of CA Studies in IS

Leveraging Market Research Techniques in IS – A Review and Framework of Conjoint Analysis Studies in the IS Discipline

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Abstract. With cloud and mobile computing, information systems (IS) evolve towards mass-market services. While user involvement is a critical factor for IS success, the IS discipline lacks methods that allow for integrating the "voice of the customer" in the case of mass-market services with individual and dispersed users. Conjoint analysis (CA), from marketing research, allows for understanding user preferences and measures user trade-offs for multiple product features simultaneously. While CA has gained popularity in the IS domain, the existing studies have mostly been one-time efforts and no cumulative research patterns have been observed. We argue that CA could have a significant impact on IS research (and practice) if it were fully developed and adopted as a method in IS. From reviewing 70 CA studies that were published between 1999 and 2019 in the IS field, we find that CA can be leveraged in the initial conceptualization, iterative design and evaluation of IS and their business models. We provide a critical account of the methodological choices along the CA procedure and synthesize our findings into a "Framework for Conjoint Analysis Studies in IS" that outlines 6 distinct applications.

Keywords: Conjoint analysis, literature review, information systems, IS design, IS evaluation

1 Introduction

With advances in technology, including mobile, cloud, and the Internet of Things (IoT), information systems (IS) target a mass market of distributed and heterogeneous users. This poses several challenges for integrating the "voice of the customer", which is the main criterion for ensuring customer acceptance (Jarke et al. 2011; Tuunanen et al. 2010). Studies in IS have shown that the main reasons for IT product failures can be traced back to the system being unable to meet users' expectations or a non-functioning system (Dwivedi et al. 2015). Therefore, understanding user requirements and involving users is considered to be "common wisdom" for IS success (Bano and Zowghi 2015; Harris and Weistroffer 2009). Traditionally, user-oriented IS design has been promoted through requirements elicitation techniques that collect data from individual or group users via interviews, surveys, focus groups, or ethnographic techniques (Nuseibeh and Easterbrook 2000). However, these techniques rely on close interactions with users or their representatives, making them difficult to apply in the context of mass-market IS with individual and dispersed users. Moreover, these techniques depend critically on participant selection, which can bias requirements elicitation and prioritization.

Market research techniques, specifically conjoint analysis (CA), are promising approaches to address these issues and to support the user-oriented design of IS. As "a practical set of methods for predicting consumer preferences for multi-attribute options in a wide variety of product and service contexts" (Green and Srinivasan 1978), CA adds quantitative measurement and allows analyzing user trade-offs in the selection of products and services, leading to successful product designs. Marketing research has argued that CA is particularly useful in new technical product development (Green et al. 2001). In the IS domain, Bajaj (1999) was the first to advocate the CA methodology's for studying human behavior in the assessment of IS for purchase decisions and adoption. Following (Bajaj 1999) CA study procedure guide, IS researchers initiated the use of CA to study adoption decisions and users' preference structures governing IS design. Among its applications are: studying the role of technology, shopping and product factors on purchase decisions in e-commerce (Schaupp and Bélanger 2005); evaluation of enterprise resource planning (ERP) packages (Keil and Tiwana 2006); understanding stakeholders' preferences regarding the design of police mobile applications and their adoption (Bouwman et al. 2008); and evaluating optimal service characteristics for cloud service design (Giessmann and Stanoevska 2012). In the context of privacy research, Krasnova et al. (2009) applied CA to investigate the monetary value of privacy in social networks, while Abramova et al. (2017) used it to study privacy and the effectiveness of trust-enhancing information cues in light of the sharing economy.

Other studies focused on understanding users' privacy tradeoffs to inform the design of different types of IS, including cloud storage services (Naous and Legner 2019) and online data sharing platforms (Schomakers et al. 2019; Wessels et al. 2019). In the emerging field of IoT, Mihale-Wilson et al. (2017), Mikusz and Herter (2016) and Zibuschka et al. (2019) investigate user preferences for privacy features in personal assistants based on CA. These studies illustrate how CA makes it possible to empirically assess (existing or planned) IS in the form of a user preference model and employ the empirical insights to meet the needs of specific user profiles or segments in terms of design and pricing strategies.

Although the number of CA studies in the IS domain has risen over the past few years, the method remains as a marketing research feature. The existing studies demonstrate the CA's value in the IS domain, but they have mostly been one-time efforts and no cumulative research patterns have been observed to date. This raises three fundamental questions: First, the existing studies show a variety of purposes and applications in IS (Bajaj, 2000; Schaupp & Bélanger, 2005; Krasnova et al. 2009), but they do not go further and analyze its relevance and role in IS. As a result, IS research and practice might miss the opportunity for using this method to assist user-oriented design due to the lack of knowledge about its applications. Second, all the studies examine the systems independently. In fact, CA, as a de-compositional method, views a system as a set of attributes and levels, which correspond to relevant system features. The existing studies do not engage in a discussion around this critical phase of attributes and levels selection, and we have not observed a reuse of previous research results in the setup of CA nor in the data analysis. Third, CA has not been used to its full extent and potential. Most IS studies apply traditional techniques of relative importance and willingness-to-pay. They have not embraced the more sophisticated techniques for simulation and variation analysis that have been developed and discussed in marketing. To summarize, we observe that there is a lost opportunity for CA to complement existing IS methods for system design and evaluation, and IS researchers lack general guidelines and recommendations for applying CA as a method in the IS field.

This motivates our research, which seeks to answer the following research questions (RQs):

RQ1: What is the current state of CA in IS?

RQ2: What are guidelines for future IS studies applying conjoint analysis?

We argue that the CA method can have several positive outcomes if applied to IS research as a data-driven approach for user-oriented IS design. With this paper, we aim to lay the foundation for future research by analyzing the current state of CA applications in the IS domain and proposing a framework for future studies. Thus, our contribution is threefold: First, we provide a comprehensive analysis of the 70 CA studies in the IS field that were published between 1999 and 2019. Aiming for exhaustive coverage of the published research, this analysis can be classified as a descriptive review that seeks to identify "interpretable patterns" or "trends" with respect to a pre-existing method (i.e., CA) in a body of empirical studies (Paré et al. 2015). Second, our study also has elements of a critical review (Paré et al. 2015) that assesses the CA application in IS from a methodological and domain-specific perspective. By providing a critical account of this method from market research in the IS field, we are able to identify recurring issues and develop recommendations to enhance the methodological support of IS-specific applications of CA. Third, based on our review, we develop a framework that supports IS researchers in developing future CA studies. Since CA has multiple implementation scenarios, the framework identifies typical applications, i.e. concrete situations where CA can be applied in different phases of the IS lifecycle. This framework highlights application areas where CA can complement existing IS methods by providing data-driven insights on user preferences in the initial conceptualization, iterative design and evaluation of IS and their business models.

The remainder of this paper is structured as follows: In section 2, we review the foundations of CA and their evolution over time. In section 3, we present our research approach in conducting the literature review. In section 4, we provide an overview of the CA studies. In section 5, we summarize the findings along the analysis framework with a critical assessment and methodological recommendations. In section 6, we present the reference framework for CA applications in IS. Finally, we conclude with a summary of our findings and limitations as well as future research opportunities.

2 Conjoint Analysis

2.1 Foundations

Conjoint analysis has its foundations in the work of Green and Rao (1971), who advocated the use of conjoint measurement in consumer-oriented marketing research. As a concept from mathematical psychology established by Luce and Tukey in 1964, conjoint measurement is used to measure "the joint effects of a set of independent variables on the ordering of a dependent variable" (Green and Rao 1971). CA allows for the exploration of consumers' preferences by studying how people value product attributes and attribute levels while CONsidered JOINTly during their evaluation. CA builds on the estimation of a preference structure by applying the economics concept of utility. Utility is a measure of the consumer's preference from a set of available alternatives. In CA, a utility function is derived from consumer evaluations of certain product attributes and levels (Green and Srinivasan 1978). This utility function can be translated into a preference structure, which provides information on the factors that most influence the consumer's decision or product choice. The preference structure not only provides importance measures but also depicts how differing levels within an attribute influences the formation of an overall preference (utility value) (Hair et al. 2010). Accordingly, it was found to be well suited to problems in marketing as an approach to quantify judgmental data related to product purchasing.

The application of CA has gained broad popularity in consumer research and has extended to applied psychology, decision theory, and economics. Previous research has exposed the different application areas in marketing (Green and Rao 1971) based on different analysis techniques: (1) **relative importance** of attributes and levels for multiple purposes, including *vendor evaluation* by developing criteria for vendor rating, *price–value relationship measurement* by analyzing the consumer trade-off for price and quality of products, and *attitude measurement* to analyze the trade-offs between several product attributes and derive the importance of functional vs. symbolic characteristics such as brand image, or to analyze utility for collections of items to facilitate the combination packaging of certain product types; (2) **cost–benefit analysis** to study the willingness-to-pay (WTP) for certain attributes and to design products accordingly; and (3) **clustering or segmentation of customers** based on their utility functions. Furthermore, (Johnson 1974) referred to another application using (4) **market simulation**, which is used to estimate the market shares of currently available or new products based on the study sample's predicted consumer preferences.

In general, a CA study can be summarized in three main phases (Figure 1): In phase 1, the product is defined in terms of the attributes and attribute levels from which product profiles are derived. Phase 2 corresponds to the consumer evaluation of the different profiles in a survey setting. From the results a preference structure based on utilities' estimation can be calculated. Finally, phase 3 corresponds to the application of the previously discussed analysis techniques.

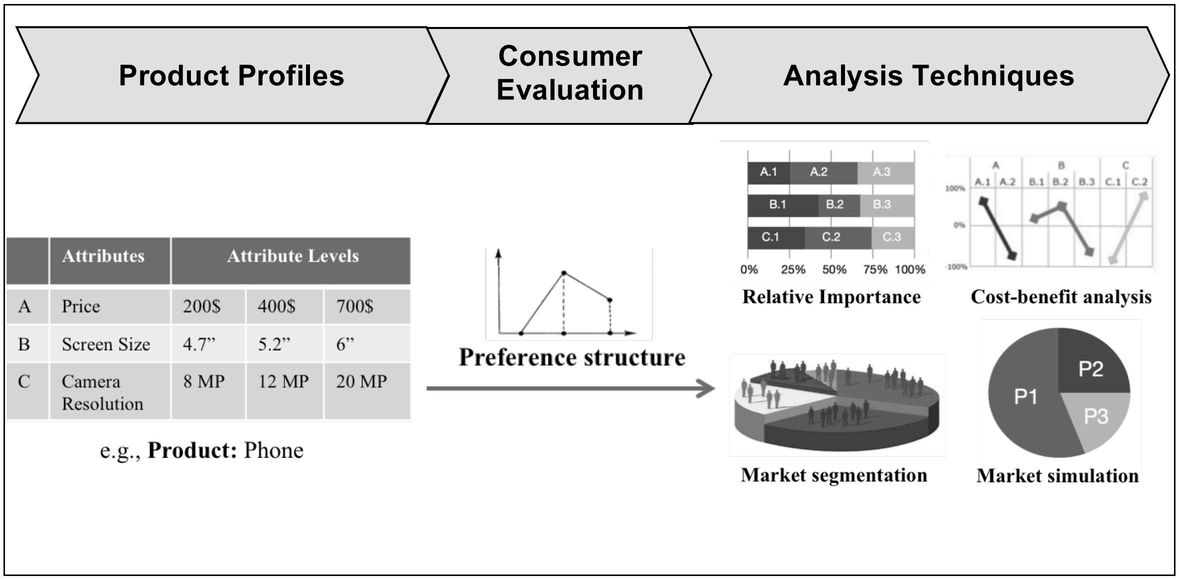

Figure 1. Three phases of a CA study

2.2 CA Methodology

Applying the CA can be challenging due to the many steps and methodological choices required to achieve the preference structure. It also involves selection from different alternatives. (Green and Srinivasan 1978) highlight some differences between the alternatives suggested for each step in a CA:

1. The **selection of a preference model** determines the preference function based on the defined attributes' influence over the respondents' utility. It forms the basis for determining partial benefit values for the respective attributes. The three main models of preference suggested are the vector (1), ideal-point (2), and part-worth (3) models. With a set of T attributes and J stimuli in a study, y_{jp} denotes a respondent's preference level for the pth attribute of the jth stimulus. The vector model depicts the respondent's preference s_j for the jth stimulus as:

$$s_j = \sum_{p=1}^{T} w_p y_{jp} \tag{1}$$

   where w_p denotes the individual's importance weight for T attributes

   The ideal-point model depicts preference s_j as inversely related to the weighted squared distance d_j^2 of the location y_{jp} of the jth stimulus from the individual's ideal point x_p, where d_j^2 is defined as:

$$d_j^2 = \sum_{p=1}^{T} w_p \, (y_{jp} - x_p)^2 \tag{2}$$

   The part-worth model depicts preference s_j as:

$$s_j = \sum_{p=1}^{T} f_p(y_{jp}) \qquad (3)$$

where f_p is a function denoting the part-worth for the levels of y_{jp} of the pth attribute

A part-worth function is mainly used in CA because of its flexibility in designing the attribute evaluation function. The part-worth function model is compatible with different shapes of preference functions, and it allows for better estimation when evaluating categorical attributes. In addition, a mixed model combining the three alternative models (vector model, ideal-point model, part-worth function model) was suggested; it introduces a dummy variable and is similar to a multiple regression approach.

2. The **data collection method** involves selecting the conjoint method for evaluation. Traditional approaches involve the full-profile or pairwise evaluation. The original approach in CA, also called *concept evaluation* or *full-profile*, is based on rank orders of consumers' preferences regarding product profiles (also called stimuli), which comprise several attributes and levels associated with the product characteristics. As such, CA provides insights into user preferences for the different attributes based on a complete product evaluation. Besides *concept evaluation,* Johnson (1974) suggests an alternative approach called the *trade-off matrix* or *pairwise approach*. In this approach, respondents evaluate a pair of attributes providing information about the trade-offs among all product features. Its strength is its ability to support a large number of attributes since it can provide predictions based on the evaluation of subsets of attribute pairs (Johnson 1974). The full-profile approach is the most frequently used one since it provides a more realistic description of the stimuli. With the extensions of the adaptive and choice-based CA methods (see 2.3), the variety of choice for evaluating the full-profiles increases.
3. For full-profile, the next step is **stimulus set construction**, which is mainly based on fractional factorial orthogonal design, which reduces the number of stimuli and facilitates evaluation. This method assumes no interaction effects between the selected attributes. For adaptive methods, partial profiles and self-explicated tasks are used to reduce complexity of the conjoint evaluation.
4. For the **stimulus presentation**, there are several variations based on verbal description, paragraph description, or graphical representation. The choice of the presentation depends on the subject of the study and can be a combination of methods. Furthermore, the application of conjoint analysis to some product categories could use other stimulus types as prototypes or actual products.

5. The **measurement scale** depends on the study purpose and the data collection method. Both the full-profile and the pairwise approach can use ranking to capture the order of preferences or purchasing intentions. The full-profile approach can also use ratings, which requires respondents to grade (subjectively) the perceived benefit on a numbered scale. As an alternative, choice-based methods introduced another measurement scale that can then be treated as a choice-probability model.
6. Finally, the **estimation method** for the partial benefit values is selected based on the dependent variable type resulting from the measurement scale. While an ordinal-scaled variable could use MONANOVA, an interval-scaled variable can use an ordinary least squares (OLS) regression, for example. In addition, LOGIT or PROBIT models can be used when the data collection method is choice-based. In that case, individual-level utility function is estimated using Hierarchical Bayes.

To illustrate the CA, consider the simplified example of a smartphone. In Table 1, we introduce attributes and attribute levels of the selected product class on the basis of existing product specifications on the market. For the conjoint method, a part-worth function model is selected (Step 1) in a full-profile approach (Step 2). The stimulus set of three attributes with three levels would lead to 27 (=3^3) product concepts. Fractional factorial design (Step 3) would be employed to arrive at a reduced design – in this case, with nine stimuli. In our smartphone example, the stimulus presentation (Step 4) can benefit from a combination of verbal description and pictorial representation (or a de facto prototype, if available) to help participants see the differences between screen sizes. This would enable them to rank (Step 5) the stimuli according to their preferences. Multiple regression analysis could be employed to estimate the part-worth utilities (Step 6). The utilities are then calculated by adding individuals' part-worth utilities, i.e., following model (3). Finally, the part-worth utilities are standardized in order to ensure the same unit of scale.

Product	**Attributes**	**Attributes' Levels**		
Mobile Phone	**Price**	$200	$400	$700
	Screen size	4.7 inches	5.2 inches	6 inches
	Camera resolution	8 MP	12 MP	20 MP

Table 1. Example for Attributes and Attribute Levels of a Conjoint Analysis

2.3 CA Development and Extensions

Due to the prevalence of the traditional CA, the methods for applying it have been further developed and improved to address limitations in terms of attribute formulation and product evaluation (Green and Srinivasan 1990). Sawtooth Software developed an adaptive conjoint analysis (ACA) to solve the traditional full-profile CA's issue with the number of attributes (Johnson et al. 2003). The ACA is based on a hybrid technique that combines self-explicated tasks with an evaluation of partial-profile descriptions (Green 1984; Johnson, 1987). The self-explicated task allows respondents to rate the attributes individually and exclude unacceptable attribute levels from the evaluation task in order to reduce its burden (Johnson 1987).

Choice-based conjoint analysis (CBCA) can be considered a replacement for ranking-based or rating-based conjoint methods. It simulates the process of purchasing a product, as participants are asked to make hypothetical choices in a scenario similar to a competitive marketplace (Johnson et al. 2003). The main concern with this approach is that participants need to evaluate a large number of purchase scenarios; however, it has the advantage of being able to deal with the complexity of choosing among competitive profiles, which makes it a mixed blessing (Green et al. 2001).

Adaptive choice-based conjoint analysis (ACBCA) is an extension of these two approaches to estimate part-worth utilities from a small sample size with fewer than 100 participants (Johnson et al. 2003). ACBCA asks participants to choose among a set of stimuli, thus simulating a purchase behavior similar to the CBCA after they perform a self-explicated task (as in ACA) to select the most relevant attributes and levels beforehand.

Further developments of the presented CA method have been discussed by several researchers (Rao 2008; Netzer et al. 2008); they mainly targeted technique and application issues (see Table 2). The selection of a CA method is typically based on several criteria, including product- and study-related factors. Orme (2009) discusses this matter comprehensively by demonstrating the advantages and limitations of each CA type and then building a recommendation guide to select the appropriate method. He proposes the following main selection criteria: number of attributes, mode of interviewing, sample size, interview time, and inclusion of pricing research in the study. Adaptive methods are more favored for a large number of attributes or when the sample size is small, and choice-based methods are preferred for pricing studies.

Steps	Traditional conjoint analysis (Green and Srinivasan 1978)	Developments and extensions (Johnson, 1987; Johnson et al. 2003; (Rao 2008);(Netzer et al. 2008)
1. Selection of a preference model	Vector model, ideal-point model, part-worth function model, mixed	
2. Data collection method	Two-factor-at-a-time (trade-off analysis), full-profile (concept evaluation)	Adaptive CA (ACA), choice-based CA (CBCA), adaptive choice-based CA (CBCA)
3. Stimulus set construction	Fractional factorial design, random sampling from multi-method variate distribution	Partial profiles, self-explicated method
4. Stimulus presentation	Verbal description (multiple cue, stimulus card), paragraph description, pictorial or three-dimensional model representation	Actual products, prototypes
5. Measurement scale	Paired comparisons, rank order, rating scales, constant-sum paired comparisons, category assignment	Choice
6. Estimation method	MONANOVA, PREFMAP, LINMAP, Johnson's non-metric trade-off algorithm, multiple regression, LOGIT, PROBIT	Hierarchical Bayes

Table 2. CA Steps and Extensions

3 Research Approach

In view of our research goals, we opted for an exhaustive review of existing CA studies in IS, which can be characterized as a combination of descriptive and critical literature review (Paré et al. 2015). As a descriptive review, we followed the recommendations from (Webster and Watson 2002) on conducting a literature review in the IS field to collect and codify the data. We reflect the "current state of applications of CA in IS" by highlighting the main patterns in literature. As a critical review, we provide a critical assessment of the main methodological choices throughout the CA procedure and recommendations for methodological improvements.

3.1 Literature Selection

Seeking to attain completeness and quality in our review, we followed recommendations from vom Brocke et al. (2015) on conducting effective literature searches and searched for peer-reviewed publications from the first IS publication on CA by Bajaj (1999) until the end of 2019. We followed a sequential process to identify and select relevant CA studies from multiple sources (comprising publications from IS journals and conference proceedings). To cover a whole range of empirical studies using CA, we started by performing an electronic search in databases including AIS Electronic Library (AISe), EBSCOHost, ScienceDirect, SpringerLink, and Wiley. Next, we carried out a Google Scholar search to cover missing literature. To ensure that we captured all relevant pieces of research, the search criteria were based on the following keywords: "*conjoint analysis*" AND (("*consumer" OR "customer" OR "user")* AND *"preferences*"). In an advanced search, we restricted the research area to information technology and business management whenever the search resulted in many irrelevant articles. In Google Scholar we restricted the search to publications in "Information Systems" journals and conferences. Subsequently, we complemented our research process with a search of publications among the top 40 rated IS journals (Lowry et al. 2013) including the *senior scholar's basket of journals* from the Association of Information Systems (AIS): European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of AIS, Journal of Information Technology, Journal of MIS, Journal of Strategic Information Systems, and MIS Quarterly. This helped us capture any additional empirical studies using CA in the IS field that earlier steps had missed.

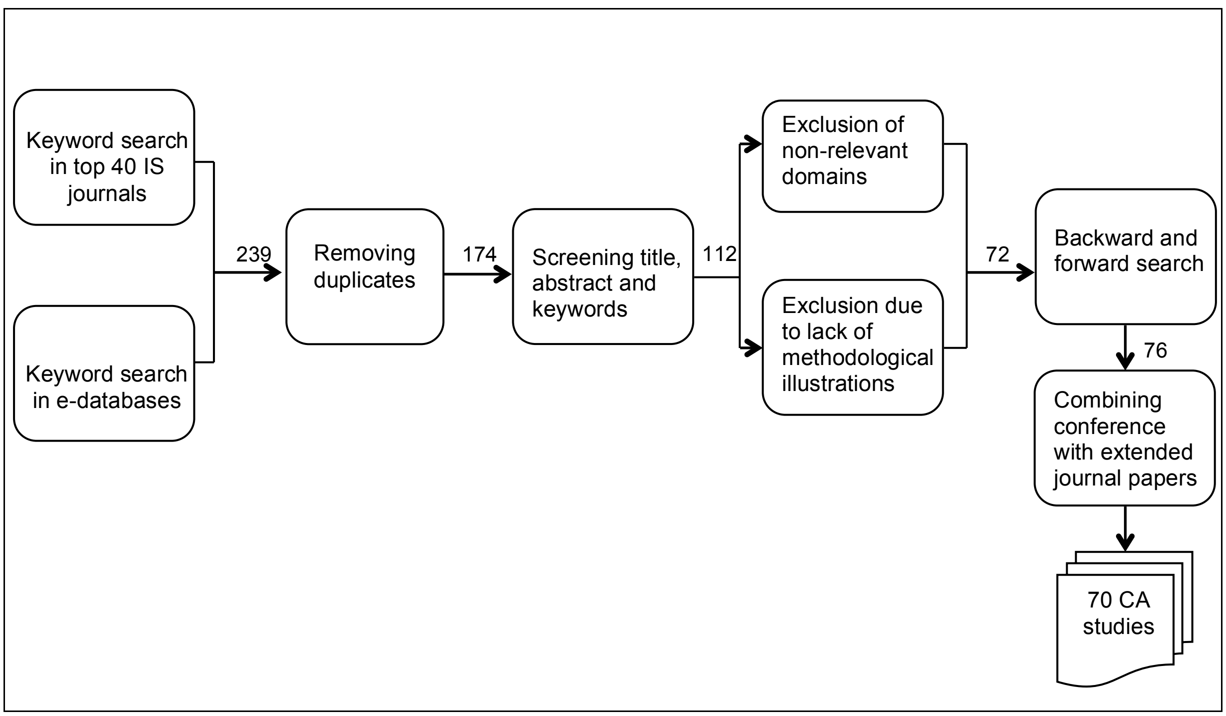

Figure 2. Literature search and selection process

The literature search phase (Figure 2) resulted in 239 publications in the proceedings of highly reputable international and regional IS conferences (including AIS conferences), as well as publications from academic journals relating to IT and business research. After removing duplicates and screening the meta-information including title, abstract and keywords, 112 publications remained. These were carefully scanned to judge their relevance; we then eliminated 40 publications lacked methodological illustrations of the CA procedure or fell outside relevant IS domains, resulting in 72 publications. For instance, decision-making studies in an IT related context that do not study system characteristics were not included in our publication list (e.g., Schuth et al. 2018). We restricted our search to purely IS related outlets, and studies outside core IS domains (e.g., health or medical) were eliminated. In addition, we performed backward and forward citation searches to identify both prior and relevant articles that the search criteria may have missed (Webster and Watson 2002). The procedure resulted in 76 publications. Bouwman et al. (2008) have two CA studies in the same publication, while certain authors published their CA study first in conference proceedings and then in a journal article. Thus, the final sample comprises 70 unique studies since we combined six studies in conferences with their extended versions in journals.

3.2 Literature Analysis & Classification

To analyze the literature, we use a concept matrix as suggested by Salipante et al. (1982) and adapted for IS literature reviews by Webster and Watson (2002). It divides the topic-related concepts into different units of analysis that make it possible to arrange, discuss, and synthesize the CA studies. In our case, the matrix is based on a CA procedure combining the most relevant aspects of Green and Srinivasan (1978) and Bajaj (1999) CA study procedure guide:

1. **Attributes and Levels Selection:** We were interested in the system class being studied, as well as the selection methods for attributes and their number, levels selection, and types relevant to each study purpose. The coding involves ***IS domain***, ***attributes selection*** (literature review, focus groups, user interviews, questionnaires, expert interviews, or existing products), ***number of attributes***, and ***attribute levels type*** (binary, multi-leveled, or multi-criterion).
2. **Data Collection Method Selection:** We wanted to understand what is mainly followed as a methodology in IS research (traditional (T) approaches based on rankings and ratings of full-profile, adaptive (ACA), or choice-based (CBCA and ACBCA)) and for what purposes. The coding includes ***method type***.

3. **Stimulus Set Construction and Presentation:** In this step, we were interested in the method for the stimuli design based on the CA type and how the stimuli are presented to gain the most valuable insights from the study participants. This includes verbal description, paragraph description, pictorial representation, mixed representation, and actual prototype. The coding includes ***stimuli design*** and ***type of stimuli***.
4. **Study Administration:** In this step, we wanted to understand how the researcher decides on the sample size and user base on which he will perform the CA study. Thus, the coding includes ***study sample size*** and ***subjects' background***. We then analyzed the ***study setup***, including face-to-face interviews, experiments, questionnaires, online surveys, and specific software to perform the study. This code is referred to as ***software-used*** and can help to provide suggestions for the designs of future studies.
5. **Data Analysis:** Finally, we were interested in the selected estimation method to analyze data and identify other data analysis techniques in CA that are frequently performed whenever a conjoint study is conducted in IS. The coding for this step includes the types of data analysis tools introduced in section 2.1. The items involved in this step are ***estimation method*** (part-worth utilities estimation, since it is the dominant preference model in conjoint analysis studies) and other ***analysis techniques***, including market segmentation (it also involves the clustering methods), willingness-to-pay (based on a defined price attribute), and market simulation (to provide a competitive analysis).

In addition, we included the ***publication type*** as well as the ***study purpose***, which was deductive based on the authors' objectives, study context and sample's background. The coding scheme allowed us to obtain insights into the existing approaches and alternatives for each CA step of the study procedure. Two authors were involved in the coding process, and validated the codes mutually. Common consensus on derived items such as the IS domains and purposes was required for completing the coding scheme. We grouped the results for each unit within the concept matrix to highlight commonly used items and provide methodological reflections. Based on our analysis, we provide guidelines for future studies and a framework for CA studies in IS to highlight implementation areas based on the study purpose.

4 Overview of CA Studies in IS

Table 3 presents an overview of the final sample of 70 unique CA studies that were published in 36 journal articles and 34 conference proceedings. It includes bibliographic and meta-information on each article (year, study objective as described in the paper, purpose, domain, CA method type, study sample size, and subjects' backgrounds). Our review identifies a large variety of more than 20 IS applications and services that were investigated using CA. Based on the type and nature of the systems, we grouped these predominantly innovative technologies into five parsimonious and inclusive domains:

- **Enterprise Systems (ES):** This domain includes studies of typical systems used in the enterprise context, including computing architecture, Office systems, and ERP systems.
- **Mobile Applications and Communications (MC):** Studies in this domain mainly cover innovative mobile platforms, mobile applications, and mobile communication (VoIP telephony).
- **Online (O) Services:** Studies cover online shopping (e-commerce), online social networks, online banking, and online information privacy.
- **Cloud (C) Services:** This domain is related to the different services provided through the cloud such as data storage or infrastructure as a service (IaaS), software as a service (SaaS) and platform as a service (PaaS).
- **Internet of Things (IoT):** Studies cover connected and smart devices.

From the study's objectives, context and results, we derived four typical purposes for applying CA in IS. These purposes can be mapped to applications in marketing research (see section 2.1) and associated with one or more CA analysis techniques (i.e., relative importance, WTP, segmentation, and simulation):

- **Decision-making (DM):** The purpose is mainly associated with situations involving a managerial decision on adopting IS in an organizational context. This includes identifying relevant decision criteria for systems evaluation based on the relative importance of the studied attributes. These studies are similar to vendor evaluations in marketing research.
- **Adoption (A):** The purpose is to understand individual preferences or behavior in adopting new technologies. While they are similar to decision-making studies, they target users' intention to use rather than the organizational rationale in selecting or evaluating a system. This is based on preference predictions derived from utilities estimated from evaluations of product characteristics to obtain the users' perspectives on the system and adoption intentions. In addition, the study could also employ segmentation to analyze different user groups' preferences. Compared with marketing research, this is part of attitude measurement.

- **Design (D):** The purpose is to elicit user preferences for designing an IS product, application, or service. This is based on measuring preferences and trade-offs among attributes and levels related to system characteristics. This will then reflect the relative importance of each attribute and levels from the estimated part-worth utilities to guide the design process of the product class. These types of studies can include analysis techniques of willingness-to-pay and user segmentation, and they also involve studies of user trade-offs for certain product attributes. CA studies can extend beyond attributes describing functional and non-functional characteristics to embrace business model or information privacy attributes.
- **Pricing (P):** The purpose is to understand the willingness-to-pay for product or service features. These studies mainly involve cost–benefit analysis. It is based on analyzing the effect of price attribute variations on the resulting user preferences and related predictions.

Coding Item	Coding Options	Number of Studies	Percentage (%)
IS Domain	Enterprise Systems	10	14.29
	Mobile Applications & Communication	23	32.86
	Online Services	24	34.29
	Cloud Services	7	10.00
	Internet of Things	6	8.57
Study Purpose*	Decision Making	8	11.43
	Adoption	21	30.00
	Design	34	48.57
	Pricing	15	21.43
Attribute Selection*	Literature Review	56	80.00
	Existing Products	24	34.29
	Expert Interviews	16	22.86
	Questionnaires	9	12.86
	User Interviews	10	14.29
	Focus Groups	7	10.00
Method Type	TCA	35	50.00
	ACA	6	8.57
	CBCA	26	37.14
	ACBCA	3	4.29
Analysis Techniques* (in addition to relative importance)	Willingness-to-pay	21	30.00
	Segmentation	30	42.86
	Simulations	7	10.00
Note: * multiple coding possible			

Table 4. Coding Results from the Literature Review of CA Studies in IS

5 Methodological Choices along the CA Procedure

5.1 Attributes & Levels Selection

Attribute selection is the most demanding step in designing a good CA, as attributes should represent the study object's most relevant characteristics and correspond to the customers' most important needs. Most CA studies rely on a literature review (80%) to select domain-specific attributes or evaluate existing product features (34.29%). More than 50% of the studies followed a multi-stage selection process. The most common combinations are a literature review plus either an evaluation of existing products or expert interviews to get insights into relevant features. In some cases, a three-stage selection process was used to get user insights through questionnaires, interviews (Choi et al. 2013), or focus groups (Brodt and Heitmann 2004; Giessmann and Stanoevska 2012b; Nikou et al. 2014).

The number of attributes ranged between 2 and 13 and extends beyond functional and non-functional attributes to cover pricing, or channel selection. Thus, we can conclude that CA is particularly interesting whenever user preferences are to be explored. In fact, the number of attributes correlates with the conjoint method selected. Most studies followed the pattern suggested by Orme (2002) on attribute selection, where traditional full-profile studies considered up to six attributes, and adaptive studies included more. However, there were exceptions where full-profile CA contained more than six attributes. These cases depend on the study purpose and were mainly in decision-making CA, where the attribute levels are limited to binary (low or high) (e.g., Benlian and Hess 2011; Keil and Tiwana 2006) or multi-level (low, medium, or high) (e.g., (Mahindra and Whitworth 2005) or in service design studies that involved bundling options with binary attributes corresponding to services (included or not included) (e.g., Daas et al. 2014).

5.2 Data Collection Method

Interestingly, studies in the IS domain relied mostly on traditional full-profile CA (35). Thus, despite criticism of the traditional CA approach, most conjoint studies in IS did not consider the developments of the method outlined in section 0. Even though studies with a large number of attributes – according to CA guidelines – should better rely on adaptive methods, there were only three applications of ACBCA; by Giessmann and Stanoevska (2012) on platform cloud services, Fölting et al. (2017) on information search mobile applications, and Naous & Legner (2019) on privacy design of cloud storage services. Choice-based CA is also being used by several IS researchers as a preference measurement tool under relatively realistic purchasing situations, where 26 studies used this variant and most frequently in recent years between 2017 and 2019.

The dominance of the full-profile CA implies that CA studies in IS rely on hypothetical system representations rather than realistic choices and are more constrained with regard to the number of attributes. It must also be noted that the methodologies were not strictly applied with the specific study purpose stated in CA literature: For instance, CBCA was applied for pricing, adoption, decision making, and service design studies, although it is said to mainly support pricing decisions.

5.3 Stimulus Set Construction and Presentation

The stimulus set construction depends on the data collection method. Studies of traditional or choice-based CA employed fractional factorial design to reduce the number of stimuli for a large number of attributes or levels. When adaptive methods are used, the self-explicated method helps to reduce the attributes set to facilitate the study procedure. Most studies employed verbal description in the form of profile cards, and paragraph description as vignettes and scenarios. Interestingly, few studies used visual representation to evaluate website features for online services (Mahindra and Whitworth 2005; Hann et al. 2007) and e-commerce (Tamimi and Sebastianelli 2015). In adoption studies of existing products in IS, an actual product would be of great significance to the study participants. This might not be applicable, as it would constrain the study setup because of the availability of resources (e.g., for enterprise systems). However, it would be of major importance and more feasible for domains like online services, cloud services, e-commerce, and mobile applications.

5.4 Study Administration

Marketing research deploys commercial panels to identify target samples, while in IS research there are no established panels for this type of methodology. So far, very few studies have used existing online panels; examples include Fritz et al. (2011) and Mihale-Wilson et al. (2017). In addition, Pu and Grossklags (2015) were first to use a crowdsourcing platform, Amazon Mechanical Turk, to hire participants and obtain a fast response rate, which can be considered a potential solution for future CA studies on mass-market systems. Although the sample in most conjoint studies exclusively comprises consumers, the sample background in the IS literature is dependent on the purpose of the study. For instance, managers are considered as a study sample in research involving organizational decision-making regarding IS purchase or adoption. Many other studies on users have used student populations because of the convenience of this sample in research. For example, students performed a decision-making study taking roles as managers in a situation that involved evaluating corporate browsers (Mahindra & Whitworth, 2005). Moreover, some researchers have applied CA to student-dedicated studies, for example, on mobile adoption (Head and Ziolkowski 2010) and cloud service adoption (Burda and Teuteberg 2015).

The typical sample size in a market research has a median of 300, especially in traditional conjoint approaches, while for adaptive methods the sample size can be smaller than 100 and still retain its statistical significance. In IS research, no specific patterns were identified. However, the median determined for the sample literature is 170, with a high variance due to studies with more than 1,000 respondents (mainly corresponding to a sample from service subscribers) and controlled studies with fewer than 30 respondents (e.g., Brinton Anderson et al. 2002).

It is worth noting that the research method influences the sample size, as this could be considered a problem of reach. In controlled studies where interviews or experiments are used, we can notice the dominance of small sample sizes. Online surveys are the most frequently used research method owing to their adaptability to a large sample size and the novelty of the CA studies in the IS domain, characterized by the high availability of online resources and survey software. Ideally, CA could be performed using statistical tools such as R and SPSS with a conjoint package integrated into them, or through the use of specialized commercial software such as Sawtooth Software, the market leader, or Globalpark Software (Mann et al. 2008). The latter typically administer an online survey and are mainly used in studies applying adaptive methods.

5.5 Data Analysis

The method for estimating the part-worth utilities of product attributes varies depending on the measurement scale. For ranking and rating OLS is the main estimation method used. As for choice-based studies, a mix of the LOGIT model is used for estimating utilities based on probabilistic assumptions from users' choices and HB for obtaining individual utilities of participants.

Besides the relative importance of attributes based on the part-worth utilities, other data analysis techniques are not very frequently leveraged in IS. **Market segmentation** is only applied by 30 studies, i.e. less than 50%. It is used to develop market segments based on groupings generated from sample demographics or specific clustering analysis techniques corresponding to the type of conjoint method (the most commonly used are k-means clustering for full-profile or ACA and hierarchical agglomerative clustering analysis for CBCA). This technique is mostly associated with studies involving end-user samples to identify unique segments with defined characteristics for IS design and adoption. **Willingness-to-pay** was used mainly in the pricing, privacy trade-off, and decision-making studies where a price attribute is included. A different application of this technique was elaborated in the study by (Baek et al. 2004), where the price was the dependent variable determined by the study participant for different online games options. Finally, **market simulation** can also be employed in the context of a competitive market analysis. It was employed by seven design studies on the list (Choi et al. 2013; Daas et al. 2014; Fritz et al. 2011; Song et al. 2009; Weinreich and Schön 2013) to predict the market shares of new products or modified existing products based on the preference models as well as to evaluate the contribution margin. In addition, the CA study on the preference structure for PaaS (Giessmann and Stanoevska 2012) suggested the simulation method as a tool to design cloud business models.

5.6 Critical Assessment & Methodological Recommendations

While the existing CA studies in IS have thus far mostly used the basic techniques, there are many more options available to use CA in specific situations. Table 5 derives recommendations to broaden the narrow focus and enhance methodological support on "how" to apply CA. These recommendations can help researchers in setting up their future CA studies and can simplify the decision process along the different CA steps for optimal conditions. We also find that domain-specific adaptations could make the procedure more efficient when it comes to attributes and levels selection, and data analysis.

1. Attributes and Levels Selection: The success of the CA relies on choosing the most relevant attributes describing the study object. However, "little guidance is given in how to select them, other than to use qualitative research methods (one-on-one interviews, focus groups), and possibly open-ended survey items as a guide" (Bradlow 2005). A mixed method approach to select attributes is common practice. In general, researchers rely on literature reviews to capture the most relevant attributes for the product class. However, the selection should also rely on two additional perspectives for a full coverage of product features and possible implementations, that is: users and experts. The users' perspective can mainly be captured using questionnaires, interviews and focus groups. The experts' perspective can be captured through interviews or through assessing existing products and features in the market for feasibility check. As domain-specific adaptations, there is a need for supporting future CA studies in IS by creating user preference models for different domains. These preference models should describe relevant properties of the core system, represented by its functional and non-functional characteristics, but also include business model elements. In addition to modeling the system itself, which can support IS concept definition and IS design iterations, other contextual and social aspects can be included in the user preference model to support IS evaluation.

2. Data Collection Method: The dominant use of traditional full-profile CA in IS represents a major shortcoming. In line with the methodological development (see 0), future CA studies in IS should opt for adaptive and choice-based methods for two reasons: number of attributes and response burden. In fact, adaptive and choice-based methods allow setting up CA studies with larger number of attributes (Johnson et al. 2003) and thereby remove the constraints for evaluating complex systems with multiple features and design aspects. Moreover, these methods simplify the survey for users by decreasing the response burden. In the adaptive methods respondents can focus on relevant features, without taking into account unwanted or must-have features in the evaluation phase of the CA survey. Also, choice-based methods rely on the selection of a product thus reducing the cognitive load of ratings or rankings required in traditional CA.

3. Stimulus Set Construction and Presentation: For this step, studies relied mainly on verbal descriptions of the attributes and levels. However, we see a potential for prototypes (and mock-ups) in this area to simulate realistic choices by displaying the features of the actual product. This would be useful in IS concept definition and IS design iterations scenarios as it allows comparison of attributes especially when it comes to addition of features or removal of existing ones.

4. Study Administration: Using specialized software packages that combine online data collection and data analysis facilitates CA studies. These packages allow for setting up the stimulus set construction and are suitable for adaptive and choice-based CA procedures. In terms of respondents, the sample size of CA studies in our discipline is restricted and relatively low in comparison to market research studies. The establishment of IS-specific online panels would enable the access to larger samples with specific interests and reduce the challenges of obtaining biased or convenient samples that might not be representative of the user population. Moreover, these panels would facilitate the application of CA for IS design iterations where continuous feedback or user evaluations are required for release planning.

5. Data analysis: In the final step of CA, IS studies do not exploit the full set of CA techniques, but often rely on relative importance measures or trade-off analysis only. We therefore recommend IS researchers to explore the different data analysis techniques (see Table 6) for IS concept definition, IS design iterations and IS evaluation, as outlined in our framework in the following section. While relative importance and trade-off analysis can support selection of design features in the first two scenarios and propose weights in a decision-making context for IS evaluation, market segmentation can help in understanding varied preferences on different levels and market simulations can have a great impact for studying alternative designs and simulations. We argue that willingness-to-pay and variation analysis are two promising techniques that assist in the design of purposeful systems that are affordable to users and correspond to their preferences.

CA Procedure	*Current State & Limitations*	*Recommendations*
1. Attributes and Levels Selection	Most studies use mixed methods in a multi-stage process for attribute selection	Creation of domain-specific user preference models to support selection of attributes that fit the study purpose
2. Data Collection Method	Traditional CA is dominant, which constrains the number of attributes	Use adaptive and choice-based methods (ACA, CBCA and ACBCA) to deal with high numbers of attributes
3. Stimulus Set Construction and Presentation	Verbal and paragraph descriptions are mostly used; only a few studies relied on pictorial representations for websites	Develop prototypes and actual products (or mock-ups) to simulate realistic choices, specifically in IS concept definition and IS design iterations
4. Study Administration	• Online surveys are mostly employed, and the subsequent analysis is based on statistical packages or commercial software • Sample depends on the study purpose (e.g., students or managers); the sample size largely varies but is often too small	• Explore of software and packages to combine online data collection and analysis • Establish IS-specific panels to increase sample sizes
5. Data Analysis	IS studies do not exploit the full set of CA techniques; they mostly analyze the relative importance of estimated utilities	Apply the recommended data analysis techniques for the different suggested scenarios in a system lifecycle (IS concept definition, IS design iterations and IS evaluation) (see Table 6)

Table 5. Critical Assessment of CA in IS and Recommendations

6 A Framework for CA Studies in IS

Based on our review and the identified purposes of CA studies, we derive a framework for applying CA in IS (Figure 3). The framework outlines opportunities for applying CA to complement existing techniques and methods in the different phases of an IS lifecycle, from ex-ante in IS conceptualization and IS design to ex-post in the evaluation of existing IS artifacts (see Table 6). For these phases, the framework identifies suitable CA applications and the relevant CA techniques. In the following we elaborate on the framework and provide recommendations for future research on "where" to apply CA for typical study purposes in IS, with the goal of promoting user involvement and data-driven approaches in user-oriented design.

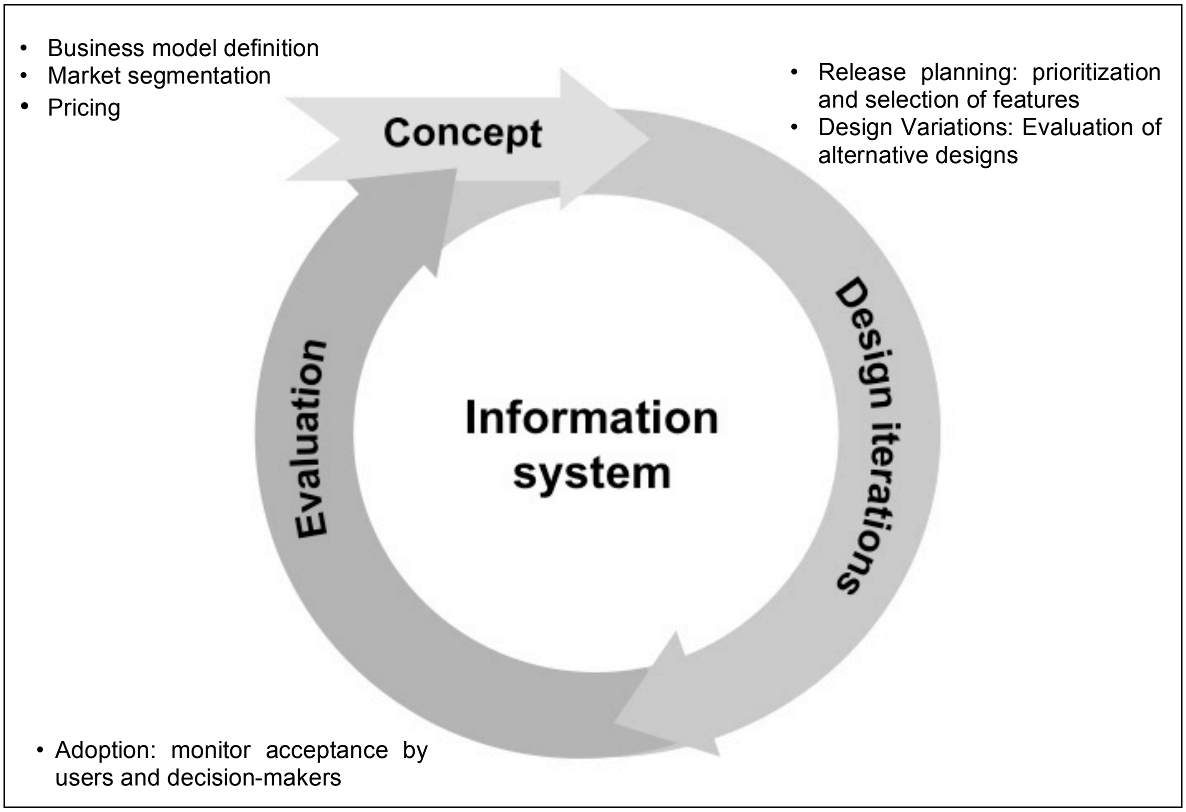

Figure 3. Framework for CA Studies in IS

6.1 CA for IS Concept Definition

CA is a well-suited methodology for preference elicitation. By offering a utility function as a quantitative measure, CA may be used to complement and validate qualitative feedback gained through direct interactions with target customers and users. It can support IS design in its initial phase through (ex-ante) evaluation of IS concepts, similar to the studies of Zubey et al. (2002) on VoIP features and Giessmann & Stanoevska (2012) on cloud platforms. Unlike traditional requirements engineering methods that tend to evaluate individual features, CA allows to evaluate complete product configurations and obtain user insights into an initial concept of the concerned product, including business model aspects. Its results could be translated into specific user requirements to build mock-ups or prototypes saving time and financial resources in the early stage of IS planning and design. It also allows for design feedback from a large number of users to be integrated, which is a particular concern in mass-market IS (Jarke et al. 2011; Todoran et al. 2013; Tuunanen et al. 2010).

Application 1.1 – Business Model Definition. CA studies extend beyond core system design to involve aspects of business model design. CA can be applied to study upfront commercial decision-making and user trade-offs with respect to business model elements. Value propositions play a central role in research on business models (Mikusz and Herter 2016), and the CA method can be used to evaluate the highly perceived value propositions of specific business models (e.g., IoT systems' value propositions (Derikx et al. 2015)). Moreover, channel selection scenarios could benefit from this type of analysis. For example, the consumer decided on the preferred format of information delivery in the case of e-commerce (Berger et al. 2015). In addition, CA can be applied to measure preferences for partnership related characteristics; for instance, migration among PaaS providers (Giessmann and Stanoevska 2012). CA's application to design business model elements can go as far as using CA as a method for scenario planning when designing business models, as suggested by Tesch (2016) for IoT business models.

Application 1.2 – Market Segmentation. CA does not only enable capturing individual and group preferences through relative importance of features, but also helps in identifying customer or user segments through application of user clustering techniques. This clustering based on user preferences for certain business model elements can serve as a reference for market segmentation applied in business model design (Osterwalder and Pigneur 2010).

Application 1.3 – Pricing. As a particular relevant aspect in these early phases, CA can be applied to support pricing decisions based on the willingness-to-pay approach (e.g., Koehler et al., 2010; Mann et al., 2008). In such scenarios, CA serves as an estimation method for consumer utilities for different price levels, which then enables the determination of attractive prices or bundle prices with respect to certain design alternatives. Moreover, CA can be used for market simulation and evaluation of market shares given the price strategy undertaken.

6.2 CA for IS Design Iterations

CA can support subsequent IS design iterations at different levels (e.g., Bouwman et al. 2008; Kim 2005). CA enables capturing individual and group preferences, which supports requirements management for customer-oriented IS (Kabbedijk et al. 2009). So far, in market-driven RE, requirements are collected from representatives of market segments or invented by developers to come up with new system design (Dahlstedt et al. 2003), then new requirements are collected by current user experience, which serve as an input to plan further incremental releases where an additional set of requirements is implemented. CA can help in understanding user preferences and tradeoffs for product attributes when assessed simultaneously as an input for different design iterations. This could be done for assessing design variations of general system features or focusing on certain functional or non-functional requirements (e.g., Naous and Legner 2019) on the design of secure cloud storage services).

Application 2.1 – Release planning. Prioritization is a central activity that supports decisions regarding product releases. It results in implementing preferential requirements of stakeholders. To prioritize requirements, users and designers have to compare requirements to determine their relative weights of importance in the implementation of a software product (Achimugu et al. 2014; Karlsson and Ryan 1997). Traditional techniques for requirements prioritization including sorting and pair-wise comparisons (such as Analytic Hierarchy Process (AHP) and the cost-value approach) (Karlsson et al. 1998; Karlsson and Ryan 1997) allow users to assess features individually to derive their relative importance. However, with the increasing number of requirements and stakeholders this process becomes more and more complex. Moreover, handling a large set of requirements would create a burden and might be tedious for the customers and engineers performing it. In modern agile software development approaches, CA can be a fundamental method for release planning and selecting relevant features based on user choices. CA combines human intuition with a systematic approach that quantifies preferences for feature selection. This could be achieved by presenting existing products or service combinations to users in order to evaluate and enhance their design. The method allows users to assess a complete product offering and rate it based on their stated preference. This is achieved taking into account feasible implementations and realistic options relying on expert assessment and validation in the first and last phases of the conjoint procedure. By measuring preferences for attributes and varied levels, this method provides quantifiable input for prioritizing and selecting features for future releases. During these iterations, CA can be also used to determine target segments with group preferences for optimal bundling.

Application 2.2 – Design variations. Another application area where CA is a venue for enhancing initial designs is testing design variations. This can be achieved through market simulations' predictions based on estimated preferences. Giessmann and Legner (2013) illustrate the use of market simulation techniques, employing a previous CA study on PaaS (Giessmann and

Stanoevska 2012), for achieving successful business models of cloud platforms. CA may support evaluation of alternative designs through the ability to perform attribute variation analysis to study the effects of varying attributes on market shares. This is important to identify which of the attributes could be refined or should be changed for better outcomes. Thus, software vendors would be aware of business model elements and system features that have significant impacts on users' choices. Market simulations based on CA also allow obtaining benchmarks for competitive analysis. They can be used to compare product combinations and their overarching business models and to generate virtual market shares for multiple vendors reflecting preferences. This can be applied taking into account individual and group utilities to assist the creation of product or service bundles in the presence of contrasting preferences.

6.3 CA for IS Evaluation

Besides the concept and design aspects, CA can be useful in the ex-post evaluation of systems by users or organizations. CA can extend established judgment models for IS success and technology acceptance and use, including diffusion of innovation (Rogers1995) and technology acceptance model/unified theory of acceptance (Davis 1989; Venkatesh et al. 2003). All these models rely mostly on traditional survey/questionnaire methods to examine a set of user beliefs or perceived values. CA could bring into the picture additional product attributes and external factors that surround them (such as business model and vendor-related aspects). CA provides insights into the relationship between tasks, technologies, and context (Schaupp and Bélanger 2005).

Application 3.1 – Willingness-to-accept. CA proved to be useful in understanding how systems are adopted. This includes decision making for the strategic purchasing of IS in organizations (Benlian and Hess 2011, 2010; Keil and Tiwana 2006) as well as individual adoption. These studies determine factors that drive software system selection in an organizational context at a managerial level. They mainly reflect the weights of evaluation criteria governed by attribute trade-offs to help assess existing systems and their selection or purchasing decisions. This could involve studying typical evaluation criteria of packaged systems (such as functionality, cost, ease of use, implementation, customization, and integration) and extending that to domain-specific and vendor-related criteria. From a user perspective, CA makes it possible to measure adoption and predict consumers' intention to use IS products (e.g., Chen et al. 2010, 2008) based on relative importance of attributes. It provides a valid and more realistic model of consumer judgments on the basis of consumer preference estimation and allows identifying user groups based on these estimations.

Phase	Role of CA	Applications (A) of CA	CA Supporting Techniques (see section 3.1)	Sample Studies
IS concept definition	Validation of new IS concepts and business models	*A1.1* – Business model definition	Define business model and value proposition - Relative importance/ Trade-off analysis	Derikx et al. 2015; Giessmann and Stanoevska 2012
		A1.2 – Market segmentation	Define target segments - Market segmentation	Giessmann and Stanoevska 2012; Krasnova et al. 2009
		A1.3 – Pricing	Define revenue model and pricing - Willingness-to-pay - Market simulation	Koehler et al. 2010
IS design iteration	Complement existing requirements engineering techniques	*A2.1* – Release planning	Prioritize & select features - Relative importance/ Trade-off analysis - Market segmentation	Bouwman et al. 2008; Naous and Legner 2019
		A2.2 – Design variation	Evaluate alternative designs - Market segmentation - Market simulations - Variation analysis	Giessmann and Legner 2013
IS evaluation	Extend IS success and adoption models	*A3.1* – Willingness-to-accept	Monitor acceptance and adoption by users and decision-makers - Relative importance - Market segmentation	Benlian and Hess 2011; Chen et al. 2010

Table 6. CA Role and Applications in the IS Lifecycle

7 Conclusion

7.1 Summary and Contributions

Market research techniques are popular for new product development but have not been fully embraced in IS research. As a marketing research approach, CA has been used by IS researchers to study user preferences from multiple perspectives. However, we observe inconsistencies in applying CA and no cumulative research on its applications. With the increasing number of studies, a fundamental discussion on integrating CA in the IS field is necessary. By conducting a systematic longitudinal review of 20 years of IS literature review and analyzing 70 CA studies, we aim at synthesizing and accumulating knowledge about CA's applications in IS. Through our review, we identify patterns and trends in the application of CA in our field to guide future research applying CA. In our study, we illustrate that CA has advantages for understanding user preferences and can be adapted to several application areas in IS covering the different phases of an IS lifecycle. We also have seen that CA, through its techniques, could support and complement other existing methods in the evaluation and design of IS.

Our findings are of interest to both IS theory and practice. For academics, we make two primary contributions: First, our review critically assesses the methodological setup or method variants from previous CA studies in IS and provides recommendations. Second, we provide guidance for future studies by proposing a reference framework for applications of CA in IS. Our framework suggests scenarios for applying CA in IS concept definition, IS design iterations, and IS evaluation starting from the core system and involving business model elements. We see empirically validated user preference models as a prerequisite for leveraging CA in the design and evaluation of mass-market IS. For practitioners, we show that CA could be employed in specific scenarios to support the user-oriented design of IS – mainly in requirements elicitation and prioritization for the development of new systems, applications, and service offerings.

We illustrate how the method allows deriving decision models for user selection and adoption patterns in IS evaluation scenarios. CA, unlike a simple survey tool, could be utilized for the estimation of a preference model. Therefore, it provides a detailed understanding of the main characteristics of the internal system and external factors that drive user's intentions to use and acceptance. Through the preference model, the conjoint methodology could extend IS theories and models on user adoption by taking into account product attributes and the external factors surrounding it to study other acceptance variables than perceptions and attitudes. Thus giving a nuanced assessment of main drivers of user adoption and also providing input to IS design.

In the design phase, CA can be used for IS concept definition to facilitate the construction of early system features for further prototyping. Through concept definition, customers can assess a complete product offering and can rate it based on their stated preferences, leading to a design process with initial product preferences. It can also support the design of business models through scenario planning by incorporating contextual and economic elements that need to be considered for the design of commercialized systems. In further stages, CA can support IS design iterations in release planning by providing quantitative insights into most valued features. It thereby combines human intuition with a systematic approach that quantifies preferences (via a relative importance measure) for further feature selection from a defined set of attributes and attribute levels. In addition, we discuss how the market simulation techniques advance a new proposition that can support the refinement of existing systems.

7.2 Limitations and Implications for Future Research

While this paper presents a comprehensive analysis of CA studies in IS, we acknowledge certain limitations. Authors' subjectivity is a main limitation when conducting literature reviews. Different search keywords could have been used, and different categorization for the domains and purposes of the studies could have been derived by different authors. However, we followed a systematic process for the selection and coding of the studies, and the results were cross-checked by two authors for validity. Another limitation is constraining the analysis to the presented IS domains for feasibility reasons. Other domains such as health IS can extend our research areas and could bring additional insights. However, our literature search focused on articles in main IS outlets for complete coverage of the IS domains. Excluding some articles was due to restrictive coverage of the specified field and the need for addressing outlets in other research areas. Finally, our analysis of the literature focuses on methodological and procedural aspects in applying CA, where we miss the discussion on the nature of attributes and levels and their reusability. However, our suggestions for domain-specific adaptations can guide future research in this specific area.

In general, our goal was to provide an overview of CA studies in IS and highlight application areas for guiding future IS research. Since CA studies in IS have mostly been one-time efforts, an important research opportunity is the methodological contributions for the domain-specific adaptation of CA. Our findings open up a new area of research integrating CA into IS design and evaluation. We foresee a particular opportunity of applying CA to initial concept definition of IS and integrating IS with business model design. Future research can also focus on the adaptation of this method to support existing methodologies in IS adoption to determine influential factors in human behavior and decision making.

Another interesting research opportunity is the creation of user preference models for typical categories of IS solutions as domain-specific adaptations of CA. The choice of attributes is often considered the most demanding phase in CA, and the success depends on selecting the right attributes and levels. To address this issue for CA studies in IS, researchers could further refine the suggested user preference models in existing studies by proposing validated catalogs of attributes and attribute levels for the related domain-specific area, thereby increasing the practicality of the CA method. This would allow researchers to construct their conjoint studies rapidly and avoid the time-consuming task of constructing attributes and levels from scratch. Besides domain specificity, these user preference models could be also categorized based on the study purpose to reflect methodological applications of conjoint analysis. For instance, technology acceptance research on enterprise systems can benefit from previous TAM-based evaluation studies (e.g., Mahindra and Whitworth, 2005) to develop future reference models involving technology and vendor-related aspects.

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Appendix

Study	Study Objectives (as stated by authors)	Domain	Purpose	Type	Sample	Subjects
(Bajaj 2000)	Identify the factors that senior IS managers across mid- to large-size organizations would consider when making decisions regarding the adoption of a new architecture for their organization	ES	DM	TCA	23	Managers
(Brinton et al. 2002)	Study the relative values of these factors in the decision models of senior IS managers, when evaluating software for use by their organization	ES	DM	TCA	24	Managers
(Zubey et al. 2002)	Suggest those VoIP technology attributes that best meet users' needs	MC	D	TCA	254	Customers
(Odekerken-Schröder and Wetzels 2003)	Examine the trade-offs end-consumers are willing to make when making online purchases (1) in terms of choice-related attributes and (2) in terms of convenience-related attributes	O	D	TCA	(1) 323 (2) 282	Customers
(Baek et al. 2004)	Examining customers' WTP (willingness-to-pay) for online games	O	P	TCA	179	Customers
(Brodt and Heitmann 2004)	Drills down to the importance of service attributes (mobile multicasting)	MC	D	ACA	103	Students
(Keen et al. 2004)	Investigate the structure for consumer preferences to make product purchases through three available retail formats—store, catalog, and the Internet	EC	D	TCA	290	Customers
(Kim 2005)	Build descriptions of hypothetical mobile service packages	MC	D	CBCA	1000	Customers
(Mahindra and Whitworth 2005)	A conjoint analysis of the contribution of these factors in a proposed corporate software purchase of browser	O	DM	TCA	28	Students
(Mueller-Lankenau and Wehmeyer 2005)	Gathering first insights into consumers' preferences for mobile couponing	MC	D	TCA	125	Students
(Schaupp and Bélanger 2005)	Examining the role of several technology, shopping, and product factors on online customer satisfaction	EC	A	TCA	188	Students
(Haaker et al. 2006)	Assess which combination of services and price is the most attractive for users	MC	P	TCA	156	Customers
(Keil and Tiwana 2006)	First empirical investigation of the relative importance that managers ascribe to various factors that are believed to be important in evaluating packaged software	ES	DM	TCA	126	Managers

(Hann et al. 2002, 2007)	Estimate the individual's utility for the means to mitigate privacy concerns	O	D	TCA	268	Students
(Tiwana and Bush 2007)	Examine the relative importance that IT managers ascribe to various factors from three complementary theories—transaction cost economics, agency theory, and knowledge-based theory—as they simultaneously consider them in their project outsourcing decisions.	ES	DM	TCA	(1) 55 (2) 33	Managers
(Mann, et al. 2008)	How consumer utility and willingness-to-pay within one specific channel may be correlated with time of availability	O	P	ACA	489	Customers
(Bouwman et al. 2008; Bouwman and van de Wijngaert 2009)	What are the relevant context-related, individual and technological characteristics that play a role in the use of mobile technologies by police officers, and where do they conflict with the requirements identified by police stakeholders?	MC	D	TCA	23	Stakeholders
			A	TCA	106	Customers
(Krasnova et al. 2009)	First attempt to assess the value of privacy in monetary terms (in the context of social networks)	O	D	ACA	168	Students
(Schwarz et al. 2009)	Provide theoretical rationalizations on the confluence of pertinent attributes when selecting an external source for an application service	ES	DM	TCA	84	Managers
(Song et al. 2009)	Estimate customer preferences and the relative importance of service factors	MC	D	TCA	-	Students
(van de Wijngaert and Bouwman 2009)	Obtain insight into the factors that influence the use of wireless grid applications before a given technology is actually introduced on the market	MC	A	TCA	257	Students
(Doerr et al. 2010)	Examines from a customer perspective, the importance of the different features of premium offers	C	P	ACA	132	Customers
(Head and Ziolkowski 2010)	Provides insights into how students value various mobile phone applications and tools	MC	A	ACA	188	Students
(Ho et al. 2010)	Find out the level of trade-offs between monetary rewards provided by the E-payment Gateways and the buyers' protection excess imposed by the E-payment Gateways	EC	D	TCA	1795	Customers
(Koehler et al. 2010)	Analyze the customer preferences for Cloud services	C	P	CBCA	60	Customers
(Lilienthal et al. 2010)	Compare the overall technology perceptions with particular attributes of product realisations with respect to their importance.	C	A	CBCA	412	Customers
(Ying-Hueih Chen et al. 2008, 2010)	Understand what factors influence consumer purchase intention and the relative importance among these factors	EC	A	TCA	1567	Students

(Benlian and Hess 2010, 2011)	The first empirical investigation to compare the relative importance of evaluation criteria in proprietary and open-source EAS selection	ES	DM	ACA	358	Managers
(Fagerstrøm and Ghinea 2011)	Expand our understanding of approach/avoidance behavior by examining the motivating impact of price relative to online recommendation at the point of online purchase	EC	A	TCA	270	Customers
(Fritz et al. 2011)	Empirically estimate consumers reaction to the offer of fair use flat rates	MC	P	CBCA	263	Students
(Giessmann and Stanoevska 2012)	Empirical investigation on the essential and necessary characteristics of PaaS from the perspective of third-party developers	C	D	ACBCA	103	Customers
(Hu et al. 2012)	Provide fuller conceptualization of technology design and advance our understanding of the impacts of essential design factors individually and jointly	MC	D	CBCA	105	Students
(Nevo et al. 2012)	Understand the relative importance of meta-memory in the transactive memory processes in order to fit the best technology support for each process	ES	D	TCA	180	Customers
(Venkatesh et al. 2012)	Examine key service attributes that affect citizens' pre-use intentions and subsequent use of transactional e-government services, as well as citizens' preferences across service attributes	O	A	TCA	2465	Customers
(Choi et al. 2013)	Assumes a consumer utility function for tablet pcs that reflects the variety of consumer preference	MC	D	CBCA	389	Customers
(Luo et al. 2013)	Identify a hierarchy of importance with regard to the critical factors influencing the adoption of mobile office	MC	A	CBCA	101	Customers
(Weinreich and Schön 2013)	Analyze customer preferences for automation of service processes in the Unified Communications (UC) industry and derive managerial implications for optimal service design	ES	D	TCA	34	Customers
(Constantinescu et al. 2014)	Understand the user's perspective on tethering and motivations for sharing	MC	A	TCA	74	Customers
(Daas et al. 2014)	Determine the reservation prices of the services and to assess what price-bundle combinations are most attractive	C	P	TCA	47	Customers
(Klein and Jakopin 2014)	Examines users perception of the utility of mobile service bundles	MC	D & P	TCA	116	Customers
(Lee and Rhim 2014)	Investigate user preferences for the information systems in order to achieve user satisfaction	ES	A	TCA	55	Customers
(Nikou et al. 2012, 2014)	Determine the most important characteristics of the mobile platforms	MC	A	TCA	166	Customers

(Rosnagel et al. 2014)	Measure the impact of various aspects of the design of FIM solutions on users' WTP	O	D & P	CBCA	249	Customers
(Berger et al. 2015)	Explore differences in consumer preferences and WTP between offline and online formats	O	D & P	CBCA	506	Customers
(Böhm et al. 2015)	Identify the relative importance of the mobile OS on the purchase decision	MC	A	CBCA	102	Customers
(Burda and Teuteberg 2014, 2015)	Uncovering the preference structure and trade-offs that users make in their choice of storage services when employed for the purpose of archiving	C	A	CBCA	340	Students
(Derikx et al. 2015)	Studies if and how privacy concerns for connected car services can be compensated financially	IoT	D	CBCA	55	Customers
(Pu and Grossklags 2015)	Quantify the monetary value people place on their friends' personal information in a social app adoption scenario	O	D	TCA	201	Customers
(Siegfried et al. 2015)	Provides a nuanced analysis of platform and environment signals that drive app installation and also contributes towards a better understanding of the underlying decision process	MC	A	TCA	121	Customers
(Tamimi and Sebastianelli 2015)	Estimate the effects of selected e-tailer and product related attributes on a consumer's likelihood of making a particular online purchase	EC	A	TCA	122	Students
(Yusuf Dauda and Lee 2015)	Analyze the technology adoption pattern regarding consumers' preference for potential future online banking services in the Nigerian banking industry	O	A	CBCA	1291	Customers
(Cwiakowski et al. 2016)	Measure willingness-to-pay (WTP) for legal rather than illegal content as it compares to valuation of other features of the product	O	P	CBCA	228	Customers
(Mikusz and Herter 2016)	Investigate how consumers evaluate value propositions of connected car services with a high option and/or indirect value-in-context	IoT	D	TCA	70	Customers
(See-To and Ho 2016)	Investigate the impacts of six design attributes of an E-payment service	O	D	TCA	1795	Customers
(Abramova et al. 2017)	Differentiate among distinct influences produced by discrete trust-enhancing cues and derive a monetary value for each of these cues as evaluated by consumers	O	D & P	CBCA	450	Customers
(Albani et al. 2017)	Understanding the customer value perceptions of smart meter services and the conditions under which customers are willing to change their behavior in order to increase the efficiency of the electricity use.	IoT	A	CBCA	1594	Customers
(Buck et al. 2017)	Targets users' preference structures when downloading apps	MC	A	CBCA	111	Students
(Fölting et al. 2017)	Measure consumers' preferences regarding product information search apps	MC	D	ACBCA	330	Students

(Mazurova 2017)	Consider the level of influence of three different factors, brand, colour and the position of the product on the screen in the conditions of simultaneous perception by the customers	O	D	CBCA	60	Customers
(Mihale-Wilson et al. 2017)	Assessing the users' preferences and willingness to pay for a highly secure and privacy stringent UPA	IoT	D & P	CBCA	274	Customers
(Rollin et al. 2017)	Investigate which attributes of a mobile gaming app have an impact on users' choice decision	MC	A	CBCA	503	Customers
(Mikusz 2018)	Examine how customers concurrently consider several features of digitized, connected products in assessing usefulness and product intelligence	IoT	D	TCA	139	Customers
(Penttinen et al. 2018)	Understanding which features companies value in selecting among platforms	ES	DM	CBCA	282	Decision makers
(Baum et al. 2019)	Explore the magnitude of user privacy concerns and preferences in the context of targeted political advertisement	O	D & P	CBCA	262	Customers
(Naous and Legner 2019)	Explore users' preferences and willingness-to-pay for privacy preserving features in personal cloud storage	C	D & P	ACBCA	144	Customers
(Schomakers et al. 2019)	Trade-offs between decisive attributes that shape the decision to share data are analyzed	O	D	CBCA	126	Customers
(Wessels et al. 2019)	Investigate the antecedents of users' willingness-to-sell information on data-selling platforms and their relative importances	O	D	CBCA	250	Customers
(Zhou et al. 2019)	We examine the role of refund policies for mobile app purchase decisions	MC	A	CBCA	52	Customers
(Zibuschka et al. 2019)	Explores users' privacy preferences for assistant systems on the Internet of Things and ultimately quantifies the willingness to pay for various privacy functions of such assistance system	IoT	D & P	CBCA	293	Customers

Table 3. Overview of CA Studies in IS (conference proceedings that were further developed into journal articles are highlighted in grey)

Incorporating the Voice of the Customer into Mass-Market Software Product Management

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Abstract. Mass-market software products, such as cloud or mobile services, target distributed and heterogeneous users with changing and evolving requirements. They impose several challenges on the software development process in terms of requirements elicitation and prioritization. Classical requirements engineering methods that rely on close interactions with users are difficult to apply for these mass-market scenarios. Therefore, new methods are required to assist product managers in designing their products while integrating the "voice of the customer". In this paper, we argue for using market research techniques in software product management to add user preference measurements, identify market segments and analyze users' willingness-to-pay. Following method engineering guidelines, we develop a method component that refines conjoint analysis (CA) for the use in software product management. We present the meta-model and procedure and demonstrate it in a study on secure cloud storage services. Our research extends existing studies that have applied CA by generalizing its application in the form of a method component that provides guidance for future studies.

Keywords: Software product management, requirements engineering, requirements elicitation, requirements prioritization, design, mass-market systems, market research, user preferences, conjoint analysis

1 Introduction

Introduction of Web 2.0, technological advances in hardware and telecommunications represented by cloud and mobile services, as well as changes in tasks and organizational environments have caused an evolution in the software industry (Jarke et al. 2011). As a result, software products have evolved from customer-specific to market-driven systems with commercial off-the-shelf (COTS) systems, mobile and cloud services. This group of software products targeting heterogeneous and distributed users can be characterized as mass-market systems. For software vendors, this shift elicits a need for more thoroughly defined products, comprising a clear functional scope as well as delivery and pricing models. Thus, product management plays an important role and is an essential area to guarantee market success and the largest business value (Van De Weerd et al. 2006).

For designing successful products, product managers have to manage requirements at different stages including elicitation, prioritization, and selection. Obtaining customer feedback is a critical aspect for these steps to understand the needs and desires, as well as expectations of the product (Fabijan et al. 2015). However, 86% of product managers do not spend enough time obtaining user feedback (Fishbein and Hennick 2019). In addition, the methods and tools with which product managers are equipped are mainly of qualitative nature and not suitable for mass-market software products. Traditional methods include customer interviews and questionnaires to get feedback on product ideas and features in the pre-development stage and customer reviews at post-development for managing requirements (Fabijan et al. 2015). For instance, for cloud services, requirements analysis remains an ad-hoc activity, where product managers talk to customers, account executives and sales people to better understand end users' needs. Thus, in the context of mass-market systems, product managers lack methodological support for systematically eliciting and quantifying user requirements in order to avoid biases and ensure customer acceptance. Consequently, they tend to overhear the "voice of the customer", while focusing on technology and schedule (Ebert and Brinkkemper 2014). This calls for data-driven methods that enable product managers to validate the market and requirements based on data from customers (Pragmatic Institute 2019).

In this paper, we aim to address the following question: How can product managers leverage market research techniques for the design of mass-market software systems? We argue for using conjoint analysis (CA) (Green and Srinivasan 1978) in order to add user preference measurements to the traditional set of techniques for requirements engineering (RE). CA is a widely established method in market research for understanding consumer preferences and predicting consumer behavior purchase decisions. It becomes increasingly popular in information systems (IS) research (Baek et al. 2004; Burda and Teuteberg 2015; Krasnova et al. 2009; Zubey et al. 2002) where it has been applied to understand design choices for mobile applications, online and cloud services. A recent review of CA studies in IS (Naous and Legner 2017) argues that CA allows for assessing requirements along multiple dimensions by a large sample of users, thereby integrating functional, non-functional and business model design and providing reliable data on users' preferences for system features. While prior studies confirm that market research techniques are very promising in system design, they mostly remain one-time efforts. To make CA an effective technique for software product management, methodological reflections and domain-specific adaptations are needed that bridge the gap between existing approaches and CA.

To address our research question, we develop a method component for requirements management of mass-market software products that integrates and refines advanced CA techniques to this specific context. The proposed method component has been developed using method engineering guidelines and is documented by means of 1) a meta-model of conceptual elements and their relationships, and 2) a procedure outlining the different phases with methodological guidance. The method allows building a reliable understanding of customer's preferences and extends the existing (qualitative) RE approaches by quantitative empirical data.

The remainder of this paper is structured as follows: We start by reviewing the literature on software product management and current applications of CA for IS design. Then, we present the method engineering approach applied for method construction. Next, we present the method component and provide illustrations through a CA study for secure design of cloud storage services. Finally, we summarize our findings and discuss future research.

2 Prior Research

2.1 Requirements Management as Core Activity in Software Product Management

Software product management is "the discipline and role, which governs a product (or solution, or service) from its inception to the market or customer delivery in order to generate biggest possible value to the business" (Ebert 2007). The product manager acts as a mini-CEO of a product, his role has a "strategic and tactical impact on all the aspects related to product analysis, development, marketing, and sales" (Maglyas et al. 2011). Requirements management is at the core of the software product management activities (Van De Weerd et al. 2006). It comprises gathering, identifying and organizing requirements and thereby links portfolio management and product roadmapping to release planning. By translating product roadmaps into detailed product requirements lists, requirements management informs prioritization and selection of requirements in the release planning.

Today, requirements are mostly collected from representatives of market segments or invented by developers to come up with new system design (Dahlstedt et al. 2003), then new requirements are collected by current user experience after the first release. In the pre-development stage, customer feedback is commonly captured through traditional methods involving interviews and questionnaires or via prototyping and A/B testing, and in post-development through reviews, usage data and support tickets (Fabijan et al. 2015). To further engage users, crowd-based approaches (Groen et al. 2017) introduce automated ways of deriving requirements through collecting and analyzing user feedback from large user groups on various channels such as app stores, forums or social media. Customer feedback serves as an input to plan further incremental releases where an additional set of requirements is implemented. The main activity is to manage new and changing requirements (Carlshamre and Regnell 2000) which creates a challenge for release planning. To prioritize requirements, users and designers have to compare requirements to determine their relative weights of importance in the implementation of a software product (Achimugu et al. 2014) (Karlsson and Ryan 1997). However, with the increasing number of requirements and stakeholders this process becomes more and more complex.

Existing approaches for requirements management are not sufficient in a mass-market context. On the one hand, the traditional approaches do not scale with the increasing number of requirements and stakeholders. On the other hand, handling a large set of requirements creates a burden and becomes tedious for the customers and engineers performing it. Therefore, the need to integrate the "voice of the customer" calls for new approaches (that target the crowds) to ensure widest customer reach and acceptance as well as the representation of users' preferences in product designs.

2.3 Conjoint Analysis for Mass-Market Software Product Design

A very promising approach is the use of techniques from consumer-oriented marketing research, such as conjoint analysis (CA), to produce a reliable understanding of consumer's preferences based on quantitative empirical data. As a concept from mathematical psychology (Luce and

Tukey 1964), conjoint measurement is used to measure “the joint effects of a set of independent variables on the ordering of a dependent variable” (Green and Rao 1971). In a CA study, a product is defined in terms of attributes and attribute levels. Based on a consumer evaluation in a survey setting, a utility function is estimated and translated into a preference structure that reflects the most accepted characteristics in a product. CA can thereby be leveraged in the context of product design in three scenarios (Green and Rao 1971): (1) relative importance of attributes and levels by analyzing the consumer tradeoffs between several product attributes; (2) cost–benefit analysis to study the willingness-to-pay (WTP) for certain attributes and design products accordingly; and (3) clustering or segmentation of customers based on their utility functions. Furthermore, (Johnson 1974) suggest using (4) market simulation to estimate the market shares of currently available or new products based on the consumers’ predicted preferences.

A recent literature review of CA in IS (Naous and Legner 2017) reveals an increasing number of CA studies targeting mass-market systems in multiple domain categories, such as mobile applications, online services covering social networks, website design and online banking services, and lately cloud services. These CA studies typically analyze user preferences for sets of 5 to 12 attributes, covering mostly combinations of functional and non-functional aspects, but also addressing non-technical aspects (i.e., economic and operational). They cover wide range of areas related to system design based on the described CA techniques. Relative importance of attributes was used by Bouwman et al. (2008), Brodt and Heitmann (2004) and Zubey et al. (2002) to come up with optimal mobile services or application designs. In the context of cloud services, Burda and Teuteberg (2015) and Koehler et al. (2010) applied CA for exploring user preferences for cloud features for further development. Other studies cover economic features and apply WTP techniques to study the tradeoffs among different attributes through variations in a price attribute (Baek et al. 2004; Daas et al. 2014; Haaker et al. 2006). Moreover, Koehler et al. (2010) applied segmentation to define user preferences for different configurations of software as a service. To conclude, existing CA studies in the domain reveal that market research techniques offer valuable insights into user preferences that may inform product design. However, existing studies remain one-time efforts and they are not integrated into requirements management. Thus, methodological reflections and adaptations are needed to fully leverage CA techniques in software product management.

3 Research Method

Our research aims at developing and evaluating a method component for eliciting and analyzing user preferences to support mass-market software design by means of advanced conjoint analysis. As method component, we denote "a self-contained part of a systems development method expressing the transformation of one or several artifacts into a defined target artifact and the rationale for such a transformation" (Karlsson and Wistrand 2006). Accordingly, the suggested method component is meant to complement existing software product management and requirements management frameworks (Van De Weerd et al. 2006). In line with Karlsson and Wistrand (2006), it adapts advanced CA techniques to cope with the specificities of mass-market systems and provides methodological guidance in applying them in the context of requirements management and prioritization. The suggested artifact is documented by two constituent elements (Braun et al. 2005): (1) a meta-model that specifies a conceptual model with main constructs and their relationships; (2) a procedure model that represents a set of ordered activities to achieve the method goals.

In constructing the method component, we follow method-engineering, i.e. "the engineering discipline to design, construct and adapt methods, techniques and tools for the development of information systems" (Brinkkemper 1996). We combine an inductive approach building on field research, and a deductive approach based on literature (Table 1) (Braun et al. 2005). This allows us to integrate practical insights from employing CA in mass-market software design with theoretical foundations from market research and software product management literature. The inductive approach is based on a field study on cloud platforms (Giessmann and Stanoevska 2012) that employed CA to identify the relative importance of cloud service attributes, segment users based on their preferences, and simulate design choices (Giessmann and Legner 2013). This study and the discussion of the results with practitioners, including cloud product managers, provided insights on how different CA techniques may inform requirements management and release planning. As part of the deductive procedure, we refined the methodological guidelines based on insights from a systematic literature review (Naous and Legner 2017). We identified a total of 17 publications, thereof 10 focusing on design, 5 on pricing and 2 on information privacy tradeoffs.

For demonstrating the method component, we applied it to a typical scenario for mass-market software product management, here: the design of security features of cloud storage services. This corresponds to a situation where user requirements related to security features are gathered as a response to the users' increasing privacy awareness and as input for the incremental release planning of cloud storage solutions. Based on a survey of 144 users of personal cloud storage, we use adaptive choice-based CA to identify relative importance of secure and privacy preserving features and segment users. The results demonstrate the feasibility and utility of the method component.

<table>
<tr><td colspan="5">I. Method Construction</td></tr>
<tr><td colspan="3">Ia. Deductive Approach</td><td colspan="2">Ib. Inductive Approach</td></tr>
<tr><td colspan="3">Structured literature review to assess existing CA studies and refine CA methodology for mass-market software product design</td><td colspan="2">Explorative study employing CA techniques to inform the design of cloud platforms and derive methodological recommendations</td></tr>
<tr><td rowspan="2">Publication Type</td><td>Journal</td><td>6</td><td rowspan="2">Purpose & Domain</td><td rowspan="2">Design and simulate business models for PaaS</td></tr>
<tr><td>Conference</td><td>11</td></tr>
<tr><td rowspan="3">Domain</td><td>Mobile</td><td>8</td><td rowspan="2">CA Type</td><td rowspan="2">Adaptive Choice-Based CA</td></tr>
<tr><td>Cloud</td><td>4</td></tr>
<tr><td>Online</td><td>5</td><td rowspan="2">Sample</td><td rowspan="2">103 developers (target PaaS users)</td></tr>
<tr><td rowspan="4">CA Techniques</td><td>Relative importance</td><td>17</td></tr>
<tr><td>Segmentation</td><td>9</td><td rowspan="3">CA Techniques</td><td rowspan="3">• Relative Importance
• Segmentation
• Market Simulation</td></tr>
<tr><td>Willingness-to-pay</td><td>9</td></tr>
<tr><td>Market simulation</td><td>3</td></tr>
<tr><td colspan="5">II. Demonstration</td></tr>
<tr><td colspan="5">Demonstration of the method component in incremental release planning (example: secure cloud storage services)</td></tr>
<tr><td>CA Type</td><td colspan="4">Adaptive Choice-Based CA</td></tr>
<tr><td>Sample</td><td colspan="4">144 cloud storage service users</td></tr>
<tr><td>CA Techniques</td><td colspan="4">• Relative Importance
• Willingness-to-pay
• Segmentation</td></tr>
</table>

Table 1. Overview of the Research Method

4 Method Component

The proposed method component supports software product managers in developing mass-market systems and planning releases by suggesting methodological guidelines: 1) how requirements should be specified and presented, to serve as input for formal consumer research methods; and 2) how these methods can inform requirements elicitation and analysis.

4.1 Meta-Model

A meta-model (Figure 1) defines the main concepts addressed by the method component and their relationships (Braun et al. 2005). It evolves around two main constructs, which are requirements and stakeholders and the relationships governing them through the requirements-related activities in product management.

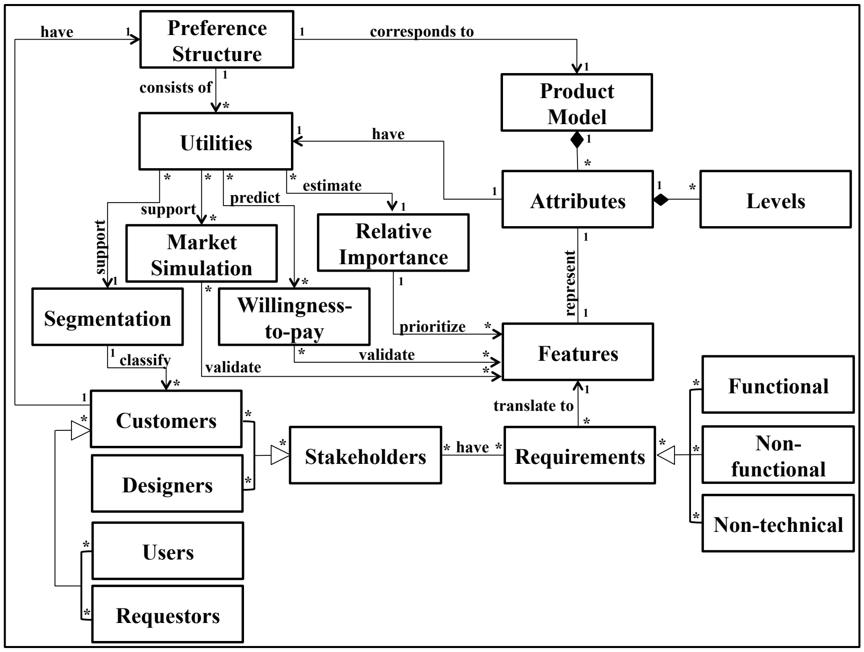

Figure 1. A meta-model of the method component

Requirements as a fundamental concept can be observed from two converging lenses: objectives or problems of stakeholders or solutions to these problems (Legner and Löhe 2012), which are ideally translated into product requirements (or features). Originally, (Pohl 1994) defines two types of requirements for software systems: 1) functional corresponding to what the system should do, and 2) non-functional corresponding to how the system functions related to performance, quality, design constraints and external interface. For mass-market systems, representing these categories of requirements is far than being sufficient, since additional economic and operational aspects (i.e., business-model elements) determine users' choices, which has been referred to, in the context of COTs, as non-technical requirements (Carvallo et al. 2006). This leads to an extended categorization of requirements into three types: functional, non-functional and non-technical.

Stakeholders are the source of these requirements, but have different roles: requestors who buy or pay for the system (individual or organization); users who practically interact with the system and are defined in different classes (novice and expert users) (Nuseibeh and Easterbrook 2000); and designers who develop the system. In the meta-model, we represent them as two categories of stakeholders that are involved in RE for providing input: (1) customers who determine system requirements, including requestors and users, and (2) designers who validate requirements. Each group has personal views of the system.

Additionally, the meta-model represents main CA constructs that support RE comprising: (1) the product model with attributes and levels corresponding to product requirements, (2) utilities as a result of customers' preference structure that governs their product choices, (3) CA techniques for processing the utilities including relative importance, WTP, market simulation that help in validating and prioritizing requirements, and segmentation for classifying customers based on different preferences.

4.2 Procedure Model

The suggested method component includes a step-by-step procedure for applying CA in the context of mass-market software design. From our inductive-deductive approach, i.e. the review of CA studies and our insights from CA applications, we derive a procedure model comprising the main activities, recommendations on methodological choices and outcomes for each step (Table 2).

4.2.1 Product Modeling. The objective of this phase is to analyze the product design options and translate them into an attribute list with attribute levels to represent the relevant characteristics of the system. A main methodological concern in this phase is the selection of suitable attributes and attribute levels that correspond to key design properties or product features for the planned releases. Attributes for mass-market services could cover any of the requirements categories identified (i.e., functional, non-functional and non-technical).

In CA studies, it is common to evaluate attributes from similar existing products or conduct expert interviews with technical specialists to gather potential and feasible characteristics of the system. Most academic studies also analyze literature for the initial selection of the attribute list describing their study object. Since getting user insights is also important at this stage to determine the set of features for evaluation, traditional approaches for requirements elicitation are employed including questionnaires and interviews (Choi et al. 2013) or group elicitation techniques including focus groups (Brodt and Heitmann 2004). It is also important to identify with users the knock-out criteria or features that are never accepted by users, and must have elements in the product release for final shaping of the attributes.

As a recommendation, selecting attributes and levels in the practical domain should employ mixed methods in a multi-stage process to gather the needs of different stakeholders, thus representing the different types of requirements. We suggest an outside-in approach: Attributes and levels are typically identified with users in a first step. Then they are validated with technical experts to assess feasibility or with similar products (in case existing) for competitive analysis.

4.2.2 Preference Elicitation. After establishing consensus on the list of attributes in the first phase, next steps focus on the set-up of the questionnaire-based survey to assess combinations from the list of attributes (i.e., profiles). This phase prepares the survey design and execution.

We propose using the advanced version of CA, which is Adaptive Choice-Based Conjoint Analysis (ACBCA). Choice-based CA (Green et al. 2001) simulates the process of purchasing a product, where participants are asked to make hypothetical choices in a scenario similar to a competitive market place, and their individual-level utility function is estimated using Hierarchical Bayes (Johnson et al. 2003).

Phase 1: Product Modeling	
Main Activities	Analyze design options and transform requirements into attributes and levels • Mixed method approach: Select attributes based on inputs from requestors, and collect feedback on feasibility of attributes and levels from designers (technical experts) or existing products • Define knock-out criteria, and must have elements during the process
Outcomes	A list of attributes and levels representing the functional, non-functional and non-technical properties for evaluation
Phase 2: Preference Elicitation	
Main Activities	2.1 Construct product profiles and design survey • Present clear definitions of attributes and levels to survey respondents to avoid misinterpretations • Develop prototypes (or mock-ups) for feature sets when possible to simulate realistic choices 2.2 Select sample of current and potential users 2.3 Execute survey
Outcomes	2.1 Survey with representation of product combinations 2.2 Sample 2.3 A data set of participants' evaluations with aggregated and individual utilities
Phase 3: Preference Interpretation	
Main Activities	Analyze utilities to answer specific questions in requirements management and prioritization: 3.1 Use relative importance of attributes for getting weights 3.2 Use WTP for measuring tradeoffs among attributes and attribute levels 3.3 Use segmentation to define user groups with similar preferences for bundling options 3.4 Use market simulation to facilitate attributes variations for competitive analysis
Outcomes	Depending on the applied technique: 3.1 Preference structure for attributes and tradeoffs 3.2 Price premium for specific attributes/ levels 3.3 User segments and their preference structure 3.4 Expected market shares for attributes combinations

Table 2. Method Component - Procedure Model

CBCA allows predicting adoption intentions based on modeling the decision-making process and the cognitive mechanism that govern the market behavior through user choices of products (McFadden 1986). Combined with the adaptive approach, respondents have to perform a self-explicated task (Johnson 1987) through evaluating attributes individually and screening product profiles to identify possibility for them to purchase or not. This enables determining unacceptable attribute levels through repetitive patterns and excluding them for further choice tasks. Therefore, this method can easily handle the high number of attributes for complex mass-market systems. Existing CA studies support our selection of this CA variant. Studies that used traditional or CBCA had an average list of 6 attributes, whereas studies that used adaptive methods evaluated more than 10 attributes.

In terms of stimulus or product profile representation, most studies employ verbal description as concepts or scenarios. Although an option for software design, only few studies present actual products or mock-ups for stimuli representation (Baek et al. 2004; Brodt and Heitmann 2004). We recommend following this approach, because it is of higher significance for participants and facilitates the evaluation.

This phase also covers the study sample selection and survey execution to produce a data set of survey responses representing participants' choices on the different stimuli. The sample size required for statistical significance is dependent on the type of CA, and the survey should target either existing or potential customers (or users) to reflect realistic choices. In marketing research, the typical sample size has a median of 300 especially in traditional conjoint approaches. The adaptive method has the advantage of requiring smaller sample size while still retaining statistical significance. For mass-market software, reaching a large sample is a challenging task due to lack of marketing panels for software products. Crowdsourcing platforms have been discussed for requirements elicitation (Hosseini et al. 2014) and represent a promising solution to the reach problem (e.g., Amazon's Mechanical Turk (MTurk) and CrowdREquire (Adepetu et al. 2012).

Once the data is collected from customers, data analysis can be performed with the following options: 1) statistical tools such as R or SPSS with a conjoint package integrated, or 2) specialized commercial software that administer an online survey and provide the CA, such as Sawtooth Software or Globalpark Software (Mann et al. 2008).

4.2.3 Preference Interpretation. CA supports product managers in analyzing product requirements, taking different perspectives: 1) customer preferences for attributes and levels based on part-worth utilities, 2) customers' sensitivity to different aspects (e.g., functional aspects, compared to privacy issues or pricing), and 3) cross-elasticity effects, and interaction effects of attributes. Most prominently, relative importance of attributes provides a prioritized list of attributes for release planning. To enhance this prioritization scheme, we suggest further analysis techniques to support the product manager in the requirements selection based on quantitative data:

- Market segmentation to develop segments based on groupings generated from sample demographics or specific clustering analysis techniques (e.g., Koehler et al. 2010). Cluster-based segmentation identifies groups of customers sharing the same preferences, attitudes or tradeoffs. The segmentation can be used to tailor targeted offerings and plan releases of product bundles.
- Willingness-to-pay for pricing or attributes tradeoffs. The inclusion of a price attribute can help in simulating realistic decisions by users through comparing different features under a cost constraint. Thus, users will be implicitly performing a cost-benefit analysis, which can help in informing the design through revealing user tradeoffs for certain attributes.
- Market simulations to determine those attributes of a product or service which will maximize its share (Johnson 1974). Simulation "as the use [..] of any artifact (i.e. model, method, instantiation) that imitates the behavior of the system under investigation" (Spagnoletti et al. 2013) was used by few studies in the literature, including Choi et al. (2013), Daas et al. (2014) and Song et al. (2009). The main purpose is to predict market shares of new products or product modifications based on preference models. This analysis technique can be very interesting as it provides data on how certain attributes (or features) can affect the market shares and thus the business value of the product. Thus, enabling well-informed decisions of requirements selection for the planned releases of the product. From our field study (Giessmann and Legner 2013), we suggest different kinds of simulations for competitive analysis: 1) competition analysis, to compare a solution with other competing solutions based on relative similarity of virtual market shares. 2) Direct benchmark analysis to obtain a detailed attribute-wise comparison views between two offerings. Also, 3) attribute variation analysis to study the effect of changing attributes on market share predictions.

5 Demonstration

We apply the method component to (re-)analyze user requirements for privacy and security features of personal cloud storage in response to increasing data protection regulations and privacy awareness (Naous and Legner 2019). Highly secure cloud storage services have had difficulties in establishing sustainable business models, as underpinned by the shut-down of the highly secure cloud service Wuala in 2015 (Wuala.com). This triggers questions regarding users' attitudes towards the use of secure personal cloud storage and its implications on their design. In this section, we demonstrate how the method component was applied to understand user preferences for secure cloud storage services. More specifically, we used the method component to understand privacy tradeoffs and preferences for enhanced privacy and security features, as well as to identify customer segments.

5.1 Phase 1 – "Product Modeling"

In the first phase of the method component, we defined the product model by selecting the relevant attributes and levels. For that, we followed a mixed method approach based on three stages: (1) as underpinned in previous academic studies, we performed a literature review on cloud storage services with a focus on security and privacy aspects resulting with 14 relevant attributes in the initial list, (2) to obtain the user perspective, we ran a focus group with 7 experienced and privacy-oriented cloud storage users to identify relevant attributes and eliminate others that were less relevant from the perceptions of the participants, and (3) we conducted a market analysis of existing services to examine and validate the attributes and identify levels. The final list contained 7 security and privacy features with their corresponding levels, covering all three requirements types (i.e., functional, non-functional and economic). In addition to storage, it included several advanced options (Table 3) and a summed price attribute based on incremental prices for attributes.

5.2 Phase 2 – "Preference Elicitation"

In this phase we conducted the ACBCA survey to estimate users' utilities through a real-life purchasing scenario. The survey was performed in three sections: 1) A self-explicated task or a "build your own" where respondents were asked to indicate their preferred levels of security attributes given a summed price that they need to keep into consideration. The base price was centered on the storage space and premiums were added on enhanced security and privacy features. Based on the answers, the following sections were adapted. 2) Screening where participants' decisions were scanned regarding possible purchases in order to recognize non-compensatory behavior. This allows identifying must-have or unacceptable features when answers show uniform decisions for certain attributes to avoid being displayed later during the survey. 3) Choice tournament where respondents evaluate concepts presented as verbal descriptions for utility analysis and preference estimation.

We selected MTurk, an online crowdsourcing platform, as a channel to hire participants of cloud storage users. MTurk provides a fast, inexpensive and convenient sampling method and is appropriate for generalizing studies (Jia et al. 2017). Aiming for high quality of responses, we restricted the participation in the survey to current cloud storage service users. Sawtooth Software was used to complete the survey and analyze the results. With 144 responses, ACBCA allowed stabilized estimates given the small sample size compared to the suggested mean in marketing studies. This approach also provides more information from the designed sections, suitable for part-worth estimations (Johnson et al. 2003).

5.3 Phase 3 – "Preference Interpretation"

We analyzed the survey data applying the different CA techniques suggested by the method component. The main results we obtained are the relative importance of attributes and levels based on part-worth utilities (Table 3). The importance for each of the features is an implicit value derived from the absolute range between the highest and the lowest part-worth utility which are normalized HB estimates (Orme 2000). The higher the part-worth utility, the stronger the respondent's preference is for certain attribute level. Our results show price as the most important attribute in personal cloud storage, followed by storage space, thereby underlining price-sensitivity for the majority of users. In terms of security and privacy features, recovery was in the third place followed by location of servers and access. Then, file change history and authentication (with less advanced options). Less importance was given to file sharing and encryption features.

Performing a WTP simulation allowed us to understand further design tradeoffs for better prioritization of attributes and levels. Given the implementation cost of certain attribute levels, users are willing to accept other design alternatives with less secure options. However, we also see that users are willing to pay more for products with certain security options, which can enhance the prioritization scheme, as previously explained. The simulation resulted with favorable preferences for more advanced file sharing options (more for sharing link with password), 2-steps authentication and end-to-end encryption.

Attribute	Attribute levels	Average Utilities	Standard Deviation
Storage Space	5 GB	-6.87	104.60
	50 GB	24.74	64.91
	100 GB	5.48	27.98
	500 GB	-5.25	60.89
	1 TB	-18.10	91.49
Accessibility	Website only	-30.90	23.43
	Website and desktop	0.89	19.95
	Website, desktop and mobile	30.01	32.03
File Sharing	Link	2.12	28.99
	Link with password	2.59	17.39
	Managed permissions	-4.70	28.16
Authentication	Password only	10.12	36.93
	2-step authentication	3.86	28.84
	Zero-knowledge	-13.98	27.15
Location of servers	Worldwide	16.26	36.68
	Worldwide (non-US)	-12.19	18.39
	Own country	-8.00	36.37
	Countries - high privacy	3.93	26.16
Encryption	Server-side	4.20	25.07
	End-to-end encryption	-4.20	25.07
Recovery	Not available	-28.93	27.49
	Limited to 30 days	-7.95	21.18
	Limited to 90 days	-8.12	24.60
	Unlimited	45.00	39.18
File Change History	Not available	-10.36	35.82
	Limited to10 versions	-3.21	16.73
	Full history with log	13.58	36.88
Price	0 $	79.27	123.88
	29 $	-79.27	123.88

Table 3. User Preferences and Part-Worth Utilities

We also used CA to determine customer segments based on individual part-worth utilities. Using k-means clustering, we performed multiple replications to obtain the most reproducible solution for the customer segmentation. We found three segments with specific preferences and privacy concerns (Table 4). The first segment represents traditional users of basic personal cloud storage services who do not have specific privacy concerns. These users target other product features than privacy and security (e.g., storage). The second segment represents a majority of users who are concerned about privacy and security, but would not pay for it. They believe privacy is a right. The last segment represents customers who seek security features and are willing to pay for them. They estimate a cost for the reduced privacy risks. Given the divergent user preferences for privacy and security features, our results suggest the implementation of product bundles to meet the requirements of the different segments, especially Cluster 3 with preferences towards advanced security options.

Our findings and segmentation results demonstrate feasibility and utility of CA for future development of cloud storage services or refinement of existing ones. They inform service providers about users' privacy preferences and their WTP for privacy preserving features for creating convenient services with advanced security options. Further simulations of market shares (e.g., with variation analysis) can help product managers in assessing the current release features and deciding on future releases based on the data and available resources.

	Cluster 1	**Cluster 2**	**Cluster 3**
# Participants	38	77	29
Privacy Concerns	Unconcerned users	Privacy-rights advocates	Privacy-concerned users
Preferences			
Storage Space	5 GB – 50 GB	100 GB – 500 GB	500 GB – 1 TB
Accessibility	Website, desktop and mobile	Website, desktop and mobile	Website, desktop and mobile
File Sharing	Sharing link	Sharing link with password	Managed permissions
Authentication	Password only	2-step	2-step
Location of servers	Worldwide	Own country or Countries of high privacy standards	Countries of high privacy standards or Worldwide
Encryption	Server-side	End-to-end	End-to-end
Recovery	Unlimited	Unlimited	Unlimited
File History	Not available	Full history	Full history
Price	High	Low	High

Table 4. Customer Segments of Cloud Storage Services

6 Conclusion

Market research techniques are popular for new product development, but have to date not been fully embraced for software product development. In this paper, we systematically develop a method component that leverages CA, from consumer research, to complement RE of mass-market software products. We demonstrate its application in the context of cloud services. Through the suggested analysis techniques, this method component provides input for design refinement and requirements prioritization in software product management.

CA allows users to evaluate product profiles simultaneously and choose the best-fit alternative corresponding to their preference model. Thus, it provides an understanding of the elements or structures widely accepted by users for product success. This method has several advantages if applied in the context of mass-market systems. It provides a data-driven approach to systematically quantify users' preferences for understanding design tradeoffs and for feature selection. Obtaining empirical data from a large set of users or potential customers is a specific advantage of this method as it helps product managers to avoid bias in design decisions through representative samples. Moreover, the ability to construct utility functions of individual and group preferences allows deriving a decision model that reflects users' behavior and establishing a prioritized list of attributes each corresponding to defined system requirements agreed upon by different stakeholders.

While this method component has several benefits if applied in the RE of mass-market software products, there are also limitations that should be taken into account when applying it. Most prominently are the length of the survey and the complexity of the study design in terms of time and efforts. Moreover, the acquisition of suitable study participants might be challenging due to the lack of relevant panels. Providing incentives for customers to participate in CA studies is a way forward. In addition, the setup of CA studies should be facilitated through the suggested crowdsourcing panels or the creation of specialized ones. Future research should focus on specifying how the method component complements existing requirements management methods and how the existing challenges can be resolved. Empirical evaluation should be done for other mass-market software classes including mobile applications and extend into market simulations.

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Incorporating the Voice of the Customer: A Preference-based Approach to Mass-Market Software Product Design

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Abstract. With mobile and cloud computing, the software industry has witnessed a shift from customer-specific systems to a mass-market scenario. Integrating the "voice of the customer" is a critical success factor for mass-market products, but remains a challenge given the heterogeneity and distribution of their users. Classical requirements engineering methods rely on close interactions to gather user requirements and feedback regarding product features. However, they are hardly applicable in mass-market scenarios, and new methods are required to assist product managers in designing their products while taking into consideration the opinion of the mass. In this paper, we argue for using market research techniques as preference-based approach in software product management. Following method engineering guidelines, we develop a method component that refines conjoint analysis for the use in software product management. We present the meta-model and procedure and demonstrate it in a study on secure cloud storage services. We evaluate the feasibility, usefulness and ease of use of the method component with experts in the RE domain. We contribute to mass-market software product management domain through a method component that builds on detailed understanding of user preferences for successful product design.

Keywords: Software product management, conjoint analysis, user preferences, requirements engineering, requirements elicitation, mass-market software design

1 Introduction

With the introduction of mobile and cloud technologies, software products increasingly target heterogeneous and distributed users. For the software industry, this implies a shift from being customer-specific to market-driven (Jarke et al. 2011). For software vendors, this shift elicits a need for more thoroughly defined products, comprising a clear functional scope as well as delivery and pricing models. Thus, product management plays an important role to guarantee market success and the largest business value (Van De Weerd et al. 2006). For designing successful products, product managers have to manage requirements at different stages starting from elicitation of requirements, their prioritization and selection, to defining product releases based on this selection. Obtaining customer feedback is a critical aspect for these steps to understand the needs, as well as user expectations towards the product (Fabijan et al. 2015). Interestingly, 86% of product managers state that they do not spend enough time obtaining user feedback (Fishbein and Hennick 2019). In addition, the classical requirements engineering (RE) methods and tools with which product managers are equipped are mainly of qualitative nature and not suitable for mass-market software products. To avoid biases and ensure customer acceptance, software product managers need more methodological support for systematically eliciting and quantifying user requirements with the heterogeneous and distributed users. This calls for data-driven methods that enable product managers to validate the market and requirements based on data from customers (Pragmatic Institute 2019).

Market research has produced a number of techniques that aim at collecting user feedback from large groups as input for commercial product design. Among these techniques is conjoint analysis (CA) (Green and Srinivasan 1978) . CA is a widely established method in market research for understanding consumer preferences and predicting consumer behavior purchase decisions. It becomes increasingly popular in information systems (IS) research (Baum et al. 2019; Bouwman et al. 2008; Koehler et al. 2010; Mihale-Wilson et al. 2017) where it has been applied to understand design choices for mobile applications, online and cloud services. A recent review of CA studies in IS (Naous and Legner 2017) argues that CA allows for assessing requirements along multiple dimensions by a large sample of users, thereby integrating functional, non-functional and business model design aspects and providing reliable data on users' preferences. While prior studies confirm that market research techniques are very promising for IS design, they mostly remain one-time efforts. To make CA an effective technique for software product management, methodological reflections and domain-specific adaptations are needed that bridge the gap between existing RE approaches and CA.

In this research, we aim to answer the following question:

How can product managers leverage market research techniques for the design of mass-market software products?

We argue for using advanced CA techniques in order to add user preference measurements, identify market segments and analyze users' willingness-to-pay. The proposed preference-based approach has been developed using method engineering guidelines (Brinkkemper 1996) in an inductive and deductive approach. It is documented by means of 1) a meta-model of conceptual elements and their relationships, and 2) a procedure outlining the different phases with methodological guidance. The method allows building a reliable understanding of user preferences and extends the existing (qualitative) RE approaches by quantitative empirical data.

We demonstrate the method component in the design of cloud services. Based on a survey of 144 users of personal cloud storage, we use adaptive choice-based CA to identify relative importance of secure and privacy-preserving features and segment users. For evaluating the method component, we perform an expert evaluation in a workshop setting and assess usefulness, ease-of-use and feasibility of the preference-based approach for mass-market IS design. Our results show that CA supports software product managers in understanding the users' perspective and provides input for design refinement and requirements prioritization in software product management.

The remainder of this paper is structured as follows: We start by reviewing the literature on software product management, user preferences and CA applications. Then, we present the research approach for method construction and evaluation. Next, we present the method component and provide illustrations through a CA study for secure design of cloud storage services. Finally, we discuss the practice-oriented evaluation of the method component. In the last section, we summarize our findings and discuss future research.

2 Prior Research

2.1 Software Product Management in Mass-Markets

Software product management is "the discipline and role, which governs a product (or solution, or service) from its inception to the market or customer delivery in order to generate biggest possible value to the business" (Ebert 2007). The product manager acts as a mini-CEO of a product, his role has a "strategic and tactical impact on all the aspects related to product analysis, development, marketing, and sales" (Maglyas et al. 2011). Requirements management is at the core of the software product management activities (Van De Weerd et al. 2006), as shown in

Figure 1. It comprises gathering, identifying and organizing requirements and thereby links portfolio management and product roadmapping to release planning. By translating product roadmaps into detailed product requirements lists, requirements management informs prioritization and selection of requirements in the release planning. Both requirements management and release planning are concerned with the RE process, which can be described as "a cooperative, iterative, and incremental process, which aims at ensuring that (1) all relevant requirements are explicitly known and understood at the required level of detail, (2) a sufficient agreement about the system requirements is achieved between the stakeholders involved, as well as [ensuring that] (3) all requirements are documented and specified in compliance with the relevant documentation formats and rules" (Pohl 2010).

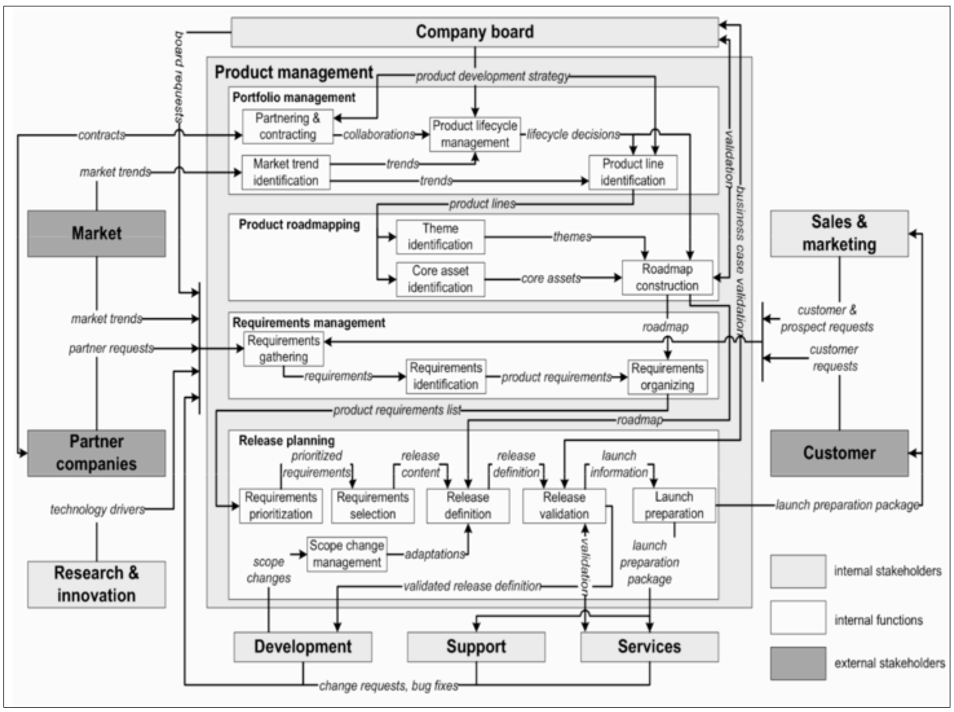

Figure 1. Software Product Management Framework (Van De Weerd et al., 2006)

Today, requirements are mostly collected from representatives of market segments or proposed by developers to come up with new system design (Dahlstedt et al. 2003). After the first release, requirements are mostly collected by current user experience and feedback. In the pre-development stage, customer feedback is commonly captured through traditional methods involving interviews and questionnaires or via prototyping and A/B testing, and in post-development through reviews, usage data and support tickets (Fabijan et al. 2015). To further engage users, crowd-based approaches (Groen et al. 2017) introduce automated ways of deriving requirements through collecting and analyzing user feedback from large user groups on various channels such as app stores, forums or social media.

Customer feedback serves as an input to plan further incremental releases where an additional set of requirements is implemented. The main activity is to manage new and changing requirements (Carlshamre and Regnell 2000) which creates a challenge for release planning. To prioritize requirements, users and designers have to compare requirements to determine their relative weights of importance in the implementation of a software product (Achimugu et al. 2014; Karlsson and Ryan 1997). However, with the increasing number of requirements and stakeholders this process becomes more and more complex.

Existing RE approaches are not sufficient in a mass-market context. On the one hand, the traditional approaches do not scale with the increasing number of requirements and a heterogeneous and distributed user base of cloud and mobile applications. On the other hand, handling a large set of requirements creates a burden and becomes tedious for the customers and engineers performing it. Therefore, the need to integrate the “voice of the customer” calls for new approaches (that target the crowds) to ensure widest customer reach and acceptance as well as the representation of users’ preferences in product designs.

2.2 Estimating User’s Preference Structure

Economic research on the choice theory (McFadden, 1986) explains that market behavior is generated by maximizing consumer preferences. Thus, modeling the decision-making process and the cognitive mechanism that govern behavior enables understanding and predicting use. As such, measuring the preference structure can help predict the mostly accepted product combinations based on inputs of product attributes, personal experiences, social and economic factors that shape perceptions and attitudes. A very promising approach in understanding user preferences is the use of techniques from consumer-oriented marketing research, such as conjoint analysis (CA). CA allows producing a reliable understanding of consumer’s preferences based on quantitative empirical data. While market research techniques are widely used for developing commercial products, to date, they have not been fully embraced for software product development.

As a concept from mathematical psychology (Luce and Tukey 1964), conjoint measurement is used to measure “the joint effects of a set of independent variables on the ordering of a dependent variable” (Green and Rao 1971). In a CA study, a product is defined in terms of attributes and attribute levels. Based on a consumer evaluation in a survey setting, a utility function is estimated and translated into a preference structure that reflects the most accepted product features. CA can thereby be leveraged in the context of product design in three scenarios (Green and Rao 1971): (1) relative importance of attributes and levels by analyzing the consumer tradeoffs between several product attributes; (2) cost–benefit analysis to study the willingness-to-pay (WTP) for certain attributes and design products accordingly; and (3) clustering or segmentation of customers based on their utility functions. Furthermore, Johnson (1974) suggests using (4) market simulation to estimate the market shares of currently available or new products based on the consumers' predicted preferences.

2.3 Review of Conjoint Studies in IS

From a comprehensive literature review of CA studies in the IS domain (Naous and Legner 2017), we observe an increasing number of CA studies targeting mass-market systems in multiple domain categories such as mobile (M) applications, online (O) services covering social networks, website design and online banking services, and lately cloud (C) services and Internet of Things (IoT) (Table 2). These CA studies typically analyze user preferences for sets of 5 to 12 attributes, covering mostly combinations of functional and non-functional aspects, but also addressing non-technical aspects including pricing, business model elements as well as security and privacy considerations.

The studies cover a wide range of areas related to IS design based on the described CA techniques. Relative importance of attributes was used by Bouwman et al. (2008), Brodt and Heitmann (2004) and Zubey et al. (2002) to come up with optimal mobile services or application designs. In the context of cloud services, Burda and Teuteberg (2015) and Koehler et al. (2010) apply CA for exploring user preferences for cloud features for further development. Other studies cover economic features and apply WTP techniques to study the tradeoffs among different attributes through variations in a price attribute (Baek et al. 2004; Daas et al. 2014; Haaker et al. 2006). Moreover, (Koehler et al. 2010) applied segmentation to define different configurations of software as a service based on users' estimated preference structure. In addition, CA is used to understand privacy tradeoffs for designing personal assistants in the IoT domain (Mihale-Wilson et al. 2017). To conclude, existing CA studies in the IS domain reveal that market research techniques offer valuable insights into user preferences that may inform software product design. However, existing studies remain one-time efforts and they are not integrated into RE. Thus, methodological reflections and adaptations are needed to fully leverage CA techniques in software product management.

Conjoint Study	Domain	Attributes Type			Analysis Techniques			
		Functional	Non-functional	Economic	Relative Importance	Segmentation	Willingness-to-pay	Market Simulation
(Zubey et al. 2002)	M		x	x	x			
(Baek et al. 2004)	O	x	x		x	x	x	
(Brodt and Heitmann 2004)	M	x	x		x	x		
(Kim 2005)	M	x	x	x	x		x	
(Mueller-Lankenau and Wehmeyer 2005)	M	x	x		x			
(Haaker et al. 2006)	M	x	x	x	x	x	x	
(Bouwman et al. 2008)	M	x	x		x			
(Mann et al. 2008)	O	x	x	x	x		x	
(Krasnova et al. 2009)	O	x	x	x	x	x	x	
(Song et al. 2009)	M	x		x	x	x		x
(Doerr et al. 2010)	C	x	x	x	x		x	
(Ho et al. 2010)	O	x	x		x	x		
(Koehler et al. 2010)	C	x	x	x	x	x		
(Fritz et al. 2011)	M	x		x			x	x
(Choi et al. 2013)	M		x	x	x			x
(Daas et al. 2014)	C	x		x	x		x	x
(See-To and Ho 2016)	O	x		x	x			
(Abramova et al. 2017)	O	x		x	x			x
(Mihale-Wilson et al. 2017)	IoT		x	x	x		x	
(Mikusz 2018)	IoT	x	x		x			
(Baum et al. 2019)	O	x		x	x			x
(Schomakers et al. 2019)	O	x	x	x	x			
(Wessels et al. 2019)	O	x	x	x	x		x	
(Zibuschka et al. 2019)	IoT	x	x	x		x	x	
Legend: (M) Mobil, (O) Online, (C) Cloud, (IoT) Internet of Things								

Table 1. An Overview of CA Studies in IS

3 Research Approach

3.1 Overview

In this research, we develop and evaluate a method component for eliciting and analyzing user preferences to support mass-market software design. A method component can be described as "a self-contained part of a systems development method expressing the transformation of one or several artifacts into a defined target artifact and the rationale for such a transformation" (Karlsson and Wistrand 2006). Accordingly, our suggested method component is meant to complement existing software product management frameworks and RE techniques (Van De Weerd et al. 2006). In line with (Karlsson and Wistrand 2006), it adapts advanced CA techniques to cope with the specificities of mass-market systems and provides methodological guidance in applying them in the context of requirements management and prioritization. The suggested artifact is documented by two constituent elements (Braun et al. 2005): (1) a meta-model that specifies a conceptual model with main constructs and their relationships; (2) a procedure model that represents a set of ordered activities to achieve the method goals.

For developing the method component, we follow method-engineering, i.e., "the engineering discipline to design, construct and adapt methods, techniques and tools for the development of information systems" (Brinkkemper 1996). We combine an inductive approach building on field research, and a deductive approach based on literature (Table 1) (Braun et al. 2005). This allows us to integrate practical insights from adapting CA into mass-market software design with theoretical foundations from market research and software product management literature. The inductive approach is based on a field study on cloud platforms (Giessmann and Stanoevska 2012) that employed CA to identify the relative importance of cloud service attributes, segment users based on their preferences, and simulate design choices (Giessmann and Legner 2013). This study and the discussion of the results with practitioners, including cloud product managers, provided insights on how different CA techniques may inform requirements management and release planning. As part of the deductive procedure, we refined the methodological guidelines based on insights from a systematic literature review (section 2.3), as described by (Naous and Legner 2017). From a total of 36 IS publications focusing on design, pricing and information privacy tradeoffs, we derived adaptations and methodological recommendations for applying CA techniques in IS.

For demonstrating the method component, we apply it to a typical scenario for mass-market software product management, here: the design of cloud storage services with a focus on security and privacy aspects. This corresponds to a situation where user requirements are gathered as a response to the users' increasing privacy awareness and as input for the incremental release planning of cloud storage solutions. Based on a survey of 144 users of personal cloud storage, we use adaptive choice-based CA to identify relative importance of secure and privacy preserving features and segment users. The results demonstrate the feasibility and utility of the method component.

<table>
<tr><td colspan="5">I. Method Construction</td></tr>
<tr><td colspan="3">Ia. Deductive Approach</td><td colspan="2">Ib. Inductive Approach</td></tr>
<tr><td colspan="3">Structured literature review of existing CA studies in IS to adapt CA techniques for mass-market software product design and derive methodological recommendations</td><td colspan="2">Explorative study employing CA techniques for cloud platform design to refine the method component based on insights from its practical application</td></tr>
<tr><td rowspan="2">Publication Type</td><td>Journal</td><td>6</td><td rowspan="2">Purpose & Domain</td><td rowspan="2">Design and simulate business models for PaaS</td></tr>
<tr><td>Conference</td><td>11</td></tr>
<tr><td rowspan="3">Domain</td><td>Mobile</td><td>8</td><td rowspan="2">CA Type</td><td rowspan="2">Adaptive Choice-Based CA</td></tr>
<tr><td>Cloud</td><td>4</td></tr>
<tr><td>Online</td><td>5</td><td rowspan="2">Sample</td><td rowspan="2">103 developers (target PaaS users)</td></tr>
<tr><td rowspan="4">CA Techniques</td><td>Relative importance</td><td>17</td></tr>
<tr><td>Segmentation</td><td>9</td><td rowspan="3">CA Techniques</td><td rowspan="3">Relative Importance
Segmentation
Market Simulation</td></tr>
<tr><td>Willingness-to-pay</td><td>9</td></tr>
<tr><td>Market simulation</td><td>3</td></tr>
<tr><td colspan="5">II. Demonstration</td></tr>
<tr><td colspan="5">Demonstration of the method component in incremental release planning (example: secure cloud storage services)</td></tr>
<tr><td>CA Type</td><td colspan="4">Adaptive Choice-Based CA</td></tr>
<tr><td>Sample</td><td colspan="4">144 cloud storage service users</td></tr>
<tr><td>CA Techniques</td><td colspan="4">• Relative Importance
• Willingness-to-pay
• Segmentation</td></tr>
<tr><td colspan="5">II. Evaluation</td></tr>
<tr><td colspan="5">Expert evaluation of the method component with 3 product managers, 1 product analyst and 2 business analysts</td></tr>
<tr><td>Evaluation Criteria</td><td colspan="4">• Usefulness
• Ease of use
• Feasibility</td></tr>
</table>

Table 2. Research Process Following Method Engineering

3.2 Inductive Approach: Adaptive Choice-Based Conjoint Analysis on Cloud Platforms

As inductive approach, a field study on the design of platform as a service (PaaS) (Giessmann and Stanoevska 2012) informs the method component construction. The study employs the most advanced variant of CA, which is adaptive choice-based CA (ACBCA) to develop a user preference model describing the drivers for successful cloud platforms. PaaS target two populations of users with platform end-users (or consumers) and external third-party developers who develop complementary applications on the platform. The study takes into account this two-sided business model to investigate characteristics that influence developers' choice of solutions.

The study evaluates three relevant attributes dimensions, i.e., functional requirements such as development and test environments, non-functional requirements including migration with other PaaS providers and mobile access, and economic requirements including pricing options. The study was completed by 103 potential users of PaaS. Based on the results, a prioritized list of customers' preferences for PaaS has been created. ACBCA provides insights into non-compensatory behavior, thus the study allowed identifying attribute levels that where unacceptable such as availability constraints, as well as must have features such as automated scalability and customizable back up routines.

CA techniques also enabled the analysis of the different potential sub-groups of users (segmentation). The results suggested diversification of platform offerings according to the specific needs of identified segments. In a follow-up study based on CA results (Giessmann and Legner 2013), we made a first attempt to facilitate cloud service design through simulation and used different kinds of simulation for cloud business models.

3.3 Demonstration and Evaluation

For demonstrating the method component, we apply it to a typical scenario for mass-market software product management, here: the design of cloud storage services with a focus on security and privacy aspects. This corresponds to a situation where user requirements are gathered as a response to the users' increasing privacy awareness and as input for the incremental release planning of cloud storage solutions. Based on a survey of 144 users of personal cloud storage, we use adaptive choice-based CA to identify relative importance of secure and privacy preserving features and segment users. The results demonstrate the feasibility and utility of the method component.

We conduct an expert workshop for a practice-oriented evaluation of the method component (Prat et al. 2015; Thoring et al. 2020). During the workshop, the method was demonstrated for multiple implementation scenarios. Experts comprise 3 product managers, 1 product analyst and 2 business analysts. They were selected for their expertise in the mass-market software product management domain and represent different industries that target mass-markets. All participants have more than 3 years experience in managing requirements and product cycles. With respect to industries and company size, participants were mainly employed in very large companies (more than 10K employees) in multiple industries. Three of the participants (2 product managers and 1 business analyst) worked in the travel industry; they designed reservation systems for airlines and lodging. Two participants worked in the banking industry (1 product manager and 1 business analyst) developing banking platforms and applications for employees and clients. The last participant (product analyst) worked in the fast-moving consumer goods industry with experience in developing e-commerce platforms. Based on the presented implementation scenarios, experts assessed the usefulness, ease-of-use, and feasibility of the preference-based approach for software product design in mass-markets.

4 Method Component

The proposed method component supports software product managers in developing mass-market products and planning releases by suggesting methodological guidelines: 1) how requirements should be specified and presented, to serve as input for formal consumer research methods; and 2) how these methods can inform requirements elicitation and analysis.

4.1 Meta-Model

A meta-model (Figure 2) defines the main concepts addressed by the method component and their relationships (Braun et al. 2005). It evolves around two main constructs, which are *requirements* and *stakeholders*, and links them to the main *CA constructs* supporting the requirements-related activities in product management.

Requirements as a fundamental concept can be observed from two converging lenses: objectives or problems of stakeholders or solutions to these problems (Legner and Löhe 2012), which are ideally translated into product requirements (or features). Originally, Pohl (1994) defines two types of requirements for software systems: 1) functional corresponding to what the system should do, and 2) non-functional corresponding to how the system functions related to performance, quality, design constraints and external interface. For mass-market software products, representing these categories of requirements is far than being sufficient, since additional economic and operational aspects (i.e., business-model elements) determine users' choices, which has been referred to, in the context of commercial off-the-shelf (COTS) products, as non-technical requirements (Carvallo et al. 2006). This leads to an extended categorization of requirements into three types: *functional*, *non-functional* and *non-technical*.

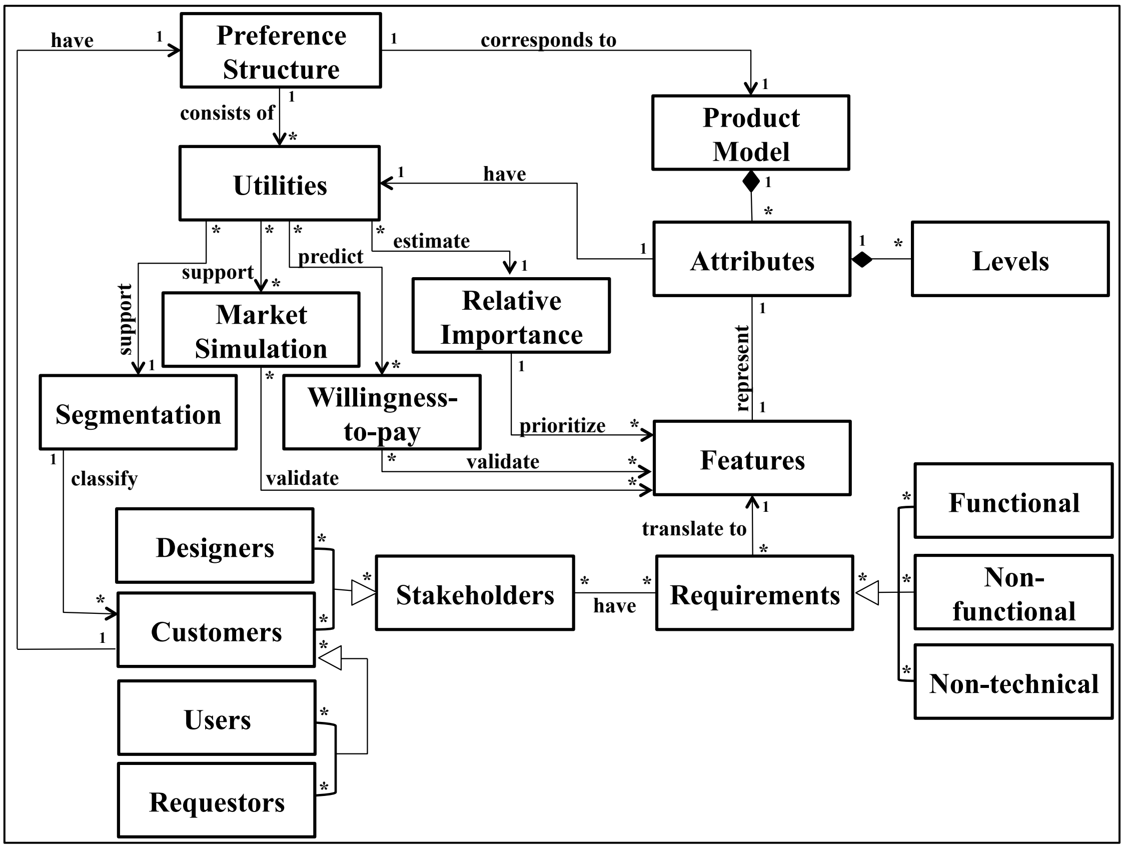

Figure 2. A meta-model of the method component

Stakeholders are the source of these requirements, but have different roles: they can be the *requestors* who buy or pay for the system (individual or organization), the *users* who practically interact with the software product (often distinguished based on their expertise in novice and expert users (Nuseibeh and Easterbrook 2000), or the *designers* who develop the system. In the meta-model, we represent them as two categories of stakeholders providing input in RE: (1) *customers* who determine system requirements, including requestors and users, and (2) *designers* who validate requirements. Each group has specific views of and interests in the software product.

Additionally, the meta-model represents main *CA constructs* that support RE comprising: (1) the *product model* with attributes and levels corresponding to product requirements, (2) *utilities* as a result of customers' preference structure that governs their product choices, (3) *CA techniques* for processing the utilities including *relative importance*, *willingness-to-pay*, *market simulation* that help in validating and prioritizing requirements, and *segmentation* for classifying customers based on different preferences.

4.2 Procedure Model

The suggested method component includes a step-by-step procedure for applying CA in the context of mass-market software design. From our inductive-deductive approach, i.e. the review of CA studies and our insights from CA applications, we derive a procedure model comprising the main activities, recommendations on methodological choices and outcomes for each step (Table 3).

4.2.1 Product Modeling

The objective of this phase is to analyze the product design options and translate them into an attribute list with attribute levels to represent the relevant characteristics. A main methodological concern in this phase is the selection of suitable attributes and attribute levels that correspond to key design properties or product features for the planned releases. Attributes for mass-market software products could cover any of the requirements categories identified (i.e., functional, non-functional and non-technical).

In CA studies, it is common to evaluate attributes from similar existing products or conduct expert interviews with technical specialists to gather potential and feasible characteristics of the system. Most academic studies also analyze literature for the initial selection of the attribute list. Since getting user insights is also important at this stage to determine the set of features for evaluation, traditional approaches for requirements elicitation are employed including questionnaires and interviews (Choi et al. 2013) or group elicitation techniques including focus groups (Brodt and Heitmann 2004). It is also important to identify with users the knock-out criteria or features that are never accepted by users, and must have elements in the product release for final shaping of the attributes.

As a recommendation, selecting attributes and levels should employ mixed methods in a multi-stage process to gather the needs of different stakeholders, thus representing the different types of requirements. In the study on cloud platforms, we employed a mixed method approach starting with a literature review to explore PaaS characteristics. This was followed by a focus group to identify essential attributes. In a third step, expert interviews helped in the validation and refinement of the attribute list and levels. We suggest an outside-in approach: Attributes and levels are typically identified with users in a first step. Then they are validated with technical experts to assess feasibility or with similar products (in case existing) for competitive analysis.

4.2.2 Preference Elicitation

After establishing consensus on the list of attributes in the first phase, next steps focus on the set-up of the questionnaire-based survey to assess combinations from the list of attributes (i.e., profiles). This phase prepares the survey design and execution.

We propose using ACBCA for estimating the preference structure for the following reasons:

First, choice-based CA (CBCA) allows predicting adoption intentions based on estimating the user's preference structure through user's choices of products (McFadden 1986). CBCA (Green et al. 2001) simulates the process of purchasing a product, where participants are asked to make hypothetical choices in a scenario similar to a competitive market place, and their individual-level utility function is estimated using Hierarchical Bayes (Johnson et al. 2003). The higher the part-worth utility, the stronger the respondents' preference for a certain attribute level. Based on the part-worth utilities the relative importance of attributes can be estimated. The importance for each of the features is an implicit value derived from the absolute range between the highest and the lowest part-worth utility of an attribute.

Second, combined with the adaptive approach, respondents have to perform a self-explicated task (Johnson 1987) through evaluating attributes individually and screening product profiles to identify possibility for them to purchase/use or not. The screening of product profiles provides insights into non-compensatory behavior. This enables determining must-have attribute levels as well as unacceptable options through repetitive patterns and excluding them for further choice tasks. Therefore, this ACBCA can easily handle the high number of attributes prevalent in software design. Existing CA studies (see section 2.3) support our selection of this CA variant. Studies that used traditional or CBCA had an average list of 6 attributes, whereas studies that used adaptive methods evaluated more than 10 attributes.

In terms of stimulus or product profile representation, most studies employ verbal description as concepts or scenarios. Although an option for software design, only few studies present actual products or mock-ups for stimuli representation (Baek et al. 2004; Brodt and Heitmann 2004). We recommend following this approach, because it is of higher significance for participants and facilitates the evaluation. Two possibilities exist, either full prototype of product combinations can be presented to users, or individual features instead. We find this to be relevant in the case of mobile applications, for example, with different screens representing different functionalities and implementation options.

This phase also covers the study sample selection and survey execution to produce a data set of survey responses representing participants' choices on the different stimuli. The sample size required for statistical significance is dependent on the type of CA, and the survey should target either existing or potential customers (or users) to reflect realistic choices. In marketing research, the typical sample size has a median of 300 especially in traditional conjoint approaches. The adaptive method has the advantage of requiring smaller sample size while still retaining statistical significance. For mass-market software products, reaching a large sample is a challenging task due to lack of marketing panels for software products. Crowdsourcing platforms have been discussed for requirements elicitation (Hosseini et al. 2014) and represent a promising solution to the reach problem (e.g., Amazon's Mechanical Turk (MTurk) and CrowdREquire (Adepetu et al. 2012).

Once the data is collected from customers, data analysis can be performed with the following options: 1) statistical tools such as R or SPSS with a conjoint package integrated, or 2) specialized commercial software that administer an online survey and provide the CA, such as Sawtooth Software or Globalpark Software (Mann et al. 2008).

Phase 1: Product Modeling	
Main Activities	Analyze design options and transform requirements into attributes and levels using a mixed method approach: • Select attributes based on inputs from requestors • Collect feedback on feasibility of attributes and levels from designers (technical experts) or/and analysis of existing products • Define knock-out criteria, and must have elements during the process
Outcomes	A list of attributes and levels representing the functional, non-functional and non-technical properties for evaluation
Phase 2: Preference Elicitation	
Main Activities	2.1 Construct product profiles and design survey Present clear definitions of attributes and levels to survey respondents to avoid misinterpretations Develop prototypes (or mock-ups) for feature sets when possible to simulate realistic choices 2.2 Select sample of current and potential users 2.3 Execute survey
Outcomes	2.1 Survey with representation of product combinations 2.2 Sample with participants representing customers 2.3 A data set of participants' evaluations with aggregated and individual utilities

Phase 3: Preference Interpretation	
Main Activities	Analyze utilities to answer specific questions in requirements management and prioritization: Use relative importance of attributes for getting weights Use WTP for measuring tradeoffs among attributes and attribute levels Use segmentation to define user groups with similar preferences for bundling options Use market simulation to facilitate attributes variations for competitive analysis
Outcomes	Depending on the applied technique: Preference structure for attributes and tradeoffs Price premium for specific attributes/ levels User segments and their preference structure Expected market shares for attributes combinations

Table 3. Method Component - Procedure Model

4.2.3 Preference Interpretation.

CA supports product managers in analyzing the customers' view on product requirements, taking different perspectives: 1) customer preferences for attributes and levels based on part-worth utilities, 2) customers' sensitivity to different aspects (e.g., functional aspects, compared to privacy issues or pricing), and 3) cross-elasticity effects, and interaction effects of attributes. Most prominently, relative importance of attributes provides a prioritized list of attributes for release planning. To enhance this prioritization scheme, we suggest further analysis techniques to support the product manager in the requirements selection based on quantitative data:

- Market segmentation to develop segments based on groupings generated from sample demographics or specific clustering analysis techniques (e.g., Koehler et al. 2010). Cluster-based segmentation identifies groups of customers sharing the same preferences, attitudes or tradeoffs. The segmentation can be used to tailor targeted offerings and plan releases of product bundles.
- Willingness-to-pay for pricing or attributes tradeoffs. The inclusion of a price attribute can help in simulating realistic decisions by users through comparing different features under a cost constraint. Thus, users will be implicitly performing a cost-benefit analysis, which can help in informing the design through revealing user tradeoffs for certain attributes.
- Market simulations to determine those attributes of a product or service which will maximize its share (Johnson 1974). Simulation "as the use [..] of any artifact (i.e. model, method, instantiation) that imitates the behavior of the system under investigation"

(Spagnoletti et al. 2013) was used by few studies in the literature, including Choi et al. (2013), Daas et al. (2014) and Song et al. (2009). The main purpose is to predict market shares of new products or product modifications based on preference models. This analysis technique can be very interesting as it provides data on how certain attributes (or features) can affect the market shares and thus the business value of the product. Thus, enabling well-informed decisions of requirements selection for the planned releases of the product. From our field study (Giessmann and Legner 2013), we suggest different kinds of simulations for competitive analysis: 1) competition analysis, to compare a solution with other competing solutions based on relative similarity of virtual market shares. 2) Direct benchmark analysis to obtain a detailed attribute-wise comparison views between two offerings. Also, 3) attribute variation analysis to study the effect of changing attributes on market share predictions.

5 Demonstration

To demonstrate the use of the suggested method component, we provide a step-by-step illustration from a study on cloud storage services as a widely adopted category of mass-market software products. We apply the method component to (re-)analyze user requirements for privacy and security features of personal cloud storage in response to increasing data protection regulations and privacy awareness (cf. Naous and Legner 2019). Highly secure cloud storage services have had difficulties in establishing sustainable business models, as underpinned by the shut-down of the highly secure cloud service Wuala in 2015 (Wuala.com). This triggers questions regarding users' attitudes towards the use of secure personal cloud storage and its implications on their design. In this section, we demonstrate how the method component was applied to understand user preferences for secure cloud storage services. More specifically, we used the method component to understand privacy tradeoffs and preferences for enhanced privacy and security features, as well as to identify customer segments.

5.1 Phase 1 – "Product Modeling"

In the first phase of the method component, we defined the product model by selecting the relevant attributes and levels. For that, we followed a mixed method approach based on three stages: First, as underpinned in previous academic studies, we performed a literature review on cloud storage services with a focus on security and privacy aspects resulting with 14 relevant attributes in the initial list. Second, to obtain the user perspective, we ran a focus group with 7 experienced and privacy-oriented cloud storage users to identify relevant attributes and eliminate others that were less relevant from the perceptions of the participants. And third, we conducted a market analysis of existing services to examine and validate the attributes and identify levels. The final list (see Table 4) contained 7 security and privacy features with their corresponding levels, covering all three requirements types (i.e., functional, non-functional and economic). In addition to storage, it included several advanced options and a summed price attribute based on incremental prices for attributes.

Attribute	**Attribute Description**	**Attribute Levels (from basic to enhanced)**
Accessibility	Options of devices supporting the service.	(1) Website only, (2) website and desktop application, and (3) website, desktop application and mobile
File sharing	Methods for sharing files with other parties.	(1) Link sharing, (2) link sharing with password, and (3) sharing with managed permissions
Authentication	Methods in which credentials are provided for accessing the service.	(1) Password only, (2) 2-steps authentication, and (3) zero-knowledge authentication
Location of cloud servers	Location of the servers that the service provider deploy to store user data.	(1) Worldwide, (2) worldwide (non-US), (3) countries with high data protection and privacy standards (e.g., Switzerland), and (4) own country
Encryption	Transformation of the customer data to cipher text using different encryption algorithms.	(1) Server-side encryption, and (2) end-to end encryption (encryption and decryption are done on the client-side with a private key)
File recovery	Data restore and recovery in case of disasters such as data loss or deletion.	(1) Not available, (2) limited to 30 days, (3) limited to 90 days, and (4) Unlimited
File Change History	File versioning and system monitoring depending on the provider's policies.	(1) Not available, (2) limited to 10 versions, and (3) full history with “Access and Activity” log
Storage space	Capacity of the file storage.	5 GB, 50 GB, 100 GB, 500 GB or 1 TB

Table 4. List of attributes and levels for personal cloud storage

5.2 Phase 2 – "Preference Elicitation"

In this phase we conducted the ACBCA survey to estimate users' utilities through a real-life purchasing scenario. The survey was performed in three sections, as Table 5 illustrates: 1) A self-explicated task or a "build your own" where respondents were asked to indicate their preferred levels of security attributes given a summed price that they need to keep into consideration. The base price was centered on the storage space and premiums were added on enhanced security and privacy features. Based on the answers, the following sections were adapted. 2) Screening where participants' decisions were scanned regarding possible purchases in order to recognize non-compensatory behavior. This allows identifying must-have or unacceptable features when answers show uniform decisions for certain attributes to avoid being displayed later during the survey. 3) Choice tournament where respondents evaluate concepts presented as verbal descriptions for utility analysis and preference estimation.

1) Build Your Own

Feature	Select Feature	Cost for Feature
Storage Space:	○ 5 GB of cloud storage ○ 50 GB of cloud storage (+ $2) ○ 100 GB of cloud storage (+ $5) ○ 500 GB of cloud storage (+ $8) ○ 1 TB of cloud storage (+ $12)	$ 0
Access:	○ Website only ○ Website and desktop application ○ Website, desktop application and mobile	$ 0
File Sharing:	○ Sharing link ○ Sharing link with password (+ $1) ○ Sharing with managed permissions (+ $2)	$ 0
Authentication:	○ Password only ○ 2-step authentication (+ $2) ○ Zero-knowledge authentication (provider has no access to password in unencrypted form) (+ $2)	$ 0
Location of servers:	○ Own country (+ $2) ○ Countries with high data protection and privacy standards (e.g., Switzerland, Iceland, Canada) (+ $2) ○ Worldwide (non-US) (+ $1) ○ Worldwide	$ 0
Encryption:	○ Server-side ○ End-to-end encryption (encryption and decryption are done on the client-side) (+ $2)	$ 0
Recovery:	○ Unlimited ○ Limited to 90 days ○ Limited to 30 days ○ Not available	$ 0
File Change History:	○ Full history with "Access & Activity" log (+ $2) ○ Limited to 10 versions (+ $1) ○ Not available	$ 0
	Total (monthly rate)	$ 0

2) Screening (non-compensatory behavior)

Unacceptable Features

We've noticed that you've avoided services with certain characteristics shown below. Would any of these features be **totally unacceptable**? If so, mark the **one feature that is most unacceptable**, so we can just focus on services that meet your needs.

○ Storage Space: - 100 GB of cloud storage
○ Storage Space: - 1 TB of cloud storage
○ Recovery: - Not available
○ Location of servers: - Worldwide
○ Authentication: - Zero-knowledge authentication (provider has no access to password in unencrypted form)
○ Encryption: - Server-side

○ None of these is totally unacceptable.

Must Have Features

We don't want to jump to conclusions, but we've noticed that you've selected cloud storage services with certain characteristics shown below. If any of these is an **absolute requirement**, it would be helpful to know. If so, please check the **one most important** feature, so we can just focus on services that meet your needs.

- ○ File Change History: - At least: Limited to 10 versions
- ○ Storage Space: - At most: 50 GB of cloud storage
- ○ Storage Space: - 50 GB of cloud storage
- ○ None of these is an absolute requirement.

3) Screening

(1 of 7)

Storage Space:	50 GB of cloud storage	50 GB of cloud storage	100 GB of cloud storage	50 GB of cloud storage
Access:	Website, desktop application and mobile	Website, desktop application and mobile	Website, desktop application and mobile	Website only
File Sharing:	Sharing link	Sharing link with password	Sharing link	Sharing link
Authentication:	Password only	Password only	Password only	2-step authentication
Location of servers:	Own country	Worldwide	Countries with high data protection and privacy standards (e.g., Switzerland, Iceland, Canada)	Countries with high data protection and privacy standards (e.g., Switzerland, Iceland, Canada)
Encryption:	End-to-end encryption (encryption and decryption are done on the client-side)	End-to-end encryption (encryption and decryption are done on the client-side)	Server-side	End-to-end encryption (encryption and decryption are done on the client-side)
Recovery:	Limited to 90 days	Limited to 30 days	Limited to 90 days	Limited to 30 days
File Change History:	Full history with "Access & Activity" log	Limited to 10 versions	Limited to 10 versions	Limited to 10 versions
Price (Monthly rate):	$7	$8	$9	$12
	○ A possibility ○ Won't work for me	○ A possibility ○ Won't work for me	○ A possibility ○ Won't work for me	○ A possibility ○ Won't work for me

4) Choice Tournament

(1 of 6)

Storage Space:	50 GB of cloud storage	50 GB of cloud storage	100 GB of cloud storage
Access:	Website, desktop application and mobile	Website, desktop application and mobile	Website, desktop application and mobile
File Sharing:	Sharing link	Sharing link	Sharing link
Authentication:	2-step authentication	Password only	2-step authentication
Location of servers:	Countries with high data protection and privacy standards (e.g., Switzerland, Iceland, Canada)	Countries with high data protection and privacy standards (e.g., Switzerland, Iceland, Canada)	Countries with high data protection and privacy standards (e.g., Switzerland, Iceland, Canada)
Encryption:	End-to-end encryption (encryption and decryption are done on the client-side)	End-to-end encryption (encryption and decryption are done on the client-side)	Server-side
Recovery:	Unlimited	Unlimited	Unlimited
File Change History:	Full history with "Access & Activity" log	Limited to 10 versions	Full history with "Access & Activity" log
Price (Monthly rate):	$10	$7	$8
	○	○	○

Table 5. ACBCA Survey Design

We selected MTurk, an online crowdsourcing platform, as a channel to hire participants of cloud storage users. MTurk provides a fast, inexpensive and convenient sampling method and is appropriate for generalizing studies (Jia et al. 2017). Aiming for high quality of responses, we restricted the participation in the survey to current cloud storage service users. Sawtooth Software was used to complete the survey and analyze the results. With 144 responses, ACBCA allowed stabilized estimates given the small sample size compared to the suggested mean in marketing studies. This approach also provides more information from the designed sections, suitable for part-worth estimations (Johnson et al. 2003).

5.3 Phase 3 – "Preference Interpretation"

We analyzed the survey data applying the different CA techniques suggested by the method component. The main results we obtained are the relative importance of attributes and levels based on part-worth utilities (Table 6). The importance for each of the features is an implicit value derived from the absolute range between the highest and the lowest part-worth utility which are normalized HB estimates (Orme 2000). The higher the part-worth utility, the stronger the respondent's preference is for certain attribute level. Our results show price as the most important attribute in personal cloud storage, followed by storage space, thereby underlining price-sensitivity for the majority of users. In terms of security and privacy features, recovery was in the third place followed by location of servers and access. Then, file change history and authentication (with less advanced options). Less importance was given to file sharing and encryption features.

Attribute	Attribute levels	Average Utilities	Standard Deviation
Storage Space	5 GB	-6.87	104.60
	50 GB	24.74	64.91
	100 GB	5.48	27.98
	500 GB	-5.25	60.89
	1 TB	-18.10	91.49
Accessibility	Website only	-30.90	23.43
	Website and desktop	0.89	19.95
	Website, desktop and mobile	30.01	32.03
File Sharing	Link	2.12	28.99
	Link with password	2.59	17.39
	Managed permissions	-4.70	28.16
Authentication	Password only	10.12	36.93
	2-step authentication	3.86	28.84

	Zero-knowledge	-13.98	27.15
Location of servers	Worldwide	16.26	36.68
	Worldwide (non-US)	-12.19	18.39
	Own country	-8.00	36.37
	Countries with high privacy	3.93	26.16
Encryption	Server-side	4.20	25.07
	End-to-end encryption	-4.20	25.07
Recovery	Not available	-28.93	27.49
	Limited to 30 days	-7.95	21.18
	Limited to 90 days	-8.12	24.60
	Unlimited	45.00	39.18
File Change History	Not available	-10.36	35.82
	Limited to10 versions	-3.21	16.73
	Full history with log	13.58	36.88
Price	0 $	79.27	123.88
	29 $	-79.27	123.88

Table 6. User Preferences and Part-Worth Utilities

Performing a WTP simulation allowed us to understand further design tradeoffs for better prioritization of attributes and levels. To understand price-sensitivity for security and privacy features, we use a reference product that is a status quo in the market and widely adopted by users (Table 7), we then estimate the change in utility from the reference product to a compared product with one varied attribute level. This change in utility corresponds to ΔWTP. Given the implementation cost of certain attribute levels, users are willing to accept other design alternatives with less secure options. However, we also see that users are willing to pay more for products with certain security options, which can enhance the prioritization scheme, as previously explained. The simulation resulted with favorable preferences for more advanced file sharing options (more for sharing link with password), 2-steps authentication and end-to-end encryption.

Attribute	**Base Level**	**Changed Attribute Level**	**ΔWTP ($)**
Accessibility	Website, desktop and mobile	Website and desktop	-2.00
		Website, desktop and mobile	-2.00
File Sharing	Sharing link	Sharing link with password	-0.20
		Sharing with managed permissions	-1.00

Authentication	Password only	2-step authentication	-1.00
		Zero-knowledge authentication	-2.00
Location of servers	Worldwide	Own country	-2.00
		Countries with high privacy standards	-1.70
		Worldwide (non-US)	-2.00
Encryption	Server-side	End-to-end encryption	-1.00
Recovery	Unlimited	Limited to 90 days	-2.00
		Limited to 30 days	-2.00
		Not available	-2.00
File Change History	Full history with "Access & Activity" log	Limited to 10 versions	-1.50
		Unavailable	-2.00

Table 7. Willingness-to-pay for changing attribute levels (monthly rate)

We also used CA to determine customer segments based on individual part-worth utilities. Using k-means clustering, we performed multiple replications to obtain the most reproducible solution for the customer segmentation. We found three segments with specific preferences and privacy concerns (Table 8). The first segment represents traditional users of basic personal cloud storage services who do not have specific privacy concerns. These users target other product features than privacy and security (e.g., storage). The second segment represents a majority of users who are concerned about privacy and security, but would not pay for it. They believe privacy is a right. The last segment represents customers who seek security features and are willing to pay for them. They estimate a cost for the reduced privacy risks. Given the divergent user preferences for privacy and security features, our results suggest the implementation of product bundles to meet the requirements of the different segments, especially Cluster 3 with preferences towards advanced security options.

Our findings and segmentation results demonstrate the utility of the method component in future development or refinement of a mass-market software product (i.e., cloud storage services). They inform service providers about users' privacy preferences and their WTP for privacy preserving features for creating convenient services with advanced security options. Further simulations of market shares (e.g., with variation analysis) can help product managers in assessing the current release features and deciding on future releases based on the data and available resources.

	Cluster 1	**Cluster 2**	**Cluster 3**
# Participants	38 (26.39%)	77 (53.47%)	29 (20.14%)
Privacy Concerns	Unconcerned users	Privacy-rights advocates	Privacy-concerned users
Preferences			
Storage Space	5 GB – 50 GB	100 GB – 500 GB	500 GB – 1 TB
Accessibility	Website, desktop and mobile	Website, desktop and mobile	Website, desktop and mobile
File Sharing	Sharing link	Sharing link with password	Managed permissions
Authentication	Password only	2-step	2-step
Location of servers	Worldwide	Own country or Countries of high privacy standards	Countries of high privacy standards or Worldwide
Encryption	Server-side	End-to-end	End-to-end
Recovery	Unlimited	Unlimited	Unlimited
File History	Not available	Full history	Full history
Price	High	Low	High

Table 8. Customer Segments of Cloud Storage Services

6 Method Component Evaluation

6.1 Evaluation Settings

In the previous section, we demonstrate how the artifact works and how it can meet its targeted goals in an illustrative scenario from the cloud domain. For further evaluating the method in a practical context, we perform a practice-oriented evaluation (Prat et al. 2015). This form of evaluation assesses the artifact in a real scenario by real people.

The experts were asked about current practices for requirements elicitation and management in the context of mass-market software design, i.e. the methods they apply and the challenges they face in integrating "the voice of the customer". We then presented the method component and illustrated its use in two scenarios: (1) cloud platform design, which represents an application of the method component for product planning and roadmapping, and (2) the design of secure cloud storage services as a release planning scenario. The participants were asked to assess three criteria (Prat et al. 2015): usefulness in supporting requirements management activities, ease of use in terms of setup and efforts required for its application, and the technical feasibility in terms of the ease with which the method component will be operated. The experts had to evaluate six statements based on a 5-Likert scale. The cumulative results are shown in Table 8. We then discussed main challenges in applying the method component to mass-market software product management.

6.2 State of Practice

To create a common understanding and discuss the state of practice, we introduced the software product management framework (from section 2.1) and asked the participants about the relevance of user feedback in the different phases. They all agree that user feedback plays a critical role in all phases, but is most important in two phases: requirements management to understand user needs before forming the product feature list, and release planning to check whether the product meets the user needs (i.e. mainly in the testing and validation of product releases). We also discussed the need for getting users' feedback in the product roadmapping phase as an input to roadmap construction. In fact, the experts agree that the earlier you get the user feedback in mass-market scenarios, the easier the RE process will be because the product roadmap will be based on validated user needs.

For the methods used in getting user feedback, participants mostly use classical qualitative methods including workshops with user representatives. The latter are most of the times selected by the marketing team or are formed by internal users in the company. Other methods involve customer surveys and A/B testing. Prototyping was mentioned by one expert as a method used for testing purposes. The advantage of prototyping is its ability to translate the user requirements into concrete product features to be assessed by the user before development. It is worth noting that none of the experts have used CA before, however two of them have limited knowledge about it from market research.

The experts also identified two main challenges regarding mass-market software product design. First, participants highlight that reach is a challenge when dealing with a large number of users. This in turn creates difficulties in selecting a representative sample for gathering user requirements and providing feedback. Second, participants emphasize that reaching consensus is a challenge in mass-market scenarios. "If you ask people what do they need or how to develop a product, they will give you an infinite set of possibilities… How will you leverage all these, and how will you reach consensus?". Since designing the optimal solution for a large set of users is a challenging task, prioritization and scoring of requirements and implementation options play an important role in addressing user needs.

6.3 Feedback to Method Component

As shown in Table 8, experts have a common opinion about the method component's usefulness in incorporating the voice of the customer. They confirm that CA can be helpful in obtaining insights form a large number of users and provides techniques that can be helpful in simulating designs. Specifically, one expert mentions that it can be complementary to existing prototyping approaches as it allows presenting product combinations and profiles as a complete set of features corresponding to requirements. This allows validating the product combinations before going into development.

However, the experts find that CA is more useful in defining roadmaps rather than product releases. The experts highlight that the method component can work very well for engaging customers in proof of concept or in a first pilot. This would allow defining the optimal product profile for a first product release. As for release planning, they raise contradicting thoughts. One product manager values having a price attribute and considers that as an innovative approach to evaluate requirements, especially in planning releases. According to him, this information can be useful in combination with the relative importance measures in specifying the successful product combination and prioritizing features. Interestingly, it also becomes evident that pricing is normally done in isolation to requirements management, so having a price attribute has to be well estimated and studied before involving such element in the study. The experts also highlight that it is difficult to apply this method to all types of requirements when there is a high number of requirements to handle, especially when applying agile methods. In fact, agile development requires fast and continuous delivery, which means that applying the method component for each release is considered burdensome. Moreover, the product analyst mentions that applying CA might result with multiple combinations of features that go together. "How can we assess that the set of combination is really significant for all users?". This is specifically noteworthy as the majority within the selected sample might not be always right or answer the users' needs.

As for ease of use, the participants tend to agree that the method component is easy to use based on the procedure model presented and the illustrated scenarios. Among the challenges discussed is again the reach aspect. Although the method allows integrating the voice of a large number of users, selecting these users and potential customers is still an issue. One product manager explained that collaboration with the marketing team facilitates to establish a panel for continuous evaluation and concepts testing. We also discussed crowdsourcing platforms as a channel for obtaining a large user base for evaluating the different design options. This would increase the reach and provide input from the mass.

Finally, the experts assessed the feasibility of the method component in the software product management activities. While they were rather positive about the usefulness, collectively, they are neutral about the feasibility of the method component in both product roadmapping and release planning. The experts agree that the CA method is interesting, and they value the analysis techniques that it provides. However, the majority believes that this method requires certain experience and skills to be applied in a real context. Also further details on how it complements existing RE methods are required for a clear integration within software product management. "We already apply a mixed set of approaches to get user feedback, CA might be useful in getting additional insights about the user preferences, but we need to fully understand its techniques to be able to use it within the product management domain". For integrating CA within the software product management domain, the experts believe that the method component should be added to the knowledge base of RE in mass-markets.

Evaluation Criteria	**Score**
The method is useful for incorporating the voice of the customer	4.5
The method is useful for managing roadmaps and requirements	3.5
The method is useful for release planning	3.1
The method is easy to use	3.7
Using this method is feasible in managing roadmaps and requirements	3
Using this method is feasible in release planning	3

Table 8. Expert Assessment of the Method Component

7 Conclusion

Understanding user preferences for product features is a first step in successful design practices. Market research techniques have proven that estimating the user preference structure based on utility measures for certain product attributes can result with widely accepted product combinations that have high market shares (Green et al. 2001). Following this line of argumentation, obtaining insights on users' preferences for commercial mass-market software products contribute to successful implementation of these products. In this paper, we systematically develop a method component that leverages CA, from market research, to complement RE of mass-market software products. We demonstrate its application in the context of cloud services, and perform a practice-oriented evaluation with RE experts including software product managers and analysts.

CA allows users to evaluate product profiles simultaneously and choose the best-fit alternative corresponding to their preference model. Thus, it provides an understanding of the elements or structures widely accepted by users for product success through a data-driven approach that systematically quantifies users' preferences for understanding design tradeoffs and feature selection. Obtaining empirical data from a large set of users or potential customers is a specific advantage of this method as it helps product managers to avoid bias in design decisions through representative samples. In the two scenarios illustrated in this paper, for cloud platforms and personal cloud storage, we show how the CA method has several advantages if applied in the context of mass-market software product management. First, it could serve for concept evaluation of new service offerings. Second, it allows establishing a prioritized list of attributes each corresponding to defined system requirements agreed upon by different stakeholders. The method allows constructing utility functions of individual and group preferences deriving a decision model that reflects users' behavior, which could support product management in design refinement and requirements prioritization.

Our empirical findings suggest that CA can provide insights into most relevant features for users and their relative importance, as well as provide information on group preferences for bundling scenarios. We illustrate how willingness-to-pay and accept simulations can inform product design and pricing decisions which are independent activities in current practices, but very important in a mass-market scenario. CA also provides an opportunity for simulating design options through various techniques including competition analysis benchmarking and variation analysis. Based on that, product managers, product owners, business analysts and product analysts can study utility changes with respect to changes in product combinations or implementation options. This is of course taking into account user's concerns as well as technical dependencies and restrictions.

Based on our insights, we provide future avenues for further extensions of the method component. As first research opportunity, we suggest to develop user preference models comprising the relevant dimensions for mass-market software categories along with a rigorously developed and validated catalogue of attributes and attribute levels for different types of services. Such a preference model will complement the suggested method component and accelerate the setup of CA studies to allow the comparison of their results for different categories. It will serve as a repository for attributes reuse and consequently requirements reuse.

While this method component has several benefits if applied in the RE of mass-market software products, there are also limitations that should be taken into account when applying it. Most prominently are the complexity of the study design in terms of time and efforts. Experts have mentioned that the feasibility of the method component is dependent on the skills and knowledge of the product management team. Thus, having step-by-step guidelines for implementing the CA method are necessary in informing their application. Also, instantiations of the method component employing advanced analysis techniques can help in promoting its use. In addition, the acquisition of suitable study participants is seen as challenging due to the lack of relevant panels. Therefore, the setup of CA studies should be facilitated through the suggested crowdsourcing panels or the creation of specialized ones. Future research should focus on addressing these issues to prove the feasibility of using this method component in real scenarios. Empirical evaluation should be done for other software classes including mobile applications, to further prove the method component's usefulness in eliciting users' preferences in the mass-market settings. In addition, evaluation should extend into market simulations to fully leverage the method component for interpreting users' preferences to result with successful product designs.

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Understanding Users' Preferences for Privacy & Security Features – A Conjoint Analysis of Cloud Storage Services

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Abstract. Digital transformation has produced different applications and services for personal use. In an interconnected world, privacy and security concerns become main adoption barriers of new technologies. IT companies face an urgent need to address users' concerns when delivering convenient designs. Applying conjoint analysis (CA) from consumer research, we explore users' preferences and willingness-to-pay for privacy preserving features in personal cloud storage. Our contributions are two-fold: For research, we demonstrate the use of CA in understanding privacy tradeoffs for the design of personal ICTs. For practice, our findings can inform service designers about preferred privacy and security options for such services.

Keywords: IS design, privacy, security, preference, trade-offs, willingness-to-pay, conjoint analysis, cloud storage.

1 Introduction

With the emerging digital age, new technologies such as mobile, cloud and internet-of-things have changed the way people communicate, work, learn and live. Normal citizens are transformed into information citizens that use a plethora of applications and services consuming and producing tremendous amounts of data. In such an interconnected world, privacy and security concerns become main adoption barriers of new technologies. Based on a survey of 12,355 Internet users, 70% of users are concerned about personal data theft and unauthorized use, and 65% are worried about data security practices of companies holding personal or financial information (Statista 2015). Users are confronted with multiple ICT offerings that they need to evaluate against various performance levels, business models and security options. As a result, IT companies and service providers face an urgent need to address users' concerns when delivering convenient designs. This calls for a clear understanding of users' attitudes and preferences for their selected and accepted services.

Cloud computing has contributed to the digital transformation through its provisioning model that facilitates access to IT resources for end-users (Rimal et al. 2010). Among the widely adopted cloud services is personal cloud storage, such as Dropbox, Google Drive and SecureSafe. These services offer infrastructure resources to users for storing data with sharing privileges and access from various devices. Price and storage capacity were traditionally among the most important features to users of such services (Burda and Teuteberg 2014). However, 44% of users store sensitive data on their devices and wouldn't want anyone to access it (Statista 2015). On the other hand, highly secure cloud storage services have had difficulties in establishing sustainable business models, as underpinned by the shut down of the highly secure cloud service Wuala in 2015 (Wuala.com). This triggers questions regarding users' attitudes towards the use of secure personal cloud storage and their implications for personal cloud storage design. Accordingly, we ask: *How do users value privacy and security features in personal cloud storage services?*

In this study, we opt for the conjoint analysis (CA), a popular market research technique, to study privacy tradeoffs in the context of cloud services and perform willingness-to-pay (WTP) simulations. CA provides insights into user preferences for the formation of services that fit users' expectations (Naous and Legner 2017), and could be useful in understanding the privacy tradeoffs for designing personal ICTs (Mihale-Wilson et al. 2017). We aim for empirical insights on users' preferences of privacy and security features that allow service providers to better design or adjust their offerings to market needs. Our results are interesting for academia and practice: They inform research on personal ICTs by demonstrating that privacy and security concerns are not uniform among users. For practice, they imply that providers need to address different segments of varied preferences.

The remainder of this paper is structured as follows: We start by elaborating on personal cloud storage services and their secure design. Next, we motivate our research approach and present the essential steps in applying the CA method and WTP simulations. Then, we present key findings from the conjoint survey. We conclude with a synthesis of our findings and implications.

2 Background: Secure Design of Personal Cloud Storage

By providing IT resources as a service over the Internet (Rimal et al. 2010), cloud computing has introduced a paradigm shift from ownership to usage of IT resources. The software as a service (SaaS) cloud model was the main driver for the personal use of cloud computing. In this model, individual users are able to access and use application software through a web interface (Gashami et al. 2014). Whereas positive outcomes include lower cost, accessibility and reliability, cloud services are associated with security and privacy risks that influence individual adoption. Among the main privacy concerns for cloud users are the unauthorized secondary use of data, improper access and control of information (Gashami et al. 2014). This suggests that cloud service providers should address these concerns through providing the necessary security and privacy features that meet user expectations.

The most commonly used cloud service targeting individuals is personal cloud storage. It is accessible from various devices (i.e. PCs, smartphones and tablets) and enables users to store, archive and share information such as personal documents and media (i.e. photos and videos). The business model mostly applied for such services is the "freemium" model, where a certain level of consumption is provided for free and revenues are made based on superior features such as additional storage or increased encryption (Trenz and Huntgeburth 2014). Hence, users' privacy concerns are not addressed and cloud service providers consider additional security and privacy protection features as premiums.

To address privacy concerns of cloud users and design secure personal cloud storage, it is necessary to understand which security and privacy features these services should have. In Zhou et al. (2010), five goals for secure cloud computing applications are identified: (1) availability for use at any time and any place which entails backup; (2) confidentiality of user's data through applying necessary encryption techniques before saving it in the cloud; (3) data integrity through protection against loss and unauthorized users; (4) control through regulating the use of the system; and (5) audit through monitoring system use and access. In addition to that, Chen and Zhao (2012) highlight security and privacy protection issues in the data lifecycle due to the openness and multi-tenancy of the cloud. This involves granularity of shared data, and user authorization for the transformation of data. Also, Rai et al. (2013) discuss cloud security challenges of authentication and authorization, backup and recovery as well as encryption of data. Moreover, the issue of resource locality is emphasized since end-users of cloud services are unaware where their data is physically stored. The multi-location aspect of cloud raises additional privacy issues due to the fact that the applicable legal regulations depend on the location of the data and which country it resides in Zhou et al. (2010). This increases the importance of having data protection laws that are relevant to the cloud scenario to ensure legal compliance and impose restrictions on the use of personal data in cloud services. In addition, Cavoukian (2008) discusses the importance of a rigorous identity infrastructure (authentications) to achieve security and privacy goals in cloud service design.

Privacy Concerns	**Security and Privacy Features**	**References**
Unauthorized secondary use of data	Encryption	(Chen and Zhao 2012; Pearson 2009; Zhou et al. 2010)
	Data segregation	(Chen and Zhao 2012; Pearson 2009)
	Location of servers	(Chen and Zhao 2012; Rai et al. 2013; Zhou et al. 2010)
	Legal compliance	(Chen and Zhao 2012; Pearson 2009; Rai et al. 2013; Zhou et al. 2010)
Improper access	System audit or monitoring	(Chen and Zhao 2012; Rai et al. 2013; Zhou et al. 2010)
	Sharing	(Chen and Zhao 2012; Rai et al. 2013; Zhou et al. 2010)
	Authorization	(Chen and Zhao 2012; Pearson 2009; Zhou et al. 2010)
	Authentication	(Cavoukian 2008; Chen and Zhao 2012; Rai et al. 2013)
Control	Backup	(Chen and Zhao 2012; Rai et al. 2013; Zhou et al. 2010)
	Recovery	(Chen and Zhao 2012; Rai et al. 2013; Zhou et al. 2010)
	Availability	(Chen and Zhao 2012; Rai et al. 2013; Zhou et al. 2010)
	Accessibility	(Chen and Zhao 2012)
	User control	(Itani et al. 2009; Pearson 2009; Zhou et al. 2010)
	Feedback process	(Itani et al. 2009; Pearson 2009)

Table 1. Security and privacy features of personal cloud storage services

While most studies in the information systems (IS) field focus on explaining information privacy, few are prescribe designs or actions (Bélanger and Crossler 2011). This calls for research on the design of services that address privacy concerns and enable the protection and control of information. From our literature review, we are able to map users' privacy concerns (Gashami et al. 2014) into security and privacy features of personal cloud storage (Table 1).

3 Methodology: Conjoint Analysis

3.1 Selection of Research Approach

Conjoint analysis, from market research, allows investigating the monetary value of privacy and exploring user preferences when using online technologies through WTP. A recent literature review on CA in IS research by Naous and Legner (2017) emphasizes that CA is a very suitable method to inform IS design through an empirical analysis of user preferences. Among IS studies that use CA for privacy tradeoffs are Hann et al. (2002, 2007) that explore the cost for revealing personal information online and Krasnova et al. (2009) that also estimates the monetary value that users associate to their own information on social networks. This motivates our research, where we employ CA to explore user preferences and tradeoffs regarding privacy and security features of personal cloud storage.

CA provides insights on user preferences for different product features based on a complete product evaluation (Green and Rao 1971), which enables the estimation of a preference structure applying the utility concept. Deriving a utility function from consumer evaluations of product features (i.e. attributes and levels), CA provides evidence on the most influencing factors on the consumer's choice of a product. This method is increasingly used for investigating user preferences in the cloud domain. Koehler et al. (2010) performed choice-based CA (CBCA) on consumers' preferences for cloud services relying on rank order of product profiles, and Giessmann and Stanoevska (2012) investigated through adaptive CBCA preferences for emerging cloud platforms. Moreover, Burda and Teuteberg (2014) investigated with CBCA consumers' choice decisions for cloud archiving services. Their study reveals price and storage capacity among the most important features, confirming a commoditization assumption.

We apply Adaptive Choice-based Conjoint Analysis (ACBCA) (Green and Srinivasan 1978). In this CA variant, we ask participants to choose among a set of profiles (or stimuli) after a self-explicated task where they rate attributes to exclude unacceptable attribute levels from the evaluation to reduce the choice burden. ACBCA was selected as it has been suggested for studies of a large number of attributes, which is typically the case when we speak about the design of IS. Moreover, the approach allows estimating utilities using a small sample size with less than 100 participants (Naous and Legner 2017). Part-worth utilities and relative importance measures are calculated using the Hierarchical Bayes (HB) (Howell 2009). We use specialized commercial software, Sawtooth Software, to administer the online survey.

3.2 Data Analysis

CA provides part-worth utility estimation for product attributes and levels, which can be translated into a relative importance score for the different attributes. Based on the data provided, other analysis techniques can be applied including market simulations (Giessmann and Legner 2016). To better understand customer tradeoffs with respect to security and privacy features, we opt for users' WTP simulation. We follow the procedure suggested by Kohli and Mahajan (1991). This involves comparing the utility of a certain product configuration with the utility of a reference product. The respondent's WTP denotes the maximum price at which the product's utility is still above the reference product's utility. Only one attribute is altered at a time, and the difference in the WTP between the new configuration and the reference corresponds to the WTP for the changed attribute level. The WTP estimation model based on the conjoint data is the following:

$$u_{it|\sim p} + u_i(p) \geq u_i^* + \varepsilon. \quad (1)$$

where u_i^* corresponds to individual i's utility of the reference product, $u_{it|\sim p}$ corresponds to the part-worth utility of the non-price attributes of product t with the changed attribute level and $u_i(p)$ is the part-worth utility due to the price attribute of t. ε is an arbitrarily small positive number.

4 CA for Cloud Storage Services

4.1 Attributes & Levels Selection

The most challenging step in CA is the determination of relevant attributes and levels that would be evaluated by users. For that, we followed a mixed method approach (Naous and Legner 2017) based on three stages: (1) A literature review on cloud storage services (section 2) with a focus on security and privacy aspects. We identified an initial list of 14 attributes (Table 1). (2) A market analysis of existing services to examine the presence of attributes from literature and identify attribute levels. Our analysis included 13 products that we selected based on reviews of cloud vendors from comparison websites (e.g., cloudwards.net). The list is composed of: big market players (Google Drive, DropBox, Microsoft One Drive and Amazon Drive), secure cloud storage services (Tresorit, SpiderOak and SecureSafe), and mid-sized players (Sync, Pcloud, Carbonite, SugarSync, Elephant Drive, Box and Mozy). We identified 10 attributes with their levels based on the analysis. (3) We finally organized a focus group of 7 researchers who are experienced cloud storage users and privacy-oriented. From the discussions among participants, we identified relevant attributes and eliminated ones that less contributing to the security and privacy perceptions of the participants.

The three phases contributed to the formation of our final list of attributes and levels with 7 security and privacy features (Table 2) in addition to storage and price.

Attribute	Attribute Description	Attribute Levels (from basic to enhanced)
Accessibility	Options of devices supporting the service.	(1) Website only, (2) website and desktop application, and (3) website, desktop application and mobile
File sharing	Methods for sharing files with other parties.	(1) Link sharing, (2) link sharing with password, and (3) sharing with managed permissions
Authentication	Methods in which credentials are provided for accessing the storage service.	(1) Password only, (2) 2-steps authentication, and (3) zero-knowledge authentication (provider has no access to the unencrypted form)
Location of cloud servers	Location of the servers that the service provider deploy to store user data.	(1) Worldwide, (2) worldwide (non-US), (3) countries with high data protection and privacy standards (e.g., Switzerland, Iceland, Canada), and (4) own country
Encryption	Transformation of the customer data to cipher text using different encryption algorithms.	(1) Server-side encryption, and (2) end-to end encryption (encryption and decryption are done on the client-side with a private key)
File recovery	Data restore and recovery in case of disasters such as data loss or deletion.	(1) Not available, (2) limited to 30 days, (3) limited to 90 days, and (4) Unlimited
File Change History	File versioning and system monitoring depending on the provider's policies.	(1) Not available, (2) limited to 10 versions, and (3) full history with "Access and Activity" log
Storage space	Capacity of the file storage.	(1) 5 GB, (2) 50 GB, (3) 100 GB, (4) 500 GB, and (5) 1 TB
Price	A summed price attribute, which is set based on incremental prices for attributes obtained from a market analysis.	Varies between 0$ to 29$/month depending on the selected attribute levels

Table 2. List of attributes and levels for personal cloud storage

4.2 Study Setup

We started our online survey by introducing personal cloud storage services and asked the participants for their demographic and professional background (gender, age, country, industry sector, and income). This was followed by questions on personal cloud storage use, i.e., purpose of use, use of paid services, and types of files stored. The survey then was based on three sections in the following order:

Section 1 – Build Your Own: In this section, participants are asked to build the most preferred configuration of cloud storage services. They select among the list of levels available given a summed price to be considered when they build their product. The base price was centered on the storage space and premiums were added on enhanced security and privacy features. Based on their answers, the following sections concentrate on the product concepts that evolve around the respondent's preferred levels.

Section 2 – Screening: At this stage, respondents are asked to evaluate product profiles that were generated as possibilities for them to purchase or not. Based on our number of attributes, we presented 7 screening tasks with three options. In line with the self-explicated task in adaptive studies, respondents were asked on must-have or unacceptable features when their answers showed uniform decisions for certain attributes. Once these features were identified, they are not further displayed.

Section 3 – Choice Task Tournament: This is the final and central component of the survey where respondents evaluate product profiles and choose among them. We present a maximum of 10 choice tasks to respondents where they need to select the most convenient service among three options for estimation of preferences.

4.3 Study Sample

In line with Pu and Grossklags (2015), we selected Amazon's Mechanical Turk (MTurk), an online crowdsourcing platform, as a channel to hire participants of cloud storage users. MTurk is widely used in behavioral studies since it provides a fast, inexpensive and convenient sampling method and is appropriate for generalizing studies (Jia et al. 2017). It is a suitable platform for our study as it allows us to obtain a diversified sample. Aiming for high quality of responses, we restricted the participation in the survey to current cloud storage service users. We used a qualification test to eliminate non-users and also prevented multiple participation of one respondent by controlling MTurk IDs. We compensated 1.50$ per response, which is an average price for a 10 minutes survey similar to ours. As MTurk participant's attention span might drop during complex tasks or bots might be used (Downs et al. 2010), we excluded responses that took less than 5 minutes.

5 Results

5.1 Sample Background

We received a total of 188 responses from which 144 were included in the analysis. Among the respondents, 57.64% are males and 42.36% females. The majority was between 25 and 45 years old (77.08%). Most respondents are from the US (76.39%). They came from different industries among them IT (18.75%), education (14.58%), manufacturing (11.81%) and healthcare (11.11%). In terms of income, 23.61% have low income, 71.53% average, and only 4.86% have high income.

As for their actual use of cloud storage services, 81.94% use free plans. The main use purposes were storing files (93.75%), sharing (72.92%) and collaboration (33.33%). They mainly store .pdf files (77.08%), official documents (45.14%) e.g., IDs and contracts, editable files (65.28%) for collaboration, and media (86.11%).

5.2 User Preferences for Personal Cloud Storage Services

In the "build your own" section, respondents were able to build their concepts by selecting preferred options simulating a real purchase scenario. They were presented a summed price, where additional storage or security and privacy features required incremental prices. They mainly selected basic features, which was reflected in the users' preferences (Table 3). However, there was a major agreement on unlimited recovery (88.89%). Also for accessibility, majority (72.22%) require the presence of different channels. This is expected from the screening section, where the full accessibility was seen as a must-have (7.64%) and no recovery was unacceptable (19.44%).

Through an HB estimation, we were able to derive part-worth utilities for the attribute levels of personal cloud storage services (Table 3). The part-worth utilities are normalized HB, where positive utlities correspond to prefered levels and negative utilities correspond to less desired levels. As suggested by Giessmann and Stanoevska (2012), we assess the "goodness of fit" using percentage certainty (PC) and root likelihood (RLH). The data show PC mean of 0.482, indicating acceptable results of fit. RLH valued 0.646, which is considered more fit than the chance level given we have three choice tasks.

Based on the part-worth utilities, ACBCA provides relative importance measures of attributes (Figure 1). The results show price (28%) as the most important attribute for users of personal cloud storage, thereby underlining price-sensitivity. This is followed by storage space (21%) as the main functionality of the service. In terms of security and privacy features, recovery ranked third with an importance of 10%, which can be related to the data loss concern of personal cloud storage users. Location of servers and access followed (8%). Then, change history and authentication (7%). Less importance was given to file sharing (6%) and encryption (5%).

Attribute	Attribute levels	Average Utilities	Standard Deviation	Distribution for BYO Section (%)
Storage Space	5 GB	-6.87	104.60	35.42
	50 GB	24.74	64.91	31.94
	100 GB	5.48	27.98	14.58
	500 GB	-5.25	60.89	9.03
	1 TB	-18.10	91.49	9.03
Accessibility	Website only	-30.90	23.43	13.19
	Website and desktop	0.89	19.95	14.58

	Website, desktop and mobile	30.01	32.03	72.22
File Sharing	Sharing link	2.12	28.99	51.39
	Sharing link with password	2.59	17.39	24.31
	Sharing with managed permissions	-4.70	28.16	24.31
Authentication	Password only	10.12	36.93	57.64
	2-step authentication	3.86	28.84	32.64
	Zero-knowledge authentication	-13.98	27.15	9.72
Location of servers	Own country	-8.00	36.37	27.78
	Countries with high privacy standards	3.93	26.16	15.97
	Worldwide (non-US)	-12.19	18.39	4.17
	Worldwide	16.26	36.68	52.08
Encryption	Server-side	4.20	25.07	63.19
	End-to-end encryption	-4.20	25.07	36.81
Recovery	Not available	-28.93	27.49	1.39
	Limited to 30 days	-7.95	21.18	6.25
	Limited to 90 days	-8.12	24.60	3.47
	Unlimited	45.00	39.18	88.89
File Change History	Full history with log	13.58	36.88	40.97
	Limited to10 versions	-3.21	16.73	16.67
	Not available	-10.36	35.82	42.36
Price	0 $	79.27	123.88	-
	29 $	-79.27	123.88	-

Table 3. User preferences and part-worth utilities of personal cloud storage attribute levels

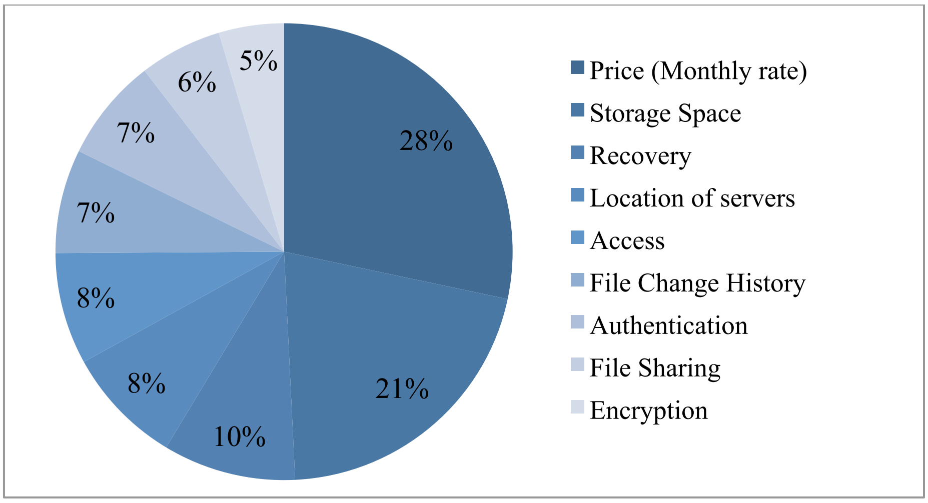

Figure 1. Relative importance of personal cloud storage attributes

5.3 Customer Segments

CA allows for determining customer segments based on individual part-worth utilities. The segmentation could be based on demographic and professional background information, which proved to be insignificant in our case. It could also be achieved through clustering analysis. Using k-means, we optimally find three customer segments of contrasting preferences towards information privacy concerns (Table 4).

All three clusters expose similar preferences for accessibility and recovery attributes, but differ with regards to other attributes. The first customer segment consists of 38 users that prefer basic privacy and security features with least storage options; they are the "unconcerned users". Surprisingly, these users have positive utility for higher prices, which means they are generally insensitive to price. The second segment is the largest with 77 users; they are the "privacy-rights advocates". These users prefer enhanced privacy and security features but with a positive utility for low prices. They require secure personal cloud storage services and believe privacy is a right without the need to pay for it. Finally, the third customer segment consists of 29 users; they are the "privacy-concerned users". This segment requires enhanced security and privacy options but have a positive utility for higher prices, which means they are aware of the cost of their privacy and the need of additional requirements to achieve that.

	Cluster 1	**Cluster 2**	**Cluster 3**
Number of participants	38 (26.39%)	77 (53.47%)	29 (20.14%)
Privacy characterization	Unconcerned users	Privacy-rights advocates	Privacy-concerned users
Preferences			
Storage Space	5 GB – 50 GB	100 GB – 500 GB	500 GB – 1 TB
Accessibility	Website, desktop application and mobile	Website, desktop application and mobile	Website, desktop application and mobile
File Sharing	Sharing link	Sharing link with password	Sharing with permissions
Authentication	Password only	2-step authentication	2-step authentication
Location of servers	Worldwide	Own country or Countries with high privacy standards	Countries with high privacy standards or Worldwide
Encryption	Server-side encryption	End-to-end encryption	End-to-end encryption
Recovery	Unlimited	Unlimited	Unlimited
File Change History	Not available	Full history	Full history
Price	High	Low	High

Table 4. Identified clusters with preferences based on customer segmentation

5.4 Willingness-to-Pay

To understand price-sensitivity for security and privacy features, we perform market simulation using Sawtooth Software to study WTP. Our study uses a reference product that is a status quo in the market and widely adopted by users. It corresponds to 100GB storage with basic security and privacy features except for recovery, access and file change history for 2$. The WTP estimation involves calculating the utility of various price points for the compared product. Our ACBCA provides utilities estimation of summed prices from 0$ to 29$, the utilities of additional price points are estimated using linear interpolation (Kohli and Mahajan 1991). The change in utility from the reference product and a compared product with varied attribute level was reported as ΔWTP. A negative change was observed for all security and privacy attribute levels, thus negative WTP. However, this varies among different attributes. A difference of 2.00$ (in Table 5) implies zero WTP for the product configuration with the new changed level, which was the case for most levels. File sharing was among the attributes that users are willing to pay for with less than 2$: 1.80$ for the password option and 1$ for managed permissions, even if it is more secure. Similarly, users are willing to pay 1$ for the same configuration but with 2-steps authentication and no WTP for the zero-knowledge option. Results also show difference of 1.70$ for the secure location of servers in countries with high data protection and privacy standards. Moreover, end-to-end encryption is worth 1$ only. No compromise was given for recovery; all levels resulted with 0 WTP. As for file change history, users were willing to pay less amount (0.50$) for limited versioning capabilities.

Attribute	Base Level	Changed Attribute Level	ΔWTP ($)
Accessibility	Website, desktop and mobile	Website and desktop	-2.00
		Website, desktop and mobile	-2.00
File Sharing	Sharing link	Sharing link with password	-0.20
		Sharing with managed permissions	-1.00
Authentication	Password only	2-step authentication	-1.00
		Zero-knowledge authentication	-2.00
Location of servers	Worldwide	Own country	-2.00
		Countries with high privacy standards	-1.70
		Worldwide (non-US)	-2.00
Encryption	Server-side	End-to-end encryption	-1.00
Recovery	Unlimited	Limited to 90 days	-2.00
		Limited to 30 days	-2.00
		Not available	-2.00
File Change History	Full history with "Access & Activity" log	Limited to 10 versions	-1.50
		Unavailable	-2.00

Table 5. Willingness-to-pay for changing attribute levels (monthly rate)

6 Discussion & Implications

In this paper, we employ ACBCA to study preference measures for privacy and security features in personal cloud storage. Thus understanding privacy tradeoffs of users and informing design of these services. Our overall results comply with the assumption of commoditized personal cloud storage services (Burda and Teuteberg 2014), where price and storage space are most important to users. For privacy and security measures, we have seen that recovery comes first. There is a consensus on its significance as an essential security aspect in cloud. Interestingly, location of servers is not of a concern for cloud users although there is a huge debate on the importance of data protection laws and regulations. Moreover, secure authentication and sharing as less critical features raises questions on the complexity of the security mechanisms that users are willing to adopt. Finally, having encryption as the least important attribute with preference towards server-side encryption shows that users are not aware of the data confidentiality issues in the cloud and secondary use of information. It can also indicate that users are not willing to do efforts for securing their data with private keys.

In line with the relative importance of attributes, our WTP simulation shows that users are unwilling to pay for additional security and privacy protection features. The freemium model of personal cloud storage provides basic functions that users take advantage of for free. Thus, users' satisfaction with basic configurations might influence their WTP for additional features (Trenz and Huntgeburth 2014). We also find that among the security and privacy attributes, the participants valued most the enhanced sharing option with password where they would pay a comparable price (1.80$) to the status quo product. This might be driven by the sensitivity of the data stored and users' concerns of improper access and unauthorized use (Gashami et al. 2014). Moreover, having no WTP for "zero-knowledge" products explains the difficulties for security-driven vendors to survive.

All these aspects could also be related to the fact that our sample is not necessarily privacy concerned. The risk factors associated to personal cloud storage services are influenced by how trustworthy is the service vendor (Li and Chang 2012). In Ermakova et al. (2014), the authors explain that establishing a trust relationship with cloud providers can mitigate information privacy concerns. The users in this study might have low risk perceptions of the use of cloud storage service based on their current experiences. Another explanation to these results can be established by the privacy paradox phenomenon (Pavlou 2011). Accordingly, individuals expressing privacy concerns can still behave contradictory to it based on their assessment of the cost and benefit for information privacy.

However, our segmentation shows that there are no uniform preferences among cloud storage users. We identified three user segments with different preference structures. The first segment represents traditional users of basic personal cloud storage services who do not have specific privacy concerns. However, their positive price part-worth utility characterizes them as price insensitive. These users target other premiums than privacy and security (e.g., storage). The second segment represents a majority of users who are concerned about privacy and security, but would not pay for it. These customers believe privacy is a right and services should be designed accordingly. The last segment represents customers who seek security features and are willing to pay for them. Their attitude can be explained based on the privacy calculus (Dinev and Hart 2006); they estimate a cost for their benefit of reduced privacy risks when their service is secure and privacy protective enough.

Our findings have implications for both research and practice. For research, we demonstrate a method for understanding user tradeoffs for privacy and security aspects to inform the design of personal ICTs. CA has been applied in previous research for estimating privacy tradeoffs in monetary value, but is not fully exploited for secure design studies. We suggest adopting market research techniques, specifically CA, as an approach for understanding user preferences in mass-market scenarios. CA techniques can be leveraged to study preferences based on utility functions, perform segmentation and run market simulations. Our empirical results show that there are no uniform preferences among personal cloud storage users. This should be further investigated in future research that can thoroughly study the identified segments' characteristics. In addition, other CA studies can be performed to assess the users' privacy concerns in different sample populations and their willingness-to-pay for secure options. Our sample is majorly from the US, which is a limitation to this study. An opportunity for research would be to apply similar CA studies to a wider sample from different backgrounds, especially with the current general data protection regulation in the European Union, for better generalizability of results.

For practice, the segmentation presented in this paper could be very useful in future development of cloud storage services or refinement of existing ones. Service providers should keep in mind users' privacy concerns and their WTP for privacy and security features to be able to deliver offerings that meet users' needs. Our results with multiple segments imply that service providers should build product bundles that take into consideration the different user preferences. Whereas the freemium model based on storage capacity can be interesting to some users, privacy-rights advocates and concerned users have other requirements. From our sample, we observe that most users underestimate the risks of privacy invasion, which should not be exploited by service providers. Users should have a better understanding of the security features provided by cloud services before deciding on its use; this is a starting point and should be treated by service providers when marketing their offerings. Concerned users should have the option to control their privacy settings at low cost.

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Information Disclosure in Location-based Services: An Extended Privacy Calculus Model

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Abstract. In today's interconnected world, disclosing information on location-based services (LBS) has several privacy implications. In line with the general privacy studies, the rationale behind individual's disclosure motivations has been studied in information systems (IS) through the lens of privacy calculus. However, existing work investigates location-information sharing as uni-dimensional user behavior under highly contextual settings. In this study, we propose an extended privacy calculus model that views location disclosure across three dimensions; (1) extent, (2) location sensitivity and (3) sharing parties. We also introduce amendments to account for data privacy regulations, data streaming economy and interdependent privacy risks. We thus provide a more nuanced conceptualization of location disclosure along with empirical insights from a large-scale empirical study (n=1050). We find that: (1) there is a need for transparent control settings, (2) users are willing to disclose for monetary incentives, and (3) they are not cognizant about interdependent privacy risks.

Keywords: Location-information disclosure, privacy calculus, location-based services, disclosure behavior, privacy, interdependent privacy, data stream economy.

1 Introduction

The proliferation of mobile devices equipped with positioning technologies such as GPS, WiFi and cellular connections has resulted in a widespread adoption of location-based services (LBS). These services span several domains ranging from navigation, ride sharing, advertising, recommender systems and social networks (including tagging options and nearby events). The advancement of artificial intelligence (AI) and the ability to micro-target people enhances LBS and has reinforced interest from the advertising industry, security agencies and government organizations. However, as location data acts as a bridge of user's offline and online lives, sharing it with service providers and third parties involves privacy implications (Krumm 2007). More specifically, location data can serve as a diagnostic representation of sensitive demographic attributes such as religious or political affiliation and possible health concerns (Gambs et al. 2011).

Accounting for this sensitive nature and the volume of the location traces aggregated by the service providers, it is important to understand user's intentions to share location data in order to understand LBS adoption and improve their design. The current privacy studies evaluate the rationale behind sharing location data from the lens of privacy calculus, which treats individual self-data disclosure as a result of a tradeoff analysis between expected benefits and perceived privacy risks (Dinev and Hart 2006). Privacy calculus and its extensions have been studied broadly in the context of e-commerce and social networking (Heravi et al. 2017; Krasnova et al. 2010). They have also been used to investigate location-information disclosure in the context of emergency services, personalized advertising and social networks, using exchange theory (Xu et al. 2009), justice theory (Zhao et al. 2012), and self-determination theory (Sun et al. 2015). However, these studies consider location-information disclosure as a single dimensional construct, thus not taking into account the nature and extent of the information shared and the context of disclosure.

In addition, in light of recent technological and regulatory developments, a major domain of privacy risks not accounted for by the current models are extrinsic privacy risks associated to interdependent privacy (Olteanu et al. 2017; Wirth et al. 2019). These risks either stem from the explicit actions of a service user (for instance, location check-ins and photo/video tags) or from the service provider's data collection on non-platform users. For instance, Facebook's Shadow profiles (Field 2018) are built independently of a legitimate registered profile, via co-located information collected from platform users and third parties. The EU General Data Protection

Regulation (GDPR) has acknowledged the criticality of location-information as *personally identifiable* by making it part of its definition of ”personal data”. While data protection regulations may reduce the risks in sharing location data with trusted parties, a bulk of location data is also collected through dark patterns (Brignull 2019). Dark patterns are used for permission settings and consent acquisition, but deceive users in signing up for terms and conditions they did not intend to. Furthermore, recent technology advances, and specifically blockchain, are removing intermediaries to directly monetize location data streams by establishing a direct link with the data brokers (e.g., *streamr.com*). The ”Data Stream Economy” will tokenize streaming data to enable a new way for people to trade it and get remunerated on a decentralized peer-to-peer network. It thereby creates new incentives for location-information disclosure.

Based on these considerations, we argue that the privacy calculus model necessitates amendments and ask the following research question (RQ): *How can the privacy-calculus model for location-information disclosure be revisited in light of (1) co-located/interdependent data, (2) increased privacy controls due to government regulations, and (3) monetary incentives for location sharing?*

In this paper, we propose an extended privacy calculus model (Dinev and Hart 2006) and represent location-information disclosure as multi-dimensional construct, accounting for the extent of location sharing, sensitivity and the sharing parties. We test our research model on empirical data collected from more than 1000 respondents in Germany and the US. Based on our empirical results, we observe that LBS users are not cognizant of extrinsic privacy risks and privacy control settings when it comes to disclosing location-information, but that the benefits associated with LBS play a crucial role in their disclosure decisions. From an academic perspective, our research contributes to a nuanced conceptualization of location-information disclosure. From a practical perspective, our results are relevant for LBS application developers, service providers and regulatory bodies. Understanding the multi-dimensional nature of location-information disclosure will assist LBS developers and providers to address privacy by design principle and regulatory bodies to operationalize new privacy regulations while actually enforcing them.

The remainder of this paper is structured as follows: We first discuss prior research related to the privacy calculus and its application in the context of LBS. Next, we present our research model and extensions to the privacy calculus. Then, we explain the empirical study followed by the data analysis and hypothesis validation. Finally, we discuss the findings and provide an outlook on future research.

2 Prior Research

2.1 Privacy Calculus and Information Disclosure

Among the most frequently used definitions of privacy is that of Westin (1967) who defines privacy as ”the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others”. Information systems (IS) research has extensively studied information privacy (Pavlou 2011). Xu et al. (2011) identify four approaches on information privacy from multiple domains: privacy as a human right, privacy as a commodity, privacy as a state of limited access, and privacy as the control of information. Based on the approach of information privacy as a commodity, privacy is considered as a tradable good or asset (Spiekermann et al. 2015). Thus, it has an economic value that could be estimated via cost-benefit tradeoff calculations. Accordingly, the privacy calculus paradigm (Dinev and Hart 2006) is used in IS studies to explain the dynamics underlying user participation or sharing, in the light of privacy concerns. It extends the cost-benefit paradigm to privacy contexts where an individual assesses privacy risks (costs) against potential benefits.

The exchange theory (Houston and Gassenheimer 1987) provides theoretical underpinnings for the privacy calculus by explaining how individuals make decisions regarding personal information disclosure (Xu et al. 2009). It categorizes different types of exchanges based on an expected outcome. This exchange can be described as ”symbolic” or ”hedonic” when personal information is given in return for value such as quality of service or personalized offers. It can be described as ”utilitarian” if goods are given in return for money or other goods (Bagozzi 1975), which relates to the case of data monetization. In addition, the justice perspective is suggested as a theoretical lens to study individual privacy calculus (Sun et al. 2014). In fact, individuals evaluate the cost-benefit tradeoff taking into consideration an optimization problem where information disclosure is linked to how benefits are comparable to costs. In that sense, their view of fairness and transparency of information treatment from the service provider affects their trust, which can then control their disclosure behavior.

2.2 Location-information Disclosure

LBS require users to share their locations to achieve certain goals such as finding nearby locations, navigation and social networking. Location-information sharing is thus a form of self-disclosure where users communicate their location to the LBS providers and possibly to other service members. The evolution of LBS allows an open access to personal data derived from location-information provided by users, which raises information privacy concerns (Krumm 2007). Moreover, with the advanced technologies including mobile, internet of things, and analytics, data can be easily collected, analyzed and used by different entities. In line with the general privacy studies, prior research on location-information disclosure mainly employs the privacy calculus and supporting theories to study the risk-benefit tradeoff. Among these studies, Xu et al. (2009) develop a framework to link three privacy assurance mechanisms with location-information disclosure: technology control, industry self-regulation, and government legislation. They studied the effects of these mechanisms in context-specific scenarios with two types of LBS applications including safety and advertising, as well as location-based social networks. Similarly, Sun et al. (2014, 2015) study location-information disclosure on social networks taking into account the benefit structure ruling this disclosure as well as gender differences. Other privacy calculus based contributions, including Keith et al. (2013), study practical information disclosure based on realistic risk perceptions. They propose a pragmatic experimental methodology to capture true perceptions of privacy risk on information disclosure decisions. Table 1 provides an overview of prior studies on location-information disclosure in LBS along with the theories supporting their research models and the variables that have been studied. We also include a study from online social networks (Krasnova et al. 2010) due to its relevance in the context of location-based social networks.

Authors	**Context**	**Theoretical Lens**	**Independent Variable**	**Dependent Variable**
(Xu et al. 2009)	Location-based services	• Justice Theory • Exchange Theory • Privacy Calculus	• Compensation • Industry self regulation • Government regulation	• Privacy benefits • Privacy risks • Intention to disclose
(Krasnova et al. 2010)	Online social networks	• Privacy Calculus	• Perceived Control • Convenience • Relationship building • Self presentation • Enjoyment	• Trust in other members • Trust in provider • Perceived privacy risk • Self disclosure
(Zhao et al. 2012)	Location-based social networks	• Justice Theory • Privacy Calculus	• Incentives provision • Interaction promotion • Privacy control • Privacy policy • Awareness of legislation • Previous privacy invasions • Personal innovativeness	• Extrinsic benefits • Intrinsic benefits • Privacy concerns • Intention to disclose
(Keith et al.	Location-based	• Privacy Calculus	• Privacy risk awareness	• Perceived privacy

2013)	applications		• Privacy concern • Perceived benefits • Employment	risks • Intention to disclose • Actual disclosure
(Sun et al. 2014)	Location-based social networks	• Justice Theory • Privacy Calculus	• Perceived benefits • Privacy risks	• Perceived justice • Intention to disclose
(Sun et al. 2015)	Location-based social networks	• Justice Theory • Self-Determination Theory • Social Role Theory • Privacy Calculus	• Utilitarian benefits • Hedonic benefits • Privacy risks • Perceived ease of use • Services	• Perceived benefits • Intention to disclose

Table 1. Prior studies of location-information disclosure on LBS applications and social networks

2.3 Research Gap

Previous studies on location-information build on the privacy calculus and use the theoretical lenses of economic exchange and social justice theories to investigate location-information disclosure behavior on LBS. Location-information disclosure has been studied previously under a highly contextual setting either with respect to LBS applications (Xu et al. 2009) or social networks (Zhao et al. 2012). However, we argue that such a distinction is not a suitable basis for understanding the user's perception towards location-information disclosure on the account of the unclear boundaries between the two. For example, Foursquare which started out as a local search-and-discovery service transitioned into Swarm App which allows users to share their locations with friends (Lee 2015). Other platforms also allow seamless delivery of services on social network platforms such as location-based event notifications on Facebook (Williams 2015). Since the boundaries between LBS applications and social networks are blurring, we need to get a wider perspective on location-information disclosure.

The existing studies examine disclosure in terms of intentions or actual behavior, but always in a single-dimensional form and based on a simplistic conceptualization of the dependent variable. They do not take into account recent developments like interdependent privacy, and privacy-control settings, which are an essential measure for achieving information privacy and promoted by recent regulations, such as EU GDPR. We therefore lack a more nuanced and realistic understanding of location-information disclosure behavior where users take disclosure decisions depending on the nature and extent of the information shared and the context in which it is disclosed.

3 Research Model

Based on the prior research, we amend the traditional privacy calculus model that studies risk-benefit tradeoffs, to reflect the reality. We study location-information disclosure in a general context and utilization framework involving the different types of LBS, thereby reflecting the convergence of location-based applications and social networks. We represent location-information disclosure as multi-dimensional construct to reflect actual user location sharing behavior. We also introduce three amendments which exert distinct effects on the location-information disclosure behavior: (1) extrinsic (interdependent) privacy risks, (2) regulations and privacy control settings, and (3) data stream economy. All the constructs of our research model, the indicators and their acronyms are presented in Figure 1.

3.1 Location-Information Disclosure

In this paper, we build on self-disclosure in terms of location-information disclosure. In contrast to prior studies, that consider location-information sharing as uniform user behavior, we suggest considering three relevant dimensions: (1) extent, (2) sensitivity, and (3) sharing parties. Extent is measured through "how much" location-information is disclosed, which is defined as information breadth (Wheeless and Grotz 1976). We study continuous disclosure, which requires uninterrupted tracking of user location or trajectory tracing (normally via uninterrupted GPS access). Location sensitivity is measured through "what" type of location-information is disclosed by a user, corresponding to the depth or intimacy of information (Wheeless and Grotz 1976). In fact, many studies in the technical sphere highlight the necessity to keep user location-information private. It has been shown that sensitive user location traces can reveal sensitive personally identifiable information to location-based services such as financial status, political and religious affiliation using simple heuristics (Gambs et al. 2011). Finally, an important aspect relates to sharing parties, that is "to whom" the information is disclosed contributing to the information depth aspect. This involves sharing locations with service providers via direct application usage, which can also entail indirect sharing with service members or users that belong to the platform community, as it is the case for social networks for example. It can also include third parties through proxy services.

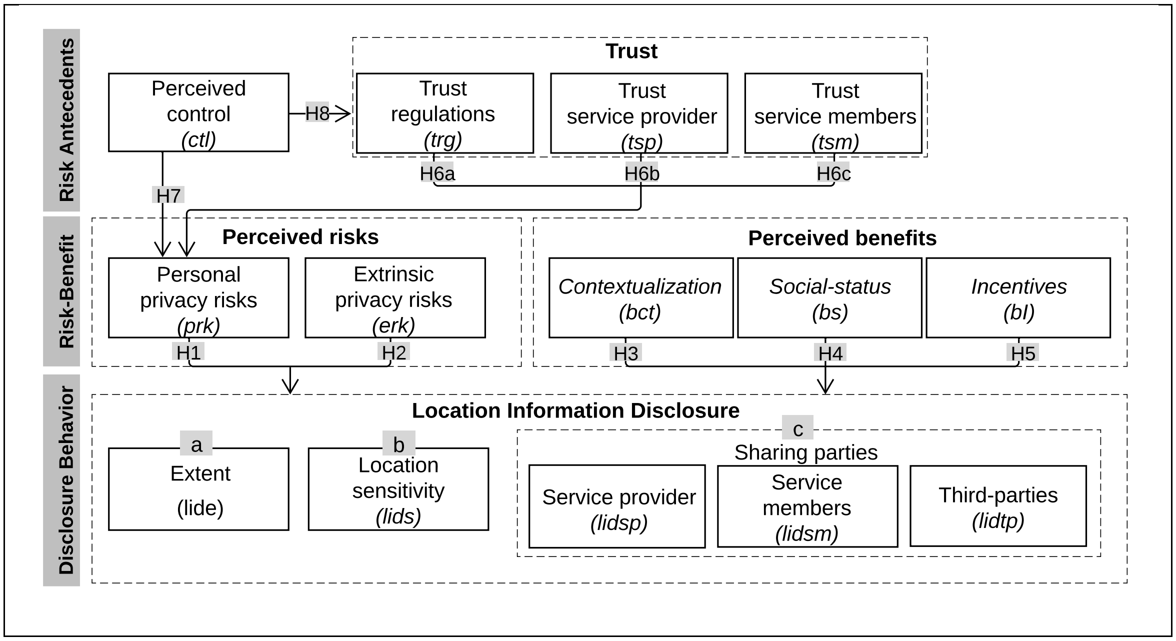

Figure 1. Multi-dimensional location-information disclosure privacy calculus model

3.2 Perceived Privacy Risks

3.2.1 Personal Privacy Risks

Previous studies in IS typically use privacy concerns or perceived privacy risks to evaluate the cost dimension when employing a privacy calculus model (Dinev and Hart 2006). In order to understand an individual's *privacy concerns*, Smith et al. (1996) suggest the so-called Concerns for Information Privacy (CFIP) that consists of four dimensions including the collection of private information by vendors, unauthorized secondary use of the data, improper access, and errors. In their Internet User's Information Privacy Concerns (IUIPC) framework, Malhotra et al. (2004) adapt the CFIP framework to online use and add control over personal data as another dimension of privacy concerns. Location-information can be considered as sensitive to users who are worried about the privacy risks associated to their sharing or disclosure behavior (Sun et al., 2014). In fact, research showed that location-information could be used to uncover users' identities, classify consumers and track their behavior based on their mobility patterns (Xu et al. 2009). As a result, the concerns here become more related to privacy invasion rather than the access itself. Similarly, the *perceived privacy risks* construct is defined as an individual's perception of privacy loss and invasion, as a result of information disclosure.

Both privacy concerns and perceived privacy risks are believed to negatively affect disclosure behavior. While privacy concerns has been treated as a multi-dimensional construct based on the previously developed frameworks, privacy risks have been treated as uni-dimensional construct related to the loss of privacy. Malhotra et al. (2004) explain that privacy concerns can be described as antecedents to risk beliefs, reflecting users expectation of losses due to information disclosure. In our study, we select the perceived personal privacy risks as a uni-dimensional construct used to measure potential privacy loss associated to location-information disclosure.

H1: Perceived personal privacy risks are negatively correlated to:
(a) the extent of location-information disclosure on LBS.
(b) the sensitivity of location-information disclosed on LBS.
(c) sharing parties (specifically service providers) for location-information disclosure on LBS.

3.2.2 Extrinsic Privacy Risks

With the introduction of location-context in social networks, users not only share their personal location-information, but also disclose information about their friends and family in their network. Interdependent location disclosure leads to revealing colocation-information of others and hence compromising their privacy, but remains an understudied phenomenon. Morlok (2016) shows that concerns for extrinsic privacy, negatively affect an individual's intentions to disclose information about others. Along similar lines, we believe perceived extrinsic privacy risks as reflections of privacy concerns, negatively affect the disclosure behavior of individuals.

H2: Perceived extrinsic privacy risks are negatively correlated to:
(a) the extent of location-information disclosure on LBS.
(b) the sensitivity of location-information disclosed on LBS.
(c) sharing parties for location-information disclosure on LBS.

3.3 Perceived Benefits

Most studies on information disclosure have highlighted the importance of symbolic or hedonic benefits when it comes to cost-benefit tradeoffs. When studying hedonic benefits, prior research has focused on personalization (Sun et al. 2015) and enjoyment (Krasnova et al. 2010). Prior research (Xu et al. 2009) has identified three values for using LBS (time-dependent, position-dependent and user-dependent) resulting with two highly correlated anticipated benefits: (1) locatability, the ability to access needed information in context at the right time and in the right place, and (2) personalization, obtaining targeted recommendations and getting relevant content depending on the user's context. We thus conceptualize a perceived benefit of contextualization as a second-order construct comprising these two first-order dimensions, which is positively related to location-information sharing on LBS.

H3: Perceived benefit of contextualization is positively correlated to:
(a) the extent of location-information disclosure on LBS.
(b) the sensitivity of location-information disclosed on LBS.
(c) sharing parties (specifically service providers) for location-information disclosure on LBS.

Additional hedonic benefit adopted from social networks, as they increasingly rely on location-context today, is social status (Krasnova et al. 2010). It is mostly associated with the enjoyment factor in which users disclose their location-information to reflect a specific social image through associating with certain places or influential people. The perceived benefit of social status should be positively affect location-information disclosure on LBS.

H4: Perceived benefit of social status is positively correlated to:
(a) the extent of location-information disclosure on LBS.
(b) the sensitivity of location-information disclosure on LBS.
(c) sharing parties (specifically service members) for location-information disclosure on LBS.

Nevertheless, location-information disclosure behavior can be associated with both hedonic and utilitarian benefits. Xu et al. (2009) have shown that utilitarian benefits can play a major role in the disclosure behavior of location-information. Using the justice theory lens, they argue that distributive justice is based on the perceived fairness of outcomes from providing information. They also predict the influence of material outcome exchange (i.e., financial compensation) on information disclosure behavior. This would be an important driver for location sharing in the emerging data stream economy that monetizes users for the data they share via the introduction of crypto-currencies (streamr.com). We hypothesize that incentives, in the form of insurance premiums, discounts or monetary rewards can positively affect location-information disclosure and even outweigh risk perceptions.

H5: Perceived benefit of monetary incentives is positively correlated to:
(a) the extent of location-information disclosure on LBS.
(b) the sensitivity of location-information disclosure on LBS.
(c) sharing parties (specifically third parties) for location-information disclosure on LBS.

3.4 Personal Risk Antecedents

In our research model, *perceived personal privacy risk* is considered as a latent variable that can be moderated via two main additional constructs: trust and privacy-control settings. We study the effects of these two factors on the risk perceptions of individuals for disclosing location-information on LBS.

3.4.1 Perceived Trust

The trust construct is multi-dimensional and context-dependent (Krasnova et al. 2010). We build on Dinev and Hart (2006)'s definition of trust as an individual's belief that a counter-party involved in an interaction has characteristics that prevent them from opportunistic behavior. In our study, we identify three parties engaged in the usage context of LBS: government (based on their regulations), service providers (based on their treatment of data), and service members (based on their behavior on LBS).

Trust in government regulations

Legislative and regulatory efforts for implementing objective information practices have an impact on individual disclosure behavior (Yang et al. 2018). In fact, the effectiveness of regulations in controlling the outcome of data access and collection by service providers can influence an individual's privacy concerns and therefore the risk perceptions and sense of security (Xu et al. 2011). Additionally, data protection regulations, such as the EU GDPR, require consent to personal information processing and considerably affect information sharing (Yang et al. 2018). As a result, users can be comfortable in sharing their information if regulatory systems promote a safe environment in which service providers have limitations and constraints in exploiting users' personal information. This privacy assurance role implemented through government regulations can be reflected as justice perceptions that enable disclosure.

Applying justice theory, Xu et al. (2009) refer to procedural justice as an explanation for the perceived fairness of procedures regarding the collection and use of data. Their model portrayed government regulations as mitigation to perceived privacy risks by ensuring respectful treatment of personal information. We argue that trust in regulations reduces risk perceptions for sharing location-information.

H6a: Trust in regulations is negatively correlated to perceived personal privacy risks on LBS.

Trust in service providers

Privacy concerns, as antecedents to risk beliefs, are mainly described in terms of the collection of personal information by vendors (Smith et al. 1996). Its four dimensions are highly reliant on the way the service provider deals with the information disclosed via its service. As such, the individual risk perceptions are correlated with the image reflected by the service provider on data treatment and the transparency of the underlying intended use of information collected. In line with Krasnova et al. (2010), we argue that user's perception of the service provider's benevolence and integrity affects the choice of disclosure on a certain LBS. Based on the trustworthiness, honesty and transparency of service providers, users will have lower risk perceptions related to information disclosure on the service provider's application or platform.

H6b: Trust in service providers is negatively correlated to perceived personal privacy risks on LBS.

Trust in service members

Given the nature of existing LBS, interactions are not only individual but also involve other service users and members such as in location-based social networks (e.g., Facebook, Instagram, etc.). In this case, previous literature has shown that privacy risk perception is not only associated with the service provider's information misuse, but also with other users' behavior (Sun et al. 2014; Zhao et al. 2012). Krasnova et al. (2010) highlight that social network users can engage in privacy violations, which lead to exposure and privacy loss for other users. In the context of LBS, Tinder users were able to correctly estimate the home locations of other members of the application without their knowledge (Veytsman 2014). Accordingly, we can consider trust in service members as an important factor when discussing disclosure behavior on LBS.

H6c: Trust in service members is negatively correlated to perceived personal privacy risks on LBS.

3.4.2 Privacy-Control Settings

Privacy-control settings are an essential measure for achieving information privacy (Malhotra et al. 2004). People feel more comfortable in using an application if they have the option of allowing data sharing or the choice to opt-out. This is normally achieved through effective and transparent privacy policies and regulations (Betzing et al. 2019) that enforce governance on users' information and describe how service providers and third parties can use this information. Thus, lowering the privacy concerns by users (Zhao et al. 2012). Practically, mobile users should be able to limit the amount of location-information collected by service providers through privacy control mechanisms that support notice, consent, proximity and locality (Anuket 2003). They have the ability to turn on/off their GPS, specify which applications have access to their location and are also able to specify the granularity of location or the audience for their sharing. However, prior research has shown that privacy-control settings are seen as insufficient by users, due to lack of granularity, or are seen as very complex (Krasnova et al. 2010).

For LBS, control was studied as self-controlling mechanisms construct by Xu et al. (2009) that diminish the perception of privacy risk. The authors show the importance of privacy assurance through privacy- enhancing technologies (PET) for users to exercise personal control over their information disclosure on LBS. Their research emphasizes, how PET results with greater consumer justice perception by limiting the information disclosed to the LBS providers and thereby reduce the privacy risk perceptions (Culnan and Bies 2003). Moreover, in the online social networks context, Krasnova et al. (2010) studied the role of control through granular privacy settings in empowering users and enabling them to limit access to their profile. Their results show a strongly significant negative correlation between perceived control and perceived privacy risks. Moreover, their study reveals how perceived control can have a positive effect on the trust in service members and users. Our model follows similar assumptions, adding into that the government regulations. We believe that the implementation of effective privacy-control settings is linked to the privacy policies legislated by the government.

H7: Privacy-control settings are negatively correlated to perceived personal privacy risks on LBS.
H8a: Privacy-control settings are positively correlated to the trust in government regulations.
H8b: Privacy-control settings are positively correlated to the trust in service providers.
H8c: Privacy-control settings are positively correlated to the trust in service members.

3.5 Control Variables

In addition to demographic factors that have been studied in previous research on information disclosure (Sun et al. 2015), prior research has investigated the role of a number of other control variables that are believed to influence the perceived privacy risks, benefits and disclosure behavior. Along the lines of Xu et al. (2009), we include additional control variables related to (1) prior experience with LBS applications, and (2) previous privacy experience. For (1), we believe that prior experience with LBS can influence participants' usage patterns and thus the disclosure behavior. We study this interaction, based on the number of applications downloaded by a participant and their intended use in the context of LBS. For (2), we believe that privacy consciousness, in terms of previous experience with privacy breaches or invasions, can affect the perceived personal risks of participants and their trust beliefs related to the disclosure of location-information on LBS. We also examine the role of purpose for disclosure on LBS. This is described through the different channels from which users share their location. It includes: navigation (e.g., Google Maps), finding points of interest such as a restaurant (e.g., Yelp), ride-sharing (e.g., Uber), and social networking with context-aware features (e.g., tagging or check-ins on Facebook and Instagram).

4 Research Method

4.1 Research Settings and Respondents

We opted for an online panel to hire our survey sample. This is mainly managed by a panel company, in our case Qualtrics, that administers the survey and recruits participants via different techniques including mailings and web advertisements. As the respondents have already agreed to be part of a panel, online samples tend to achieve high and fast response rates (Redmiles et al. 2019). Qualtrics online panels provide access to nationally representative samples around the world with an audience mix to help find the right insights (qualtrics.com). We performed a survey with 1050 participants with an equal split from USA and Germany and compensated the respondents with the average rate for a 10-min survey suggested by Qualtrics team to obtain quality responses (4$ per respondent for the USA sample and 4€ per respondent for the German sample). To ensure the sample experience with LBS, participants were screened and selected based on several criteria such as their smartphone usage patterns (only smartphone users were recruited from the panel who also have an experience with social networking websites) and reliance on location-based services (reflected by the number of LBS used). Furthermore, in order to have adequate variances in the model variables, we selected participants based on diversity of their LBS application usage. This can lead to risk-benefit evaluation based on different services and potentially reduce any inherent biases. We provide detailed statistics on the experience of our survey sample with LBS in Table 2. Finally, we performed a quality check on our sample data through monitoring the response time, where we excluded responses that took less than 5 minutes as this can imply randomness or low attention spans.

Amongst the respondents, 45.86% were of age less than 35 and approximately 50% of the respondents were females. Above 40% of the respondents had 3 or more LBSs installed on their smartphones and more than 43% had a minimal understanding of the privacy implications and the potential misuse of user's digital information. Among the participants, 82% use LBS primarily for navigation, 27.90% ride-sharing and 27.81% locating point of interest applications, 34.54% for social networking, while others also use dating, tracking or weather applications. It is worth noting that the American and German populations show very similar characteristics in terms of LBS experience, except for ride-sharing applications, which is mainly due to the different implementation and usage of the public transportation systems in both countries.

Variable	**Level**	**Percentage (%) Overall sample**	**Percentage (%) USA**	**Percentage (%) Germany**
Number of LBS	1-3	52.67	53.33	52.00
	4-7	30.00	29.71	30.29
	8-10	7.33	7.24	7.43
	>10	6.29	6.10	6.48
	Don't know	3.71	3.62	3.81
Type of LBS	Navigation	82.00	80.00	84.00
	Ride-sharing	27.90	38.48	17.33
	Point of interest	27.81	25.14	30.48
	Social networking	84.57	84.19	84.95
	Other (dating, weather, tracking, etc.)	21.05	20.76	21.33
Privacy Consciousness	Not informed	30.95	29.71	32.19
	Moderately informed	43.62	44.57	42.67
	Well informed	25.43	25.71	25.14

Table 2. Experience with LBS

4.2 Measures

In operationalizing our constructs, we mainly relied on pre-tested and valid scales from prior studies where possible and developed scales for newly introduced constructs. A seven-point Likert scale ranging from *strongly disagree* to *strongly agree* was used for all items in the study. Both perceived risk constructs (personal and extrinsic) were adapted from Xu et al. (2009). Similarly, for the measures of the perceived benefit of contextualization (including personalization and locatability). For risk antecedents, we mainly relied on scales from Krasnova et al. (2010) except for the trust in government regulations that was adapted from Xu et al. (2009). It is also worth noting that we based the *previous privacy experience* control variable on Xu et al.

(2009). More details on the constructs and measurement scales are provided in Table 5 of Appendix A.

We developed new scales for the perceived benefits of social status and incentives as well as the multi-dimensional location-information disclosure constructs. The self-developed items aimed to measure user's perceived benefits on specific scenarios of location-information sharing as well as the different contexts. We performed a pre-test survey with 18 LBS users to test content validity of the new items. All the items resulted with satisfactory inter-item correlations and were used in the study.

5 Data Analysis and Results

Our analysis is based on partial least squares (PLS) for structural equation modeling (SEM). PLS can estimate the measurement model and the structural model simultaneously and systematically (Hair et al. 2011). It is also well suited for studies dealing with a mixed model of reflective and formative natured constructs (e.g., perceived personal risks and dimensions of location-information disclosure behavior in our case). SmartPLS was used as the analysis tool.

5.1 Measurement Model

Reliability. The first-order perceived constructs in our model were measured reflectively and other constructs were measured formatively. Composite reliability (CR) and average variance extracted (AVE) were used as indicators of the construct reliability (Fornell and Larcker 1981). As shown in Table 6, the composite reliabilities for all the constructs were greater than 0.6 and the AVEs greater than 0.4. Thereby, showing that all our constructs are reliable (Fornell and Larcker 1981).

Factor Analysis. Next, we examine if there is a potential common method bias as all the constructs were subjectively measured from the same sources. We thus examine the substantive factors and the method factors and compare the variances as suggested by Podsakoff et al. (2003) and shown in Table 7. We observe that the substantive factors explained nearly 30% of all the total variances while the method factor loadings explained 70%, implying that common method bias was not a significant concern in the study. The above results show that our data passes the reliability and bias tests.

5.2 Hypothesis Testing

PLS results of the structural model are presented in Table 3 for a traditional privacy calculus model with a single dimensional location-information disclosure construct, and in Table 4 for our multi-dimensional model. The results show that for the traditional model comprising a general location-information disclosure, the perceived benefits of contextualization and social status have significant positive impact on location-information disclosure and LBS use. However, incentives did not result with a significant relationship to location-information disclosure. Thus, only supporting hypothesis H3 and H4. Perceived personal and extrinsic privacy risks did not have any significant relations with location-information disclosure, thus not supporting H1 or H2. Regarding risk antecedents, we observe that the three trust constructs (i.e., in regulations, service providers and service members) bear no significant relation with perceived privacy risks thereby not supporting H6a, H6b or H6c. For perceived control, no significant correlation with perceived privacy risks is observed thereby not supporting H7. However, privacy-control bares significant positive correlations with trust in regulations, service providers and service members lending support to H8a, H8b and H8c. Surprisingly, none of the trust constructs has shown a significant relationship with privacy risk perceptions, thus rejecting H6a, H6b and H6c.

In comparison to the traditional model, our multi-dimensional model provides more detailed information regarding the disclosure behavior on LBS. The results show significant positive correlations for all the perceived benefits with the specificities of the location-information disclosure dimensions (i.e., extent, sensitivity and sharing parties). Thus, confirming the willingness to share behavior in return for an expected outcome. Contextualization has significant relationships with the extent, location sensitivity and sharing with service providers. Thus, supporting H3a, H3b and H3c. Interestingly, we also see a strong significant correlation between contextualization and sharing with service members. This could be related to the current use of recommendations feature in some social networks such as Facebook where a user can share his location and ask for recommendations of restaurants or touristic attractions for example. Moreover, the perceived benefit of social status has significant positive correlations with extent of disclosure, location sensitivity and sharing with service members. Thus, supporting H4a, H4b and H4c. In fact, users are willing to share their location-information (even sensitive) to boost their social image within their community. As for the utilitarian benefit of incentives, our results show positive correlations with disclosure extent, location sensitivity and sharing with third parties (e.g., data brokers). Thus, unlike the traditional model, supporting H5a, H5b and H5c. Perceived personal and extrinsic privacy risks also did not have any significant relations with any of the dimensions of location-information disclosure, thus not supporting H1 or H2. In addition, H8a, H8b and H8c are still supported within the extended model.

Hypothesis	Construct A → Construct B	Coefficients	P-Values
H1	personal privacy risk→location-information disclosure	-0.0952	0.8689
H2	extrinsic privacy risk→location-information disclosure	0.0223	0.9687
H3	contextualization→location-information disclosure	0.5586	0.0000***
H4	social status→location-information disclosure	0.2028	0.0003***
H5	incentives→location-information disclosure	0.0779	0.2100
H6a	trust in regulations→personal privacy risk	0.4065	0.9844
H6b	trust in service providers→personal privacy risk	-2.5236	0.9841
H6c	trust in service members→personal privacy risk	2.8627	0.9790
H7	perceived control→personal privacy risk	-0.3537	0.9774
H8a	perceived control→trust in regulations	0.7505	0.0000***
H8b	perceived control→trust in service providers	0.9034	0.0000***
H8c	perceived control→trust in service members	0.8955	0.0000***

Table 3. Hypothesis testing (traditional privacy calculus model)
(Note: *p <0.05, **p <0.01, ***p <0.001)

Hypothesis	Construct A → Construct B	Coefficients	P-Values
H1a	personal privacy risk→extent	-0.3270	0.6690
H1b	personal privacy risk→ location sensitivity	0.0370	0.9330
H1c	personal privacy risk→sharing service provider	0.0010	0.9980
	personal privacy risk→sharing service members	-0.3370	0.6950
	personal privacy risk→sharing third parties	-0.1430	0.7400
H2a	extrinsic privacy risk→extent	0.2660	0.7260
H2b	extrinsic privacy risk→location sensitivity	-0.0310	0.9440
H2c	extrinsic privacy risk→sharing service provider	0.0950	0.8750
	extrinsic privacy risk→sharing service members	0.2670	0.7570
	extrinsic privacy risk→sharing third parties	0.2280	0.5970
H3a	contextualization→extent	0.4100	0.0000***
H3b	contextualization→location sensitivity	0.2220	0.0000***
H3c	contextualization→sharing service provider	0.7620	0.0000***

	contextualization→sharing service members	0.5100	0.0000***
	contextualization→sharing third parties	-0.0240	0.7390
H4a	social status→extent	0.3630	0.0010**
H4b	social status→location sensitivity	0.5750	0.0000***
H4c	social status→sharing service provider	0.0730	0.4620
	social status→sharing service members	0.3580	0.0010**
	social status→sharing third parties	0.5680	0.0000***
H5a	incentives→extent	0.1830	0.0070**
H5b	incentives→location sensitivity	0.2100	0.0000***
H5c	incentives→sharing service provider	0.0180	0.7350
	incentives→sharing service members	0.1440	0.0210*
	incentives→sharing third parties	0.2230	0.0000***
H6a	trust in regulations→personal privacy risk	0.4080	0.9760
H6b	trust in service providers→personal privacy risk	2.8700	0.9720
H6c	trust in service members→personal privacy risk	-2.5310	0.9770
H7	perceived control→personal privacy risk	-0.3540	0.9670
H8a	perceived control→trust in regulations	0.7500	0.0000***
H8b	perceived control→trust in service providers	0.8950	0.0000***
H8c	perceived control→trust in service members	0.9030	0.0000***

Table 4. Hypothesis testing (extended privacy calculus model)

(Note: *p <0.05, **p <0.01, ***p <0.001)

6 Discussion

6.1 Academic contributions

As contribution to research, our work is a first step into a more nuanced and realistic understanding of location-information disclosure and thereby extends prior studies in this field. Our study treats location-information disclosure as a multi-dimensional construct, which allows evaluating the granularity of disclosure behavior. It also takes into account interdependent privacy, controls and monetary incentives, which have not been fully covered in previous studies of LBS. Our results show that disclosure behavior might vary depending on the extent of sharing (or mechanism), sensitivity of location-information to the users and the sharing parties involved within the disclosure frame. Our amendments to the privacy calculus model and the associated empirical results suggest several recommendations discussed hereafter:

Motivations for location-information disclosure. We observe that users value the benefits higher than the risks. They might be willing to share continuously on LBS if a high service level of contextualization is offered and no access by other entities is guaranteed. Moreover, users are willing to share sensitive location-information with service members to achieve social status and with third parties in return of monetary incentives.

Transparent privacy control settings. Our analysis surprisingly finds that perceived control has no significant effect on privacy risk on the contrary to other studies (Krasnova et al. 2010). This might be explained by the increasing adoption of dark patterns in order to hide the control settings by service providers. For example, applications such as Facebook, demand location access to show nearby friends and to access messenger chat (Brignull 2019), or Android phones selecting high accuracy location mode by default (Hildenbrand 2018). Such practices have effectively tricked users in giving up location-information since controlling the access and granularity is challenging to locate for an average user. The low user awareness is productively used by the service providers, which highlights the necessity of effective regulations such as opt-out by default as implemented by GDPR. Although, the relationship between perceived control and risk perception is non-significant, we find a strong correlation between perceived control and trust. This applies to all the entities including the government, service providers and service members. In fact, trust has been proven to have a diminishing effect on privacy perception in previous studies (Sun et al., 2015; Zhao et al., 2012). Risk perceptions are mainly associated to misuse of location data by service providers. However, service members can also pose privacy risks to other users that might not be aware of it. A prime example of this is Tinder's security vulnerability that allowed users to locate other members of the service, which surprisingly saw a positive impact on its adoption (Veytsman 2014). This emphasizes the importance of ensuring transparent privacy control settings in gaining trust from end users, which in turn can diminish the effect of privacy risk perceptions for disclosure.

Recognizing interdependent privacy risks. We highlight the importance of interdependent privacy risks in the increasingly interconnected ecosystem, which brings several inconceivable privacy threats. In contrast to Morlok (2016), our results clearly show that users do not consider interdependent privacy threats as relevant which results in non-significant correlations with the considered constructs. This can have implications for service providers who should take into consideration the unconscious users.

From our control variables, we observe that respondents with high privacy consciousness and low trust will disclose more than others in the presence of monetary incentives. In addition, we see that the higher the number of LBS present on a user's smartphone, the lower is the perceived privacy risk and the higher is the tendency of sensitive data disclosure to a continuous extent. This trend suggests formulation of new business models around monetizing location data according to its sensitivity and extent.

6.2 Implications for practice

The empirical findings from our study are highly relevant for service providers, regulatory bodies and data monetization platforms. The suggested dimensions of location-information disclosure allow understanding users' motivations for location disclosure, which is of relevance for (1) designing privacy aware LBS, (2) enforcing regulatory standards compliant with user privacy perceptions, and (3) designing business models for location data monetization.

Most importantly, our empirical study reveals opportunities for the emerging data stream economy. We observe that users are willing to disclose to third parties and to give up sensitive location data for monetary incentives. This is a positive aspect for the upcoming data stream economy, where users will be able to share location data in exchange of monetary rewards. This also opens up an opportunity for location-information sharing in return for other types of incentives. An example would be public good to improve standards of living. Users could have a direct value from sharing their location-information to improve public services such as national security, urban planning, traffic management and mobile communication services. Public services can rely on information disclosed by citizens to analyze certain patterns and plan accordingly. We already see such practices in the real world including the growing concept of smart cities. For instance, city of York collects phone locations for efficiently managing traffic flows (Rudgard 2018)

7 Limitations and Future Research

A limitation of our study is that it stems from the reliance on privacy calculus model, which views privacy-related-decision-making as a rational process. As situation-specific assessment of risks and benefits is bounded by several factors (e.g., pre-existing attitudes) (Kehr et al. 2013), it is necessary to complement our study by exploring location-information disclosure through the lens of other frameworks which goes beyond such a rational based setting. For example, users' sharing behavior of location information can be affected by their attitude towards a service provider due to a pre-existing reputation of privacy invasion. In that regards, future research can focus on the conceptualization of location-information disclosure by taking into consideration user attitudes and perceptions of the LBS that can impact the user's intentions to disclose or their disclosure behavior.

Future research in this domain can also investigate specific disclosure dimensions with different samples for generalizing findings. For instance, researchers could further study the extent and data sensitivity as a dimension of location-information disclosure. Moreover, results on the perceived benefit of monetary incentives raise questions on the future of LBS and how the data stream economy can affect the use of such services. Future research should therefore focus on the conceptualization of data markets with a specific interest in location data streams. Finally, future research can explore the effect of new regulations on the privacy risk perceptions of users reflected through enhanced control settings. The strengthening of data privacy laws in Europe through the EU GDPR will allow users to gain complete access and control over information held by the service providers. Our findings suggest that the placement of such laws changes users' perceptions toward usage of these services, which is an interesting avenue for exploration.

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Appendix A

Construct		**Measures**	**Adapted**
Perceived Privacy Risk (prk)	prk1	Disclosing my location to location-based service providers (e.g., Uber or Facebook) would involve many unexpected problems.	Xu et al. 2009
	prk2	Disclosing my location-information to the service provider may bring potential losses.	
	prk3	Disclosing my location-information to the service provider is risky.	
Perceived Extrinsic Risk (erk)	erk1	Tagging my friends on location-based service platforms may bring unpredicted problems to them.	Self-developed
	erk2	Checking-in with my friends on location-based services would be risky to them.	
	erk3	Tagging my friends on location-based services may bring potential losses to them.	
Contextualization (bct)	bct1	With location-based services I am able to get up to date information/services whenever I need to.	Xu et al. 2009
(Locatibility)	bct2	With location-based services I am able to access the relevant information/services wherever I want to.	
	bct3	With location-based services, I am able to access the relevant information/services at the right place.	
	bct4	Location-based services can provide me with personalized services tailored to my activity context.	Xu et al. 2009
(Personalization)	bct5	Location-based services can provide me with more relevant information tailored to my preferences or personal interests.	
	bct6	Location-based services can provide me with the kind of information or service that I might like.	
Incentives (bi)	bi1	Location-based services can help to decrease my car insurance premiums.	Self-developed
	bi2	Location-based services allow me to discover discounts or deals at shops, restaurants or bars.	
	bi3	Location-based services associated with data brokers allow me to obtain monetary rewards.	
Social Status (bs)	bs1	Sharing my location at certain places would help to boost my social image	Self-developed
	bs2	Sharing my location along with certain people would help boost my social image	
	bs3	Posting a picture at a social event along with other people would help boost my social image	
Location-information Disclosure (lid)	lid1	I am willing to share my location-information on location-based services.	Xu et al. 2009
	lid2	I am likely to share my location-information on location-based services.	
	lid3	It is likely that I share my location-information on location-	

		based services.	
Extent (lide)	lide1	I am likely to keep my GPS switched on at all times to provide my real- time location to location-based services.	Self-developed
	lide2	I am willing to keep my GPS switched on at all times to provide my location to location-based services	
	lide3	It is probable that I keep my GPS switched on at all times to provide my real-time location to location-based services.	
Location Sensitivity (lids)	lids1	I am willing to check-in on location-based services at sensitive locations.	Self-developed
	lids2	I am likely to share my sensitive locations on location-based services.	
	lids3	It is probable that I check-in at sensitive locations on location-based services.	
Sharing Parties: Service Provider (lidsp)	lidsp1	I am willing to share my location-information on location-based services given that my data is not shared with any other entity.	Self-developed
	lidsp2	I am likely to share my location-information on location-based services given that my data is not shared with any other entity.	
	lidsp3	It is probable that I share my location-information on location-based services given that my data is not shared with any other entity.	
Sharing Parties: Service Members (lidsm)	lidsm1	I am willing to share my location-information on location-based services given that the service members can view it.	Self-developed
	lidsm2	I am likely to share my location-information on location-based services given that the service members can view it.	
	lidsm3	It is probable that I share my location-information on location-based services given that the service members can view it.	
Sharing Parties: Third Parties (lidtp)	lidtp1	I am willing to share my location-information with location-based services even if they sell my data to third-party providers such as data brokers or advertisers.	Self-developed
	lidtp2	I am likely to share my location-information with location-based services even if they sell my data to third-party providers such as data brokers or advertisers.	
	lidtp3	It is probable that I share my location-information with location-based services even if they sell my data to third-party providers such as data brokers or advertisers.	
Perceived Control (ctl)	ctl1	I feel in control over the location-information I provide to location- based services (e.g. location granularity on Google maps).	Krasnova et al. 2010
	ctl2	Privacy settings present in location-based services (e.g., Tinder or Facebook) allow me to have full control over the location-information I provide.	
	ctl3	I feel in control of who can view my location-information provided on location-based services.	
Trust:	trg1	Government regulations protect my personal location-	Xu et al. 2009

Regulations (trg)		information provided to location-based services.	
	trg2	Government regulations protect me from any misuse of my location-information by location-based service providers.	
	trg3	Government regulations protect me from unauthorized use of my personal location data disclosed on location-based services.	
Trust: Service Providers (tsp)	tsp1	Location-based service providers are trustworthy and will not misuse any of my location-information.	Krasnova et al. 2010
	tsp2	Location-based service providers are honest in its dealings with me.	
	tsp3	Location-based service providers are interested in the well being of their members.	
Trust: Service Members (tsm)	tsm1	Users of the location-based service I use are trustworthy and would not attempt to harm me.	Krasnova et al. 2010
	tsm2	Users of location-based services I use are helpful and receptive to the needs of other users.	
	tsm3	Users of location-based service I use are honest in dealing with each other.	

Table 5. Constructs and measures

Appendix B

Construct	**Cronbach's Alpha**	**rho_A**	**Composite Reliability**	**Average Variance Extracted (AVE)**
Location-information disclosure	0.8157	0.8170	0.8164	0.5972
Extent	0.8573	0.8577	0.8574	0.6673
Location sensitivity	0.7967	0.7967	0.7966	0.5663
Sharing service provider	0.8315	0.8329	0.8323	0.6234
Sharing service members	0.7333	0.7598	0.7314	0.4836
Sharing third parties	0.7331	0.7481	0.7347	0.4837
Personal privacy risk	0.8720	0.8730	0.8721	0.6946
Extrinsic privacy risk	0.6851	0.6877	0.6866	0.4224
Contextualization	0.7473	0.7513	0.7492	0.4995
Social status	0.8466	0.8469	0.8466	0.6480
Incentives	0.8208	0.8225	0.8213	0.6053
Trust in regulations	0.7788	0.7800	0.7787	0.5401
Trust in service members	0.8157	0.8170	0.8164	0.5972
Trust in service providers	0.8573	0.8577	0.8574	0.6673
Perceived control	0.7858	0.7859	0.7859	0.5502

Table 6. Quality criteria

Variable	Substantive factor loading $(R_1)^2$	Method factor loading $(R_2)^2$	Variable	Substantive factor loading $(R_1)^2$	Method factor loading $(R_2)^2$
lid1	0.3974	0.7878	bct1	0.1943	0.6883
lid2	0.3956	0.7841	bct2	0.1931	0.6842
lid3	0.3763	0.7458	bct3	0.1975	0.6997
lide1	0.3804	0.8222	bct4	0.2191	0.7763
lide2	0.3831	0.8281	bct5	0.2281	0.8083
lide3	0.3701	0.8000	bct6	0.2268	0.8034
lids1	0.4029	0.7503	bs1	0.3860	0.8609
lids2	0.3975	0.7401	bs2	0.3604	0.8039
lids3	0.3947	0.7349	bs3	0.3742	0.8346
lidsp1	0.3914	0.7449	bi1	0.4414	0.6744
lidsp2	0.3990	0.7594	bi2	0.4046	0.6182
lidsp3	0.3957	0.7532	bi3	0.4292	0.6559
lidsm1	0.3976	0.7863	trg1	0.3851	0.8135
lidsm2	0.3987	0.7886	trg2	0.3725	0.7868
lidsm3	0.3738	0.7394	trg3	0.3855	0.8143
lidtp1	0.3870	0.7932	tsp1	0.3699	0.7407
lidtp2	0.3951	0.8096	tsp2	0.3968	0.7945
lidtp3	0.3734	0.7653	tsp3	0.3983	0.7976
prk1	0.4094	0.6813	tsm1	0.3801	0.6974
prk2	0.5018	0.8351	tsm2	0.4127	0.7571
prk3	0.3231	0.5377	tsm3	0.4082	0.7489
erk1	0.4097	0.6873	ctl1	0.4318	0.7466
erk2	0.3516	0.5899	ctl2	0.3851	0.6658
erk3	0.4733	0.7941	ctl3	0.4081	0.7057

Table 7. Factor analysis

Understanding User Adoption of Contact Tracing Apps

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Abstract. Contact tracing apps are mobile applications equipped with proximity or location tracking that alert individuals of the need to self-isolate in case of contact with a COVID-19 infected person. These apps have been developed in various countries and their main purpose is to slow down the spread of COVID-19 and ease up lockdown measures. For them to be completely effective in suppressing the spread of the virus, the app should be adopted by more than half of the population in the country. However, the adoption of contact tracing apps worldwide lacks behind expectations. In fact, digital contact tracing raises user privacy concerns associated to information sharing within the app, which impacts its use. We aim to study the users' perspective on contact tracing apps to understand adoption motivations and barriers. We apply a two-method approach to study users' intention to use under privacy trade-offs. In a first approach, we employ privacy calculus to understand users' perceptions on benefits and risks of using the app. In a second approach we apply conjoint analysis to understand users' preferences for privacy-preserving app features and value-added services. Our research contributes to both academia and practice. The empirical results derived provide a nuanced understanding of the adoption of contact tracing apps, and provide input on the most successful design options that foster app use.

Keywords: contact tracing; IS adoption; privacy calculus; conjoint analysis

1 Introduction

The COVID-19 pandemic has created a state of emergency in countries worldwide. Governments imposed lockdown measures to help control the fast spread of the virus and slow down its transmission. However, lockdowns resulted with economic and social consequences (Trang et al. 2020) that required substantial solutions for fighting the pandemic. Accordingly, contact tracing has become one of the main approaches to control the spread of the virus. COVID-19 contact tracing apps are mobile applications designed to keep a trace of close contacts through proximity or location tracking (Legendre et al. 2020). This digital solution alerts individuals of the need to self-isolate in case of contact with an infected person, which helps in controlling the spread of COVID-19.

Contact tracing apps have been developed in various countries, among them SwissCOVID in Switzerland, StopCOVID in France, Corona-Warn-App in Germany, COVIDSafe in Australia, TraceTogether in Singapore and many more. For these apps to be effective at preventing the transmission of the virus, an adoption rate of more than half the population (ideally 60%) is necessary (Trang et al. 2020). However, in many countries their introduction is accompanied by controversial debates about their privacy implications, and adoption rates to date fall below expectations. Contact tracing apps require sharing of contact information as well as location information in some cases for achieving its goals. However, the public debate is primarily conducted by experts and at the political level, but lacks consideration of the users' perceptions. Von Wyl et al. (2020) emphasize that more research in the acceptability of the COVID-19 contact tracing aps is required to provide an understanding of the rationale behind contact tracing app use. To address this gap, this study aims to answer the following questions:

- What are users' perceptions regarding the use of contact tracing apps?
- What are users' preferences for contact tracing app features?

We argue that empirical insights on user preferences and perceptions can inform privacy-aware design of contact tracing apps and drive user adoption. Following a multi-method study approach (Venkatesh et al. 2013), we conduct two empirical studies for understanding adoption intentions of contact tracing apps and deriving concrete recommendations for contact tracing app design. In the first study, we build on the large body of research in IS literature that has studied information privacy (Bélanger and Crossler 2011; Smith et al. 2011; Xu et al. 2011) and specifically the privacy calculus paradigm (Dinev and Hart, 2006) to explain the dynamics of underlying user participation in the light of privacy concerns. Based on that, we study user's disclosure behavior or intention to use contact tracing apps as trade-off analysis between expected benefits and perceived privacy risks. The empirical analysis of data collected from a representative sample of 1022 participants in Germany reveals that there exists a discrepancy in the understanding of the associated benefits to contact tracing apps. Moreover, it shows how trust and privacy control play an important role in diminishing perceived privacy risks, which in turn can affect intentions to use and information disclosure on the app.

The second study extends beyond the theoretical understanding of system acceptance and use, provided by the privacy calculus, to gain more actionable insights in terms of contact tracing app design. A promising approach is the use of conjoint analysis (CA), from market research, that allows approximating user preferences in a trade-off scenario (Green and Srinivasan 1990) and has been occasionally used for understanding the privacy trade-offs in the design of personal ICTs (Mihale-Wilson et al. 2017; Naous and Legner 2019). The method provides insights into users' preferences allowing the formation of applications and services that fit users' expectations, with implications for service providers to better design and adjust their offerings. We apply Adaptive Choice-Based CA on a sample size of 300 participants to assess user preferences for core and value-added services of such apps and the platform design. Our empirical results of the CA confirm that users are reluctant to using apps that are based on location tracking, but prefer pure contact tracking or hybrid apps. Following market simulations based on our empirical data, we also find that value-added services would foster the adoption of such apps.

The remaining of the paper is structured as follows: First we provide a background on contact tracing, emphasizing privacy concerns. We then discuss the research approach. Afterwards, we present the two empirical studies with results. Finally, we discuss our findings and conclude with implications for research and practice.

2 Background

2.1 Contact Tracing and Disease Control

Contact tracing is a key control measure in the battle against infectious diseases. The World Health Organization (WHO) defines contact tracing as "the process of identifying, assessing, and managing people who have been exposed to a disease to prevent onward transmission" (WHO 2018, p. 2). Contact tracing can break the chains of transmission when systematically applied. It has been traditionally performed by health authorities using expert-led interview-based contact tracing techniques. Contact tracing is an extreme form of locally targeted control and has the potential to be highly effective when dealing with a low number of cases (Eames and Keeling 2003).

In the case of COVID-19, contact tracing requires identifying people who may have been exposed to COVID-19 and following up with them daily for a period of at least 14 days from the last point of exposure (Ahmed et al. 2020). The fact that symptom onset may only occur days after infection makes it difficult for traditional approaches to map the network of potential exposure traces and thus control the transmission rate of the virus. Therefore, advanced techniques are required for effective contact tracing in the COVID-19 context.

2.2 Contact Tracing Apps for COVID-19

Mobile technology enables easier and faster contact tracing versus traditional methods and has evolved into one of the key instruments to fight this worldwide pandemic of COVID-19. Governments and health authorities over the world therefore promote mobile applications that enable digital contact tracing, to monitor the spread of the virus and ease lockdown measures. Researchers and technology companies, such as Google and Apple, have been developing such tools in the form of contact tracing apps. This health technology provides a fast and reliable solution to support traditional contact tracing approaches performed by the public health authorities in fighting pandemics. The goal of these contact tracing apps is to continuously track user's proximity and to notify them in the event of possible COVID-19 exposure for self-isolation (Walrave et al. 2020).

Common tracing mechanisms rely on smartphone's absolute location (in the case of location-based contact tracing) or relative location (in the case of proximity-based contact tracing) to other smartphones (Legendre et al. 2020). Proximity-based contact tracing relies on proximity detection via Bluetooth Low Energy (BLE) to infer the relative proximity of smartphones (up to 50m outdoors and 25m indoors), while location-based contact tracing uses GPS traces for precise location. Various national apps have been designed and are voluntarily used in various countries (Table 1). However, the critical mass adoption threshold for these apps remains unattainable to date. Simulations confirm that if approximately 60% of the population uses the requisite country app, alongside other interventions, it has the potential to stop the epidemic and keep countries out of lockdown (University of Oxford 2020).

Among the first countries to develop and launch a contact tracing app was Singapore with TraceTogether. The app has to date 2.3 million users indicating around 40% adoption rate (tracetogether.gov.sg). Based on the same framework, the Australian app (COVIDSafe) currently boasts a user base of around 7 million, which represents over a quarter of the Australian population (Norman 2020). In Europe, Austria's Stopp Corona App was first launched in March. Currently uptake is 8% remaining well below expectations (Reuters 2020). Italy, which was among the mostly affected countries with COVID-19, launched Immuni app in June, but its adoption rate remains at 14% (Follis 2020). France also launched StopCOVID in the same period, and has only 3% adoption rate (archyde 2020). Among the countries that witnessed a higher rate of adoption in Europe are Germany and Switzerland. Germany's Corona-Warn-app was launched in June and has over 17 million users (over 20% of the population) 4 months after the launch (Cellan-Jones and Kelion 2020). Switzerland also launched its SwissCOVID app in June, 3 months later, it has over 1.5 million users, however lags behind the active user goal of 3 million for SwissCOVID to be effective (FOPH 2020).

Whereas most countries use BLE technology in building their contact tracing apps, only few have adopted a location tracing mechanism for cross-checking paths including Hamagen, which has 17% adoption rate to date.

2.3 Privacy Concerns in Contact Tracing Apps

The major obstacles to achieving broader adoption for contact tracing apps are often cited as reservations about data privacy, possible identification or privacy infringements via location tracking and fear of citizen monitoring by the state. Contact tracing apps require active information disclosure and sharing of sensitive data. Users might share personal information, health information, contact information and possibly location information on the app, which results in privacy concerns.

Sharing contact information can result in identification of users through their social graphs (Legendre et al. 2020). Moreover, sharing location information on the app can result in identification of mobility patterns that can serve as diagnostic representation of sensitive demographic information such as religious or political affiliation (Gambs et al. 2011). As for health information, infected users might be particularly concerned in this case since they share their health status information on the app to facilitate exposure notification (Legendre et al. 2020). Fears arise around states establishing Corona maps like South Korea has done (Klatt 2020), showing the movement of COVID-19 patients, whereby the health authorities have access to everything from credit card information to CCTV camera footage. For this reason, governments around the world have been continuously evaluating and enhancing the different implementation options of contact tracing apps. The main purpose is to have applications that are privacy-preserving and do not reveal any Personally Identifiable Information (PII) about their users (Ahmed et al. 2020), which can put them at risk of being tracked or under government surveillance. This in turn aims at fostering the adoption of the apps and reaching a critical mass.

App (by country)	Launch Date	Number of users	% of total of population	Approach	Technology	User Identification
TraceTogether (Singapore)	March 20th	+2M	~42%	Centralized	based on legacy BLE	Phone number required
Hamagen (Israel)	March 22nd	+1.5M	~17%	Decentralized	Cross-referencing of GPS data	No information required
StoppCorona (Austria)	March 25th	+700K	~8%	Decentralized	based on legacy BLE	Phone number required
COVIDSafe (Australia)	April 26th	+7M	~28%	Centralized	based on legacy BLE	Personal information required
Immuni (Italy)	June 1st	+4M	~7%	Decentralized	Apple-Google Exposure Notification	Region required
StopCOVID (France)	June 2nd	+2M	~3%	Centralized	ROBERT (centralized based on legacy BLE)	No information required
Corona-Warn-App (Germany)	June 16th	+17M	~20%	Decentralized	Apple-Google Exposure Notification	No information required
SwissCOVID (Switzerland)	June 25th	+2M	~18%	Decentralized	DP-3T and Apple-Google Exposure Notification	No information required
NHS COVID-19 (UK)	Not launched	-	-	Decentralized	Apple-Google Exposure Notification	Region required
PathCheck: MIT SafePlaces	-	-	-	Decentralized	Cross-referencing of GPS data	No information required

Table 1. Overview of Contact Tracing App

There has been considerable debate on platform design used for contact tracing (i.e., BLE technology versus location-tracking). In addition, the alerting mechanism (i.e., centralized versus decentralized approaches) has been discussed thoroughly for designing these apps. While both approaches require a central server for exchanging the pseudo IDs of users, the matching of traces with positive user IDs is the main difference. With the centralized approach, IDs are shared with the central server managed by the public health authorities for matching with positive cases and notifying the close contacts. With a decentralized approach, the matching is done on the user's smartphone with the list of infected IDs (Legendre et al. 2020). Both approaches communicate anonymously, however the decentralized approach is regarded as more privacy-preserving since no logging data is exchanged with the server from the user's smartphone, except in the case of infection. The list of infected users is available to all app users in this approach, which is one downside of this approach. The centralized version allows authorities to have a controlled environment for fighting the pandemic since the alerting is carried out by the central server in case of a match. It is worth noting that the majority of European countries have decided to follow a decentralized approach relying on Google and Apple API using BLE technology for proximity detection (e.g., Switzerland, Germany, UK).

Among the countries that follow a centralized approach is France with the StopCOVID app, which is built based on the ROBust and privacy-presERving proximity Tracing protocol (ROBERT). It is worth noting that apps with centralized architecture might require pre–registration with personal information (e.g., TraceTogether and COVIDSafe) for verification by the central server, however, apps relying on the ROBERT protocol do not require such information (Ahmed et al. 2020).

2.4 Research Gap

User adoption of contact tracing apps has proven to be a challenge, and the public debate led by experts and politicians has mostly focussed on privacy concerns as adoption barriers (Cho et al. 2020). Walrave et al. (2020) highlight the ethical and legal user concerns for digital contact tracing, calling for transparent relationship with the user and clear processing of their information. Existing studies on contact tracing apps has mostly focused on the technology design for privacy preserving apps (Ahmed et al. 2020; Cho et al. 2020; Yasaka et al. 2020). So far, the user perspective is mostly neglected. Therefore, it is crucial to understand the user's perspective on digital contact tracing (Redmiles 2020), to understand the widely accepted characteristics by users that foster adoption and reach the required critical mass for effective results. Accordingly, there is a pressing need for empirical studies that investigate whether individuals are willing to use these apps and under what circumstances they will disclose or withhold their data.

A clear understanding of the benefit structure of the contact tracing apps is required. In particular, how people perceive the benefits associated to the app would provide insights on most valuable features that can drive user adoption. Moreover, the alleviated concerns and perceived risks of using contact tracing apps should be further explored. In line with the risk of identification, there exist user privacy concerns related to the data management aspects within contact tracing apps which can compromise users' privacy (Ahmed et al. 2020). It is therefore important for users to know what data is exchanged on the app, where it is stored, who can access this data and for which purposes. Therefore, involving the users in the discussion on app characteristics and data transparency aspects related to the data processing is critical for ensuring mass acceptance.

3 Overview of Studies

We follow a multi-method approach based on two empirical studies. Through a combination of two approaches that involve different research paradigms, we aim to provide a deeper understanding of the user's perspective towards contact tracing apps (Venkatesh et al. 2013) . Our approach aims to provide an understanding of the users' perceptions towards the contact tracing apps as well as users' preferences for the app design. Thus, offering a holistic view on the user's perspective, which can help in improving app design and enhancing adoption.

Study 1 focuses on understanding the users' perceptions by employing privacy calculus. This allows for understanding the general perceptions about benefits and risks and how they affect adoption of contact tracing apps. This can help in obtaining insights on users' motivations and barriers to using the contact tracing apps for fighting the COVID-19 pandemic.

To gain additional insights for prescriptive design and actions (Bélanger and Crossler 2011), we integrate the CA method in a subsequent step in order to improve the understanding of users' preferences and privacy trade-offs. Study 2 with conjoint analysis focuses then on understanding app characteristics that are widely accepted by users, which secures app use. Both studies aim to provide input for privacy-aware design of COVID-19 contact tracing, which can foster their adoption and gain the critical mass required for their effective use.

4 Study 1 – Understanding Users' Perceptions on Contact Tracing Apps

4.1 Research Model

Whether individuals are willing to share their data within these apps, and under what circumstances users decide to disclose or withhold their data, is vital in understanding and increasing the uptake of contact tracing apps within general populations (von Wyl et al. 2020). Privacy calculus provides a conceptual framework to analyse the trade-off individuals face in terms of weighing up potentially harmful risks versus expected benefits, when deciding whether to withhold or disclose personal information (Dinev and Hart 2006). It therefore allows explaining the adoption of COVID-19 contact tracing apps that are at the cusp of two domains within IS research, namely location-based services and mobile health (mHealth). Privacy calculus has received attention within the healthcare context, in terms of explaining this risk-benefit trade-off process in the intention to adopt and use mHealth technology (Anderson and Agarwal 2011; Rahman 2019; Zhang et al. 2018). Applied to contact tracing apps, the privacy calculus lens allows studying user's intensions to use as a trade-off analysis between perceived risks and benefits (Figure 1).

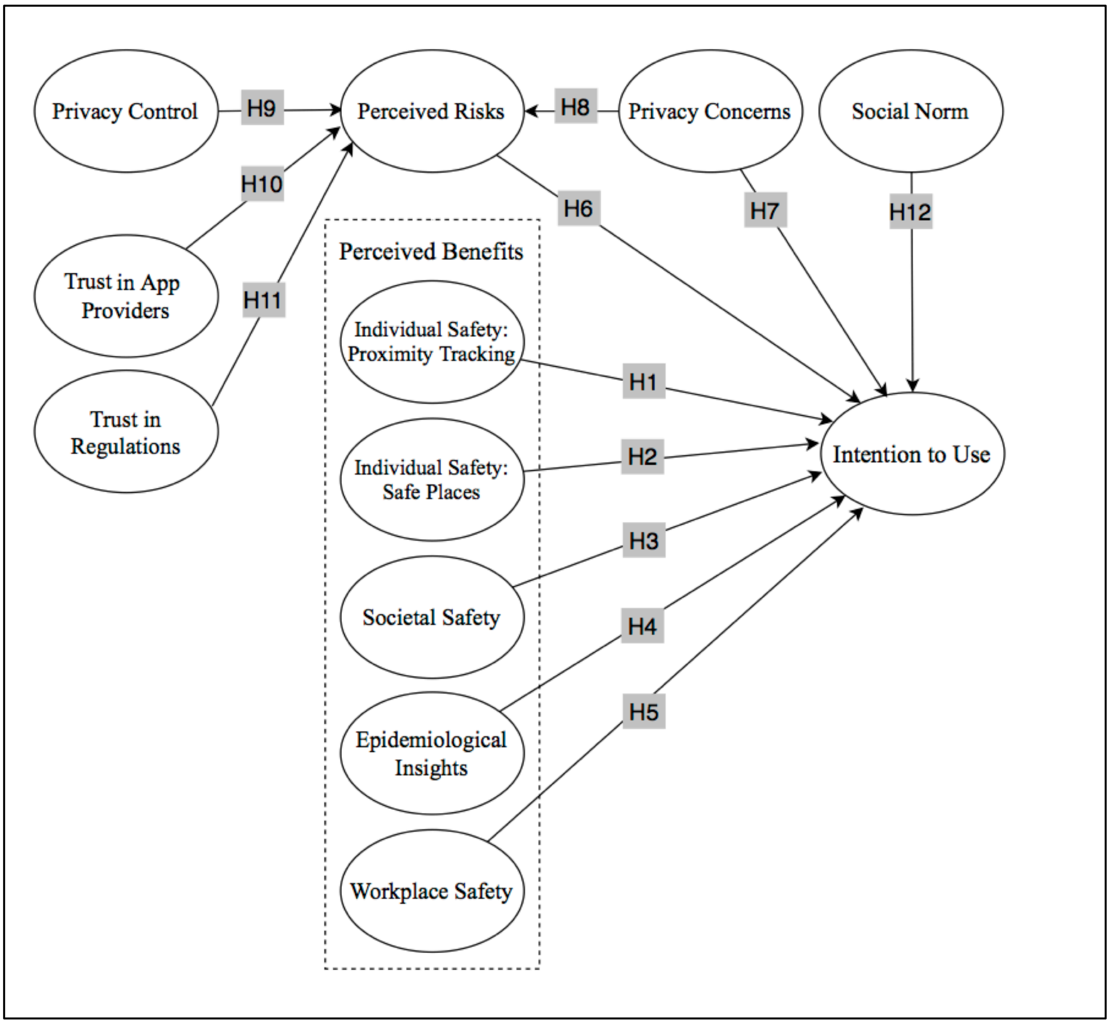

Figure 1. Traditional Privacy Calculus Model – Intention to Use

4.1.1 Perceived Benefits

For contact tracing, a more thorough understanding is required in terms of user benefits. Trang et al. (2020) discuss two types of benefits for contact tracing apps; related to self and society. We suggest taking a broader perspective that integrates benefits from the user perspective at three different levels; individual (or self), society as well as workplace. Based on these three levels characterized mainly by safety considerations, we define five benefit constructs. First, individual safety benefits related to proximity tracking corresponding to the app being able to detect possible encounter with an infected person and receiving exposure notifications. Second, individual benefits of getting notifications about safe places, i.e., identification of hotspots and safe zones similar to MIT's SafePlaces app. However, location sharing is a pre-requisite to enjoying the benefit of safe places. So by default, its inextricably linked to a location-information component. Third, societal safety benefits whereby the user is able to share their status with people they have been in contact with in case they test positive for COVID-19 and notify recent contacts accordingly, thus protecting family, friends and general public from infection. Fourth, the benefit of generating epidemiological insights via the usage of the contact tracing app (e.g., TraceTogether, Corona-Warn-App, Hamagen). This is key in improving the quality of reporting on COVID-19 and performing research on specific patterns in the population that can help in curbing the spread of the virus. However, as is the case with all benefits related to self and society, their value only becomes significant should uptake gain sufficient critical mass. Fifth, workplace safety benefit, which corresponds to employers being able to monitor any cases of COVID-19 amongst employees and take necessary actions to implement safety measures within the company. For instance, in Singapore, employers are encouraged to ensure that their employees have TraceTogether installed and activated if they cannot work from home, as part of their safety measures. Our hypotheses related to benefits are as follows:

H1: perceived benefit of individual safety for proximity tracking is positively correlated to intentions to use contact tracing apps.

H2: perceived benefit of individual safety for safe places is positively correlated to intentions to use contact tracing apps.

H3: perceived benefit of societal safety is positively correlated to intentions to use contact tracing apps.

H4: perceived benefit of epidemiological research is positively correlated to intentions to use contact tracing apps.

H5: perceived benefit of workplace safety is positively correlated to intentions to use contact tracing apps.

4.1.2 Privacy Concerns and Perceived Privacy Risks

An upper barrier to the minimum uptake threshold of contact tracing apps can be due to a lack of trust and transparency in how these apps are being developed, amongst the citizens and authorities deploying them (Gupta and de Gasperis 2020). Most notably, the Norwegian government and Norwegian app provider Smittestopp had to heed to a temporary ban of the app from the Norwegian Data Protection Authority (NDPA) and have had the app removed from the Google Play and Apple App stores due to privacy concerns raised. As the time of writing, Smittestopp remains offline.

Privacy concerns and perceived privacy risks are generally considered to negatively affect disclosure behaviour and are typically used in IS studies to evaluate the cost dimension when employing a privacy calculus model (Dinev and Hart 2006). Concerns for Information Privacy (CFIP) framework by Smith et al. (1996) focuses on four areas; the collection of private data by app providers, unauthorized secondary use of data, improper access and errors. Users' concerns associated to contact tracing apps revolve around the first two areas corresponding to misuse of the information by app providers, and identifying personal aspects as social graphs and mobility patterns (Legendre et al. 2020). These concerns formulate the individual's risk perceptions and can be barriers to using these apps. We hypothesize:

H6: perceived privacy risks are negatively correlated to intentions to use contact tracing apps.

H7: privacy concerns are negatively correlated to intentions to use contact tracing apps.

H8: privacy concerns are positively correlated to perceived privacy risks

4.1.3 Perceived Privacy Control

Privacy controls can help mitigate perceived privacy risks if the user has more control over their data sharing, in terms of both extent (how much personal data is being shared, when and where, and for what period of time) and type of information shared (Ahmed et al. 2020; Trang et al. 2020). In the context of contact tracing, privacy control can be achieved by the privacy settings enabled on the app. Firstly this is achieved by the mode of data communication on the app. Anonymous communication of data can guarantee privacy for users, therefore it should be a definite aspect in contact tracing apps. In addition, permissions and user consent on sharing any type of information and who can access this information are two important aspects for ensuring control. Hence, we propose the following hypothesis:

H9: privacy control is negatively correlated to perceived personal privacy risks

4.1.4 Perceived Trust

The general population's trust is a central element when mass-level coordination across cultures is needed, as is the case with adoption of contact tracing. Trust is key for voluntary utilization, especially in places where it is hard to enforce top-down (e.g., well-functioning democracies) (Gupta and De Gasperis 2020). We build on Dinev and Hart (2006)'s definition of trust as an individual's belief that a counter-party involved in an interaction has characteristics that prevent them from opportunistic behaviour. We study two trust constructs and corresponding hypotheses, which relate to the user's perceived risks. First, trust in app providers based on treatment of data and second, government based on regulations.

Individual risk perceptions are correlated with the user perception of the contact tracing app provider, typically the national health institutions, on data treatment and the transparency of the underlying intended use of information collected. In line with Krasnova et al. (2010) we argue that user's perception of the app provider's benevolence and integrity affects the choice of disclosure via contact tracing apps. Based on the trustworthiness, honesty and transparency of app providers, users will have lower risk perceptions related to information disclosure on the app.

H10: trust in app providers is negatively correlated to the perceived privacy risks

Legislative and regulatory efforts for implementing objective information practices have an impact on individual disclosure behaviour (Yang et al. 2018). The central tenet being that if regulatory systems promote a safe environment in which service providers have limitations and constraints in exploiting users' personal information and against unauthorized use, users can be comfortable in sharing their information. This privacy assurance role implemented through governmental regulation can be viewed as justice perceptions that enable self-disclosure. Applying justice theory, Xu et al. (2009) refer to procedural justice as an explanation for the perceived fairness of procedures regarding the collection and use of data. Their model portrayed government regulations as mitigation to perceived privacy risks by ensuring respectful treatment of personal information. We argue that trust in government regulations reduces risk perceptions for information disclosure on contact tracing apps that are normally developed by the authorities and should typically follow regulations that protect user privacy.

H11: trust in government regulation is negatively correlated to the perceived privacy risks

4.1.5 Social Norm

Social norm correlates to whether or not an individual is compelled to use the app simply because everybody else seems to be using it (Min and Kim 2015) and more so than everybody else, people important to the individual user including influencers. In the context of contact tracing apps, we believe that individuals might be willing to use the app if their social circle uses it, and if using the app is well promoted in the society by influential people and companies as a protective measure against COVID-19.

Based on these arguments, we hypothesize the following:

H12: Social norm is positively correlated to intentions to use contact tracing apps.

4.1.6 Control Variables

In addition to demographic factors that have been used in other studies on information disclosure (Sun et al. 2015) we include previous privacy experience as a control variable for privacy consciousness as suggested by Xu et al. (2009). The item examines whether users are aware of past privacy breaches or invasions, and if it affects the perceived personal risks.

4.2 Research Settings

To understand users' perceptions on COVID-19 apps, we conducted an online survey with a representative sample from German population (n = 1,022). Participants were recruited from the Innofact AG online panel via different techniques including mailings and web advertisements. The respondents were smartphone owners and existing or potential contact tracing app users. We only included respondents who have at least heard about the contact tracing app and have a minimum knowledge about its functionalities.

Our questionnaire comprised two parts: Part 1 comprised a series of questions pertaining to demographics (age, gender, residence and questions related to smartphone apps usage). Part 2 involved questions on users' perceptions of benefits and risks associated to contact tracing app use, opinions concerning usage and sharing of information via the app, opinions related to COVID-19 app providers and regulations in country of residence, and questions related to mobile app usage and potential misuse of data. All the questions were translated to German. The study setup was examined by the Ethics Committee within our academic context to guarantee that respondents' participation was completely anonymous and all data collected is treated confidentially and will not be disclosed in its original form.

Variable	**Level**	**%**
Gender	Male	50.20
	Female	49.80
Age	18-25	11.94
	26-35	17.91
	36-45	16.24
	46-55	21.82
	56-65	18.79
	66-75	13.31
Privacy Consciousness	Not informed	44.52
	Well informed	55.48

Table 2. Demographic and background information on survey participants

Demographic information about the sample is presented in Table 2. The average age of participants was 46 years, with 49.8% females. Of these respondents, 6.9% stated that their highest level of education completed was middle school or equivalent, 60.4% had vocational training or equivalent and 32.7% held a university degree or equivalent. Majority of respondents are employed, 46.97% full-time and 28.58% part-time. The respondents use a number of context-aware services including 67.81% navigation apps, 75.34% social networking apps and 29.84% transportation apps. In addition, 31.60% use mobile apps for health and fitness tracking. Regarding their opinion on contact tracing apps, it is noteworthy that 36.21% think that the app should be mandatory and 22.11% are indifferent about that topic. While the Corona-Warn-App is voluntary in Germany, this raises questions on whether it should be enforced for taking the necessary measures in fighting COVID-19 with the increased number of cases and ease of lockdown measures.

4.3 Measures

To operationalize the model constructs, we mainly relied on pre-tested and valid scales from prior studies where possible and developed scales for new constructs. All items are studied through a seven-point Likert scale ranging from *strongly disagree* to *strongly agree*. The perceived risk construct was also adapted from Xu et al. (2009). For risk antecedents, trust in app provider relied on scales from the study of Krasnova et al. (2010) on social networks, as well as privacy control items that were modified to the context of contact tracing. While trust in government regulations was based on items from Xu et al. (2009). In addition, we adapted the social norm construct from the study of Min and Kim (2015) on social networks.

The self-developed items aimed to measure user's perceived benefits on specific scenarios of contact tracing as well as the different contexts. We also developed scales for privacy concerns in relation to what we discussed in the background section. We performed a pre-test survey with five users to test content validity of the new items; they resulted with satisfactory inter-item correlations. More information on the measurement items per each construct with descriptive statistics is available in the Appendix.

4.4 Results

We perform a partial least squares (PLS) analysis for structural equation modelling (SEM). PLS analysis is typically used in privacy calculus studies and is well suited for dealing with a mixed model of reflective and formative constructs such as in our model. It can estimate both measurement and structural models simultaneously and systematically (Hair et al. 2011). To run the simulations, we used SmartPLS3 v3.3.2 as an analysis tool.

4.4.1 Factor Analysis

We measure the first-order perceived constructs reflectively, and privacy-related constructs formatively. Composite Reliability (CR) and average variance extracted (AVE) were used as indicators of construct reliability (Fornell and Larcker 1981). The composite reliabilities for all the constructs were greater than 0.6 and the AVEs greater than 0.4, thereby, showing that all our reflective constructs are reliable (Fornell and Larcker 1981). We examine substantive and method factors and compare variances (Podsakoff et al. 2003). Regarding the formative constructs, we check variance inflation factors (VIFs) to assess common method bias. "The occurrence of VIFs greater than 3.3 is proposed as an indication of pathological collinearity, and also as an indication that a model may be contaminated by common method bias. Therefore, if all VIFs resulting from a full collinearity test are equal to or lower than 3.3, the model can be considered free of common method bias" (Kock 2015). Our results show that VIFs for the formative constructs are less than 3.3, implying common method bias is not of concern in our study.

4.4.2 Hypothesis Testing

Results from our model (Table 3) show positive and significant correlations for individual benefits of proximity tracking in relation to intention to use. Positive and significant correlations are also shown for the epidemiological benefits and intention to use the respective contact tracing app. However, results show a negative correlation for German respondents in relation to intention to use, when it comes to the benefits of safe places. This might be related to the fact that the benefit of safe places is associated to location sharing, which is considered to be sensitive for users and thus creates barriers for intentions to use. The benefit of societal safety is positively correlated to intention to use however slightly significant. Unexpectedly, we did not find a significant correlation for workplace safety benefit. This might be related to the fact that users are reluctant of using apps that allow their employers to monitor their behaviour and that the existing contact tracing apps do not provide this option. Based on that, H1, H3 and H4 are supported in terms of perceived benefits. Perceived privacy risk negatively correlates to intention to use and is significant, supporting H6. Privacy concerns have no significant correlation with intention to use, but correlates positively with perceived risks, as outlined in H8. Perceived control negatively correlates to perceived risk and is significant, thus supporting H9. The relationship between the trust items in both app providers and regulations is significantly negative to perceived privacy risk, supporting H10 and H11. This also applies for social norm, where we observe significant positive correlation with intention to use, supporting H12.

	Construct A → Construct B	Coefficients	P-values
H1	Benefit Individual Safety: Proximity Tracking → Intention to Use	0.152	0.000***
H2	Benefit Individual Safety: Safe Places → Intention to Use	-0.055	0.069
H3	Benefit Societal Safety → Intention to Use	0.070	0.024*
H4	Benefit Epidemiological Insights →Intention to Use	0.167	0.000***
H5	Benefit Workplace Safety → Intention to Use	-0.044	0.039*
H6	Perceived Privacy Risk → Intention to Use	-0.255	0.000***
H7	Privacy Concerns → Intention to Use	-0.038	0.106
H8	Privacy Concerns → Perceived Privacy Risk	0.557	0.000***
H9	Privacy Control → Perceived Privacy Risk	-0.131	0.011*
H10	Trust in App Providers → Perceived Privacy Risk	-0.118	0.013*
H11	Trust in Regulation →Perceived Privacy Risk	-0.168	0.001**
H12	Social Norm → Intention to Use	0.448	0.000***

Table 3. Hypothesis Testing- Traditional Privacy Calculus Model (Note: *p <0.05, **p <0.01, ***p <0.001)

5 Study 2: Understanding Users' Preferences for Contact Tracing Apps

5.1 Research Model

The privacy calculus model provides insights into users' perceptions of app benefits and risks. However, it provides only limited insights on application features that could inform contact tracing app design. Thus, we employ CA to explore users' preferences and trade-offs regarding contact tracing app design and privacy-preserving features that increase adoption. As a popular market research technique, CA enables the estimation of a preference structure applying the utility concept from economics (Green et al. 2001). It thereby provides evidence on the most influencing factors on the consumer's choice of a product. For these reasons, CA is gaining popularity to study information privacy tradeoffs in different types of online services (Zibuschka et al. 2019; Wessel et al. 2019; Baum et al. 2018, Mihale-wilson et al. 2017; Ho et al. 2010; Krasnova et al. 2009). A recent literature review on CA in IS research by Naous and Legner (2017) emphasizes that CA is a very suitable method to inform IS design through an empirical analysis of user preferences. We apply ACBCA, which extends the traditional full-profile CA (Green and Srinivasan 1978). In this CA variant, we ask participants to choose among a set of profiles (or stimuli) after they perform a self-explicated task to assess different implementation options and exclude unacceptable attribute levels from the evaluation to reduce the choice burden. Based on users' choices, part-worth utilities and relative importance measures are calculated using the Hierarchical Bayes (HB) estimation (Howell 2009).

5.2 User's Preference Model for Contact Tracing Apps

The first step of CA is to select relevant attributes and levels describing the contact tracing app as input for user evaluation. This would result with a user preference model corresponding to favoured app characteristics. In selecting the attributes and levels, we followed a mixed method approach (Naous and Legner 2017) based on four stages: (1) a literature review on contact tracing apps to assess core functionalities and privacy related characteristics, (2) an analysis of existing contact tracing apps, (3) a focus group with current and potential users of SwissCOVID app, and finally (4) an assessment with two privacy experts with a market overview of contact tracing apps to gain insights on feasible features.

In the first stage, the literature review allowed us to identify 12 attributes corresponding to four dimensions that represent the main contact tracing app features along with privacy-related aspects (Table 4): *initiation* of the app, *core functionalities* involving exposure logging and notifications, *transparency and control* related to data management aspects, and *platform characteristics* in terms of approach and integration. While some attributes were clearly defined in the literature, the second phase of selection (i.e., analysis of existing apps) allowed us to examine realization options and identify the attribute levels. Based on the analysis of the ten contact tracing apps shown in Table 1, we were able to add two attributes to our list characterized as value-added services that can provide additional benefits and attract more users: diagnosis and contextual services. For diagnosis, some apps included symptoms checker based on a health checklist (e.g., Stopp Corona and NHS COVID-19 apps), and artificial intelligence may be used for automatic diagnosis and detection based on sensor information (CORDIS, 2020). For contextual services, some apps (e.g., TraceTogether) provide a check-in service with QR codes for safe entry. In addition, they allow identification of safe places and infected zones, in case they rely on location information (e.g., SafePlaces).

In the third phase of the attributes and levels selection, we organized a focus group with five current and potential users of COVID-19 apps. The focus group provides insights from users (Morgan and Scannell 1998), which allows us to identify important attributes and eliminate unacceptable realization options in view of their relative value and users' privacy perceptions. From the discussion, we were able to eliminate five attributes that had uniform consensus on their implementation options and users accepted no other alternatives in any case.

The users emphasize that participation in such apps should always be voluntary and no enforcement is acceptable, which is also conserved by law. Moreover, a discussion of the available contact tracing mechanisms (i.e., centralized versus decentralized) shows that the applications can function without any personal information being shared in both architectures respecting the data minimization approach (Legendre et al. 2020). Also, users emphasize the unlikelihood of sharing personal information on contact tracing apps. Log duration did not seem of importance to users, it should only respect the scientific specifications related to the spread of the virus and specified in the incubation period of 14 days (Legendre et al. 2020). In terms of transparency and control, data storage was eliminated due to unacceptable options related to worldwide cloud storage, which might compromise their data.

Dimension	Attribute	Description
Initiation	User registration	Specifies the information required at registration
	User participation	Specifies whether the app is voluntary or mandatory
Core Functionalities	Exposure logging	Specifies the type of traces stored
	Test result sharing	Specifies the mechanism in which positive test results are shared on the app
	Exposure notification	Specifies the form of notification in case of contact with a positive case
Transparency and Control	Dashboard	Specifies the information available to the user on data treatment
	Data sharing	Specifies the purpose of sharing and with which parties
	Data storage	Specifies the location of data stored
Platform Characteristics	App Architecture	Specifies the contact tracing mechanism
	Log duration	Specifies the duration for which the traces are stored on the app
	Interoperability	Specifies the scope of integration

Table 4. Initial list of attributes

This phase also allowed us to add one attribute that we did not consider in our initial list related to health information. The ability to provide a risk assessment on the app might require additional health information for accurate estimations. We therefore consider health information registration as an option for the initiation dimension.

We finally assess the list of attributes and levels with two privacy experts (who are also familiar with the different contact tracing apps) that validated the attributes and the levels. Two levels were discussed in details due to their critical effect on the privacy of app users. First, we considered an option to add medical history information on the app. This type of information is considered to be sensitive and might be a barrier for adoption, therefore we suggest only to have information about health status relative to the risk groups identified for COVID-19. Second, for the exposure notification attribute, we suggested a live notification in case of a positive ID is detected nearby as proposed by users in the focus group. This was expected to be helpful in detecting users who are not respecting the self-isolation rule in case of infection. However, the experts explain that the app is made to inform users who have been in close contact to positively diagnosed users before they were tested. Therefore, this option was defined as privacy intrusive for infected people, which might cause them to stop using the app.

Dimension	**Attribute**	**Attribute Levels**
Initiation	Health Information registration	No information is required
		Health status (i.e., COVID-19 risk groups information)
Core Functionalities	Exposure Logging	Contacts (Bluetooth)
		Locations (GPS Traces)
		Contacts & Locations
	Test Results Sharing	User can share symptoms or positive test results on app
		User can share positive test results on app only with a validation code by the healthcare provider
		Healthcare provider directly shares test results (positive/ negative) with users
	Exposure Notification	Alert only if you had contact with an infected person
		Alert if you had contact with an infected person; includes risk assessment (low, medium, high)
Value-added Services	Diagnosis services	No in-app diagnosis
		Simple diagnosis: Symptoms tracking with a checklist
		Advanced diagnosis: Using sensors to capture symptoms (e.g., breathing, coughing)
	Contextual services	No additional services
		Check-in service with QR code in public places for safe entry (e.g., restaurants, supermarkets)
		Maps with indication of safe areas/ infected zones
Transparency and Control	Dashboard	Basic dashboard on data logging
		Detailed dashboard on data logging, updates and sharing
	Data sharing	Restricted to contact tracing (sharing with app provider, i.e., public health authorities)
		Contact tracing, epidemiological insights and research (sharing with public health authorities, healthcare providers and researchers)
		Contact tracing, research and specific purposes for safety measures (e.g., restaurants, transportation providers, workplace)
Platform Characteristics	App Architecture	Centralized: matching with positive cases done by a central server
		Decentralized: matching with positive cases done on your phone
	Interoperability	Cross-country integration
		No cross-country integration

Table 5. List of attributes and levels

We finally assess the list of attributes and levels with two privacy experts (who are also familiar with the different contact tracing apps) that validated the attributes and the levels. Two levels were discussed in details due to their critical effect on the privacy of app users. First, we considered an option to add medical history information on the app. This type of information is considered to be sensitive and might be a barrier for adoption, therefore we suggest only to have information about health status relative to the risk groups identified for COVID-19. Second, for the exposure notification attribute, we suggested a live notification in case of a positive ID is detected nearby as proposed by users in the focus group. This was expected to be helpful in detecting users who are not respecting the self-isolation rule in case of infection. However, the experts explain that the app is made to inform users who have been in close contact to positively diagnosed users before they were tested. Therefore, this option was defined as privacy intrusive for infected people, which might cause them to stop using the app.

Based on these phases, our final list was formed of ten attributes with their corresponding levels (Table 5). The list includes the following attributes and their realization options:

Initiation:

- Health information registration: specifies whether data about health status (e.g., COVID-19 risk groups) is required on the app or not for a more robust data analysis and ideally risk assessment.

Core Functionalities: (realized by existing COVID-19 apps)

- Exposure logging: corresponds to the tracing mechanism employed on the app. It could be proximity tracing with Bluetooth technology, location tracking via GPS traces or a combination of both.
- Test results sharing: indicates how the exposure notification is triggered on the app; it could be via user sharing on the app symptoms or positive test results, sharing positive test results validated by the healthcare provider, or direct sharing of test results by the healthcare provider (i.e., also includes clearing status in case of negative test results).
- Exposure notification: refers to how users get notifications in case of encounter with an infected person. It could be alerting only in case of exposure, in addition users can get risk assessment based on information on country region, health status and possibly other background information.

Value-added services: (not yet in scope of the COVID-19 apps, but could provide additional benefits to users)

- Diagnosis services: can be used for checking COVID-19 symptoms; they can be either through basic health checklists on possible symptoms or advanced diagnosis with machine learning on mobile sensor data (i.e., heart rate, breathing, coughing strength, etc.).
- Contextual services: correspond to additional services related to safety measures; examples are check-in services for safe entry in public places based on customer count or identification of safe places and infected zones through interactive maps.

Transparency & Control:

- Dashboard: corresponds to the transparency about the data usage on app; could be a basic dashboard on status and data logs or detailed with sharing information on data logging, contact traces and sharing parties.
- Data sharing purpose: refers to what is the target of data sharing and with whom it will be shared; it can be restricted to contact tracing (sharing with app provider, i.e., public health authorities only), involves epidemiological insights and research (sharing with public health authorities, healthcare providers and researchers), or also includes sharing for additional safety measures (for instance check-in at restaurants, public transports or workplaces).

Platform characteristics:

- App Architecture: corresponds to the communication structure of the app. Platforms communicate anonymously in a centralized or a decentralized approach. In a centralized architecture, users share their IDs with a central server managed by the public health authorities and matching with positive cases is done on the server. In a decentralized approach, only an infected person is required to share his data with the server and all matching with positive cases is done on the user's smartphone that periodically receives the list of infected IDs from the server.
- Interoperability: corresponds to the cross-country integration options; it could be a national app that can only be used in the specific country, or a national app that allows safe information exchange with other apps to be used when travelling.

5.3 Study Sample

In order to obtain qualified results, we targeted 300 participants from Germany who are users or potential users of the national contact tracing app (Corona-Warn-App). We selected Prolific.co as crowdsourcing platform to hire survey participants from an online pool of users. Crowdsourcing platforms, such as MTurk and Prolific, provide fast, inexpensive and convenient sampling method and are appropriate for generalizing studies (Jia et al. 2017). They have been widely used in research on security and privacy (Redmiles et al. 2019) and allow a wide reach in CA studies (Naous and Legner 2019; Pu and Grossklags 2015). Participants were screened based on their smartphone use and knowledge about the COVID-19 app. Survey respondents were compensated 2.50£ for their participation, which is a fair amount for a 15-20 minute survey on this platform. As quality criteria, we eliminated any response that took less than 7 minutes for survey completion, which might affect the consistency of the analysis.

From the total sample of 300 respondents, we included 283 in the final data analysis. We had 55.83% male participants and 44.17% females. A total of 94% of participants aged less than 46 years old. The majority aged between 26 and 35 years old (50.18%). Our respondents are mostly privacy aware (82.33%) and have knowledge about the misuse of user information. In addition, the majority of respondents (77.03%) have university education on multiple levels. Among them, 52.30% are employed and 35.34% are students. In terms of mobile app use, our sample is tech-savvy and uses plenty of applications. For context-aware apps, 95.41% use navigation apps and 79.86% use social networking apps. As for mHealth apps, 54.77% use health and fitness tracker apps. Finally, we note that 62.54% of the respondents think that the COVID-19 contact tracing app should be mandatory.

Variable	**Level**	**%**
Gender	Male	55.83
	Female	44.17
Age	18-25	31.10
	26-35	50.18
	36-45	12.72
	46-55	3.53
	56-65	2.12
	66-75	0.35
Privacy Consciousness	Not informed	17.67
	Well informed	82.33

Table 6. Sample demographics and background information

5.4 Study Setup

We used specialized commercial software, Sawtooth Software, to administer our study and run our online survey. The survey started with an introduction about contact tracing apps and the conjoint survey sections. We then explained the attributes involved and the different levels (or options) before collecting user choices in the typical ACBCA sections. We added screenshots of the app when possible to illustrate the differences between levels, this was done for two attributes: exposure notification and dashboard (Figure 2). Prototyping and visual description of the attribute levels would make it easier for the users to select based on concrete realization instead of verbal descriptions (Naous and Legner 2017). The last phase of the survey included questions on demographics (gender, age) and professional background, as well as questions on general mobile app use and opinion about the COVID-19 app.

(a) Exposure notification **(b) Dashboard**

Figure 2. Mobile screenshots for attributes levels

The ACBCA survey sections comprised four sections that should be completed in the following order:

- Section 1 – Build Your Own (BYO): Participants are asked to build the most preferred configurations of the contact tracing app from the list of available attributes and levels. The following sections are then adapted to the preferred levels selected by the participants.
- Section 2 – Screening: Participants are asked to evaluate the possibility of using multiple combinations of product profiles. The survey contained 7 screening tasks that showed 3 options each. As part of the self-explicated task, respondents are asked about must have and unacceptable features based on their response pattern within the screening task. These identified features will not be displayed in the choice tournament later on during the survey to avoid bias in selection.
- Section 3 – Choice Task Tournament: Participants are then asked to evaluate contact tracing apps combinations and choose the best option among them. We present a maximum of 10 choice tasks to respondents with three options in each task. This would allow us to estimate the user preferences for the different attributes and levels based on the choice data.

- Section 4 – Calibration: A benefit of traditional CBCA is the ability to include a "None" option. However, this is not available in ACBCA, instead a "None" threshold can be estimated via the Screening section and Calibration that allow to perform additional step in calibrating utilities (Sawtooth Software 2014). This is an optional section of ACBCA in which participants are shown six concepts, including the concept identified in the BYO section, the concept winning the Choice Tournament as well as four previously shown concepts that were either accepted or rejected. The participant is asked about their likelihood to use these concepts using five-point scale from "Definitely would not" to "Definitely would".

5.5 Results

5.5.1 Build Your Own

The BYO section provides insights into mostly preferred application characteristics by users assessed independently of each other. A majority of participants in our study had a tendency to select the privacy-preserving options, but also selected some options that provide an enhanced service. For example, the majority selected the risk assessment option for the exposure notification (59.72%), also 47.35% selected having a simple diagnosis service to check symptoms, and 85.87% selected the cross-country integration option. We provide a detailed distribution of the BYO section in Figure 3.

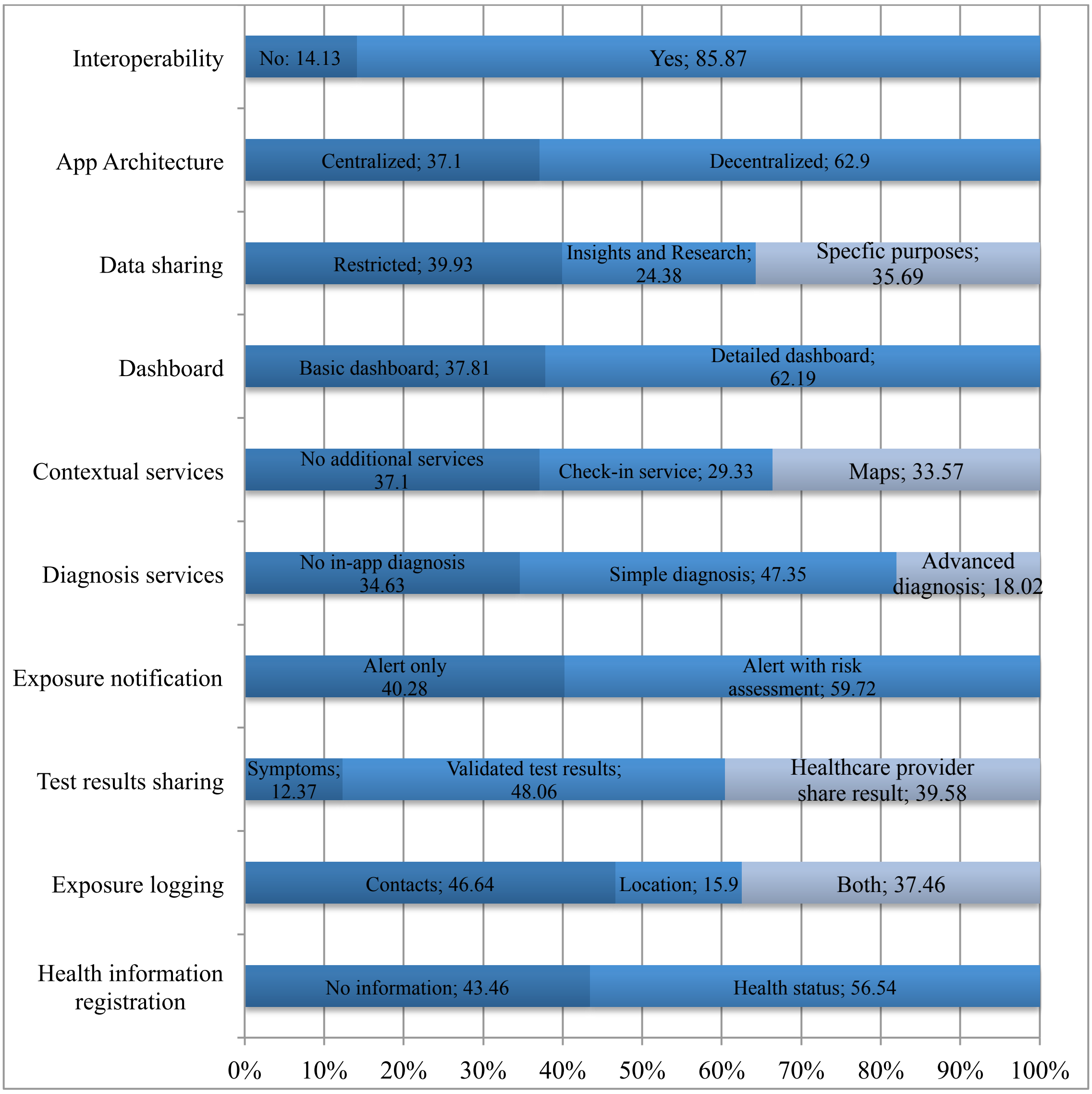

Figure 3. BYO section distribution

5.5.2 Part-worth Utilities and Preferences

CA provides part-worth utility estimation for product attributes. The part-worth utilities are normalized HB estimated, where positive utilities correspond to preferred levels and negative utilities correspond to undesired levels. We assess the “goodness of fit” using percentage certainty (PC) and root likelihood (RLH) (Giessmann and Stanoevska 2012). We obtained a PC mean of 0.486, indicating acceptable results of fit. RLH valued 0.654, which is considered more fit than the chance level given we have three choice tasks.

Compared to the BYO, the part-utility distribution (Table 7) allows us to identify attribute levels that are mostly selected by users through the choice options, thus correspond to their preference structure with respect to the overall app design. Interestingly, we observe that users prefer to provide information about their health status on the app, we expect that this is related to the fact that this information would help to provide more targeted analysis of their situation in regards to COVID-19. In terms of exposure logging, contact tracing via Bluetooth - the most privacy-preserving option - has the highest utility, while GPS tracking had a negative utility and a combination of both has positive utility. For test results sharing, users have positive utilities for trusted and officially validated test results sharing. However, the highest utility was for sharing by the user via a validated code from the healthcare provider. For exposure notification, users appreciate having a risk assessment in addition to the notification. In terms of value-added services, the highest utilities were for simple diagnosis service. Although advanced diagnosis options with mobile sensors can be of great help in detecting patterns and assessing severity of symptoms, users do not value it much based on our results. This is probably due to increased concerns of extensive data collection via the app. For contextual services, users seem to prefer the second option with maps identifying infected zones. However, when assessed individually in the BYO section, results show that users would not prefer an additional contextual service with the app. Probably due to associated location sharing component and the related concerns. For transparency and control, higher utilities were recorded for the detailed dashboard and restricted data sharing, which are more privacy-preserving options. For the choice of platform, users have positive utilities for the decentralized approach as more privacy-preserving approach also. Finally, the cross-country integration is preferred by users who would be interested to use the app while traveling and across-borders. This topic has been recently discussed in media, and finally European Union (EU) member states have agreed on a technical framework for cross-country contacts tracing for travellers and cross-border employees (Lomas 2020).

Attribute	Attribute levels	Average Utilities	Standard Deviation	Distribution for BYO Section (%)
Health information registration	No information is required	-2.86	51.16	43.46
	Health status (e.g., COVID-19 risk groups information)	2.86	51.16	56.54
Exposure logging	Contacts (via Bluetooth)	41.46	113.56	46.64
	Location (via GPS)	-50.00	83.95	15.90
	Contacts and Location (Bluetooth & GPS)	8.54	62.07	37.46
Test results sharing	User can share symptoms or positive test results on app	-51.42	58.06	12.37
	User can share positive test results on app only with a validation code by the healthcare provider	32.69	42.74	48.06
	Healthcare provider directly shares test results (positive/ negative) with users	18.72	51.74	39.58
Exposure notification	Alert only if you had contact with an infected person	-7.01	30.56	40.28
	Alert if you had contact with an infected person with risk assessment (low, medium, high)	7.01	30.56	59.72

Diagnosis services	No in-app diagnosis	5.74	53.54	34.63
	Simple diagnosis: Symptoms tracking with checklists	25.83	31.15	47.35
	Advanced diagnosis: Using sensors to capture symptoms (e.g., breathing, coughing)	-31.57	57.32	18.02
Contextual services	No additional services	-4.52	51.02	37.10
	Check-in service with QR code in public places for safe entry (e.g., restaurants, supermarkets)	-8.67	52.58	29.33
	Maps with indication of safe areas/ infected zones	13.19	32.43	33.57
Dashboard	Basic dashboard on data logging	-9.30	18.76	37.81
	Detailed dashboard on data logging, updates and sharing	9.30	18.76	62.19
Data sharing	Restricted to contact tracing	11.12	41.96	39.93
	Contact tracing, epidemiological insights and research	3.39	26.85	24.38
	Contact tracing, research and specific purposes for safety measures (e.g., restaurants, transportation providers, workplace)	-14.51	46.59	35.69
App Architecture	Centralized: matching with positive cases done by a central server	-37.37	69.83	37.10
	Decentralized: matching with positive cases done on your phone	37.37	69.83	62.90
Interoperability	No cross-country integration	-45.09	44.76	14.13
	Cross-country integration	45.09	44.76	85.87

Table 7. User preferences and part-worth utilities (preferred levels are highlighted)

5.5.3 Relative Importance

Part-worth utilities can be translated into relative importance scores to understand user preferences (Figure 4). Our results show exposure logging (19%) as the most important attribute for users of such app. This means that the tracing mechanism (i.e., via Bluetooth or GPS) is very important in their acceptance criteria. Test results sharing (13%) is the second most important attribute, which shows that users are concerned about how their test result would be communicated on the app and by who. The app architecture (12%) comes next, which is a consequence of the general debate about central and decentralized architectures. Diagnosis services (11%) come next, where users would be interested to know if the app helps them to check their symptoms. Interoperability (i.e, cross-country integration) and contextual services follow with 10% importance score. Data sharing and health information registration had a similar importance of 8%. Although these two attributes are concerned about user privacy on the app and the associated risks, they seem to be less important to users who most importantly focus on core functionalities as criteria for using the app. In addition, exposure notification (5%)

was less important to users who might not be interested on the method or form of the notification about exposure (i.e., simple notification versus a risk assessment included). Finally, the transparency on the app did not seem to have importance to users as the dashboard feature was least important with a score of 4% which contradicts other studies on privacy concerns and transparency in data management (Ahmed et al. 2020).

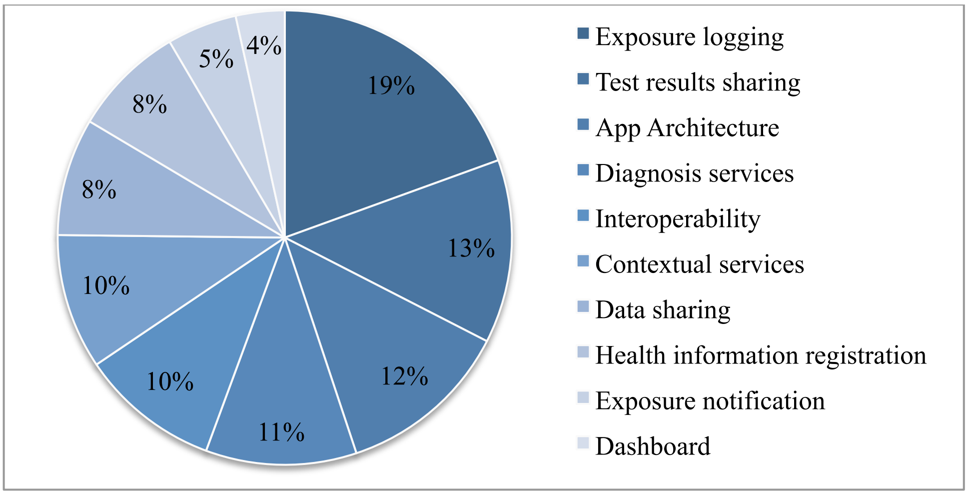

Figure 4. Relative importance of contact tracing app attributes

5.5.4 User Segmentation

To gain insights into user segments for contact tracing apps, we performed a cluster analysis based on the individual part-worth utilities. By applying k-means clustering using the Convergent Cluster & Ensemble Analysis module from Sawtooth, we derived three clusters of users with varying preferences with respect to privacy-preserving features and value-added services (Table 8). While the first two clusters (with majority of users combined) are privacy concerned and prefer basic features that guarantee user privacy, the third cluster is unconcerned and would prefer all options that provide an enhanced app. In terms of value-added services, clusters two and three have a preference towards apps with value-added services with varying levels.

The first two clusters are similar by their preferences to privacy-preserving features when it comes to the core functionalities including contact tracing via Bluetooth and sharing only validated test results to avoid false alerts. However, for exposure notification, the second group prefers having a risk assessment in addition to the notification. In addition, both segments do not prefer to share any health information on the app. For transparency and control, they prefer a detailed dashboard and no data sharing with other parties than the public health authorities. For platform characteristics, both segments prefer a decentralized approach, however a cross-country integration. The main difference is in the value-added services, where the first segment does not prefer any value added-service, while the second segment prefers at least a simple diagnosis service for tracking COVID-19 symptoms, and a contextual service that provides information about infected zones and safe places. The third cluster, with largest number of users, prefers enhanced features on all attributes. Major differences to the previous segments are in the health information registration, exposure logging, and diagnosis services where this segment would prefer an app that is based on contact and location tracking, as well as advanced diagnosis services. This segment also has inherent trust in the authorities, and would choose all options that guarantee the proper functioning of the app even if it would be privacy intrusive. This is shown in their choice of test results sharing by the authorities and the centralized approach. In addition, data sharing for this segment can be for different purposes that help fight the pandemic in different contexts.

	Cluster 1	**Cluster 2**	**Cluster 3**
Number of participants	76 (26.85%)	92 (32.51%)	115 (40.64%)
Privacy Characterization	Privacy concerned users	Privacy concerned users	Unconcerned users
Value-added services	No additional services	Included	Included
Preferences			
Health information registration	No information is required	No information is required	Health status information
Exposure logging	Contacts (via Bluetooth)	Contacts (via Bluetooth)	Contacts and Location (Bluetooth & GPS)
Test results sharing	User can share positive test results on app only with a validation code by the healthcare provider	User can share positive test results on app only with a validation code by the healthcare provider	Healthcare provider directly shares test results (positive/ negative) with users
Exposure notification	Alert only if you had contact with an infected person	Alert if you had contact with an infected person with risk assessment (low, medium, high)	Alert if you had contact with an infected person with risk assessment (low, medium, high)
Diagnosis services	No in-app diagnosis	Simple diagnosis: Symptoms tracking with checklists	Advanced diagnosis: Using sensors to capture symptoms
Contextual services	No additional services	Maps with indication of safe areas/ infected zones	Maps with indication of safe areas/ infected zones
Dashboard	Detailed dashboard on data logging, updates and sharing	Detailed dashboard on data logging, updates and sharing	Detailed dashboard on data logging, updates and sharing
Data sharing	Restricted to contact tracing	Restricted to contact tracing	Contact tracing, research and specific purposes for safety measures
App Architecture	Decentralized: matching with positive cases done on your phone	Decentralized: matching with positive cases done on your phone	Centralized: matching with positive cases done by a central server
Interoperability	Cross-country integration	Cross-country integration	Cross-country integration

Table 8. Identified clusters with preferences based on customer segmentation (common preferences are highlighted)

5.5.5 *Variation Analysis*

Variation analysis allows us to study the effect of changing attributes on market share predictions. Thus, it provides a market simulation based on reliable quantitative data that can feed the design of the app and improve the adoption. With the ACBCA, a None parameter can be estimated in market simulations to predict whether the respondents would be selecting a proposed option or not. Based on that, if the utility of the product concept proposed is higher than the None utility, it will be chosen (Sawtooth Software 2014). Then, the market simulations would allow us to study adoption intentions in addition to the design preferences for value-added services as they have varying preferences among users.

Wortmann et al. (2019) propose that goal-congruent feature additions to the core features of a system can result in higher adoption. Accordingly, we study with this simulation if having value-added services with the proposed contact tracing app can result in higher market shares, thus better adoption rates. As a reference app, we have the characteristics of the Corona-Warn-App that is currently active in Germany. We then propose 5 variations on the value-added services (Table 9) corresponding to the multiple combinations of value-added services. App 1 has a simple diagnosis service for checking symptoms via checklists. App 2 has an advanced diagnosis service based on data processing of sensor data (e.g., heart rate, breathing, coughing, etc.) and applying machine learning algorithms on that. App 3 has a safe entry check-in service with QR code that can be used in public places for tracking the count of people inside a place and tracking positive check-ins. App 4 has a map function with indications of safe places and infected zones within a region. The final app (App 5) combines two value-added services that are selected with highest utilities: simple diagnosis and map function.

Based on the simulation results, we observe that all apps generate market shares. This means that their utility is higher than the None threshold, and people would be willing to adopt such apps. However, the difference in market shares compared to the reference app (i.e., Corona-Warn-App) vary in strength. We observe that App 1 and App 4 would result in higher market shares with slightly better results for the diagnosis service in App 1. Consequently, App 5 with a diagnosis service of symptoms tracking and contextual service of maps also resulted in higher market shares corresponding to 60% of users.

Label	Reference	App 1	App 2	App 3	App 4	App 5
Description	Corona-Warn-App	Simple Diagnosis	Advanced Diagnosis	Check-in Service	Maps	Simple Diagnosis + Maps
Health information registration	No information is required					
Exposure logging	Contacts (via Bluetooth)					
Test results sharing	User can share positive test results on app only with a validation code by the healthcare provider					
Exposure notification	Alert if you had contact with an infected person with risk assessment					
Dashboard	Basic dashboard on data logging					
Data sharing	Restricted to contact tracing					
App Architecture	De-centralized					
Interoperability	No cross-country integration					
Diagnosis services	No in-app diagnosis	Simple diagnosis: Symptoms tracking with checklists	Advanced diagnosis: Using sensors to capture symptoms	No in-app diagnosis	No in-app diagnosis	Simple diagnosis: Symptoms tracking with checklists
Contextual services	No additional services	No additional services	No additional services	Check-in service with QR code in public places for safe entry	Maps with indication of safe areas/ infected zones	Maps with indication of safe areas/ infected zones
Market share		**57%**	**39%**	**49%**	**56%**	**60%**

Table 9. Scenarios for variation analysis simulation

6 Discussion

This research aims to understand the user perspective on contact tracing apps that are at the center of attention in the current worldwide pandemic of COVID-19. They are arguably one of the best tools we currently have available to avoid a second wave of COVID-19 and potential re-lockdown. We primarily address Pillar III of Von Wyl et al.'s (2020) research agenda for digital tracing apps, on acceptability of tracing apps as part of health technology. This is achieved by providing a micro perspective (i.e., that of the user), providing insights into the users' perceptions of individual benefits and risks of app usage, as well as users' preferences for contact tracing apps through evaluation of feasible design options. This will help in driving uptake based on empirical evidence. Empirical insights into understanding the user perspective and the motivation to use amidst privacy concerns are investigated. As theoretical lens, we employ two methods from IS research that study user adoption and trade-offs.

6.1 Users' Perceptions on Contact Tracing Apps

The empirical results show that respondents do not understand all benefits related to safety when it comes to using contact tracing apps or simply they do not perceive them as benefits for this app. It is especially the case for individual benefit of safe places and workplace safety. Safe places can imply sharing location information versus proximity only. Germany, where our survey was conducted, adopted a proximity-based approach with the Corona-Warn-App, which can partially explain these results. Previous research on location-based services (Naous et al. 2019; Xu et al. 2009) shows that location information is considered to be sensitive to users and can be associated to multiple risks of identification based on mobility traces. This would support the more privacy-preserving approach of proximity tracking via BLE, in terms of users' perceived privacy risks and privacy concerns, versus having an exact location component per mobile network or GPS. Only few countries have followed a location-based approach due to the privacy constraints involved (Legendre et al. 2020). Trang et al. (2020) discuss that societal benefits are a more powerful antecedents to contact tracing app adoption than individual benefits. Our model shows that societal safety and epidemiological insights have positive significant relationship with intentions to use contact tracing apps, workplace safety seems to be less valued by users. To guarantee the application of safety measures within the workplace, the contact tracing app provides a helpful solution. However, having the employer's control over employee data might be the main barrier for using the app within the workplace environment.

From the analysis, we see that privacy concerns do not necessarily impact the intentions to use contact tracing apps. However, we observe that participants who have high privacy consciousness due to previous experience have higher privacy concerns, which significantly impact the intentions to use. Previous research in the domain of social networks and e-commerce discusses how privacy concerns and their resulting privacy risk perceptions act as impediments to the disclosure behaviour and intentions to use (Xu et al. 2009; Krasnova et al. 2010). However, Acquisti and Grossklags (2004) explain that users' attitudes can be contradictory with their behaviors, resulting with a privacy paradox phenomenon. A recent review on the privacy paradox by Barth and de Jong (2017) discusses that users are willing to compromise their privacy based on their assessment of the cost-benefit trade-offs. As such, they are willing to use or disclose information in return of an expected benefit, which can be critical in this situation of contact tracing apps for fighting the pandemic.

Moreover, our results show a negative relationship between the risk antecedents and the perceived privacy risks. Empirical results emphasize how the perceived privacy control by users can decrease their perceived privacy risks, which can result in higher intentions to use. This also applies for the trust items, where trust in government regulations for protecting the individual and the trust in the app provider as the authorities is important in diminishing the effect of privacy risks. This shows the importance of transparency within the app and the communications from the government to the citizens. Having control over the information and visibility on the data processing and treatment by the app provider is needed to minimize risk perceptions. One avenue to explore, in order to augment the app acceptability per Pillar III of Von Wyl et al.'s (2020) research agenda would be to follow participatory design principles or co-creation (user and provider) principles, as it can solidify user's trust through the equalizing of power (Gupta and De Gasperis 2020).

Our results also show the positive impact of social norms on the intention to use. This is a very important point to consider for increasing adoption. In fact, users would be willing to use the app if others are using it (Min and Kim 2015). This is the case especially for people who influence their decisions and behaviour. In the age of social media, influencers can play a decisive role in gaining critical mass and communicating the benefits of the contact tracing app. Germany's neighbour, Switzerland, had 30 influencers promote SwissCOVID on Instagram and had 1.4 million views of an advertisement for the app, placed by @swisspublichealth on the Tik Tok platform. Moreover, employers and essential businesses can drive this adoption rate by promoting and recommending the use of app on their premises. Numerous multinationals have issued internal circulars to this end. Indeed, the app is not useful if there is not a critical mass using it. As soon as there are enough other users, the corresponding network effects will serve to increase user confidence and in turn their intentions to use it.

6.2 Users' Preferences for Contact Tracing Apps

The privacy calculus provides insights into the motivations and barriers for users' intentions to use contact tracing apps, however we conclude that no concrete system realizations can be achieved unless an evaluation of system features is also performed. Our empirical study with CA provides this system evaluation through features, and allows for a detailed understanding of users' preferences. We highlight which privacy-preserving features are required or mostly valued by users via part-worth utility measures and relative importance of features. Results from the conjoint study show that the exposure logging and test results sharing are the most important features in the contact tracing apps. In fact, as the core features they should be able to provide a reliable service for users. In general, the participants have preferences for contact tracing through proximity (i.e., Bluetooth) and would not prefer a location-based tracking via GPS. Moreover, the test results sharing should be done in a trustworthy manner to avoid any false notifications and lack of information. Therefore, a validation code provided by the healthcare providers or shared directly by them can guarantee a high level of trustworthiness for users. In addition, the application architecture is of importance to users because it specifies how the data is shared and how the matching with positive cases is performed. The users prefer a decentralized approach as it is considered to be more privacy-preserving than the centralized approach where data would be shared with the authorities. However, the results show that transparency (via the dashboard for example) and data sharing purposes are least important to users. Although the privacy calculus model shows a significant relationship between privacy control settings and perceived risks, the results of users' preferences might be explained by the fact that these apps should have privacy by design principles as they are implemented by authorities who should protect the privacy rights of citizens. As per the EU General Data Protection Regulation (GDPR), improper access to information, misuse and secondary use of personal information are legally prohibited. Moreover, user consent is required for sharing personal data and before any data processing can be done (Yang et al. 2018). Therefore, it seems that users within our sample have trust in the current law enforcement practices by the government and do not expect any negative outcomes. This is a starting point for achieving higher adoption rates, since results from the privacy calculus show that trust in government regulations plays positive role in diminishing users' perceived risks.

Our analysis also provides insights into group preferences, represented by the user segments identified. While we observe a tendency for privacy-preserving features and basic functionalities (in the first and second segments), group preferences also show the importance of value-added services. In fact, Wortmann et al. (2019) have argued that adding goal congruent features to the core system may result in higher adoption. This is shown within our results, because a large number of users have a preference for extended features within the apps, and confirmed by the market simulation and variation analysis from the current contact tracing app in Germany. As an implication, the current contact tracing app could achieve higher market shares if value-added services for diagnosis of symptoms and contextual services for identifying safe places were added beyond the basic app for tracing encounters. Another option would be to develop auxiliary apps that can be integrated within the COVID-19 app. For instance, Singapore has merged the national TraceTogether app for contact tracing via Bluetooth with the SafeEntry app that is used in businesses and public places for safe check-ins as part of the safety measures to increase adoption rate (Lee 2020).

7 Conclusion

A major contribution of this research is the empirical contributions on IS adoption under privacy trade-offs. The empirical studies improve the understanding of the user's perspective on for security and privacy features, willingness to accept as well as market reactions to design variations for a specific application category of context-aware service for the COVID-19 pandemic. Applying privacy calculus, our results provide insights into the motivations and barriers behind the use of contact tracing apps for a better understanding of benefit and risk perceptions by users. For this application category, we provide a list of attributes and levels in five categories. Our instantiation of the ACBCA provides insights on how this method can extend existing adoption approaches through estimating a utility function that corresponds to users' preferences. Moreover, we illustrate through market simulations how we can predict users' intentions to use product concepts through market shares as a measure of adoption. Future research should assess the applicability of this approach to study users' preferences for understanding the impact of design variations on improving the app adoption. In addition, we encourage additional studies for understanding users' perceptions and preferences on contact tracing apps in different settings. Our study has focussed on a sample from Germany with apriori model of decentralized contact tracing, but contact tracing apps have a national scope and thus may be impacted by the specific national implementation as well as contextual factors. It would be interesting to have comparative studies in other countries that have introduced centralized proximity or location-based tracing apps to assess the different design options.

From a practical perspective, our results are relevant to application developers and service providers of contact tracing apps. Understanding user's privacy trade-offs assists developers and providers to address the privacy by design principle through operationalizing features valued and accepted by users. Most importantly, it provides insights on what information can be shared within the app, how and for which purposes. Additionally, our results show that an improved understanding of the benefits of contact tracing app would augment user information disclosure and consequently adoption. Moreover, the preference model resulting from the CA study provides concrete realization options of the contact tracing app to be taken into consideration in order to gain sufficient critical mass and acceptability amongst users. In addition, our simulation results on value-added services are an important topic for consideration in further developing and improving the current apps through targeted and extended services.

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Appendix

Construct		Adapted	Measures	Mean	Standard deviation
Perceived Privacy Risk (prk)	prk1	Xu et al. 2009	I feel that using the COVID-19 app would involve many unexpected problems.	4.02	1.85
	prk2		Overall, I see no real threat to my privacy when using the COVID-19 app.*	4.46	1.99
	prk3		I feel that using the COVID-19 app is risky.	3.54	1.93
Privacy Concerns	pc1	Self-developed	I am concerned that with the COVID-19 app my personal information could be misused.	3.71	2.06
	pc2		I am concerned that with the COVID-19 app others can identify myself through my mobility patterns.	3.71	2.00
	pc3		I am concerned that the COVID-19 app exposes my social interactions.	3.45	1.97
Benefit: Individual Safety - Proximity Tracking (bisp)	bisp1	Self-developed	I trust that the COVID-19 app reliably identifies actual contact with a person infected with COVID-19.	4.55	1.77
	bisp2		I trust that the COVID-19 app notifies me on exposure to the virus.	4.86	1.79
	bisp3		I trust that the COVID-19 app detects possible encouter with a person infected with COVID-19.	4.76	1.74
Benefit: Individual Safety - Safe Places (biss)	biss1	Self-developed	I trust that the COVID-19 app detects locations that have reported high number of infections.	4.67	1.76
	biss2		I trust that the COVID-19 app informs me about safe places where no COVID-19 cases have been detected.	4.16	1.78
	biss3		I trust that the COVID-19 app informs me about locations in which infected persons have recently been.	4.48	1.82
Benefit: Societal Safety (bcs)	bcs1	Self-developed	With the COVID-19 app, I am able to share my status with people I have been in contact with in case I had COVID-19.	4.81	1.72
	bcs2		With the COVID-19 app, I am able to notify my recent contacts in case of infection with COVID-19.	4.87	1.70
	bcs3		With the COVID-19 app, I am able to protect my family and friends through notifying them in case of infection with COVID-19.	4.67	1.84
Benefit: Epidemiological Insights (ei)	ei1	Self-developed	I trust that, with the COVID-19 app, authorities are able to better monitor the spread of COVID-19.	4.58	1.83
	ei2		I trust that the COVID-19 app improves the statistics on the spread of the virus.	4.70	1.76
	ei3		I trust that the COVID-19 app provides relevant information for deciding on measures that reduce the spread of the virus.	4.64	1.74
Benefit: Workplace Safety (bws)	bws1	Self-developed	With the COVID-19 app, my employer is able to monitor any cases of COVID-19 amongst employees.	3.70	1.86
	bws2		With the COVID-19 app, my employer is able to implement safety measures within the company.	4.01	1.79
	bws3		With the COVID-19 app, my employer is able to identify concerned employees who have been exposed to COVID-19.	3.81	1.84
Intentions to	i1	Xu et al.	I am likely to use the COVID-19 app authorized by	4.12	2.14

use (i)		2009	public health authorities.		
	i2		I am willing to use the COVID-19 app authorized by public health authorities.	4.18	2.15
	i3		It is probable that I use the COVID-19 app authorized by public health authorities.	4.16	2.16
Social Norm (sn)	sn1	Min and Kim 2015	I feel that I should use the COVID-19 app because everybody else seems to be using it.	3.72	1.97
	sn2		I feel that most people who are important to me think I should use the COVID-19 app.	3.61	1.88
	sn3		I feel that people who influence my behavior think that I should use the COVID-19 app.	3.44	1.84
Perceived Control (ctl)	ctl1	Krasnova et al. 2010	I feel in control over my data if the COVID-19 app uses anonymous communication (through anonymized user IDs).	4.16	1.87
	ctl2		Privacy-preserving settings present in COVID-19 apps allow me to have full control over the data I provide.	4.05	1.86
	ctl3		I feel in control of who can view my data if the COVID-19 app uses informed consent.	3.90	1.87
Trust: Regulations (trg)	trg1	Xu et al. 2009	Government regulations protect my information provided on the COVID-19 app.	4.15	1.91
	trg2		Government regulations protect me from any misuse of my information on the COVID-19 app.	4.15	1.91
	trg3		Government regulations protect me from unauthorized use of my information disclosed on the COVID-19 app.	4.16	1.91
Trust: App Providers (tsp)	tsp1	Krasnova et al. 2010	I trust that COVID-19 app providers are trustworthy and will not misuse any of my information.	4.07	1.89
	tsp2		I trust that COVID-19 app providers are honest in their dealings with me and my data.	4.07	1.81
	tsp3		I trust that COVID-19 app providers are interested in the well being of individuals.	4.30	1.83