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# Past, Present, and Future of Form-based User Interfaces

## Innovative Design for Evolving the 'Form' User Interface Metaphor

DISSERTATION

submitted in partial fulfillment of the requirements for the degree of

**Doktor der technischen Wissenschaften**

by

**Dipl.Ing. Johannes Harms**
Registration Number 0426887

to the Faculty of Informatics
at the Vienna University of Technology

Advisor: Thomas Grechenig

The dissertation has been reviewed by:

(Thomas Grechenig) (Univ-Prof. Dr. Manfred Tscheligi)

Wien, 03.12.2015

(Dipl.Ing. Johannes Harms)

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Vienna, 03.12.2015

# Statement by Author

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# Kurzfassung

Formular-basierte Benutzerschnittstellen (User Interfaces, UIs) sind eine wichtige Design-Option für heutige Software Anwendungen. Laufende Kritik bezüglich mangelnder Interaktivität, schlechter Usability, bürokratischer Konnotation und Langweiligkeit dieser UIs weist auf die Dringlichkeit der Aufgabe hin, die aktuelle Design-Praxis zu verbessern. Die diesbezüglichen Beiträge der vorliegenden Dissertation sind theoretisches Verständnis und praktische Verbesserungen.

Der theoretische Teil dieser Arbeit präsentiert eine Untersuchung historischer Formulare, eine neue Definition von Formular-basierten UIs und eine systematische Analyse von Forschungszielen. Die Definition versteht Formular-basierte UIs mit Hilfe des Konzepts der User Interface Metaphor und hilft, kontingente Eigenschaften von konstitutiven klar zu unterscheiden. Die Definition basiert auf einer umfassenden Übersicht verwandter Literatur und auf einer Untersuchung von historisch invarianten Eigenschaften von Formularen. Implikationen der Definition wurden mittels Theorie aus Semiotik ausgearbeitet. Das ermöglichte eine systematische Analyse wichtiger Ziele für zukünftige Forschung in Formular-Design. Zusammenfassend helfen die theoretischen Beiträge dieser Arbeit, Formular-basierte UIs besser zu verstehen, klar zu definieren und in Zukunft hinsichtlich vierzehn konkret beschriebenen Forschungszielen zu verbessern.

Der praktische Teil dieser Arbeit trägt zu drei Forschungszielen in Formular-Design bei. In Bezug auf Navigation in langen Formular-basierten UIs schlägt die vorliegende Arbeit erstens vor, das Fokus-und-Kontext Prinzip aus Informationsvisualisierung auf Formular-Design anzuwenden. Ein solches, neuartiges Design wurde auf stationären Desktop-Computern und mobilen Geräten (Smartphones) evaluiert. Die Evaluationsergebnisse waren vielversprechend. Auch unerfahrene Benutzer konnten das neue Design ohne Probleme oder Performance-Einbußen verwenden. Eine zusätzliche Erkenntnis war, dass Designer von mobilen Applikationen andere Designpatterns an Stelle von Scrolling verwenden sollten, die einen besseren Überblick gewähren. Zweitens präsentiert die vorliegende Arbeit eine Designspace Analyse hinsichtlich Kollaboration in Formular-basierten UIs und zeigt so die verfügbaren Design-Optionen systematisch auf. Diese Analyse war Ausgangspunkt für das Erstellen eines Rapid-Prototyping Tools. Das Tool ermöglicht Designern, viele Design-Optionen einfach und schnell zu konfigurieren, statt sie zeitaufwändig zu implementieren. Auf diese Weise unterstützt das Tool iteratives Design, vergleichende Evaluationen und empirisch fundierte Design-Entscheidungen. Drittens adressiert diese Arbeit hedonische Qualitäten von Formular-basierten UIs sowie deren viel-kritisierte Langweiligkeit. Es wird ein neuartiger Design-Prozess vorgeschlagen, mit welchem Online-Umfragen "gamifiziert", d.h. mit Spielelementen umgestaltet werden können. Der Prozess wurde erfolgreich in zwei Fallstudien angewandt. Die resultierenden Designs haben die User Experience signifikant verbessert.

Zusammenfassend trägt die vorliegende Dissertation zu einem tieferen theoretischen Verständnis von Formular-basierten UIs bei und präsentiert praktische Beiträge, um Formular-Design hinsichtlich Effizienz, Interaktivität und User Experience zu verbessern.

## Schlüsselwörter

Formular-Design, Mensch-Computer Interaktion, User Interface Metapher, Geschichte, Semiotik, Navigation, Kollaboration, Gamifizierung

# Abstract

Form-based user interfaces are an important design option for today's software. Nonetheless, ongoing criticism regarding lack of interactive features, dullness, and bureaucracy indicates a need to improve the current design practice. The present dissertation addresses this need by providing theoretical and practical contributions for form design.

The theoretical contributions of this work include an investigation of historical forms, a novel definition of today's form-based user interfaces (UIs), and a systematic analysis of research goals. The definition is based on the concept of UI metaphor. Its main practical advantage is that it allows one to clearly distinguish constitutive characteristics from contingent ones. The definition is firmly grounded in a comprehensive review of related work and an investigation of historically time-invariant characteristics of forms. Implications of the definition were elaborated using Semiotic theory of UI metaphor. This allowed to analyze metaphorical entailments and derive a list of fourteen research goals for future form design. In summary, the theory provided in this work clears the current confusion over defining characteristics of form-based UIs and can inspire future research in innovative form design.

The practical part of this work addresses three research goals related to navigation, collaboration, and gamification in the context of form-based UIs. Contributions made regarding these three goals include analyses of available design options, proposals for novel form designs, and empirical evaluations of these designs. First, regarding navigation in long form-based UIs, this work applied the Focus&Context principle from information visualization to form design. The novel design was evaluated on desktop and mobile devices with promising results. Even novice users could easily work with the new design. An additional insight gained from the evaluation is that Scrolling should be avoided on mobile devices in favor of other design patterns that provide a better overview. Second, regarding collaboration, this work presents a design space analysis of available design options for designing collaborative form-filling. The analysis provided a basis for developing and proposing a rapid prototyping tool. The tool allows for quick configuration (instead of time-consuming implementation) of various design options and thus supports iterative design, comparative evaluations, and empirically-grounded design decisions. Third, hedonic qualities of form-based UIs and their much criticized dullness were addressed through gamification. Specifically, this work proposed a novel design process for gamifiying online surveys. The process was successfully employed in case studies. The resulting gamified survey designs significantly improved the respondents' user experiences.

In summary, the theoretical and practical contributions of this work helped to advance the understanding of form-based UIs and to evolve the current design practice towards more efficiency, interactivity, and towards a more pleasant user experience.

## Keywords

Form Design, HCI, UI Metaphor, History, Semiotics, Navigation, Collaboration, Gamification

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# 1 Introduction

**Chapter Summary.** Forms are widely employed in user interfaces (UIs) of a large variety of applications. This chapter introduces to the design of form-based UIs by referencing related guidelines and best practices that correspond to the established state-of-the-art in form design. It also discusses recent criticism regarding the usability of form-based UIs and the current confusion regarding their defining characteristics. These problems motivate the goals of the present dissertation. Firstly, to clear the current confusion by providing a new definition that clearly distinguishes essential characteristics from contingent design practice. Secondly, to improve usability and user experience through innovative form design. This chapter summarizes corresponding contributions and provides an outlook on the approach and structure of the dissertation.

## 1.1 Background

Form design has meant different things to different people depending on their specific interests and background disciplines. Besides various other disciplines and perspectives taken in related work – including forms in public and private administration, public relations, visual design design, and corporate identity – the focus of the this dissertation is on human-computer interaction (HCI) and user interface design.

**Forms in Public and Private Administration.** Related work has often discussed electronic and paper forms in administrative contexts. Corresponding historical overviews of form-based artifacts in public and private administration have been put forth by several authors including Abdullah et al. [2], Barnett [17, 18], Burkhard [33], and Eisermann [63]; compare Chapter 3 for an in-depth discussion of the history of forms. These works highlighted the past and present importance of forms for structuring the communication between bureaucratic organizations and citizens or customers.

For example, in the context of business administration, Barnett [18, p.3] described forms as “the basic business tool for collecting and transmitting information”. Form design is thus seen as an essential means for structuring internal and external business processes. Barnett [18, ch.5] consequently recommended that large organizations should have their own “forms department” to manage their business processes as well as the corresponding forms. In a similar way, Abdullah et al. [2] and Schwesinger [166] discussed the importance of form design for an organization’s external communication. They recommended that the graphical design of forms should consistently communicate the corporate identity.

In the context of public administration, Becker [20] characterized forms as means for conducting dialogue between citizens and public administration. Grosse et al. [79] and Sarangi et al. [161] further characterized the nature of this dialogue as asymmetric, authoritative, and bureaucratic. Both paper and electronic forms in public administration fulfill a similar purpose and have been subject to similar criticism. For example, Axelsson et al. [15] understood electronic forms as instruments through which citizens communicate with government agencies and proposed principles and guidelines for improving this communication through well-designed e-government forms.

a)

b)

c)

d)

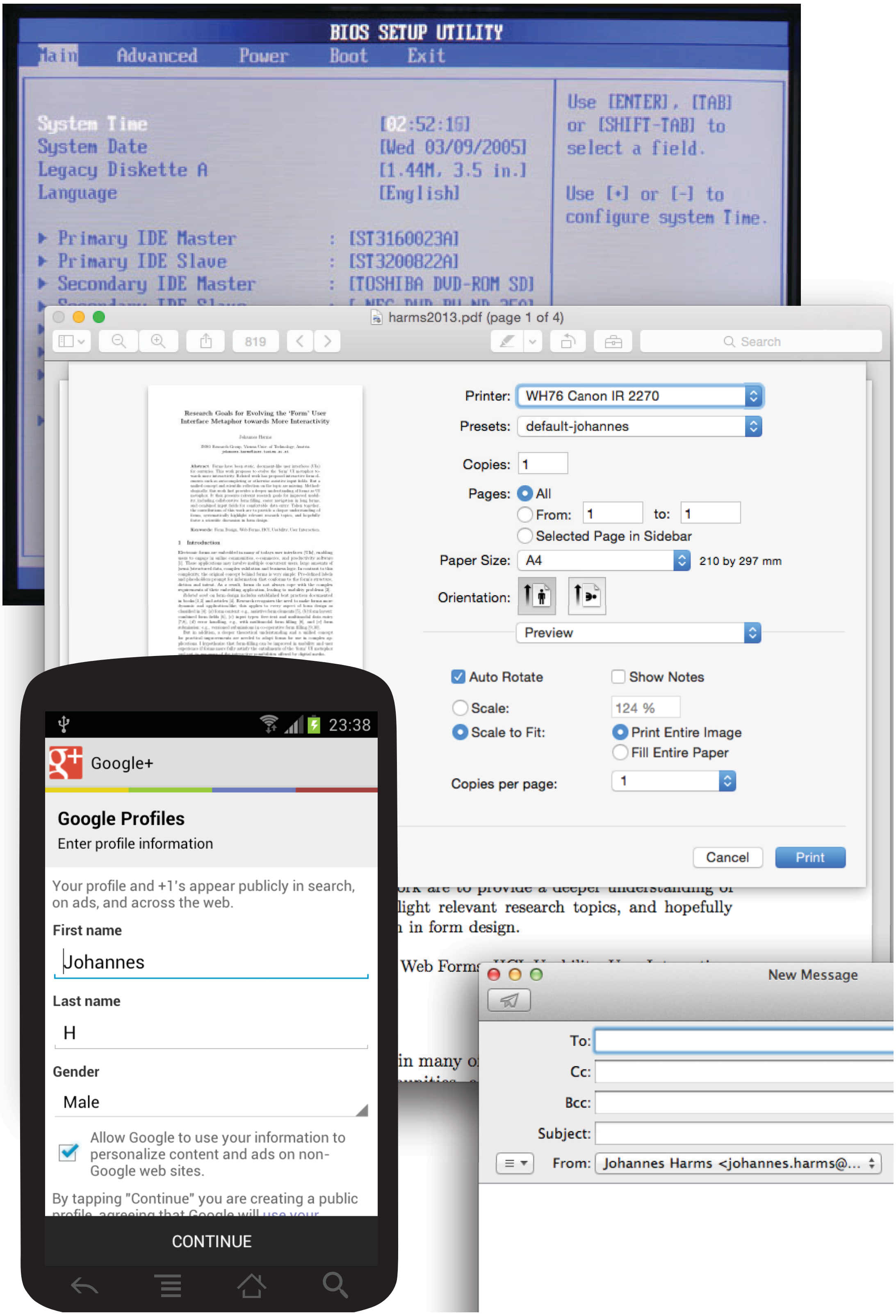



**Figure 1.1:** Examples of form-based user interfaces to illustrate their variety of uses in desktop and mobile applications. The above screenshots show (a) a textual UI for editing BIOS system settings, (b) print functionaliy and (c) e-mail composition in the Mac OS 10.10 operating system, as well as (d) a registration form on an Android smartphone – all of these user interfaces are based on forms.

**Form-based User Interfaces.** Despite the popularity of forms in administration, not all forms are used in administrative contexts – for example, millions of people use forms every day to log into their computers, search the internet, send messages, and to buy and sell things. And not all forms are used for human communication – for example, the form data that users fill into a BIOS screen or print dialogue, as shown in Figure 1.1a and b, is processed by a machine instead of communicated to fellow humans. These forms are employed as user interfaces to enable human-computer interaction; hence the notion of form-based UIs. Further examples of form-based UIs are shown in Figure 1.1, including the composition of e-mail messages and a sign-up form on mobile devices. Additional examples will be discussed in later chapters of this work, including form-based UIs for social network profile pages, medical documentation, customer support, and online surveys. Also, many further examples of form-based UIs are provided in related books on form design, compare for example Jarrett et al. [112] and Wroblewski [205].

It is evident from the above examples that form-based UIs are a very general design option for a large variety of user interfaces. Form-based UIs allow users to create, revise, read, and communicate semi-structured data in many additional contexts besides administration. The design of such form-based UIs is of primary interest for the present dissertation.

**Larger, Historical Context.** As suggested by its title, the present dissertation investigates historical forms, today's form-based UIs, as well future trends in form design. Figure 1.2a accordingly visualizes this work within a larger, historical context that spans many centuries. Note that a detailed discussion of the historical artifacts shown in Figure 1.2a is provided in Chapter 3.

On a large time scale, humans have used increasingly complex, written artifacts to support cognition and to structure society. Goody [78] analyzed this process and put forth that lists, tables, and forms provided increasingly sophisticated means for abstracting individual life experiences into standardized representations. Such historical considerations are important – we will shown in Chapters 3-4 that today's form-based UIs serve the same purpose.

Despite the importance of this historical background, the focus of this dissertation are form-based UIs and thus a much smaller time scale, as visualized in Figure 1.2b. Hence the primary interest of the historical investigations presented in Chapter 3 of this work is to better understand today's UIs. The directions for future research in form design that are put forth in Chapter 5 likewise focus on a small time scale. Although they may look like tiny steps if viewed on a large time scale, they provide very specific and realistic directions for the next decade.

**Terms and Conventions.** Note that the term "form-based UI" is newly introduced in this work as a synonym referring to digital artifacts previously discussed in related work as "electronic forms", "forms" (if their digital nature is implied by the context), or (pars pro toto) "web forms". The new term "form-based UI" helps distinguish from a more general notion of forms that includes paper-based or other artifacts that do not qualify as user interface. Nonetheless, the term conveys a large extension and refers to form-based artifacts in a large variety of applications, not just for stereotypical use cases such as registration or application in administrative contexts. The term's novelty has the benefit of providing a neutral ground for analyzing the defining characteristics of corresponding UIs, compare the theoretical part of this work in Chapters 2–6.

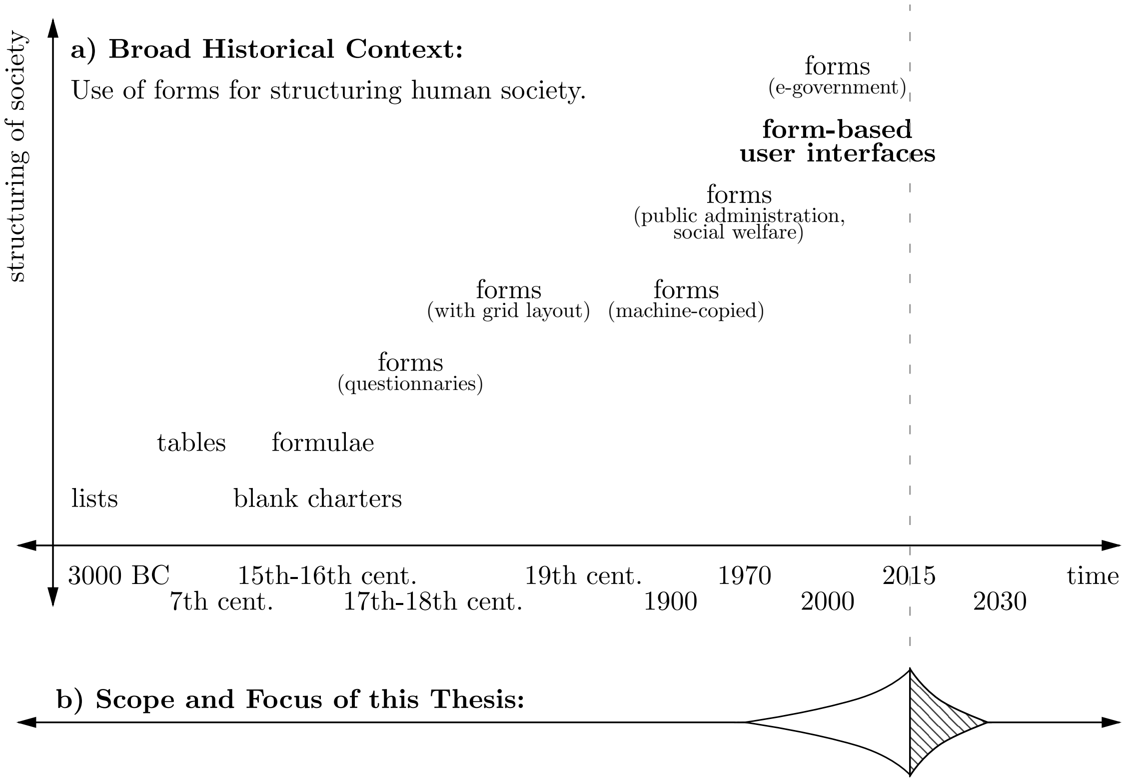



**Figure 1.2:** The scope and focus of this dissertation within a broad historical context. As visualized in part (a) of the graphic, various form-based artifacts have been used throughout the centuries and have increasingly supported the organization and structuring of human society. Within this large historical context, the scope and focus of this dissertation (b) is on a much shorter time span related to form-based user interfaces.

## 1.2 State-of-the-Art

This section introduces to the state-of-the-art in the design of form-based UIs by referring to current guidelines and best practices. It seeks to provide a high-level overview with references to relevant literature. Note that more detailed discussions of related work are provided as needed in the subsequent chapters.

### 1.2.1 Related Disciplines

Thematically, the present dissertation fits into human-computer interaction (HCI), but methods and knowledge from additional disciplines are necessary to analyze and improve form-based UIs.

*Design Disciplines:* The research on form-based UIs that is presented in this thesis primarily fits the HCI (human-computer interaction) discipline. Relevant related disciplines include usability engineering, form design, user interface design, experience design, interaction design, and graphic design.

*Engineering Disciplines:* The creation of form-based UIs involves and requires software engineering. Web engineering is particularly relevant for this work because all prototypes were created using web technology such as JavaScript, HTML, and CSS.

*Theoretical Foundations:* Several disciplines provide relevant theoretical foundations for this work. Historical disciplines helped understand how forms have developed throughout the centuries, compare Chapter 3 for a historical overview. Furthermore, Semiotics and Cognitive Science have allowed this work to elaborate the understanding of form-based UIs as UI metaphor (compare Chapter 4) because both disciplines provide relevant theories of metaphor that have been influential in the context of HCI.

*Social Sciences*: Multiple disciplines are important to study humans in the context of form-based UIs. Sociology is relevant for investigating human behavior and the socio-cultural function of forms in human society, as discussed in the definition of form-based UIs that is put forth in Chapter 4. Psychology is relevant for investigating an individual user's perceptions, affect, emotions, and actions, e.g., in the context of usability evaluations, as documented in the practical part of this work in Chapters 7 to 9.

*Formal Disciplines:* Empirical evaluations of form-based UIs, as conducted in the practical part of this work in Chapters 7–9, require formal, mathematical and statistical methods. Specifically, the practical part of this work comparatively evaluated multiple form designs and analyzed data using descriptive and inferential statistics.

The above overview shows that research in form design involves many theoretical and applied scientific disciplines. Comprehensive overviews for each of these disciplines would clearly exceed the scope of this work. Instead, select aspects shall be discussed as "related work" in each of the following chapters, allowing to focus on those particular aspects that are relevant for each chapter. Additionally, a general overview on the state-of-the-art in form design is provided in the following.

### 1.2.2 Form Design Guidelines

State-of-the-art form design can be seen in guidelines and best practices, as documented in international standards, scientific articles, and recent books.

**International Standards.** A good overview on established form design guidelines is provided in the international standard DIN EN ISO 9241-143 [54]. The standard is part of the ISO 9241 series on "ergonomics of human-computer interaction". This implies the same perspective as taken in this work, namely that forms are one design option (amongst many others) for user interface design and human-computer interaction. The standard correspondingly defined forms as a "structured display of fields and other user interface elements that the user reads, fills in, selects entries for (e.g., through check boxes or radio buttons) or modifies". It covers recommendations for many aspects of form design, including information presentation and layout, interaction and data input, feedback mechanisms and validation, as well as descriptions of various form elements and advice regarding their choice.

**Guidelines in Scientific Articles.** Scientific research has also published guidelines that describe the state-of-the art in form design. Bargas-Avila et al. [16] reviewed large amounts of related literature to derive a set of 20 guidelines for form design that cover the following topics: form content, layout, input types, error handling, and submission. Seckler et al. [169] subsequently employed these guidelines to re-design 23 newspaper registration forms. Usability evaluation results showed that the re-design led to strong improvements in usability, indicating that the guidelines provide valuable design advice. Design patterns for mobile form design have furthermore been discussed by Nilsson [146]. More guidelines for form-based UIs in an e-government context have been provided by Axelsson et al. [15], Idrus et al. [107], and Money et al. [142].

**Guidelines in Related Books.** Related books on form design have provided practical advice and recommendations. Corresponding literature has mostly focused on web form design and mobile form design because these areas have seen a lot of innovation during the past few years.

Jarrett et al. [112] and Wroblewski [205] wrote excellent books on web form design. Although both book titles include the term "web forms", the guidelines and principles advocated in these books are applicable to a wide range of form-based user interfaces and are not limited to web technology. Both books provide comprehensive overviews on many aspects of form design, detailed recommendations, and many illustrated examples.

Form-based UIs also play an important role in mobile applications. Corresponding advice has been given in related books about mobile UI design patterns, compare Hoober et al. [104, ch.11] and Neil [143, ch.2].

Further related books by Abdullah et al. [2] and Schwesinger [166] discuss form design from a graphical design perspective. The authors of both books provided many visual examples that provide useful inspiration. But they emphasized print design of paper-based forms, as opposed to electronic form-based UIs that are of primary interest in this work. Readers interested in state-of-the-art graphical design of form-based UIs may furthermore consult guidelines published by vendors of modern software products.

**Products and Online Resources.** State-of-the-art form design can also be seen in products of today's leading software vendors. The user interface design guidelines of the corresponding operating systems and platforms also cover form-based layouts and form controls, compare for example Apple's "OS X Human Interface Guidelines" [W4], Google's "material design" guidelines [W18] for the Android operating system, and Microsoft's guidelines about "design for the Windows desktop" [W23]. Further user interface design guidelines have been published on the usability.gov website [W36], including 25 guidelines in the 'forms' category.

Programming frameworks allow to implement a large variety of UIs, including form-based designs. For example, Apple's Xcode Interface Builder [W6] includes many form control and provides automatic layouting features. Twitter's Bootstrap framework [W10] and many, similar CSS frameworks provide code for styling web forms in various horizontal and vertical layouts. The Bootstrap framework has been used in the practical part of this work to create interactive, web-based prototypes.

In contrast to the above general-purpose products, platforms, and frameworks, other products have specialized on forms, allowing users to create, publish, and manage form templates as well as to process submitted form data. These include, amongst others, Adobe's Business Catalyst [W1], Google Forms [W17], Microsoft's InfoPath [W24], Orbeon Forms [W26] (partly open source), Wufoo Form Designer [W37], and Zoho Forms [W39]. The above products provide web-based installations that allow users to easily create forms in rather restricted, pre-designed layouts for the main purpose of business administration.

### 1.2.3 Form Design Processes and Evaluation Methods

Form-based UIs may be designed and evaluated using standard usability engineering methods and processes, but a specialized form design process also exists, as put forth by Jarrett et al. [112].

Usability is an important goal for the design of form-based UIs. It has been defined in DIN EN ISO 9241-11 [53] as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". This definition described usability as a product quality that depends on specific users, goals, and usage contexts. It furthermore listed the following three measures for determining the usability of a product: effectiveness (the accuracy and completeness with which users achieve specified goals), efficiency (low effort or expense to reach these goals), and satisfaction (a user's positive attitude towards the product). Nielsen [145] put forth a similar list of usability measures. His list includes efficiency and satisfaction, as in the ISO standard. It subsumes effectiveness under efficiency. And it additionally includes learnability (whether a product is usable for novice users), memorability (whether it is easy to remember how to use the product), and errors (a low number of errors with a low severity). Form-based UIs – and, in this respect, any kind of user interface – should have a high usability. The discipline of usability engineering recommends methods and processes for engineering usable products; it is therefore highly relevant for the design of form-based UIs.

Usability engineering methods and processes are well-described in corresponding textbooks. For example, compare the short, introductory books by Nielsen [145] from an industrial perspective and by MacKenzie [132] from a research perspective. Longer, more comprehensive textbooks with more detailed descriptions have been provided, e.g., by Benyon [23], Dix et al. [55], and Mayhew [139]. A brief summary of how the proposed methods fit into a structured process can be found in Nielsen [145, ch.4]. Accordingly, usability engineering should start by analyzing users, tasks, and context. Based on this knowledge, designers should set usability goals for the intended system and create prototypes. They should iteratively evaluate their design, fix usability errors, and continue to improve and evaluate the system until they reach their previously set usability goals.

Form design may employ general-purpose usability engineering methods and processes, but a process that specifically targets form design has also been proposed by Jarrett et al. [112], compare Figure 1.3 for a visualization. The process is structured into "three layers of form design", as described in the following. In the "relationship layer", designers should analyze the relationship to form fillers and the data that should be retrieved. This roughly corresponds to the analysis of users, tasks, and context that is recommended in general usability engineering processes, e.g., compare Mayhew [139]. In the "conversation layer", designers sketch and prototype the intended user interface and thus design, metaphorically speaking, the conversation that users are going to have with the UI. Corresponding design activities include conceptual design, mockups, and prototyping. In the "appearance layer", designers elaborate the detailed, visual appearance of the form-based UI, seeking to make the form look easy and to polish detailed aspects of UI design. As typical for iterative design processes, Jarrett et al. [112] also recommended to evaluate the resulting form-based UI through usability testing and to fix usability problems in subsequent design iterations.

Evaluation methods for form-based UIs can be distinguished into usability testing and expert-based reviews. The same distinction has been made regarding general-purpose usability engineering methods, e.g., compare the taxonomy put forth by Seffah et al. [170]. The difference between corresponding methods is that in usability tests, real users are observed while they use a system. In contrast, expert reviews are performed without users. Instead, usability experts analyze the UI to identify hypothesized usability problems.

Expert reviews have been successfully used to evaluate and improve form-based UIs. Jarrett et al. [113] recommended to incorporate a user perspective by defining personas (i.e., stereotypical descriptions of example target users) prior to performing an expert review. Bargas-Avila et al. [16] and Seckler et al. [168] created and used a set of 20 guidelines for form design as heuristics for evaluating form-based UIs in an expert review. This allowed to identify several usability problems and significantly improve the usability.

Usability testing should be preferred over expert reviews according to Jarrett et al. [112, ch.9] because it allows to identify more realistic problems, as opposed to the necessarily hypothetical problems identified through expert reviews. Furthermore, usability testing is better suited for scientific evaluations (as in the practical part of this work) because guidelines and heuristics can only capture the state-of-the-art in form design, as opposed to novel, innovative designs that correspond-

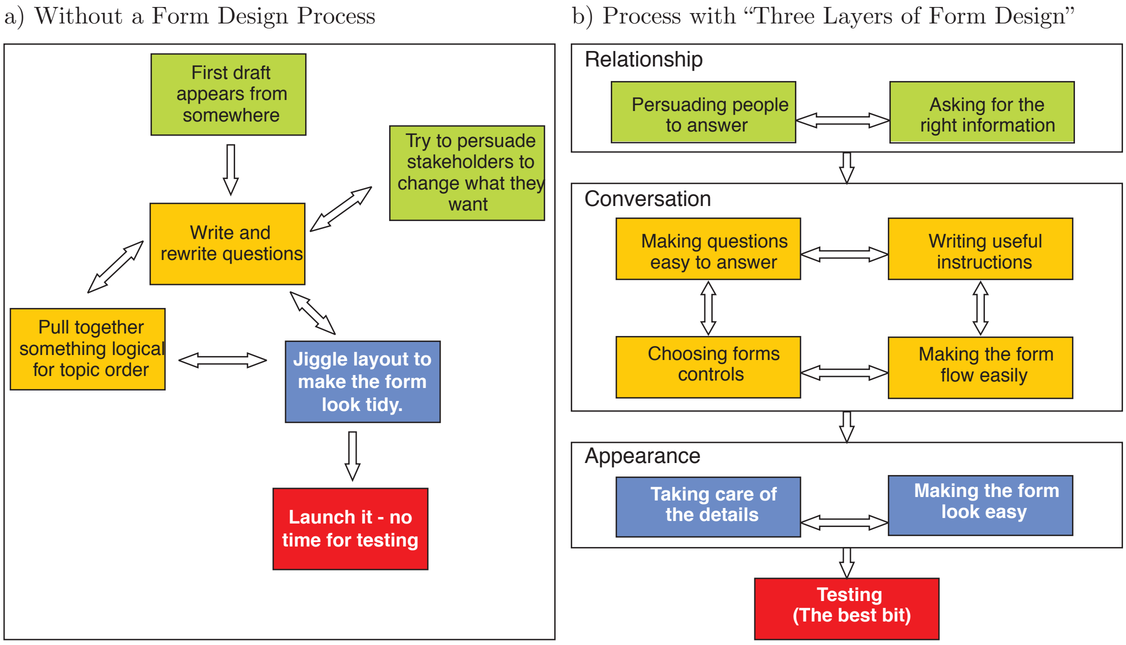



**Figure 1.3:** A form design process is needed to avoid messy design activities and bad results, as shown in part (a) of the above figure. The process put forth by Jarrett et al., shown above in part (b) of the figure, consists of "three layers of form design". Accordingly, designers should first analyze the relationship with form fillers, then conceptually design the "conversation" that these users are going to have with the form-based UI, thirdly optimize the visual appearance, and lastly test and iteratively improve the form. Graphic based on Jarrett et al. [112, p.7–8].

ing research seeks to evaluate. Usability tests may employ various methods of data collection. Conventional data collection methods include observations of user behavior, automatically logged user behavior, post-test questionnaires, and interviews. Furthermore, eye tracking has been successfully used in evaluations of form-based UIs by Strohl et al. [176] and Wroblewski [205]. A recent study by Nomura et al. [148] additionally combined eye tracking with electro-encephalogram measures of the users' current level of aversion. This allowed take quantitative measures of the emotional impact of observed usability problems.

Note that many of the above processes and methods have been applied in the practical part of this work. Chapters 7–9 describe corresponding design activities that included sketching, prototyping, usability testing, and design iterations.

### 1.2.4 Challenges and Difficulties in Form Design

Form-based UIs have been subject to harsh criticism regarding a lack of usability and interactivity and regarding a dull user experience. The corresponding debate in related HCI literature left it unclear if this critique concerns essential characteristics or contingent design practice. In the first case, form-based UIs should be avoided in favor of other UI design patterns. In the second case, designers should seek to improve the current design practice. Later parts of this work will argue for the second case and propose specific improvements to evolve the current design practice.

**Challenging Complexity.** Form-based UIs are employed in complex usage scenarios and applications. As described in a previous publication [88] by the author of this dissertation, they are used for editing and viewing data in applications with multiple concurrent users, large amounts of data, repeating blocks of data, hierarchically structured data, inter-field dependencies, complex validation logic, and complicated business rules. Such complexity can, for example, be found in e-Health, e-Government, administrative software, system preference dialogues, social network profile pages, and online surveys.

In contrast to this complexity, the original concept behind forms is very simple. As characterized in [88], "pre-defined labels and placeholders prompt for information that conforms to the form's structure, diction and intent". As a result, form-based UIs do not always cope with the complex requirements of their embedding application, which may produce usability problems. Some authors consequently proposed to make form-based UIs more dynamic and application-like in order to make them suited for complex requirements, compare, e.g., Harms [88], Jarrett et al. [112], and Wroblewski [205]. Others concluded that form-based UIs are generally unsuited for complex scenarios and that they should therefore be avoided, an opinion strongly expressed, for example, by Nielsen [W25].

**Recent Critique and Current Confusion.** In the introduction of his book on form design [205], Wroblewski stated, "Forms suck. If you don't believe me, try to find people who like filling them in". This points at fundamental problems related to the usability and user experience of form-based UIs. Related discussions in HCI literature reveal uncertainty and confusion if the criticized characteristics are necessary or contingent for form-based UIs.

One reason for much related critique is that many of today's form-based UIs do not follow state-of-the-art principles and best practices. For example, Seckler et al. [169] showed that applying recent guidelines to re-design 23 newspaper registration forms achieved significant usability improvements. In a similar way, Wroblewski's book on form design [205, p.16] reported that re-designed web forms produced an average increase in completion rate of 10-40%. Bad form design, to say the least, can be very annoying for users. This is evidenced, for example, by the BadForms.com website [W7] which provides a channel for users to express their miscontempt with poorly designed form-based UIs. The consequences of bad form design can also be more drastic. For example, Jarrett et al. [112, p.2] referred to a study by Hoffmann et al. [100] where 41% of users unintentionally provided contradictory responses to a medical form. It is evident from Seckler et al.'s study [169] that many such usability problems can be fixed if form designers follow established guidelines and use recommended form design processes – compare the previous Sections 1.2.2 and 1.2.3 for a summary of state-of-the-art guidelines and best practices.

Nonetheless, related work suggests that the state-of-the-art is not good enough. For example, users of the redesigned form-based UI's in Seckler et al.'s study [169] still made a lot of errors. Furthermore, in the context of online surveys, form-based UIs were criticized by Downes-Le Guin et al. [60] for their dullness and for the resulting negative respondent behavior. In the context of business administration, Lutteroth et al. [131] recently sought to replace a university's paper forms with electronic equivalents, but found that none of the investigated systems satisfied all functional requirements. Harms [88] and Nielsen [W25] criticized that today's form-based UIs are still reminiscent of static paper forms instead of fully using the interactive possibilities of software.

Reactions to the above critique indicate a confusion regarding the defining characteristics of form-based UIs. One reaction, expressed for example in Nielsen's blogpost [W25], is to interpret the criticized characteristics as being constitutive for form-based UIs and to consequently recommend that designers should avoid them. Another reaction is found in related work that proposed remedies and improvements and thus interpreted the same, criticized characteristics as contingent design practices that should rather be changed. These two reactions point at conflicting views and at a current confusion over the defining characteristics of form-based UIs. Firm, theoretical foundations are needed to clarify the defining characteristics of form-based UIs. Such foundations can justify one of the two reactions and thus provide important directions for future form-based user interface designs.

## 1.3 Goals of this Work

The present dissertation aims at providing theoretical foundations and practical improvements in form design.

More specifically, the theoretical goals of this work are to provide theory for form design, to clarify the defining characteristics of form-based UIs, and to formulate perspectives for future improvements.

The practical goal of this dissertation is to evolve the current practice in form design through innovative design enhancements and corresponding empirical evaluations. The proposed enhancements seek to improve utilitarian and hedonic qualities of form-based UIs in the following three areas of research: efficient navigation in long form-based UIs, improved support for real-time collaborative form filling, and pleasant user experiences in online surveys.

In summary, the above goals seek to inform designers and evolve the current design practice towards more pleasant and efficient interactions in form-based user interfaces.

## 1.4 Summary of Contributions

The present dissertation makes the following contributions for the design of form-based UIs.

A novel definition of form-based UIs is put forth in the theoretical part of the dissertation. The definition is based on and justified by a large review of related work as well as investigations of historically time-invariant characteristics of forms. We elaborated the definition using Semiotic theory of UI metaphor, demonstrating that it has explanatory power for analyzing and describing the interpretation of form-based UIs by designers and users.

The dissertation furthermore provides a systematic analysis of fourteen goals for future research in form design. These research goals are derived from the theory put forth in this work. They correspond to beneficial metaphorical entailments that should be fulfilled in today's form-based UIs, as well as negative ones that should rather be avoided. Each research goal is described along with links to prior, related work in the respective area of research.

Practical contributions are presented regarding three of the fourteen proposed research goals, namely navigation, collaboration, and gamification in the context of form-based UIs. Contributions made regarding these three goals include analyses of available design options, proposals for novel form designs, and empirical evaluations of these designs.

First, regarding navigation in long form-based UIs, this work applied the Focus&Context principle from information visualization to form design. The novel design was evaluated on desktop and mobile devices with promising results. Even novice users could easily work with the new design. An additional insight gained from the evaluation is that Scrolling should be avoided on mobile devices in favor of other design patterns that provide a better overview.

Second, regarding collaboration, this work presents a design space analysis of available design options for designing collaborative form-filling. The analysis provided a basis for developing and proposing a rapid prototyping tool. The tool allows for quick configuration (instead of time-consuming implementation) of various design options and thus supports iterative design, comparative evaluations, and empirically-grounded design decisions.

Third, hedonic qualities of form-based UIs and their much criticized dullness were addressed through gamification. Specifically, this work proposed a novel design process for gamifiying online surveys. The process was successfully employed in case studies. The resulting gamified survey designs significantly improved the respondents' user experiences.

## 1.5 Prior Publications

Select contributions of this dissertation have priorly been published in renowned scientific venues, as described in the below list.

- J. Harms. „Research goals for evolving the 'form' user interface metaphor towards more interactivity". In: *Human Factors in Computing and Informatics*. Ed. by A. Holzinger, M. Ziefle, M. Hitz, and M. Debevc. Vol. 7946. Lecture Notes in Computer Science. Springer, 2013, pp. 819–822
- J. Harms, C. Wimmer, K. Kappel, and T. Grechenig. „Design space for focus+context navigation in web forms". In: *Proceedings of the 2014 ACM SIGCHI Symposium on Engineering Interactive Computing Systems*. EICS '14. ACM, 2014, pp. 39–44
- J. Harms, M. Kratky, C. Wimmer, K. Kappel, and T. Grechenig. „Navigation in long forms on smartphones: scrolling worse than tabs, menus, and collapsible fieldsets". In: *Proceedings of the 15th IFIP TC 13 International Conference Human-Computer Interaction – INTERACT'15*. Ed. by J. Abascal, S. D. J. Barbosa, M. Fetter, T. Gross, P. Palanque, and M. Winckler. Vol. 9296. Lecture Notes in Computer Science. Springer, 2015
- J. Harms, C. Wimmer, K. Kappel, and T. Grechenig. „Gamification of online surveys: conceptual foundations and a design process based on the MDA framework". In: *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*. NORDICHI '14. ACM. 2014, pp. 565–568
- J. Harms, S. Biegler, C. Wimmer, K. Kappel, and T. Grechenig. „Gamification of online surveys: design process, case study, and evaluation". In: *Proceedings of the 15th IFIP TC 13 International Conference Human-Computer Interaction – INTERACT'15*. Ed. by J. Abascal, S. D. J. Barbosa, M. Fetter, T. Gross, P. Palanque, and M. Winckler. Vol. 9296. Lecture Notes in Computer Science. Springer, 2015, pp. 214–231
- J. Harms, D. Seitz, C. Wimmer, K. Kappel, and T. Grechenig. „Low-cost gamification of online surveys: improving the user experience through achievement badges". In: *Proceedings of the 2nd ACM SIGCHI annual symposium on Computer-Human Interaction in Play*. CHI PLAY '15. ACM, 2015

The above publications were created as part of the present dissertation; the author of this dissertation is first author and primary contributor of all the publications. Nonetheless, to acknowledge the work by co-authors, this documents uses the first person plural (e.g., "we", "our") in numerous places to collectively refer to author and co-authors. Materials from the above publications, if used or reproduced in this document, have been labelled with references to the original publications.

Some other contributions are being published for the first time in this dissertation document. Most notably, this includes the theoretical contributions in Chapters 2–6 and the practical contributions in Chapter 8 related to collaborative form filling.

## 1.6 Structure of Work

The remaining chapters of this dissertation are structured into a theoretical and a practical part, as visualized in Table 1.1.

The chapters in the theoretical part are closely connected to each other and are therefore surrounded by an introduction, discussion, and conclusion, as follows. Chapter 2 introduces to the theoretical part of the dissertation, reviews prior definitions of form-based UIs and describes theoretical foundations needed in the following chapters. Chapter 3 contributes an overview on the historical development of form-based artifacts. This allowed to compare historical forms with today's form-based UIs and identify time-invariant characteristics. Chapter 4 puts forth a novel definition of form-based UIs based on the review of prior definitions and based on historically time-invariant characteristics. It elaborates the definition using Semiotic theory of UI metaphor, allowing to explain the interpretation of form-based UIs by designers and users, as well as the current habituation and conventionalization of the 'form' UI metaphor. Chapter 5 discusses the possibility for designers to re-interpret the 'form' UI metaphor in order to arrive at a fresh understanding and to break away from the current, much criticized design practice. As a result, the chapter presents a systematic analysis of fourteen research goals that can inspire future form design. Lastly, Chapter 6 summarizes and discusses the theoretical contributions made in this thesis.

The practical part of the dissertation contributes research in three areas of form design. Its three chapters are largely unrelated and therefore have their own introductions, discussions, and conclusions. Chapter 7 presents a novel application of the focus-and-context principle from information visualization to form design, aiming to improve navigation in long, form-based UI. The proposed design was evaluated on desktop and mobile devices with promising results. Chapter 8 addresses difficulties in designing collaborative form filling. It contributes a design space analysis and a rapid

| | | |
|---|---|---|
| **Introduction** (Chapter 1) | | |
| **Theoretical Part**<br>Analysis and Evolution of Form-based UIs (Chapter 2) | | |
| **Past** (Chapter 3)<br>History of Forms | **Present** (Chapter 4)<br>Definition of Form-based UIs | **Future** (Chapter 5)<br>Goals for Future Research |
| **Discussion and Conclusion** (Chapter 6) | | |
| **Practical Part** | | |
| **Navigation** (Chapter 7)<br>Navigation in long, form-based UIs | **Collaboration** (Chapter 8)<br>Real-Time Collaborative Form-Filling | **Gamification** (Chapter 9)<br>Gamified, Form-based UIs in Online Surveys |
| **Overall Discussion** (Chapter 10) | | |
| **Conclusion** (Chapter 11) | | |

**Table 1.1:** Visualization of the structure of work. The present dissertation consists of a theoretical and a practical part. The theoretical part covers a large narration spanning the past, present, and potential future of form-based UIs. The practical part addresses navigation in long, form-based UIs, collaborative form filling, and gamification of online surveys.

prototyping tool. Lastly, Chapter 9 focusses on hedonic qualities of form-based UIs. Specifically, it addresses the often criticized dullness of online-surveys and contributes a novel design process for survey gamification which was successfully employed in two case studies to gamify an online survey about sports and leisure activities amongst teenagers and young adults. The resulting, gamified survey designs significantly improved the respondents' user experience.

Finally, the overall contributions of the dissertation are discussed in Chapter 10 and conclusions are presented in Chapter 11.

# Part I
# Theoretical Contributions

**Overview.** The theoretical part of this dissertation takes a multi-disciplinary approach at providing theory for form design. It seeks to resolve ambiguities regarding the defining characteristics of form-based user interfaces (UIs) and to derive prospective improvements. Its chapters provide a large narration spanning the past, present, and potential future of form-based user interfaces. Its specific contributions are, firstly, to put forth a novel definition of form-based UIs understood as UI metaphor. The definition is based on and justified by a review of related work as well historical investigations. It is elaborated using Semiotic theory of UI metaphor, allowing to describe the interpretation, habituation, and conventionalization of the ‘form’ UI metaphor from the perspectives of designers and users. As a second contribution, we systematically identified directions for future research in form design. In summary, the theory provided in the following chapters clears the current confusion over defining characteristics of form-based UIs and can inspire future research in innovative form design.

# 2 Analysis and Evolution of Form-based User Interfaces

**Chapter Summary.** This chapter reviews related work and motivates the theoretical part of this dissertation. Although form-based user interfaces (UIs) are widely employed in many of today's applications, related literature reveals a confusion and conflicting understandings regarding their defining characteristics. It is the goal of the theoretical part of this dissertation to clear this confusion and to provide firm, theoretical underpinnings for form design. Towards this goal, the sections in this chapter contribute a review of prior definitions of form-based UIs, introduce to the concept of UI metaphor that will subsequently be used in our definition of form-based UIs, and explain Semiotic and Cognitive Science theories of UI metaphor that we will use to elaborate our definition.

## 2.1 Introduction

Form design is employed in many of today's user interfaces (UIs) in a wide variety of applications and domains such as online communities, e-commerce, and productivity on desktop and mobile devices. Given the widespread use of form-based UIs in many of today's software applications, the topic is sufficiently important to warrant firm, theoretical foundations and a formal, precise definition.

**Problem Definition.** Despite the popular use and general importance of form-based UIs, contemporary HCI (human-computer interaction) literature reveals a confusion regarding their defining characteristics and thus a lack of firm, theoretical understanding. As briefly discussed in Chapter 1 and as elaborated in this chapter, the confusion is particularly evident in how related work dealt with criticism concerning the usability of form-based UIs. Some authors interpreted the criticized characteristics as being constitutive and consequently recommended to avoid form-based UI designs. Others interpreted them as contingent design practices and consequently proposed remedies and improvements. These different reactions highlight the practical relevancy of the research goal addressed in the theoretical part of this dissertation, i.e., to provide theory for form design and to put forth a clear definition of form-based UIs.

**Summary of Contributions.** To investigate the defining characteristics of form-based UIs, we reviewed related work, analyzed historical forms, and compared them to today's form-based UIs. This allowed to formulate and contribute a novel definition of form-based UIs understood as UI metaphor, as well as to derive research goals for future form design. Some of these contributions have priorly been published by the author. The short conference paper by Harms [88] already included a notion of the 'form' UI metaphor, as well as four goals for future research. The following chapters heavily extend this prior paper by reviewing related work, surveying the historical development of forms, putting forth a clear definition, elaborating that definition, and by providing a much more comprehensive list of research goals.

**Intended Use of the Contributed Theory.** The author's intention in providing theoretical contributions for form design can be described by quoting Imaz et al. [108, p.16]: "What new forms of interaction will there be, what are the potential pitfalls, and what are the potential benefits? Unfortunately, we cannot answer these questions yet. What we can do is to develop literacy in designers, and provide designers with an understanding of the underlying concepts of the digital medium and its interaction with people". Thus, by providing theory about form-based UIs, the author seeks to provide designers with a deeper understanding and inspire researchers as well as practitioners towards new, innovative form designs.

**Theoretical Underpinnings.** The present dissertation primarily adopts an HCI perspective on form design. To further specify our theoretical underpinnings, we briefly state the ontological and epistemological assumptions underlying this work using concepts from Tedre et al. [182]. Ontologically, we understand our research as dealing with primarily mind-dependent phenomena, for example, intension and extension of the term "form-based UI" and the meaning communicated through corresponding designs. Epistemologically, propositions about these phenomena are subject to a certain degree of subjectivity, as evidenced by partly conflicting related work (compare Section 2.2). Nonetheless, the methods and results of this work aim to accomplish a high degree of intersubjectivity by reviewing large amounts of related work and investigating historically time-invariant characteristics.

**Structure of Work.** The methodological approach of this work is visualized in Figure 2.1. It is also reflected in how the remainder of this work is structured. Section 2.2 provides a review of related work. It analyzes and summarizes characteristics of form-based UIs that have been put forth in prior definitions and highlights the need for a better, more comprehensive definition. This is followed by three chapters that provide a large narration spanning the history, present, and future of form-based UIs.

Chapter 3 discusses select topics in the historical development of forms. There are three motivations for contributing a historical overview. Firstly, the overview will reveal some characteristics of forms to be largely invariant over time. We will use these time-invariant characteristics as basis for a novel definition of today's form-based UIs. Secondly, it will become evident that many other characteristics have been subject to temporal change. Thus today's form-based UIs have a very different nature, although they are still called 'forms' not just in everyday language, but also in related, scientific publications. We will argue that similarities and differences can best be explained using the concept of UI metaphor. Thirdly, since "How we think about things is affected by history" [108, p.10], historical knowledge about forms allows to analyze the status quo and consider goals for the future.

Chapter 4 analyzes today's form-based UIs and contributes a novel definition grounded in the concept of UI metaphor. We justify the definition based on the review of related work and the historical overview. We elaborate the definition, demonstrating its explanatory power for describing interpretations of the 'form' UI metaphor by designers and users, the current habituation and conventionalization, and possible re-interpretations.

Lastly, Chapter 5 employs the metaphoric understanding to derive a systematic analysis of directions for future research. This resulted in a list of fourteen research goals that are each described along with references to related work.

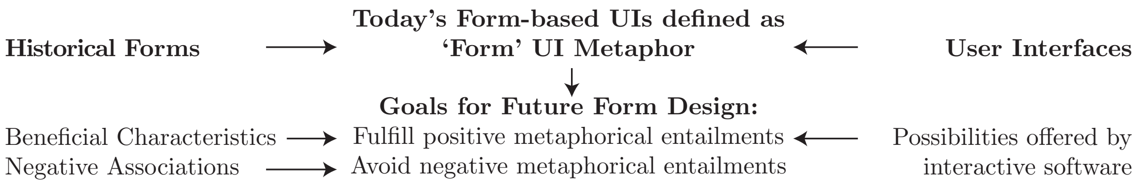



**Figure 2.1:** The approach of this work connects the past, present, and future of form design. More specifically, a novel definition of form-based UIs as UI metaphor is put forth in this work. Investigating the metaphor's vehicle (general, historical, other forms) and tenor (user interfaces) allowed to derive goals for future research in form design, i.e., to fulfill positive metaphorical entailments and avoid negative ones.

## 2.2 Related Work and Prior Definitions of Form-based User Interfaces

Confusion in the current debate about the usability of form-based UIs motivates the need for a better definition. Toward this goal, this section provides an extensive review of existing definitions of form-based UIs. It furthermore introduces to the concept of UI metaphor (that, as will be shown in Chapter 4, is apt for characterizing form-based UIs) based on foundations from Semiotics and Cognitive Science.

### 2.2.1 Current Confusion and the Need for a Clear Definition

The need for a better definition and firm, theoretical foundations is evidenced by ongoing discussions in HCI regarding the usability of form-based UIs and current confusion over their defining characteristics. This has been briefly described in Chapter 1 and will be elaborated in the following paragraphs.

Nielsen [W25] stated that "Forms are rarely the best metaphor for complex interactions with computers", arguing that because forms lack interactive features, the intended functionality is in many situations better supported by an "application". He consequently put forth several criteria for deciding "whether to present a form or a more interactive design", recommending to avoid forms if the requested information is complex, if the number of steps in a workflow are large, if parts of the UI are to be conditionally shown based on previous selections, and if the workflow is not strictly linear. The argument mistakes contingent characteristics (i.e., the criticized lack of interactive features and the alleged inadequacy for complex information and workflows) for constitutive ones, as evidenced by related work that made form-based UIs more interactive and suited for complex scenarios, including collaboration in medical forms (Gaubatz et al. [75]), navigation in long, complex UIs (Harms et al. [90, 92]), and efficient data entry (Wang et al. [193]). Many further references to related work that sought to evolve and improve form-based UIs to make them suited for complex requirements have been provided by Bargas-Avila et al. [16] and Harms [88].

In the same way, the common critique that form-based UIs are disengaging and dull, articulated recently in Wroblewski's book on form design, "Forms suck. If you don't believe me, try to find people who like filling them in" [205, p.2], is not constitutive for form-based UIs, as revealed by recent work that produced pleasant user experiences with form-based UIs – compare, for example, the author's work on gamified online surveys in Harms et al. [89, 91, 93].

The above critique demonstrates difficulties in distinguishing between essence and circumstance regarding form-based UIs. Criticized characteristics (e.g., dullness and lack of interactive features in the two above examples) were interpreted to be constitutive or contingent by different authors. The first perspective, i.e., that the criticized characteristics are essential, defining, and constitutive for form-based UIs, led to the recommendation that designers should avoid form-based UIs

| Discipline | Related Definitions of Form-based UIs |
|---|---|
| Technical | Atkins et al. [13], Boyer et al. [27], Firmenich et al. [68], Gehani [77], Shu et al. [172], Tsichritzis [189], Vaskevitch [191], and Wang et al. [193] |
| Design | Axelsson et al. [15], Bargas-Avila et al. [16], Barnett [17], DIN EN ISO 9241-143 [54], Frank et al. [69], Frohlich et al. [70], Harms [88], Jarrett et al. [112], Nielsen [W25], Tjin-Kam-Jet et al. [185], Weir et al. [195], Wright [203], and Wroblewski [205] |
| Historical | Becker [20] and Burkhard [33] |
| Legal | Gantner [73] |
| Sociological | Grosse et al. [79] |

**Table 2.1:** Disciplines and according perspectives taken in related work that provided definitions or discussed the defining characteristics of forms and form-based UIs.

altogether. The second perspective viewed the very same characteristics as nothing more than a contingent design practice that should rather be changed through specific remedies and improvements. A clear definition can help to avoid the above confusion by providing a distinction between essential, constitutive, defining characteristics, as opposed to contingent characteristics that depend on circumstance and current design practice.

### 2.2.2 Existing Definitions of Form-based UIs

Related work has provided various definitions of form-based UIs; this section contributes a review of corresponding literature. Methodologically, a total of 168 peer-reviewed publications and books collected during four years of research in form design were included in the review. We filtered the publications looking for explicit definitions but also discussions or implicit mentions of defining characteristics of forms and form-based UIs, resulting in a list of 43 works. We listed the defining characteristics put forth in each corresponding publication. The fact that some characteristics (such as the use of form-based UIs for data entry) were described in many publications allowed to exclude those publications with redundant definitions of lesser clarity from the review, resulting in a list of 25 remaining publications that will be discussed in this section. The large majority of these publications had a background in HCI or software engineering, but the review also includes works with historical, legal, and sociological perspectives; see Table 2.1 for an overview.

One comprehensive definition of form-based UIs can be found in the international standard DIN EN ISO 9241-143 [54] "*Ergonomics of human-computer interaction – Part 143: Forms*". It defined form-based UIs as follows: A "structured display of fields and other user-interface elements that the user reads, fills in, selects entries for (e.g. through check boxes or radio buttons) or modifies". The definition described visual appearance (a structured display), structure (fields and other UI elements), and interactions (reading, filling, selecting, modifying) as being constitutive. We found that most characteristics from other definitions can be categorized using the same three terms, i.e., as being related to either the specific appearance, structure, or interactions of form-based UIs; compare Table 2.2. Some definitions additionally described socio-cultural functions of forms and form-based UIs, these are shown separately in Table 2.3. The characteristics and according definitions are discussed in more detail in the following subsections.

**Appearance.** Related work has put forth the visual appearance of form-based UIs to be a defining characteristic, compare Table 2.2a. This is vaguely suggested in the definition of forms as "struc-

| Characteristics | Related Work |
|---|---|
| **a) Appearance** | |
| Input fields | Jarrett et al. [112] |
| Structured display | DIN EN ISO 9241-143 [54] |
| **b) Interaction** | |
| Access control | Gehani [77] |
| Information retrieval, search forms | Tjin-Kam-Jet et al. [185] |
| Input, data entry | Atkins et al. [13], DIN EN ISO 9241-143 [54], Gehani [77], Jarrett et al. [112], Tjin-Kam-Jet et al. [185], Tsichritzis [189], and Wang et al. [193] |
| Manipulation, additional operations such as computing aggregate values | Tsichritzis [189] |
| Manipulation, editing pre-filled contents | DIN EN ISO 9241-143 [54] and Gehani [77] |
| Manipulation, selecting values | DIN EN ISO 9241-143 [54] |
| Presentation, receiving and reading filled-out contents | Atkins et al. [13], DIN EN ISO 9241-143 [54], and Tsichritzis [189] |
| Reviewing, approval, signature | Boyer et al. [27] |
| Submission, sending, communication | Atkins et al. [13], Axelsson et al. [15], and Tsichritzis [189] |
| Validation and error checking | Gehani [77] |
| **c) Structure** | |
| Fields | DIN EN ISO 9241-143 [54], Gehani [77], Jarrett et al. [112], Tjin-Kam-Jet et al. [185], and Vaskevitch [191] |
| Fixed vs. variable parts | Burkhard [33] |
| Nested HTML elements | Wang et al. [193] |
| Prompts and values | Vaskevitch [191] |
| Questions and answers | Wright [203] |
| Schema and data | Tsichritzis [189] |

**Table 2.2:** Characteristics of forms and form-based UIs, as put forth in related work. The above table categorizes these characteristics as being related to either appearance, interaction, or structure.

tured display" in DIN EN ISO 9241-143 [54], but the chapter "some definitions and two processes" in Jarrett et al.'s book on web form design [112] more explicitly states, "You know a form when you see it. [...] Even at a glance, you can immediately identify the [screenshot] that is a form: it's the one with the fields to type into". Accordingly, the same field-like visual appearance lets readers of Jarret's book know which amongst two screenshots depicts a form and also allows users to immediately recognize the presence of a form-based UI.

**Interactions.** Many definitions list possible or typical interactions with form-based UIs, compare Table 2.2b for an overview. For example, the definition from DIN EN ISO 9241-143 [54] mentions reading, filling, selecting, and modifying entries. In a similar way, Atkins et al. [13] described functions for data presentation and data collection: "A form provides a user interface that presents service data to the user (such as a list of accounts), collects information from a user (such as the selected account), and returns it to the service". Gehani [77] additionally mentioned error checking, and access control: "Electronic forms offer the user of an automated office the ability to operate upon logically related data as an entity, a good user interface, automated error checking, and control over authorized data access".

One problem is that many publications appear to have tailored their proposed definitions to their respective interests. For example, both of the above definitions by Atkins et al. and Gehani are strongly linked to the terms and topics of their respective papers. In a similar way, Wang et al. [193] emphasized data entry in correspondence with their paper's topic of automatic data entry of user information: "a web form usually consists of a set of input elements [...] to capture user information". Similarly, Boyer et al. [27] described form-based UIs in terms of interactive documents, the latter being the topic of their paper. From the perspective of this dissertation, the tailoring of definitions could be criticized as problematic bias. But clearly, not all of the above publications aimed at formulating a general purpose definition of form-based UIs, but rather sought to justify and describe their specific approach and thus had a less general, perhaps even persuasive goal in mind.

Nonetheless, the total list of all form-based interactions mentioned in related work allows to generalize and paint a rich picture of typical form-based interactions. The total list includes viewing, editing or otherwise manipulating data, as well as less commonly noted interactions related to access control (to specific fields or form areas), information retrieval (e.g., through search forms), validation, reviewing, approving, signing, and final submission; see Table 2.2b for according references.

A further problem with definitions based on form-based interactions is that the interactions are not specific to form-based UIs. Each and all of the interactions in the above list could be realized through a variety of other UI designs such as tabular user interfaces (e.g., spreadsheets), command-line interfaces, or spoken dialogue systems. We conclude that lists of form-based interactions have helped describe the perceived value or purpose of form-based UIs for a given project or publication. They may further be useful for ostensively pointing out stereotypical interactions. But they poorly serve as defining characteristics in intentional definitions because they do not help discriminate form-based UIs from other UI designs.

**Structure.** Related work has defined form-based UIs based on their specific structure, compare Table 2.2c for an overview. Many definitions hold that the structure of form-based UIs is composed of fields. For example, the definition in DIN EN ISO 9241-143 [54] describes form-based UIs as being composed of "fields and other user-interface elements". In a similar way, Jarrett et al.'s definition [112] speaks of "fields to type into". The more technical definition by Wang et al. [193] likewise refer to a composite structure: "A Web form is defined by an HTML FORM tag [and] usually consists of a set of input elements [...] to capture user information". Furthermore, pairs of questions and answers have been suggested to be an additional structural characteristic of form-based UIs. Various terms have been used to describe the dichotomy. Wright [203] speaks of questions and answers, Vaskevitch [191] of prompts and values, Tsichritzis [189] of schema and data, Burkhard [33] of fixed and variable information. The common ground of the above structural definitions is that form-based UIs are composed of fields that combine fixed questions with variable information that users provide as answers.

**Socio-Cultural Function.** Many definitions of form-based UIs as well as of forms in a more general sense have described socio-cultural characteristics. Our review categorizes them into the following three categories: interfaces to computer systems, interfaces to other people, and means for abstraction, compare Table 2.3.

The notion of form-based UIs as interfaces is encompassed by many definitions, albeit with significant differences whether these interfaces connect humans with computers or humans with other humans. The first perspective of form-based UIs as a means for human-computer interaction is expressed, for example, by Frohlich et al. [70] as follows. “Form-filling is a particularly convenient way of communicating a complex request to a computer. By typing information into areas on a screen-displayed form, users can organize extremely detailed messages prior to submitting them to the computer for execution”. In a similar way Firmenich et al. [68] stated, “For many Web applications, forms are essential components that allow users to provide data and interact with the system”. Shu et al. [172] praised forms as “the most natural interface between a user and data”, thus using metonymy by referring to the computer as data. Similarly, Nielsen [W25]’s critique, “Forms are rarely the best metaphor for complex interactions with computers”, shares the same understanding of form-based UIs as interfaces to computer systems.

The above definitions are in strong contrast to other publications that described forms as interfaces for interacting with other humans. This second perspective is held by publications on form-based UIs as well as by historical and sociological accounts of (mostly paper) forms, compare Table 2.3 for an overview on corresponding references. For example, Frohlich et al. [70] summed up prior definitions of form-based UIs as follows: “What is common to most definitions is the notion that a form facilitates some kind of communication between an organization and an individual”. In a similar way, the more recent work by Bargas-Avila et al. [16] described the role of web forms as “the main contact point between users and website owners”. In the context of e-Government, Axelsson et al. [15] stated likewise, “we define forms as instruments for communication and, thus, also instruments through which citizens perform different communicative actions towards government agencies”. Becker [20] also characterized forms as means for conducting dialogue between citizens and public administration. Grosse et al. [79] and Sarangi et al. [161] further characterized the nature of this dialogue as asymmetric, authoritative, and bureaucratic.

A third socio-cultural characteristic of forms is their function for abstracting and classifying persons or individual life experiences into standardized cases. Related work has described this characteristic with regard to paper-based forms; we will examine in this work if and how it also applies to form-based UIs. According to Becker [20], forms help administrative organizations to abstract, classify, and categorize individual experiences into institutionalized representations. This abstraction and classification has also been described from a juridical perspective by Gantner [73] as a means for legal subsumption. One benefit of the abstraction and classification provided by forms is that “forms allow to reduce complex factual situations to simple, unambiguous information”, compare Burkhard [33]. One difficulty for users is that they must comply to the form schema – the definition by Barnett [17] correspondingly speaks of forms as “prescribed written means of shaping information for communicating ideas”.

**Relationship between Form-based UIs and other Forms.** Various terms have been used for describing the relationship between form-based UIs on the one hand and general or paper-based forms on the other hand.

One group of publications has understood form-based UIs to be similar to, but more powerful than traditional, paper-based forms. Within this direction, Gehani [77] postulated a relationship of analogy by stating, “An electronic form is the computer analog of a paper form. Fields in an electronic form are filled as in a paper form. However, fields in electronic forms are much more powerful [...]”. In a similar way, Tsichritzis [189] holds that form-based UIs are more powerful and thus more general than paper forms: “We define forms by making some generalizations on text forms”. The specific generalizations described in Tsichritzis’s paper are that (1) electronic

| **Socio-Cultural Function** | **Form-based UIs** | **General forms** |
|---|---|---|
| Interface for interacting with a computer system | Atkins et al. [13], Firmenich et al. [68], Frohlich et al. [70], Nielsen [W25], Shu et al. [172], and Tjin-Kam-Jet et al. [185] | |
| Interface or gatekeeper for communicating with people or organizations | Axelsson et al. [15], Bargas-Avila et al. [16], Frohlich et al. [70], and Wroblewski [205] | Barnett [17], Becker [20], and Grosse et al. [79] |
| Means for abstraction, classification, categorization, legal subsumption | | Barnett [17], Becker [20], Burkhard [33], and Gantner [73] |

**Table 2.3:** Socio-cultural functions of form-based UIs and of forms in general, as put forth in related work.

forms support communication media other than text, (2) multiple form templates may be used for the same form data, (3) templates may adapt to form data, and that (4) electronic forms support additional operations such as computation of aggregate values.

Another group of papers discussed the relationship between form-based UIs and traditional forms using the concept of metaphor. For example, a prior paper by the author of this dissertation [88] states, "The 'form' UI metaphor is a device for explaining the functionality of a UI by asserting its similarity to conventional (e.g., paper) forms". The paper also discussed historical characteristics of forms and goals for future research in form design. The present work is an extension since it provides a much more in-depth discussion of similar topics. The idea that users understand form-based UIs through their knowledge of traditional forms has also been described by Frank et al. [69], albeit without explicit reference to the concept of metaphor: "Many software applications solicit input from the user via a "forms" paradigm that emulates their paper equivalent. It exploits the users' familiarity with these and is well suited for the input of simple attribute-value data (name, phone number, etc.)". Nielsen [W25] and Weir et al. [195] also described form-based UIs as metaphor but did not further define the concept or discuss its implications.

**Summary and Discussion of Existing Definitions.** Related work has defined various characteristics of form-based UIs. The above literature review categorized the characteristics into appearance, interaction, structure, and socio-cultural function and provided detailed descriptions for each of the categories. The review also revealed a need for further clarification and investigation. We observed a lack of comprehensiveness and completeness since none of the definitions covered all four categories. We furthermore questioned the generality and objectivity of some definitions since they appeared to be tailored to the specific interests of the respective publications. Also, the form-based interactions listed in many definitions poorly serve as defining characteristics since none of them is specific to form-based UIs alone. Moreover, many definitions left it unclear which of the proposed defining characteristics apply specifically to form-based UIs, as opposed to paper forms or forms in a more general sense. Lastly, the relationship between form-based UIs on the one hand and general, traditional, paper-based, or historical forms on the other hand remained unclear. Prior publications have postulated various relationships such as similarity, analogy, generalization, and metaphor. This indicates a need for further investigation and a more comprehensive definition.

### 2.2.3 User Interface Metaphor

The relationship between form-based UIs and traditional (e.g., paper-based) forms can be understood in terms of metaphor, as previously formulated by Harms [88], Nielsen [W25], and Weir et al. [195] and as elaborated in Chapter 4 of this work. This section provides corresponding theoretical foundations by introducing to the concept of UI metaphor. The concept of UI metaphor will then be used in Chapter 4 where we adopt, justify, and elaborate the metaphoric understanding of form-based UIs.

Metaphor has been grounded in various disciplines including philosophy, linguistics, Cognitive Science, and Semiotics; compare Barr et al. [19], Blackwell [25], Imaz et al. [108, ch.3], and Pirhonen [154] for introductions within the context of HCI. One common understanding is that metaphor relates two different concepts, tenor and vehicle, by asserting their identity. This is unlike analogy which asserts that one concept is *like* another concept, compare Imaz et al. [108, p.38]. Therefore, as described by Lattmann [128], metaphoric sentences may sound contradictory if understood as proposition, but they represent a novel, different meaning if understood as metaphor. It has likewise been argued by Pirhonen [154] that the power of UI metaphor lies in the stimulation provided by differences between tenor and vehicle, as opposed to a simulation approach to UI design that maximizes similarities. The two concepts related in a metaphor, i.e., tenor and vehicle, are commonly illustrated using the phrase JULIET IS THE SUN[1] from Shakespeare's play "Romeo and Juliet", act 2, scene 2. The tenor (Juliet) is declared to be identical with its vehicle (the sun), which allows to infer meaning about the tenor (e.g., amongst other interpretations, that Juliet is warm and nurturing).

UI metaphor is a special kind of metaphor. The distinguishing criterion, as defined by Barr et al. [19], is that a UI metaphor's tenor, i.e., that which is being explained, is a user interface. Examples of popular UI metaphors include THE UI IS A DESKTOP, THE CLICKABLE AREA IS A PUSHBUTTON, and THE UI IS A FORM, see Blackwell [25] and Imaz et al. [108, ch.6] for more examples. Over time and through widespread use, people get used to metaphors, a process which has been described as the metaphor's 'lifecycle' by Pirhonen [154]. Accordingly, a metaphor is born when it is interpreted for the first time, it gains power when people elaborate and complete the metaphorical entailments, and it gradually dies when the metaphor becomes so common that people stop interpreting it as such and instead rely on previously learned meaning. All of the above example UI metaphors (desktop, pushbuttons, and forms) are dead in this sense. Lattmann [128] stated that dead metaphors can be revived through fresh (re-)interpretations. Note that Chapter 5 of this work likewise is the result of a fresh re-interpretation of the 'form' UI metaphor – we investigated metaphorical entailments to gain fresh insight and derive research goals.

UI Metaphor has a long and troubled history in the discipline of HCI. As described by Blackwell [25], the discipline of HCI has "reified" the abstract concept of metaphor into a concrete tool for user interface design. Metaphor as design tool has however been subject to much critique since it has not guaranteed resulting UIs to be natural or intuitive. In contrast to this sobering critique, Blackwell has provided directions for how metaphor can prove useful in HCI. Researchers can use metaphor to analyze, deconstruct, and criticize complex UIs. Designers can use metaphor to invoke rich, creative, unforeseen creative experiences amongst users, similar to how people respond to artwork or literature. Metaphor can furthermore have a generative function for designers, allowing them to break existing patterns and establish new design lexicons for future products. Note that the goals of this work can be described in terms of the above recommendations. It employed metaphor to analyze form-based UIs and formulate research goals, aiming to re-consider existing patterns and evolve the current design practice.

[1] Note the convention of spelling metaphors in small capitals.

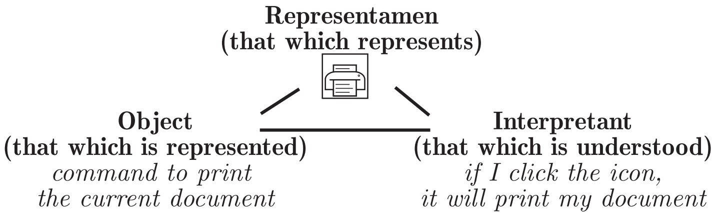



**Figure 2.2:** User's interpretation of the 'print-button' sign, as described by Barr et al. [19].

### 2.2.4 Semiotic Foundations of UI Metaphor

From a Semiotic perspective, user interfaces are understood as signs. Signs are ternary relationships between representamen (that which represents), object (that which is represented), and interpretant (that which a person understands from a sign), compare Barr et al. [19] and Lattmann [128] for introductions. Taking the example of a print button as in Barr's work (compare Figure 2.2), the sign's representamen is the visual button, the object is the functionality that clicking the button opens a print dialogue, and the interpretant can be anything a person understands from the print button sign. A user's interpretant may correspond to the meaning that was originally intended by the designer, e.g., "I may click the button to print the document", but this is not necessarily the case.

Signs – and hence also UIs – can be studied regarding syntax, semantics, and pragmatics; compare, for example, Liu [130]'s extensive framework for systems design that is based on this distinction. Syntax refers to rules about how signs may be combined. Semantics refers to the meaning communicated through signs. Pragmatics is about the contextual and intentional use of signs. Regarding form-based UIs, syntax corresponds to what other UI elements a form may be structurally composed of, and how form-based UIs may be embedded in other UIs. This aspect is well-covered in related books on form design, compare for example Jarrett et al. [112] and Wroblewski [205]. Semantic and pragmatic aspects are the primary interest of this work, i.e., the meaning communicated through form-based UIs, as well as their practical, socio-cultural use.

The Semiotic Engineering meta-communication model by Souza [173] allows to investigate these aspects from a design perspective. According to the model, designers communicate a meta-message about their UI design to users, a message that can be paraphrased as, "Here is my understanding of who you are, what I have learned you want or need to do, in which preferred ways, and why. This is the system that I have, therefore, designed for you, and this is the way you can or should use it in order to fulfill a range of purposes that fall within this vision" [173]. Regarding form design, the formulation "this is the way you can or should use it" in the above paraphrase describes the designer's intent in choosing a form based UI and the expected user interpretation related to it.

Semiotic models of UI metaphor allow to investigate in more detail the design intent that is communicated through metaphoric UIs. One such model has been put forth by Barr et al. [19] based on Peircean Semiotics. The model encompasses two steps, corresponding to the fact that UIs are first designed and then used. Both steps involve Semiosis, i.e., the process whereby humans interpret meaning from a sign. Despite complex descriptions of how Semiosis works, humans are very good and very fast at it; people interpret metaphors and derive meaning from signs every day [108]. We briefly summarize the model's two steps using Barr's example metaphor THE DATA IS A DOCUMENT.

In the first step, a designer interprets the metaphor by incorporating the abstract idea that data can metaphorically be represented by a document in her design. The metaphor THE DATA IS A DOCUMENT has various metaphorical entailments, i.e., it entails various parallelisms between data and documents. Not all of them may be suited for the designer's purposes. For example, her design may purposely or unknowingly ingore the fact that paper documents can contain drawings and that paper sheets can be burned. But other metaphorical entailments may be well-suited for expressing her design intent. For example, her design may visualize data on a white sheet of paper and allow data editing, similar to how documents may be edited on paper sheets. The result of her interpretation is a UI that communicates her design intent by use of metaphor.

In the second step, a user interprets the UI during interaction. The 'document' UI metaphor, as realized in the UI, has various UI-metaphorical entailments. It may occur that only some of the entailments were originally intended by the designer and that only some of them are understood by the user. Thus during a user's interaction with the UI, he may recognize that the design metaphorically references documents. This allows him to interpret the metaphor (depending on contextual factors and his prior knowledge about forms and UIs) and infer meaning from and about the UI. For example, he may understand that data can be edited, as entailed by the UI metaphor and as intended by the designer. He may further understand that data can be drawn by hand – but although this is entailed by the UI metaphor, the he may find this entailment unfulfilled in the UI design.

The above theoretical concepts are useful for the purpose of this work of analyzing form-based UIs. The Semiotic model of UI metaphor can be specialized to describe the 'form' UI metaphor, compare Sections 4.2 and 4.3. It furthermore provides structure and terms for reasoning about metaphorical entailments – in Chapter 5, we will analyze entailments of the 'form' UI metaphor and propose unfulfilled but useful entailments as goals for future research.

### 2.2.5 Cognitive Science Foundations of UI Metaphor

Metaphor, as understood in Cognitive Science, plays a central role in design, compare Imaz et al. [108], and generally in human thinking, compare Lakoff et al. [127]. The human brain interprets metaphor through a process called blending or conceptual integration.This process has been nicely summarized by Imaz et al. [108, ch.3]. First, a mapping is established between elements of the input spaces. Second, a generic mental space is created to reflect the abstract structure and organization shared by the input spaces (e.g., by forms and UIs). Third, the generic space is partially projected into a final, blended space. Completion and elaboration of the blended space, also termed "running the blend", can create new structures not originally provided by the input spaces.

Blending describes the interpretation of metaphor not just as parallelisms between the two concepts of tenor and vehicle, but as integration and elaboration of a network of multiple, inter-related conceptual spaces. For example, Fauconnier et al. [66] demonstrated that the metaphor TIME IS SPACE involves many such conceptual spaces as well as emergent structures in the blended space. Imaz et al. [108, ch.3] provide a similar analysis regarding UI metaphors using the example metaphor THE OPERATING SYSTEM IS AN OFFICE DESKTOP. Blending is a relevant concept for this work because form-based UIs, being composed of "fields and other UI elements" according to the definition in DIN EN ISO 9241-143 [54], involve a network of multiple conceptual spaces – some apparent ones being forms, fields, UIs, and elements. Such networks can be understood in terms of "blended interaction", as proposed by Jetter et al. [114]. Accordingly, blended interaction refers to blends between individual interactions, social interactions, workflows, and the physical environment.

## 2.3 Discussion and Outlook

This chapter provided an in-depth review of prior definitions of form-based UIs and introduced to theories of UI metaphor. The review revealed a need for further clarification regarding various issues, as described in Section 2.2.2. These issues imply that novel, better definitions should have the following, desirable properties.

Definitions should be comprehensive and complete, covering various aspects including the specific appearance, interaction, structure, and socio-cultural function of form-based UIs. Definitions should be general, as opposed to prior definitions that appear to be tailored to the specific interests of the corresponding publications. Lastly, definitions should clearly discern necessary characteristics from contingent ones. This implies that they should clarify the relationship between form-based UIs and other forms and clearly state which characteristics apply to form-based UIs, as opposed to paper forms or other kinds of forms.

The following Chapter 3 will analyze historical forms and compare them with today's form-based UIs. This provides the basis for Chapter 4 where a novel, comprehensive, general, and clear definition of form-based UIs will be put forth.

# 3 Past: Historical Ancestors of Today's Form-based User Interfaces

**Chapter Summary.** Histories of forms have been written from various perspectives. This chapter reviews and summarizes corresponding works and discusses select topics, thus aiming to shed light on past and present characteristics of forms and form-based user interfaces. The additional, novel contribution of the overview provided in this chapter is a comparison of similarities and differences with today's form-based UIs. This comparison will inform the subsequent definition and analysis of today's form-based user interfaces in Chapter 4.

## 3.1 Introduction

Understanding the history of forms allows to reflect about today's form-based user interfaces (UIs) and provides perspectives for their future development.

**Background and Motivation.** As stated by Imaz et al. [108, p.10], "How we think about things is affected by history". This applies to usage, design, and research related to form-based UIs, i.e., to how users interpret form-based UIs in order to work with them, how designers conceive of forms when designing corresponding applications, and how researchers understand form-based artifacts and related design practices. Therefore, in order to understand and clearly define form-based UIs in Chapter 4, this chapter reviews and summarizes their historical development.

**Related Histories of Forms.** Related histories of forms have focussed on different periods of time and on different artifacts used for a variety of purposes in different cultures. As visualized in Figure 3.1, corresponding histories have been written from different research perspectives and using different historiographical methods.

Goody [78] described the importance of forms (as well as of lists and tables) as means for structured inscriptions in early, written cultures. Eisermann [62, 63] provided a detailed description of the earliest, printed form known in western culture, i.e., an indulgence letter from the year 1454 (see Figure 3.2). Burkhard [33] published a similar history of forms from a communication and media perspective. Schwesinger [166]'s book about the visual design of mostly paper-based form designs also discusses the history of corresponding artifacts. Barnett's book [18] about form design in a business management context includes a historical introduction and highlights the importance of early copying machines for reproducing blank preprints. Becker's historical overviews [20, 21] investigated the role of forms in public administration.

The above works provided a high-level overview over a large variety of artifacts and a long period of time, each with a slightly different perspective and topic of interest. Note that none of these prior works could provide comprehensive details along every dimension shown in Figure 3.1. Instead, it is necessary (for related histories as well as for this chapter) to define a narrower focus by setting specific goals.

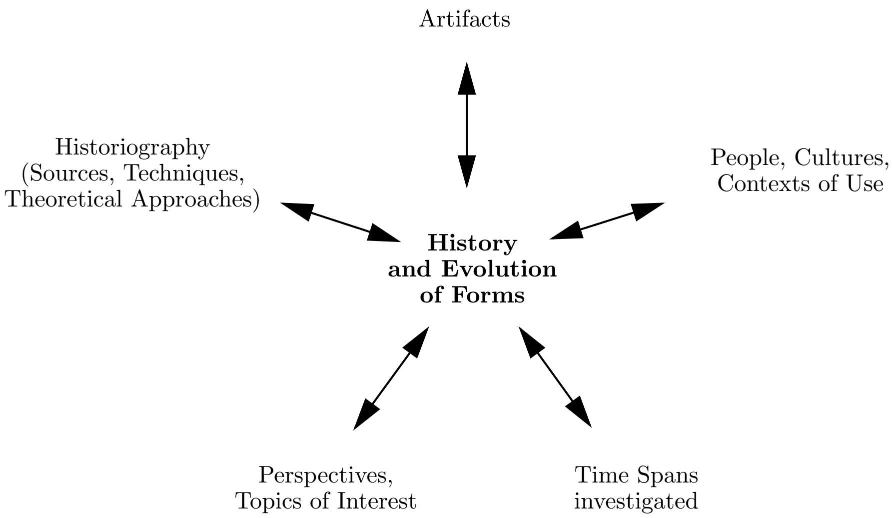



**Figure 3.1:** Dimensions of possible histories describing the evolution of forms. Each arrow in the above graphic visualizes one axis or dimension along which a histories of forms may be characterized. Thus histories of forms may be written about different artifacts used by different people and cultures in varying contexts of use. Histories may investigate different time spans (or points in time) regarding different perspectives and research topics. They may furthermore use a variety of historiographical methods, different sources, techniques, and theoretical approaches.

**Specific Goals and Contributions.** It is the goal of this chapter to discuss the history of forms regarding select topics that are of particular interest for understanding electronic, form-based artifacts that serve as user interfaces in modern software application.

The goals and scope of this chapter can be described more specifically along the dimensions shown in Figure 3.1. The primary topic of interest of this chapter is to compare historical characteristics of forms with those of today's form-based UIs. Methodologically, this chapter builds on related histories of forms that have been written in prior works, i.e., on secondary sources. Note that going back to primary sources would clearly exceed the scope of this dissertation. This time span that is discussed in this chapter is large and it is consequently only possible to provide a high-level overview of a variety of artifacts used in various contexts in western European societies. The choice of specific topics that are investigated in this chapter is motivated by the following considerations.

Firstly, we sought to discuss topics that were considered to be important in related work. For example, several authors including Becker [20], Burkhard [33], and Schwesinger [166] described one line of ancestors of modern forms that is characterized by the use of left-empty placeholders. This topic is discussed in Section 3.2 of this chapter. A second line of ancestors relates to the socio-cultural function of forms for abstracting individual life experiences into standardized, written representations, as described by Becker [20], Burkhard [33], and Goody [78] and as discussed in Section 3.3.

Secondly, this chapter seeks to clarify questions raised in the review of related definitions of form-based UIs in Section 2.2. For example, related work in HCI revealed uncertainty regarding the relationship between general or historical forms on the one hand and today's form-based UIs on the other hand. Related work furthermore includes conflicting notions that form-based UIs serve as interfaces either between humans and computers or between humans and other humans. The present chapter seeks to clarify these questions, uncertainties, and conflicts.

| Time | Artifact | Characteristics and Purpose of Use |
|---|---|---|
| Since 3000 BC | Lists (flat, hierarchical) | Inscription, abstraction, implicit categorization. Compare Becker [20] and Goody [78]. |
| Around $7^{th}c.$ | Formulae | Placeholders in cloze-like layout, re-use of formulations to guarantee consistent wording. Compare Eisermann [63]. |
| Around $15^{th}c.$ | Hand-written blank charters | Scheduling writing work. Trust, authenticity. Compare Eisermann [62, 63]. |
| Since $15^{th}c.$ | Pre-printed charters | Reduction of writing work. Compare Eisermann [62, 63]. |
| Since $16^{th}c.$ | Data Tables | Abstraction and explicit categorization in public administration. Compare Becker [20]. |
| Since $16^{th}c.$ | Questionnaires | Standardized abstractions and categorizations, instructions combined with data entry. Compare Becker [20]. |
| Since $17^{th}c.$ | Forms with grid layout | Explicitely labelled placeholders, better overview than cloze-like layouts. Compare Barnett [18] and Burkhard [33]. |
| $19^{th}/20^{th}c.$ | Machine-Copied Forms | Widespread use of forms in business automation. Compare Barnett [18]. |
| Mid $20^{th}c.$ | Social Welfare Forms | Widespread use of forms as interfaces to citizens or customers. Compare Becker [20]. |
| Since 1960s | Early electronic forms | Prompts and values mandated by input/output devices, interfaces for human-computer interaction. Compare Frohlich et al. [70] and Imaz et al. [108, p.4ff]. |
| Since 1970s | Form-based GUIs | Deliberate design choice for explaining a UI through forms. Compare Harms [88]. |

**Table 3.1:** Historical forms and corresponding characteristics. The above table provides a chronological overview on historical, form-based artifacts. While many of their characteristics have changed over time, some characteristics have time-invariantly applied. These include the use of placeholders in forms as well as the use of forms for abstraction, categorization, and standardization.

Thirdly and lastly, the overall goal of this chapter is to provide a foundation for a novel definition of form-based UIs. Towards this goal, this chapter summarizes and reviews historical characteristics of forms, as visualized in Table 3.1. This allowed to identify several time-invariant characteristics that have uniformly applied to historical forms for centuries and that still apply to today's form-based UIs, making it very unlikely for them to change in the near future. These historically time-invariant characteristics will provide firm grounds for our definition of form-based UIs in Chapter 4.

**Structure of Work.** The following sections summarize the historical development of forms by investigating three main characteristics discussed in related histories of forms. These include the use of placeholders in forms (Section 3.2), the socio-cultural use of forms for abstraction, classification, and standardization (Section 3.3), and the use of forms as interfaces for communicating with humans or computers (Section 3.4). Lastly, we discuss similarities and differences to today's form-based UIs (Section 3.5). This will allow to identify the first two characteristics, i.e., the use of placeholders in forms and the use of forms for abstraction and standardization, to be largely time-invariant. In contrast, we will show that the use of forms as interfaces for human communication has not been a necessary characteristic and that the use of forms as interfaces between humans and computers is a recent development that solely applies to form-based UIs.

## 3.2 Placeholders to be Filled Later – From Formulae to Forms

One line of ancestors in the genealogy of forms, as constructed by Becker [20], relates to the principle of labels and placeholders. Labels and placeholders have also been discussed in other histories of forms, compare Burkhard [33], Eisermann [63], and Schwesinger [166]. Placeholders were first employed in formulae of the 7th century, i.e., in text templates used to guarantee consistent wording in juridical and liturgical use. Handwritten blank charters also had placeholders, allowing to fill in the recipient's name at a later time and thus flexibly schedule writing work, compare Becker [20] and Eisermann [63]. The earliest printed form in western culture, an indulgence letter from 1454 (see Figure 3.2) was pre-printed with placeholders on vellum and was sealed after filling to increase trust and authenticity, as described by Eisermann [62, 63]. These early forms employed a cloze-like layout with empty spots in otherwise continuous text serving as placeholders. In contrast, grid-like form layouts with separate labels for each placeholder were first used in British military of the 1600's, see Barnett [18, p.5]. According to Burkhard [33], this layout became widely spread in business forms since the 18th century when lower papers costs made this more generous design economically feasible.

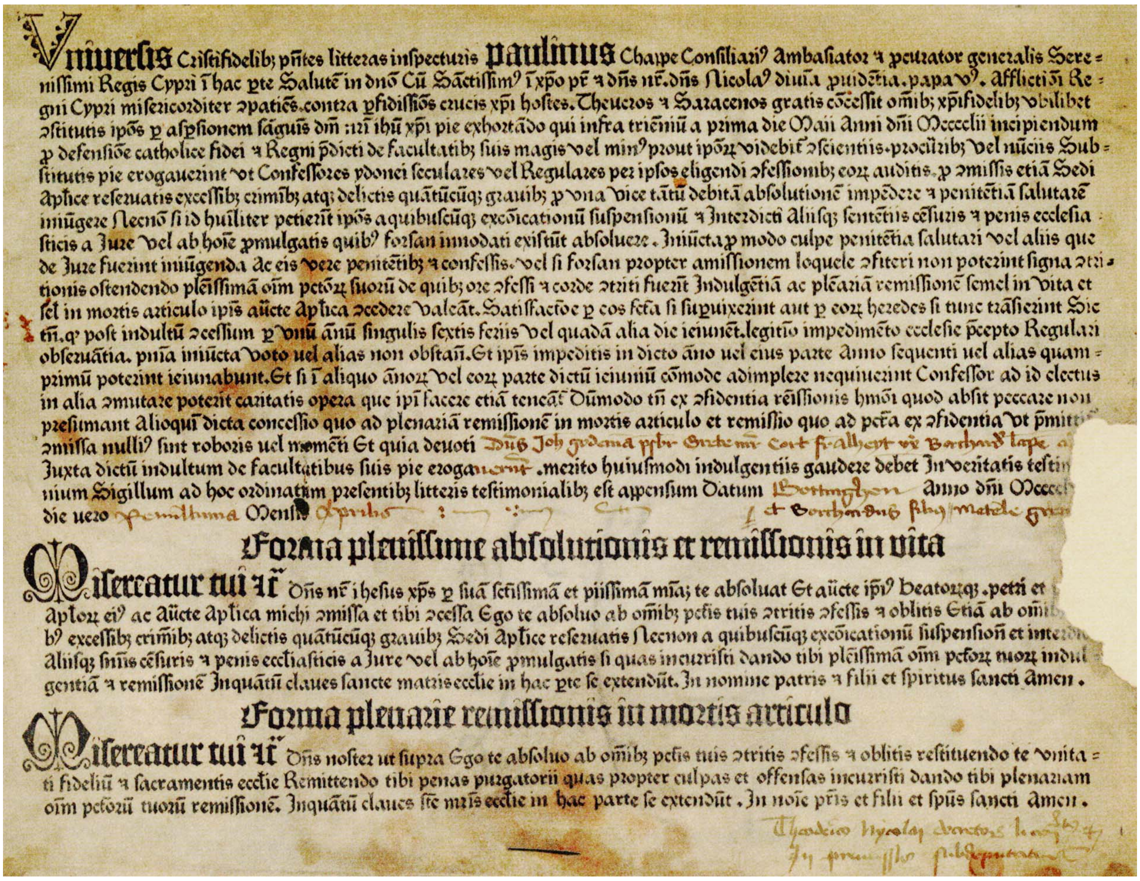
The principle of placeholders and labels can also be found in early computing where human-computer interaction highly resembled form filling. One very early example of such interaction is a form-based hospital information system described by Allen et al. [6] and depicted in Figure 3.4. The system enabled users to freely define form schemas and subsequently fill the corresponding forms in order to document medical data. The interaction style was largely dictated by the available input and output devices. A teletype machine printed labels or 'prompts' on paper. Users answered each prompt by typing text that was also printed by the teletype machine.

Today, the use of labels and placeholders in UI design is no longer necessitated by the available input/output devices. Instead, as previously argued by Harms [88], form-based UIs are a deliberate design choice. Firstly because designers can employ other UI metaphors. For example, a study by Weir et al. [195] evaluated the 'form' UI metaphor in comparison to tables in online banking. Another example is described by Johnson et al. [117] where form-based medical UIs were replaced with another design that employed the document metaphor to implement free-form, narrative text documents.

Mobile form-based UIs, as their desktop counterparts, are also deliberate design choices. For example, Wroblewski [204] described an alternative design that may be used instead of form-based UIs to conduct surveys on mobile devices. His book [204] provides a detailed account of how the "Polar" app's design deliberately deviated from traditional form design in favor of an innovative, alternative design that did not use form fields and only showed one question per screen.

Lastly, novel interaction paradigms (instead of windows, icons, menus, and pointers, as typical for graphical UIs) largely eliminate the need for form-based UIs. Designers can employ these paradigms instead of form-based UIs. For example, spoken dialogue systems and tangible interaction through physical objects are unlikely to involve typical elements of form design.

In summary, the use of placeholders in modern user interfaces is not necessitated anymore by the available input/output devices but corresponds to a deliberate design decision. Given that placeholders have been a historically time-invariant (and hence highly typical) characteristic of forms, today's design practice for designing form-based UIs likewise implies the use of placeholders.


Uniuersis Cristifidelibus presentes litteras inspecturis Paulinus Chappe Consiliarius ambasiator et procurator generalis Serenissimi Regis Cypri ...

Forma plenissime absolutionis et remissionis in vita

Misereatur tui ...

Forma plenarie remissionis in mortis articulo

Misereatur tui ...

**Figure 3.2:** The earliest known pre-printed form is an indulgence letter dating back to 1454. Its placeholders were initially left empty and later on filled out by hand [62, 63]. Graphic from [63].

```
1  FIELD #1 NAME:  UNIT NUMBER
  1.1  UNIQUE TO RECORD?  YES
  1.2  TYPE:  REGULAR
  1.3  COLUMNS:  1-7
  1.4  SYNTAX DEF:  9999999
          TRY ME:  0012876...OK.
          TRY ME:  012314...NOT OK.
          TRY ME:

2  FIELD #2 NAME:  AGE
  2.1  UNIQUE TO RECORD?  YES
  2.2  TYPE:  DECIMAL NUMBER
  2.3  COLUMNS:  8-9
  2.4  SYNTAX DEF:  99
          TRY ME:  45...OK.
          TRY ME:  A1...NOT OK.
          TRY ME:
```

**Figure 3.3:** Form schema definition in the 1966 hospital information system described by Allen et al. [6]. The user's input through a Teletype machine (displayed as underlined text in the above graphic) defines two form fields, field #1 "unit number" and field #2 "age".

```
RESEARCH TELETYPE INPUT

1  LIST OF FILE NAMES?  N
2  FILE NUMBER:  38  RESEARCH - 1 (JET)
  2.1   CONFIDENTIAL CODE:  888
  0.1  REC-ID:  0002165
1  UNIT NUMBER:  ←CO.1  0002165
2  AGE:  23
```

**Figure 3.4:** Form filling in the same hospital information system described by Allen et al. [6]. The user's input (displayed as underlined text) provides data for the two form fields "unit number" and "age".

## 3.3 Abstraction, Classification, and Standardization – From Lists, to Tables, to Forms

A second line of ancestors in Becker's genealogy of forms [20] is that lists, tables, and forms have historically provided increasingly powerful means for inscription, abstraction, and classification. This development has also been described by Burkhard [33] and Goody [78].

Lists are amongst the earliest inscriptions known, dating back to cultures in Egypt and Mesopotamia around 3000 BC [33]. They allowed to keep record of the current state of affairs (e.g., inventories of goods), track past events and things to be done in the future (e.g., shopping lists), and generally to group and order words (e.g., to describe a hierarchical view of society); compare Goody [78, ch.5] for a more in-depth description. Lists are the means for and result of an intellectual transformation that abstracts and categorizes life experiences into list items; the categorization is implicit because all list items share the same category.

Tables, in comparison to lists, allowed a more explicit categorization. Becker [20] describes G. F. Leibniz' "Staatstafeln" as an early example of the use of tables for explicit categorization. These tables allowed to create institutionalized representations of the situations to be administered.

Forms supported even more sophisticated categorization. One of the earliest examples of the use of forms for this purpose are questionnaires used by local officers in colonies of Philipp II of Spain since the late 16th century, as described by Becker [20]. The questionnaires allowed to standardize the creation of institutionalized representations by coupling instructions with data entry. In contrast to large-scale public administration projects, private businesses took more time to adopt the use of forms for similar purposes. Barnett [18, ch.1] describes how the invention of carbon paper and machine-copied form templates revolutionized the use of forms for business administration in the late 19th and early 20th century. One example in his book [18, p.20] illustrates the connection between forms and tables particularly well. So-called "one-write" forms, compare Figure 3.5, provided small paper sheets, each of which included a small, single-lined form. The filled form could be torn off and given away as a receipt. A copy of the form data was carbon-copied during filling unto an underlying tabular sheet. It is evident from this example that both the form-based and the tabular representation helped to abstract business transactions into standardized, written representations.

Today's form-based UIs, similar to their historical predecessors, also require users to conform to a standardized, pre-defined classification. The form schema enforces a certain structure and vocabulary and corresponding validation logic rejects any non-conformant input. As described by Harms [88], this standardization has the benefit of automated data processing, but also the drawback of authoritative communication as otherwise encountered in bureaucratic settings – compare Grosse et al. [79] for more about the asymmetrical, authoritative communication enforced through forms and Sarangi et al. [161] for an in-depth analysis of bureaucratic language.

In summary, the above overview has revealed that both historical forms and today's form-based UIs have time-invariantly fulfilled a specific, socio-cultural function, i.e., to abstract individual experiences into standardized representations.

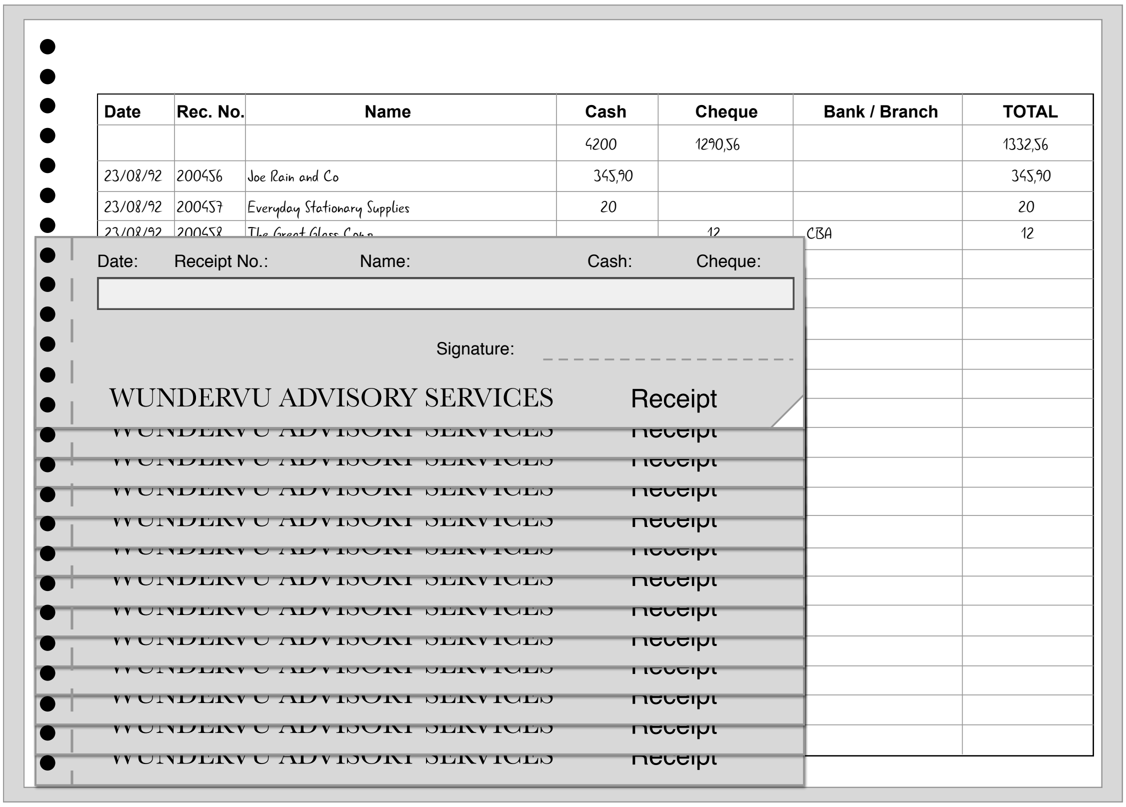



**Figure 3.5:** Forms and tables for business administration, combined in so-called "one-write" form systems. "One-write" form systems, as shown in the above graphic, provided small paper sheets, each with a single-lined form. Upon filling, a layer of carbon paper copied the form data into the underlying table. The small paper sheet could then be torn off and given away as a receipt. Graphic redrawn from Barnett [18, p.20].

## 3.4 Forms as Interfaces

The earliest historical forms fulfilled an organization's internal function of abstracting and standardizing information, as described in the previous section. In contrast and addition, Becker [20] described an external, communicative function of forms, which allows to characterize them as interfaces for human communication.

Widespread use of forms as interfaces (e.g., between government and citizens) is relatively young. According to Becker [20], it only goes back to the second half of the 20th century. Earlier public administrations also used forms and questionnaires, but these were filled by officers instead of by citizens, and thus by members of the same organization. In contrast, 20th century governments delegated the increasing administrative workload that resulted from large social welfare programs to citizens – who then had to fill out forms on their own. In consequence, forms took over the role of officers as mediating interfaces between citizens and public administration [20]. Modern public administration uses electronic forms for the same purpose, compare, e.g., the definition of e-government forms by Axelsson et al. [15] as "instruments [...] through which citizens perform different communicative actions towards government agencies".

Not all of today's form-based UIs serve as interfaces for human communication. For example, operating systems typically feature print dialogues with form-based UIs. These allow users to configure various settings before sending data to a printer. The data entered into the corresponding form fields is not sent to other people – it is exclusively processed by a computer. Frohlich et al.

[70] correspondingly understood form-filling as a "way of communicating a complex request to a computer". The same understanding is entailed by the HCI discipline that metaphorically referred to input and output capabilities of computers as user interfaces that enable human-computer interaction, compare Imaz et al. [108, p.4ff] and Shu et al. [172] for more about the 'human-computer interaction' metaphor. Early computers were also explained using further metaphors such as 'dialogue' to suggest that users were communicating and discussing things with the computer [108, p.4ff]. Related work in form design has likewise understood form-based UIs as interfaces for human-computer interaction and form-based interactions as dialogues or conversations between user and UI, compare the review of related work in Section 2.2.2.

Obviously, earlier, historical, paper forms never served as interfaces for human-computer interaction. This difference, namely that form-based UIs are interactive and that paper forms are not, is even more evident and explicit if expressed in Semiotic terms. Thus, according to Souza [173], UIs are capable of symbol manipulation and of limited Semiosis, a characteristic that is clearly absent in paper forms.

In summary, forms have historically served as interfaces that enabled and regulated communication between humans. In contrast to this historical tradition, form-based UIs do not always enable communication between humans, but sometimes solely serve the purpose of enabling human-computer interaction.

## 3.5 Discussion and Outlook: Similarities and Differences between Historical Forms and Today's Form-based UIs

The historical overview has revealed some largely time-invariant characteristics of forms that are also shared by today's form-based UIs, as well as other characteristics that have changed over the centuries, compare Table 3.1 for a summary.

Time-invariant characteristics of forms that also apply to form-based UIs are firstly, the use of forms for abstraction, classification, and standardization, and secondly, the use of placeholders.

In contrast, other characteristics have lost their relevance. Re-use of formulations (as in juridical formulae), flexible scheduling of writing work (as in hand-written blank charters) and reduction of writing work (as in pre-printed forms) are not associated with today's forms or form-based UIs anymore. Today, copying machines, digital printers, and mail-merge functionality of word processors allow to reduce writing efforts as well as re-use and personalize text templates for a large variety of document types.

The historical overview also allowed to clarify the role of forms as interfaces. Related work in HCI (Section 2.2) left unclear if form-based UIs primarily serve as interfaces for interacting with computers and/or as interfaces for communicating with other people. Regarding this question, the historical investigations presented in this section revealed that forms as interfaces for human communication are a rather recent development and that, most importantly, not all form-based UIs share this function. Furthermore, the notion of forms as interfaces for human-computer interaction specifically and exclusively applies to forms on computers (early electronic forms as well as today's form-based UIs). This points at form-based UIs being fundamentally different from historical (paper) forms because UIs are interactive.

The following Chapter 4 builds on the above findings to analyze characteristics of today's form-based UIs and put forth a novel definition.

# 4 Present: A Novel Definition of Form-Based UIs as 'Form' UI Metaphor

**Chapter Summary.** A novel definition of form-based UIs understood as UI metaphor is put forth in this chapter. The definition is based on the extensive review of related work in Section 2.2, as well as on the historical investigations presented in Chapter 3. Our goal in putting forth a novel definition is to provide theory, structure, and vocabulary for designers to analyze and design form-based UIs.

## 4.1 Definition of Form-based UIs

The definiendum "form-based UI" refers as a synonym to digital artifacts that have also been called "electronic forms" in related work, or "web forms" if implemented using web technology, or simply "forms" when their digital nature was implied by the context. We define it as follows.

*Definition:* Form-based UIs are UIs that metaphorically reference forms. More verbosely and explicitly, form-based UIs are user interfaces and thus enable interaction between humans and computers. This is what sets form-based UIs apart from other, e.g., paper-based forms. The characteristic which furthermore distinguishes form-based from other UIs is that form-based UIs metaphorically reference forms, i.e., they employ the 'form' UI metaphor, paraphrased as THE UI IS A FORM.

*Conventional characteristics of form-based UIs:* Various entailments of the 'form' UI metaphor are conventionally fulfilled in form-based UIs. We interpret those characteristics that have uniformly been suggested in related work and that have time-invariantly applied to historical forms and today's form-based UIs as being constitutive and put them forth as further necessary characteristics of form-based UIs, as follows.

The *appearance* of form-based UIs (as well as of forms) is characterized by placeholders, i.e., spaces left empty to be filled out later, arranged in a structured display, possibly and popularly using a grid-like layout with individual labels for each placeholder.

The *structure* of form-based UIs (as well as of forms) is composed of fields. Fields consist of fixed and variable parts, a dichotomy that can also be described in terms of questions and answers, prompts and values, or schema and data. Form-based UIs may additionally be composed of other UI elements (that are not fields), and may be embedded in other UIs (that are not form-based).

One necessary *socio-cultural function* of form-based UIs (as well as of forms in general) is to abstract and categorize human experiences into standardized representations.

### 4.1.1 Explication

The above definition is intensional, i.e., it distinguishes the definiendum (form-based UIs) from a genus (UIs) by means of a criterion (a metaphoric reference to forms). We will explain these concepts in the following.

*User Interfaces:* The genus of UIs implies that form-based UIs are essentially, first, and foremost UIs – and thus distinguished from other, e.g., paper-based, forms that are not UIs. This is in line with related work that has characterized form-based UIs as interfaces for human-computer interaction, compare, e.g., Firmenich et al. [68], Frohlich et al. [70], Nielsen [W25], and Shu et al. [172], and in line with the definition in DIN EN ISO 9241-143 [54], according to which form-based UIs are composed of, inter alia, UI elements. Note that the optional function of form-based UIs as interfaces for communication between humans has been purposely excluded from the definition because not all form-based UIs serve this function.

*Metaphor:* The definition postulates a metaphorical reference to (other, general, historical, paper, etc.) forms as distinguishing criterion. Firstly and most obviously, this implies the relationship between form-based UIs and forms to be one of metaphor. Secondly, it introduces a strong subjective element into the definition – UIs never are metaphoric in and for themselves, but always and necessarily have to be interpreted as such. We will discuss these issues in the following subsections.

*The 'Form' UI Metaphor:* The metaphorical relationship is described as 'form' UI metaphor in the above definition. The metaphor's paraphrase THE UI IS A FORM implies that its tenor is a user interface and its vehicle is a form. We adapt Barr's definition of UI metaphor [19] to more specifically describe the 'form' UI metaphor as follows: The 'form' UI metaphor is a device for explaining the functionality of a UI by asserting its identity to other (e.g., current, historical, paper) forms. The key here is that forms are something already familiar to the user, which provides a base level of comfort and knowledge.

*Forms:* The 'form' UI metaphor's vehicle are forms. Since people interpreting the metaphor may associate different artifacts and experiences with forms, we use the term in a most general, extensive sense, referring to, e.g., historical and present forms, paper and digital artifacts, as well as forms in various domains and applications. Interpretation of the 'form' UI metaphor may consequently include partly self-referencing structures, whereby a user may associate a form-based UI with other, previously encountered form-based UIs.

*Conventional Characteristics of Form-based UIs:* Various characteristics are entailed by the 'form' UI metaphor, only some of which are conventionally fulfilled in form-based UIs. Related definitions of form-based UIs have interpreted various such characteristics to be constitutive for form-based UIs. The historical overview has revealed that a subset of the characteristics has time-invariantly applied to historical forms as well – making it very unlikely for any of these characteristics to change in the near future. The above definition only includes characteristics that have uniformly been suggested in related work and that have been time-invariant for centuries. This ensures a high degree of inter-subjectivity and increases chances that the definition will remain valid for a long time. Note that the existence of such habituated, conventionalized characteristics highlights the fact that the 'form' UI metaphor is not novel anymore. Instead, designers and users alike have become accustomed to one common, habituated, conventionalized interpretation, compare Section 4.4 for a detailed description.

*Form-based Interactions:* Note that form-based interactions, in contrast to characteristics related to appearance, structure, and socio-cultural function, are not necessary characteristics, and therefore have not been included in the above intensional definition. Nonetheless, they provide examples for use in an ostensive definition, i.e., for illustrating the character of form-based UIs through examples. In this sense, typical examples of form-based interactions include viewing and editing of semi-structured data, as well as less commonly noted interactions related to access control, information retrieval, selecting values, validation, reviewing, approving, signing, and submission.

### 4.1.2 Justification

This section justifies the metaphor-relationship between form-based UIs and forms, and thus the definition that form-based UIs employ the ‘form’ UI metaphor. Prior work has also described form-based UIs in terms of UI metaphor. This section additionally examines if other concepts such as identity, similarity, specialization, and analogy could also explain the relationship between form-based UIs and other (e.g., general, historical, paper-based) forms.

Both everyday language and scientific publications suggest an identity relationship by simply referring to all of the above artifacts as forms. The identity relationship is obviously suited for explaining similarities but fails to explain differences – compare Section 3.5 for a summary of similarities and differences between form-based UIs and other forms. A relationship of similarity or analogy, as, e.g., proposed by Gehani [77], is therefore better suited to account for observed similarities and differences.

A more specific nature of similarity has been suggested in related work that postulated a relationship of generalization between form-based UIs and other forms. Generalization understands one concept to be similar to and more general than the other. However, this understanding allows for two partly conflicting views. Firstly, one could assume general forms to have characteristics shared with all specialized sub-categories of forms (e.g., with historical forms, current paper forms, and today’s form-based UIs). Indeed, we have shown that common, time-invariant characteristics do exist, as well as differences between form-based UIs and other forms. But secondly, form-based UIs have also been understood as generalizations of other forms. This view is held, e.g., by Tsichritzis [189] who defined form-based UIs “by making some generalizations on text forms”. In summary, the postulated relationship of generalization leads to difficulties and different understandings regarding which of the related concepts is more general than the other.

In contrast, postulating a metaphor relationship between historical forms and form-based UIs, as previously and rather implicitly suggested by Harms [88], Nielsen [W25], and Weir et al. [195], does not have the above drawbacks. Metaphor affirms identity for non-identical objects without being contradictory, compare Imaz et al. [108] and Lattmann [128]. This fits well with everyday language use of the term “form” for various digital and paper artifacts. A metaphor’s tenor and vehicle can be totally different concepts – therefore form-based UIs and other forms need not (but may) share common characteristics to qualify for a metaphor relationship. Also, the concept of UI metaphor is well-grounded in the discipline of HCI, allowing to analyze the meaning that designers communicate through form-based UIs and that users may consequently understand from the UI.

### 4.1.3 Discriminative Power and Inherent Subjectivity

The above definition of form-based UIs has discriminative power for discerning form-based UIs from other UIs. The notion of metaphor properly accounts for subjectivity inherent to corresponding judgements.

According to the definition put forth above, the distinguishing characteristic of form-based UIs is their use of the ‘form’ UI metaphor. This implies a certain degree of subjectivity regarding the question whether or not a specific UI involves the ‘form’ UI metaphor. This should not be seen as a weakness of our definition because the meaning that a user may understand from a UI (or, more generally, from any sign) is neither fixed nor limited, but always subjective to a certain degree. Thus the concept of UI metaphor that is used in our definition allows to properly account for the subjectivity that is inherent in the interpretation of UIs by users. UI metaphors, like signs in general, “never are metaphors [...] in and for themselves, but they always and necessarily have to be interpreted as such”, compare Lattmann [128].

Despite the subjectivity that is inherent in propositions about the defining characteristics of form-based UIs, the definition allows individuals to make a well-founded decision whether or not a UI involves a metaphoric reference to forms. During interaction, users and researchers alike can judge if metaphorical entailments of the 'form' UI metaphor are fulfilled in a specific UI. This judgment is part of the interpretative process described in more detail in Section 4.3.

The definition provides additional characteristics that allow to discern form-based UIs based on their specific appearance, structure, and socio-cultural function. These characteristics correspond to a habituated, socio-culturally conventionalized understanding of form-based UIs that is commonly shared amongst both designers and users. The characteristics provide rather sharp decision criteria. But they only capture conventional meaning and thus cannot account for fresh use of metaphor that can represent novel thought (Lattmann [128]) and stimulate creative, unforeseen designs (Blackwell [25]) and interpretations thereof (Pirhonen [154]). The conventionalization of the 'form' UI metaphor is discussed in more detail in Section 4.4.

### 4.1.4 Combinations of Form-Based and Other UIs

The definition is not restricted to purely form-based UIs, but also allows to discuss mixed (i.e., only partly form-based) UIs. One popular example is that form-based UIs are often embedded into a website's navigational UI. Furthermore, form-based UIs may contain UI elements that are (per se) not form-based. For example, form-based UIs for booking a flight often include a non-form-based UI element that schematically visualizes the airplane and allows users to pick a seat. Mixed UIs typically involve combinations of multiple metaphors that can be analyzed using concepts from Cognitive Science as large blends, compare Imaz et al. [108]. For example, the UI shown in Figures 4.1 and 4.2 includes multiple metaphoric references to windows, buttons, and forms.

The above definition implies that mixed UIs qualify as "form-based", provided they (or parts thereof) include a metaphorical reference to forms. A user's interpretation of mixed UIs will very likely account for the fact that the metaphoric reference to forms is more prominent in some parts of the UI than in others. Hence users will more strongly expect characteristics of form-based UIs in those parts of the UI where the reference to forms is more evident.

### 4.1.5 Example: Form-based UIs for Editing Calendar Entries

One example of a form-based UI is the design shown in Figures 4.1 and 4.2 for adding calendar entries. Note that very different designs exist for the same purpose. This highlights the fact that form-based UIs are employed as deliberate choice instead of by necessity. For example, the calendar application in the Mac OS X operating system features a single text box where users can enter calendar entries in natural language instead of through a form-based UI.

From a design perspective, a UI is form-based if and only if its designer employed a metaphoric reference to forms. The designer may have been aware at design time of her use of metaphor and she may have explicitly considered which entailments of the 'form' UI metaphor appear suited for communicating her design intent, as shown in Figure 4.1, compare the following section for a more detailed description. Or she may have been unaware of her use of metaphor during design and only recognize later that the chose to metaphorically represent the UI through a form, as evidenced by the UI's form-like appearance, structure, and function.

In the same way, from the perspective of users working with a UI (or researchers inspecting a UI), the UI is form-based if and only if it employs a metaphoric reference to forms. For example, the overall form-like appearance, structure, and function of the UI shown in Figure 4.2 suggest the presence of such a metaphoric reference. Closer examination of UI metaphorical entailments and judgements about whether these entailments are fulfilled in the UI confirm this hypothesis.

## 4.2 Designers' Interpretation of the 'Form' UI Metaphor

The concept of UI metaphor, as encompassed in our definition, allows to analyze how designers create and users interpret form-based UIs. This section describes the design perspective; the following Section 4.3 describes the user perspective.

We primarily based our descriptions on the Semiotic Engineering meta-communication model by Souza [173], the Semiotic model of UI metaphor by Barr et al. [19], as well as on Peircean Semiotics of metaphor described by Lattmann [128]. Note that Cognitive Science theories of UI metaphor, compare Fauconnier et al. [66] and Imaz et al. [108], would yield different descriptions but similar results: Designers interpret an (abstract) UI metaphor when designing a metaphoric UI. Users may recognize the (specific) UI metaphor embedded in the UI. They will consequently interpret the metaphor and derive meaning from and about the UI.

From a designer's perspective (see Figure 4.1), the 'form' UI metaphor is a sign whose representamen is the abstract notion that THE UI IS A FORM. Its object are metaphorical entailments, i.e., all parallelism involved between current / digital / paper / historical forms and current / historical UIs. Its interpretant, i.e., the result of a designer's interpretation, is (besides other arbitrary interpretations) a specific, form-based UI. The process whereby the 'form' UI metaphor – and generally, any metaphor – is consciously or unknowingly interpreted is called Semiosis. According to Lattmann [128], this process consists of abduction, deduction, and induction.

A designer may thus abduct from system requirements and usability goals the hypothesis that the UI can metaphorically be represented by a form, as in THE UI IS A FORM. She will predict the consequences of this hypothesis by deduction of metaphorical entailments, e.g., that "the UI has placeholders to be filled in", or that "the UI is made of paper". This is where her prior knowledge about forms, as well as possibly about historical forms, comes into play. The designer will finally test the metaphorical entailments by induction, i.e., by inspecting the context of the UI and by accounting for other knowledge about forms and UIs, leading to a conclusion about the entailments' and the overall metaphor's suitability for communicating her design intent. The above steps can be repeated in a process of potentially infinite Semiosis, compare Barr et al. [19] and Lattmann [128], wherein the designer interprets the result of her previous interpretation. This is typical for iterative design processes where designers interpret previous sketches in order to evaluate and subsequently refine them. As a final result, the designer's interpretant of the 'form' UI metaphor is the design of a specific, form-based UI.

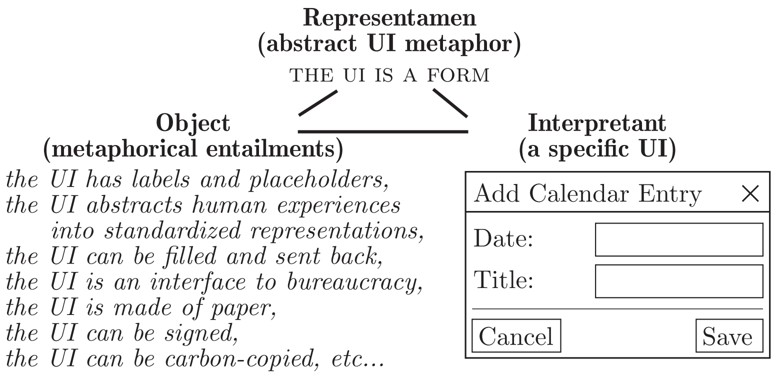



**Figure 4.1:** Designer's interpretation of the (abstract) 'form' UI metaphor, resulting in a specific, form-based UI (for adding calendar entries in the above example).

## 4.3 Users' Interpretation of the 'Form' UI Metaphor

Towards users, a UI acts as a sign through which designers communicate meaning, compare Souza [173]. In other words, the UI acts as the "designer's deputy" for communicating with users at interaction time [173]. Thus from a user's perspective (as well as from the perspective of researchers inspecting a UI), the 'form' UI metaphor is the metaphoric sign THE UI IS A FORM that was embedded by a designer in a form-based UI. As shown in Figure 4.2 based on Barr et al. [19], the sign's representamen is the UI, as perceived by users during interaction. Its object is the meaning that the designer wanted to communicate, i.e., those entailments of the 'form' UI metaphor that the designer chose to fulfill. Its interpretant is any meaning a user may interpret from the form-based UI. The process whereby users interpret the 'form' UI metaphor is structured into abduction, deduction, and induction, as follows.

A user's interpretation of the 'form' UI metaphor can be described based on Lattmann [128] as follows. A user, while interacting with a UI, may abduct the explanative hypothesis that THE UI IS A FORM, i.e., that forms have a representative quality in respect to the UI by some parallelism. The abstract consequences of this hypothesis are then predicted by deduction of UI-metaphorical entailments (e.g., "the UI has placeholders to be filled", but also possibly unfulfilled entailments such as "the UI can be signed") and finally tested by induction (by inspecting the context and by accounting for other knowledge about forms and UIs), so that a verification or falsification of the hypothesis is achieved.The above process of Semiosis can be potentially infinitely continued, e.g., when unexpected UI behavior leads a user to adjust previously understood meaning. The final interpretant depends on context and prior knowledge; it is whatever meaning a user understands from the UI.

Note that although the above interpretative process is inherently subjective, the above description allows to reason and argue if and why a specific UI involves a metaphoric reference to forms and which specific entailments are fulfilled in the UI. Such reasoning and argumentation provides the basis for scientific discussion and allows to establish a high degree of inter-subjectivity.

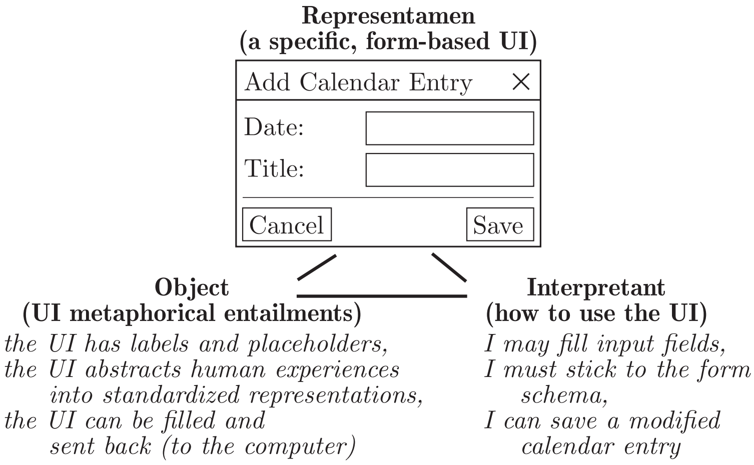



**Figure 4.2:** User's interpretation of the 'form' UI metaphor encountered in a specific, form-based UI, resulting in a specific understanding of how to use the UI, and for what purpose.

## 4.4 Habituation, Conventionalization, and Refinement

The popularity of form-based UIs has habituated users and designers alike to one common, socio-culturally conventionalized interpretation of the 'form' UI metaphor. It can therefore be described using terms from Pirhonen [154] as a 'dead' UI metaphor at the end of its lifecycle. People interpret dead metaphors as conventional symbols or 'idioms' from which they infer previously learned, socio-culturally conventionalized meaning; compare Lattmann [128] and Pirhonen [154]. Regarding form design, Jarrett et al. [112] described the effect as follows, "you know a form when you see it". In other words, habituation has progressed to such a degree that there exist conventional characteristics which allow to easily discern form-based from other UIs. Indeed, we have identified such characteristics and described the conventional appearance, structure, and socio-cultural function of form-based UIs in our definition.

The process of habituation can go along with continuous refinement. For example, Imaz et al. [108, p.50ff] described the refinement of the 'desktop' UI metaphor. In a similar way, the 'form' UI metaphor has also been refined during many decades. As a result, form-based UIs today fulfill many entailments of the 'form' UI metaphor and include additional features that complete the blend between forms and UIs. For example, form-based UIs include a large variety of input fields, primary and secondary buttons, help texts, error and success messages, and input validation, as documented in recent books on form design, compare for example Jarrett et al. [112] and Wroblewski [205].

One benefit of habituation is that metaphors become much easier to understand for both designers and users because their meaning has already been learned in repeated encounters. But according to Pirhonen [154], the power of metaphor for stimulating novel, creative design is lost. The practical consequence for form design is that designers have ceased interpreting the 'form' UI metaphor when designing form-based UIs, but stick with conventional meaning learned from previous interpretations. In the same way, users have ceased interpreting the 'form' UI metaphor when interacting with form-based UIs, but rely on conventional meaning. Unfortunately, the conventional meaning of the 'form' UI metaphor and resulting form-based UI designs have been subject to much criticism, as evidenced by ongoing critique regarding the usability of form-based UIs; compare Section 2.2.1.

## 4.5 Re-Interpretation by Designers

Fresh (re-)interpretations of the ‘form’ UI metaphor by designers allow to break away from conventional meaning and the habituated, much criticized design practice. From a theoretical perspective, this is firmly supported by Semiotic theory where metaphor is seen as representing novel thought, compare Lattmann [128]. Cognitive Science theories of metaphor likewise hold that metaphoric blends produce novel structures, compare Imaz et al. [108]. In a similar way, related work about the application of metaphor in HCI has highlighted the power of metaphor for breaking design rules, as described by Blackwell [25], and for stimulating unforeseen, creative experiences, compare Pirhonen [154]. The above theory suggests that a fresh re-interpretation of the ‘form’ UI metaphor, as presented in Chapter 5, has a potential for stimulating novel, innovative form designs.

## 4.6 Discussion and Outlook

This chapter analyzed the defining characteristics of form-based UIs and provided the following, novel definition. “Form-based UIs are UIs that metaphorically reference forms”. We justified this definition based on related work and on historically time-invariant characteristics. We elaborated the definition using Semiotic theory of UI metaphor. This allowed to discuss interpretations of the ‘form’ UI metaphor by designers and users, as well as the need for fresh re-interpretations.

The following chapter provides one such re-interpretation of the ‘form’ UI metaphor in order to formulate goals for future research in form design.

# 5 Future: Specific Research Directions for Evolving the 'Form' UI Metaphor

**Chapter Summary.** The current habituation of the 'form' UI metaphor (as explained in the previous chapter) means that users and designers alike have settled for one conventional interpretation of the 'form' UI metaphor, i.e., for one common understanding of what is a form-based UI. Ongoing criticism regarding the usability of form-based UIs suggests that this conventional interpretation can and should be improved. Towards this goal, a fresh re-interpretation of the 'form' UI metaphor by designers, as provided in this chapter, can inspire improved designs.

Methodologically, we investigated entailments of the 'form' UI metaphor and considered their suitability for improving form design. The entailments are derived from our historical investigations in Chapter 3, as well as from recent trends in UI design.

As a result, this section presents directions for future innovation in form design, as summarized in Table 5.1. Firstly, some useful characteristics are entailed by the 'form' UI metaphor; these entailments should be fulfilled in form-based UIs. Secondly, some negative entailments are fulfilled in some of today's form-based UIs, but should better be avoided. Thirdly, the metaphoric combination of UIs and forms can be refined and completed.

The directions for future research in form design that are put forth in this chapter may look like tiny steps if viewed on a large time scale. Nonetheless, they provide very specific and realistic directions for the next decade. Further note that some of the research goals described in this section differ in scope and difficulty. Some goals, such as the suggestion to enable permanent drafts, are easy to implement – all the better. It will nevertheless take time to change common design practice and user expectations. Other goals correspond to large fields of research that we could only briefly sketch within the scope of this work. Our list of research goals provides a common frame for these fields of research and emphasizes their importance.

| Forms | Directions for Future Form Design | User Interfaces |
|---|---|---|
| | *a) Fulfilling Positive Metaphorical Entailments:* | |
| Paper forms → | 1. Permanent Drafts | |
| → | 2. Personal Copies | |
| → | 3. ‘Material’ Form Design | |
| Precious charters → | 4. Trustworthiness in Form Design | |
| Seals, stamps, → signatures | 5. Easy Signatures | ← Usable Security |
| Paper-based → Collaboration | 6. Collaborative Filling | ← CSCW |
| Administration → | 7. Automated Form Filling | ← Office Automation |
| | 8. Adaptive Form Design | ← Adaptive UIs |
| | 9. Navigation in Form-based UIs | ← Navigation |
| | 10. Multimodal Form Filling | ← Multimodal UIs |
| | *b) Avoiding Negative Metaphorical Entailments:* | |
| Bueraucracy → | 11. Un-Authoritative Communication, Schema-Free Form Filling | |
| Dullness → | 12. Pleasant Form Filling | ← UX, Gamification |
| | *c) Refining the Blend, Bridging Paper and Digital Forms:* | |
| | 13. Digitally Augmented Paper Forms | ← Augmented Reality |
| | 14. Physically Augmented Form-based UIs | ← Tangible UIs |

**Table 5.1:** Directions for future research in form design were obtained by re-interpreting the ‘form’ UI metaphor. Specifically, form design should seek to (a) fulfill positive metaphorical entailments, (b) avoid negative ones, and (c) further refine and complement the blend between forms and UIs.

## 5.1 Permanent Drafts

Paper forms (as a natural consequence of being made of paper) permanently store partly-filled form contents. One resulting benefit is that form filling can be interrupted and resumed at any time. This benefit is metaphorically entailed by the ‘form’ UI metaphor, but insufficiently fulfilled in current form-based UIs, especially if implemented using web technology. Users of web forms risk losing data should they (intentionally or by accident) navigate away or postpone submission for longer than the session timeout allows. Technical solutions to this problem exist. For example, the jQuery plugins Garlic.js [W14] and Sisyphus.js [W31] continuously save drafted form contents in the webbrowser’s local storage. Future research should analyze the design space and seek to establish best practices. Relevant design questions include how to communicate the availability of permanent drafts to users, whether forms should auto-save or provide explicit save buttons, and whether reset-functionality is needed to clear obsolete form contents.

## 5.2 Personal Copies

The possibility to make personal copies of filled-out forms is a metaphorical entailment of the 'form' UI metaphor that is mostly unfulfilled in modern form design, but that can be beneficial for many users. The historical background to this suggested research direction is that the widespread availability of photocopy machines since the late 20th century enabled people to not only reproduce blank forms, but also copy filled-out forms prior to submission, compare Barnett [18, ch.1]. The latter characteristic was lost in the transition to digital forms – despite the fact that digital information can easily be copied without loss in quality. Current best practices in web form design address the users' need to obtain a copy by recommending confirmation pages after form submission that they can optionally print out, followed by a similar confirmation sent via e-mail, compare Bargas-Avila et al. [16, guideline 20]. Additionally, future form design should investigate possibilities for giving users more control concerning if, when, and how they wish to make a copy, and in which file format. The copy could be useful for a variety of purposes, e.g., for keeping a record and for re-submitting similar content.

## 5.3 Material Form Design

Paper forms have typical characteristics that result from them being written on paper. These physical characteristics are not shared by user interfaces. Nonetheless, recent design has metaphorically explained the functionality of UIs by equipping them with quasi-physical properties, e.g., see Apple's 'inertia' scrolling [W5] and Google's 'material design' guidelines [W18]. Future work could more closely examine how the two metaphors THE UI IS PHYSICAL MATERIAL and THE UI IS A FORM play together and could specifically investigate potential (quasi-)physical properties of form elements. For example, when and why can or should form fields and labels have a thickness, cast shadows, and transform their shapes? Whence should they appear, and whereto disappear? Industrial practice in the rapidly evolving mobile industry will likely need and provide answers to these questions. The concept of UI metaphor can provide means for reflecting and better understanding the corresponding designs.

## 5.4 Trustworthiness in Form Design

Trustworthiness was communicated in historical forms by use of hand-written signatures, official seals, precious materials such vellum, and novel technology that was not easily available at the time (e.g., printing technology for early, pre-printed charters), compare Eisermann [62, 63]. Semiotic theory allows to understand these characteristics as signs of trustworthiness. Game theory furthermore allows to describe how such signs are exchanged between trustor and trustee, as analyzed by Riegelsberger et al. [159]. Since historical forms featured mechanisms for communicating trustworthiness, the same capability is entailed by the 'form' UI metaphor for today's form-based UIs. Hence designers and users of today's form-based UIs should likewise be able to exchange signs of trustworthiness. We will discuss these goals first from a designer's perspective in this section, followed by a discussion from a form filler's perspective in the following section.

Related work has put forth recommendations for designing trustworthy appearances in form design. For example, Jarrett et al. [112, p.20] put forth the following six guidelines. (1) Show that the form is published by a real organization. (2) Make it easy to contact the organization that publishes the form. (3) Ensure that the form has a clear purpose. (4) Make sure that the form looks as if it has been designed by a professional. (5) Keep advertising away from the form. (6) Check that the form works correctly: no defects, no typographical errors. Wroblewski [205, p.183] additionally recommended to display small graphics (badges or banners) whereby a third party asserts the trustworthiness of the site. Such design recommendations are typically short-lived because they can easily be faked by malevolent actors and consequently lose significance, compare Riegelsberger et al. [159] for more about faked signs of trustworthiness. As proposed by Riegelsberger, future research should instead focus on the longer-lived goal of finding ways to foster correct behavior amongst both trustor and trustee. In the area of form design, future research may for example may investigate ways for encouraging truthful answers in online surveys and for detecting and reacting to negative respondent behavior. To provide another example, form design in public administrations software may research ways for stipulating correct behavior amongst officers entrusted with sensitive form data. Specifically, form design could seek to increase the officers' ability (by educating) and motivation (by formulating and encouraging high moral norms), and may additionally design trust-warranting features, e.g., by making it transparent to citizens when and where their form data is accessed.

## 5.5 Easy Signatures

Users of form-based UIs should be able to create and communicate signatures and other signs of trustworthiness to certify the authenticity and integrity of signed form data.

Historically, paper forms have enabled easy, handwritten signatures. They optionally provided advanced security features such as seals, stamps, and watermarked paper. It shall be noted that handwritten signatures do have security problems – e.g., they can be spoofed and do not protect signed data from subsequent manipulation – but they are easy to use and legally binding. The 'form' UI metaphor entails that today's form-based UIs should also support being signed, that signatures should likewise be easy to use, and that it should be possible to employ additional, more advanced security features.

Electronic signatures are a wide area of research and technical solutions to the problem do exist – modern cryptography allows to sign arbitrary data. Nonetheless, signatures are not yet widely used in the context of form-based UIs and corresponding UI patterns have not converged to a common best practice. When developing sign-able forms, a special focus should be placed on usability because security has inherent properties that make it a difficult domain for UI design, see Whitten et al. [199] for a detailed analysis. Requirements for sign-able web forms have been formulated by Honkala et al. [103] and Jøsang et al. [118], describing the important principle of "What You See Is What You Sign", i.e., that users should never (knowingly or unknowingly) sign unseen data, and that those validating a signature should see the same document that the user saw when signing it. Future research should explore the design space of sign-able, form-based UIs and consider the different semantics of signed form contents. E.g., by signing a form, consumers may indicate their willingness to enter a contract, doctors may approve of a collaboratively written therapy concept, citizens may assert that the data they provided is correct, and users of productivity or communication software may wish to prove their authorship.

## 5.6 Collaborative Filling

Historically, paper forms have enabled collaboration between authors and respondents of questionnaires since the 16th century, compare Eisermann [63]. A more recent example of collaborative paper forms are grayed-out areas labelled ‘for office use only’, indicating that another person will fill the area at a different time and place. A third example is the official European Accident Statement form available, e.g., from the CarTravelDocs.com website [W13] that enables “same space, same time” collaboration between the two parties of a car accident. Each party can document their own view of how the accident happened in separate columns with identical form fields. UIs also have a long tradition of supporting collaboration, as evidenced by the CSCW (computer-supported cooperative work) discipline. Nonetheless, recent work has described challenges in collaborative form filling. For example, Harms [88] described form-based UIs in a medical application that did not provide enough awareness about concurrent usage. Gaubatz et al. [75] also described a medical scenario where form-based UIs should be enhanced with fine-grained access control for specifying which roles may view and modify specific form data. Solutions to these problems are not difficult to implement, but one challenge for designers are the many available design options and thus the many design decisions to be made. For example, how to design for different types of collaboration (within or across same/different time, space, and organizations), how to provide awareness of concurrent activities without distracting, how to sync, lock, or merge form data in a way that scales for the intended number of users, and how to visualize versions. Regarding these questions, there exist no clear guidelines or proven best practices. Consequently, designers have to make, evaluate, and reconsider design decisions in multiple iterations, a process which is hindered by the current lack of rapid prototyping tools. Future research should systematically explore the design space for collaborative form filling, create rapid prototyping tools for easy configuration (instead of time-consuming implementation) of the various design options, and seek to identify best practices that are likely to depend on characteristics of users, tasks, and context.

## 5.7 Automated Form Filling

Historically, forms in public administration have enabled efficient and consistent processing of the cases to be administered, compare the description of forms as “conveyor belts of information” by Becker [20]. In a similar way, today’s form-based UIs enable computers to automatically process semi-structured data that conforms to the form schema. This implies that historically and currently, those who receive form data have profited most from consistency and automation, as opposed to those who provide the data and must obey the form schema. Related work has consequently investigated means for automating and easing the work of form fillers. One branch of research has investigated automated form filling with the purpose of retrieving information hidden in the “deep web behind search forms”, compare Kantorski et al. [120] for an overview on recent literature. The corresponding methods for identifying form fields and recognizing their meaning are also relevant for another branch of research that has sought to more directly support end users. Within this direction, Firmenich et al. [68] have proposed a personal information manager located in a side panel of the browser window. Users can drag personal information and previously filled form contents from the side panel unto the fields to be filled. The form filling process is partly automated through semantically annotated fields. Future research should seek to further automate the process. Quantitative comparisons of precision and recall can help compare the underlying algorithms. Widespread adoption, e.g., by browser vendors, may evolve the conventional understanding of form-based UIs away from manual interaction. Instead, people may understand future form filling as semi-automated, computer-assisted matching of personal or other information unto foreign data schemas. Such new conceptions will also require novel UI designs.

## 5.8 Adaptive Form Design

One feature offered by interactive software (and thus entailed by the 'form' UI metaphor) is dynamic adaptation. As a defining characteristic, adaptive systems modify their behavior based on runtime models in order to improve the interaction with the user, compare Malinowski et al. [136]. To implement adaptation of form-based UIs, Harms et al. [92] proposed that runtime models should track user behavior and influence the current state of the UI. Related work has used adaptive form design for various purposes. Frank et al. [69] and Malinowski [135] investigated adaptation to reduce visual clutter and ease data entry. Zimmermann et al. [208] employed adaptation to improve the accessibility of form-based UIs. The author's own works, compare Harms et al. [90, 92], used adaptation to improve navigation in long, form-based UIs. To continue this research, the taxonomy of adaptive UIs provided by Malinowski et al. [136] can inspire many further possibilities for adaptive form design. For example, an application may adapt its visible, form-based UI and/or the underlying functionality by enabling, switching, or re-configuring models of users, tasks, application, and dialogue in order to achieve various goals such as increased ease of use, efficiency, and usability, decreased complexity, possibly for heterogeneous user groups.

## 5.9 Navigation in Long Form-based UIs

Both paper forms and form-based UIs can grow long depending on the amount of data edited through them – Harms et al. [92] provided examples of forms with several hundred fields. Both paper and digital artifacts have developed their own means of supporting navigation. Some paper forms employ multiple pages that can be flipped and that may be numbered; they may also feature sections, headings, tables of content, and thumb indices. E.g., the United States' "Census 2000 Long Form Questionnaire" [W35] used many of these features. Many form-based UIs are likewise designed to enable navigation, a concept which metaphorically likens information seeking in virtual environments to navigation in the physical world, compare Dørum et al. [58] for more about the 'navigation' metaphor. Various design patterns exist for supporting navigation in long form-based UIs, for example scrolling, tabs, menus, and collapsible fieldsets. Future research is needed to compare benefits of the various design options in different scenarios through quantitative evaluations.

## 5.10 Multimodal Form Filling

Multimodal user interfaces respond to user input in more than one modality or communication channel, including for example gesture, gaze, facial expressions, and voice; compare Jaimes et al. [111] for an overview. Form-based UIs can likewise support multimodal interactions. Related work has investigated multi-modal form filling from various perspectives. For example, Sturm et al. [177] analyzed speech-based data entry and error correction in form-based UIs. Niraula et al. [147] investigated automatic dialogue generation from web forms. Honkala et al. [102] proposed a tool for authoring multimodal form filling experiences. Future work in this area should seek in incorporate additional modalities (such as handwriting, gestures, brain-computer interfaces) and ease adoption through solutions that work in any modern web browser.

## 5.11 Un-Authoritative Communication & Schema-Free Form Filling

Forms have a strong association with bureaucratic encounters – they have even been described by Becker [20] as “materialized bureaucracy”. The ‘form’ UI metaphor likens bureaucratic organizations (towards which forms have often served as interfaces) to computer programs (towards which form-based UIs serve as interfaces). As a benefit, this may help explain to users why they must conform to pre-defined abstractions and classifications (as required by bureaucratic organizations and as needed for automated data processing). Nonetheless, designers clearly want to avoid their form-based UIs being associated with bureaucracy.

Related guidelines have addressed the need to avoid bureaucratic communication in form design. For example, Bargas-Avila et al. [16] recommended to let people “provide answers in a format that they are familiar with from common situations” and to allow “answers in any format” if the answer is unambiguous. Attention should also be paid to friendly language: “Error messages should be polite [... and ...] should apologize for the mistake”. Future work can investigate more radical approaches for avoiding authoritative communication. For example, users could be given the freedom to ignore the form schema – while still enabling automated data processing. Related research in this direction includes publications by Meng [140], Tjin-Kam-Jet et al. [185], and Wang et al. [192] about smart, combined, freetext search fields that parse natural language. Another field of application described by Johnson et al. [117], Schnipper et al. [164], and Tange et al. [181] is structured data obtained from spoken or written, natural-language, narrative medical records. Future research can investigate if schema-free form filling through natural language processing, as described in the above papers, is also suited for other, more general usage scenarios.

## 5.12 Pleasant Form Filling

Many people dislike forms and perceive them not as useful means, but rather as barriers for accessing services in various domains; compare Wroblewski [205, p.2]. Future work should therefore investigate ways of making form filling more pleasant and possibly gameful or playful.

Negative form filling experiences are particularly common in online surveys. Corresponding form-based UIs have been criticized for their dullness and for resulting negative user behavior such as random responding, speeding, premature termination, and lack of attention, compare Kaminska et al. [119] and Krosnick [126] for more about the underlying attitude called “satisficing”. Related work has consequently sought ways to make form filling a more pleasant experience and has proposed to apply gamification to online surveys, compare, for example, the works by Cechanowicz et al. [37] and Downes-Le Guin et al. [60] as well as Harms et al. [89, 91, 93]. Proponents of gamification have argued that game elements can be transferred to a large variety of applications – compare the according definition of gamification by Deterding et al. [49] – in order to produce beneficial psychological and behavioral outcomes, as summarized in a recent literature review by Hamari et al. [87]. Nonetheless, the review also showed that outcomes of gamification were not always as desired and strongly depended on the users and the context in which gamification was applied.

Future research should investigate factors that influence the success of gamification in the context of form-based UIs such as, for example, online surveys. Influencing factors include the “level” of gamification, ranging from simple, decoratively visual designs to functionally visual enhancements up to fully gamified designs; see Downes-Le Guin et al. [60] for a comparative evaluation of three such designs. It also remains unclear to date if gameful or playful designs are better suited for online surveys and which specific design elements provide most benefits for specific usergroups in specific contexts. Future work may also investigate if gamification of form-based UIs provides benefits in additional domains besides online surveys.

## 5.13 Digitally Augmented Paper Forms

Future research should seek to further refine and complete the blend between forms and UIs. Related work has provided a corresponding conceptual framework called “blended interaction”, compare Jetter et al. [114]. The framework allows to discuss innovative combinations of individual interactions, social interactions, workflows, and physical environments. One example are hybrid sticky notes that blend characteristics of paper and digital notes. Regarding form design, we argue in line with Jetter’s framework that future form-based UIs should seek to bridge the divide that separates the paper and digital medium in order to combine the respective advantages of paper forms and form-based UIs.

Thus future work could investigate ways for digitally augmenting traditional, paper-based forms. These forms would benefit from the interactive capabilities offered by the software medium. For example, a smartphone app could provide an augmented reality view through the built-in camera, or portable pico projectors could project digital content directly onto a paper form. This would allow designers to provide interactive support, auxiliary information, and multimedia content for the various form fields. Another approach has been put forth by Abdelrahman et al. [1]. As described in their article, paper forms may be digitally enriched by printing interactive UI elements unto paper sheets using electrically conductive ink. Although further refinement of the technology is needed, an evaluation of their prototype showed very promising results.

## 5.14 Physically Augmented Form-based UIs

Future form-based UIs could be enhanced with physical interactions to further refine and complete the blend between forms and UIs. For example, filling a form-based UI on a mobile device is cumbersome. Future work can examine multiple ways for circumventing limitations of the digital medium in general as well as of specific digital devices. One solution is to print a form and quickly fill it by hand. The handwritten form data can then be digitized, e.g., using an approach similar to Philippot et al. [151] where Bayesian networks are used to discern filled-out from empty form fields. An alternative, more innovative approach would allow save paper resources by using pico projectors or wearable data glasses. This would allow to visually augment any blank sheet of paper with the respective form fields. Handwritten content could likewise be digitized back into the original form-based UI. Future work may additionally investigate how physical, tangible interactions and haptic devices may be used in this context to support form filling.

## 5.15 Discussion and Outlook

This chapter put forth fourteen goals for future form design.

Methodologically, the list of research goals was derived from a fresh interpretation of the ‘form’ UI metaphor, i.e., we investigated metaphorical entailments of the ‘form’ UI metaphor that are implied by either properties of modern user interfaces or by characteristics of general and historical forms. We argued that useful metaphorical entailments should be fulfilled in today’s form-based UIs and that negative entailments should rather be avoided. We furthermore proposed to continue the refinement and completion of the metaphoric blend between forms and UIs.

Although the list of fourteen research goals presented above is comprehensive, it cannot be said to be exhaustive. Instead, future research may extend the list of research goals by considering further characteristics of the ‘form’ UI metaphor’s tenor (UIs) and vehicle (forms).

Our main intention in providing the list of research goals is that future research in form design should investigate the proposed goals and thus evolve and improve form-based UIs.

The remainder of this work addresses three of the fourteen research goals. More specifically, this dissertation document presents empirical research on navigation (Chapter 7), collaboration (Chapter 8), and gamification (Chapter 9) in the context of innovative, form-based UIs.

# 6 Discussion and Conclusion regarding the Theoretical Part

The theoretical part of this dissertation set out to provide a large narration spanning the past, present, and future of form design. Indeed, the previous chapters covered characteristics of historical forms (Chapter 3), a novel definition of today's form-based UIs (Chapter 4), and a systematic analysis of goals for future research (Chapter 5). This chapter discusses the contributions from these chapters regarding potential applications in HCI and form design.

## 6.1 Discussion

We initially claimed that recent discussions in HCI reveal uncertainty and confusion regarding the defining nature of form-based UIs. A comprehensive review of related work confirmed this claim and revealed a need for clarification. We showed that the novel definition put forth in this work is able to provide such clarification. The definition states that a metaphoric reference to forms is what distinguishes form-based from other UIs. Other characteristics of form-based UIs, including the dullness and lack of interactivity that have been criticized in related work, have thus been shown to be a contingent design practice that should rather be changed.

Semiotic theory of UI metaphor proved well-suited for elaborating our definition. Specifically, it allowed to describe interpretation of the 'form' UI metaphor by designers and users, the current habituation and conventionalization, as well as the possibility of and need for fresh (re-)interpretations. We additionally related our findings to Cognitive Science theories of UI metaphor. In particular, we explained the interpretation of UI metaphor using concepts of blending and conceptual integration. Nonetheless, we must leave a more detailed investigation of the 'form' UI metaphor from a Cognitive Science perspective for future work.

We carefully dealt with subjectivity inherent in our research topic and consequently chose methods that achieve a high degree of inter-subjectivity. We thus based our definition on a review of related literature and on an investigation of historically time-invariant characteristics. Moreover, the definition itself properly accounts for the subjectivity inherent to interpretations of a user interface – UIs never are metaphoric in and for themselves, but always and necessarily have to be interpreted as such. Despite this inherent subjectivity, our detailed description of the interpretative process allows individuals and groups to plausibly reason, discuss, and decide if a specific UI involves a metaphoric reference to forms and if it therefore qualifies as "form-based" in the sense of our definition.

Future work can empirically challenge or confirm the proposed definition. This can be achieved by investigating if all characteristics put forth in the defintion apply to form-based UIs in various applications and domains. Furthermore, future applications of this work by practitioners in the disciplines of HCI and form design will validate the practical usefulness of this work. We argue based on Latour's understanding of science, as described regarding UI metaphor by Blackwell [25], that precisely such practical applications will determine not only the relevance, but ultimately also the truth of the proposed theory in the context of further scientific discourse.

A first, practical application of the proposed theory was presented in Chapter 5 of this work. We employed our own theory, re-interpreted the ‘form’ UI metaphor by investigating its metaphorical entailments, and, as a result, described fourteen directions for future form design. Within the scope of this work, we could only briefly sketch each direction, but sought to provide references to relevant literature. In summary, we hope that the theoretical contributions of this work provide designers with a deeper understanding and inspire new, innovative form designs. Within this direction, the practical part of this work (compare Chapters 7–9) contributes innovative designs for three of the fourteen proposed research goals. Future research is needed to further evolve the ‘form’ UI metaphor in these and other areas of research.

## 6.2 Conclusion

The theoretical part of this dissertation addressed the current confusion over defining characteristics of form-based UIs and provided a novel, clear definition. It elaborated the definition and thus contributed a detailed, theoretical account, as well as directions for future research in form design.

As a first contribution, we put forth a novel definition of form-based UIs. Methodologically, a review of related work and historical observations have allowed to substantiate and justify the understanding of form-based UIs as UI metaphor. The resulting definition states that “form-based UIs are UIs that metaphorically reference forms”. We elaborated the definition based on Semiotic theory of UI metaphor. This provided structure and vocabulary for discussing the meaning that designers communicate through and users understand from form-based UIs. We furthermore discussed habituation and conventionalization of the ‘form’ UI metaphor and argued that fresh interpretations are needed to break away from the current, much criticized design practice.

As a second contribution, we provided a systematic, comprehensive outlook on fourteen directions for future research in form design. More specifically, we suggested that form design should seek to fulfill positive metaphorical entailments, avoid negative ones, and further refine the metaphoric blend. We hope that the fourteen corresponding directions for future research will inspire designers to evolve their interpretations the ‘form’ UI metaphor when designing form-based UIs – away from the current, socio-culturally conventionalized, often criticized design practice, towards more pleasant, efficient, and interactive form designs.

Part II

# Practical Contributions

**Overview.** The practical part of this dissertation presents contributions in three areas of form design. Specifically, the following chapters address navigation, collaboration, and gamification in the context of form-based user interfaces. Each of these topics has been investigated from a user interface design perspective, aiming to inform designers about available design options, propose and evaluate new design solutions, and support iterative design processes. The resulting contributions are practical steps towards the research goals formulated in the theoretical part of this dissertation. In other words, easy navigation, instant collaboration, and game-like user experiences evolve the 'form' UI metaphor towards a new design practice and more pleasant and efficient user interfaces.

# 7 Navigation: Focus&Context Interactions in Long, Form-based UIs

**Chapter Summary.** Navigation in long form-based UIs commonly employs user interface design patterns such as scrolling, tabs, and menus. These patterns hide contextual form fields outside the viewport or behind other tabs or pages, which may result in a loss of context and disorientation for the user. The work presented in this chapter therefore proposes to apply the Focus&Context (F&C) principle from the information visualization discipline to form design. It contributes a design space analysis, a specific design for a prototype in a case study, and evaluations on desktop and mobile devices.

The space of possible design options for F&C navigation in long, form-based UIs was systematically analyzed to understand the available design options and inspire subsequent designs. Usefulness and applicability of the resulting design space were evaluated in a case study about social network profile page editing. We found the design space has fostered creativity and helped to clearly document design decisions, indicating it can be a valuable support for engineering intelligent, form-based user interfaces. The resulting prototype features collapsible fieldsets that visualize information in varying levels of detail, depending on the user's current focus of interest.

The prototype's novel design was evaluated in two empirical studies, first on desktop and then on mobile devices. This allowed to contribute the following evaluation results. The study on desktop devices revealed no significant differences between any of the designs – a positive aspect of this result is that the novel design worked as well as other, state-of-the-art solutions that were evaluated as control conditions. The study on mobile devices also confirmed collapsible fieldsets to be a viable alternative to existing designs and furthermore showed that scrolling should be avoided on small-screen devices in favor of other, more structured and interactive design patterns that provide a better overview.

## 7.1 Introduction

Forms are widely employed as user interface metaphor for data entry and subsequent editing. Since paper forms have for a long time supported navigation through structured displays (including fields, sections, and titles) as well as through pages and according page indices, the 'form' UI metaphor entails that long form-based UIs should likewise allow for easy navigation.

Note that the length of form-based UIs is understood in this work as a spatial measure relating to how much screen space is occupied. This is in contrast to other possible understandings, including how long it takes to fill the form and measures based on cognitive complexity. Put simply, the long form-based UIs investigated in this work are 'long' because their many fields use a lot of screen space.

**Motivation.** The general motivation for the work presented in this chapter are applications requirements for long form schemas, designer needs for designing well-functioning form-based UIs, and last, not least, user needs for easy navigation.

From an engineering perspective, application requirements for long form schemas can result from the need to allow editing of large sets of data in domains such as business administration, social networking, e-health e-government, and software engineering. Examples of long, form-based UIs in desktop and mobile applications – some of them with more than 300 form fields – are shown in Table 7.1.

Designers of such applications need well-functioning and usable design patterns for navigation. From a design perspective, long form-based UIs are often considered bad design practice – e.g., an empirical study by Wroblewski [205, p.294] and guidelines by Bargas-Avila et al. [16] recommend against long forms and unnecessary questions. But long form-based UIs cannot always be avoided because of the application requirements described above. The design problem is further aggravated by recommendations to avoid multiple columns and to only ask one question per row, compare the guidelines in Bargas-Avila et al. [16] and Jarrett et al. [112, p.164].

From a user perspective, the length of many form-based UIs implies that users need effective solutions for navigation. Existing navigation design patterns (NDPs) are problematic because either the whole form is shown on one page and requires a lot of scrolling, or else the form is split into tabs or pages. Both options hide the majority of contextual form fields (either outside the viewport or in other tabs), which can lead to a loss of context for the user. The underlying 'loss of context' problem has been addressed in other domains using the Focus&Context (F&C) technique from the information visualization discipline, compare Card et al. [35] and Furnas [71]. These works from information visualization suggest that applying F&C techniques to form design has the potential to improve navigation performance and subjective satisfaction amongst users of long, form-based UIs.

**Methodology.** The work presented in this chapter analyzed the design space for how the F&C principle from information visualization can be applied to web form design in order to improve navigation in long form-based UIs. The design space was employed to re-design navigation in a social network profile page editing scenario. The resulting design employs the F&C principle by providing collapsible fieldsets that visualize information in varying levels of detail. The benefits of this novel design were evaluated in two usability tests.

**Summary of Contributions.** The primary contributions described in this chapter consist of the design space and its evaluation regarding usefulness and practical applicability in a case study where navigation was redesigned for a social network profile page scenario, see Figure 7.1 for the design of the resulting prototype. The prototype was evaluated in two empirical studies, allowing to contribute evaluation results on desktop and mobile devices. Parts of these contributions have been published in conference papers by the author of this thesis, see Harms et al. [90, 92].

**Structure of Work.** The remainder of this chapter is structured as follows. The following Section 7.2 discusses related work about navigation in form-based UIs. Section 7.3 presents a design space analysis, i.e., a systematic analysis of options for designing F&C navigation in long, form-based UIs. The subsequent Section 7.4 describes a first application of the design space in a case study on navigation in social network profile pages. The resulting, innovative design employs collapsible fieldsets, allowing to visualize each fieldset in varying levels of detail that depend on the user's current focus of interest. Sections 7.5 and 7.6 contribute empirical evaluations of the novel design on desktop and mobile devices.

| Domain and Exemplary Form-based UI | Number of Fields |
|---|---|
| *Desktop Applications:* | |
| Business Administration: Editing a person in JFire | 35 |
| Social Networking: Profile page in Xing | 66 |
| E-Health: OpenClinica Docetaxel sample study | 143 |
| E-Government: US 1040 tax return form | 246 |
| Software Engineering: Eclipse preferences dialog | > 300 |
| *Mobile Applications:* | |
| Calendars: Adding a calendar entry on Android devices | 28 |
| Contacts: Editing a contact in the iOS address book | 43 |
| Social Networking: Profile Page in Facebook's mobile app | 88 |
| System Preferences: Samsung Galaxy system settings | > 350 |

**Table 7.1:** Examples of long form-based UIs on desktop and mobile devices in various applications and domains. The number of fields was counted as input fields, including available options for each field (e.g., radiobuttons or checkboxes) and excluding headings, labels and buttons. Based on Harms et al. [90, 92].

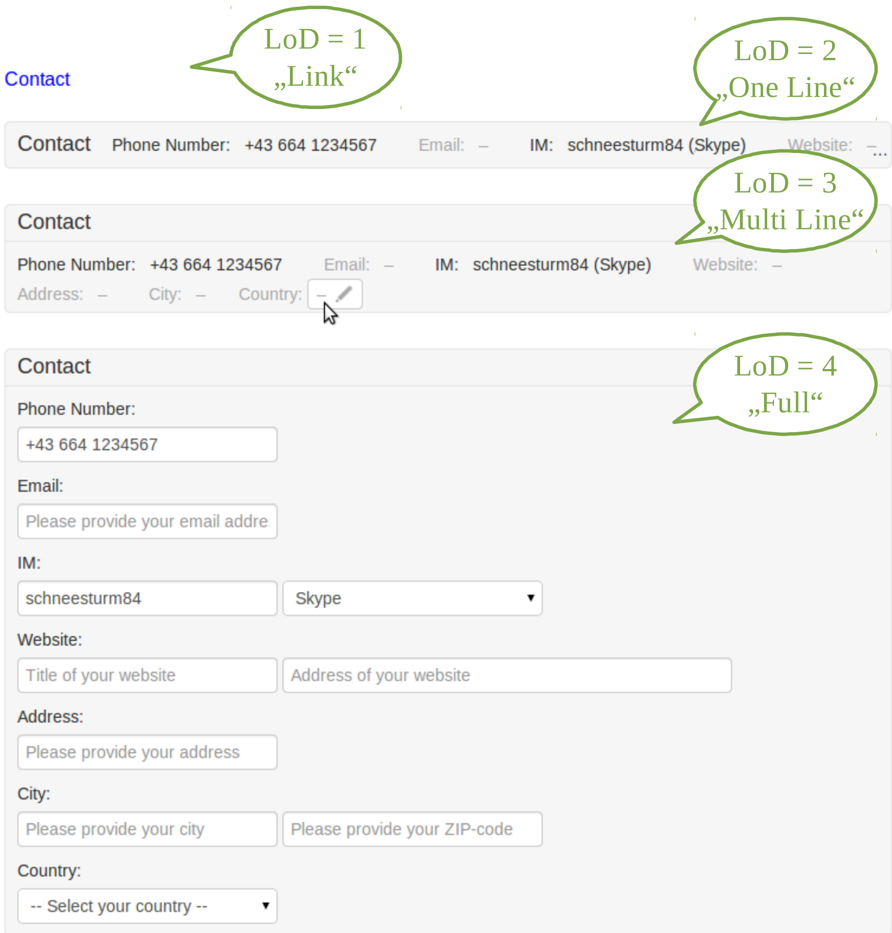



**Figure 7.1:** Collapsible fieldsets designed for the social network profile page editing scenario. The design employs the Focus&Context principle, i.e., the level of detail (LOD) in which parts of the UI are shown depends on the user's current focus of interest. The design features four LODs, including "link" where an entire fieldset is collapsed to a link, "one line" where it is compressed to a single line, "multi line" with a compact layout that may nonetheless occupy multiple lines, and "full" where each field is shown on a separate line. Graphic originally published by Harms et al. [92].

## 7.2 Related Work

This section describes related work from the disciplines of form design, navigation, information visualization, and adaptive UIs. The information visualization discipline is particularly relevant for this work because it has reflected on possible means of visualizing large amounts of data (e.g., as in long, form-based UIs) on limited screen space (e.g., on desktop or mobile devices).

### 7.2.1 Form Design

Best practices for form design are captured in guidelines (e.g., Bargas-Avila et al. [16] and DIN EN ISO 9241-143 [54]) and books (e.g., Jarrett et al. [112] and Wroblewski [205]), compare Section 1.2 for a more comprehensive overview on state-of-the art guidelines and recommendations in form design. One important distinction in form design is the degree to which a user's task involves linear form filling, as opposed to non-linear navigation throughout the form.

Linear navigation is typical for initial form filling, i.e., when users fill a form-based UI with no pre-filled values. This type of scenario with a predictable number of steps or pages can be supported with progress indicators, as suggested, e.g., by Jarrett et al. [112] and Wroblewski [205]. Progress indicators should communicate scope (overview of the overall steps), position (the current page), and status (of the form submission) [205]. Designers may enforce linear navigation by using the 'wizard steps' design pattern [205]. In this pattern, users must click 'previous' or 'next' buttons to navigate. This restriction has the advantage that designers may adapt the form-based UI based on input from previous wizard pages.

Non-linear form filling is typical in the domains shown in Table 7.1, e.g., in business administration and in software preferences. Many scenarios in these domains involve not just initial filling, but also subsequent revision of form data. Users correspondingly navigate freely in a non-linear manner around the various form sections in order to view, revise, and edit form data.

### 7.2.2 Navigation

Navigation is a widely used concept in HCI research that metaphorically likens information seeking in electronic environments to navigation in the physical world, compare Dillon et al. [51] and Dørum et al. [58] for more on this metaphoric understanding of navigation. The cognitive processes involved in human navigation have been detailed by Spence [174] who provided a definition for navigation both in physical and virtual environments. Accordingly, "navigation is defined as the creation and interpretation of an internal (mental) model, and its component activities are browsing, modelling, interpretation and the formulation of browsing strategy". Spence derived several design recommendations from this definition, i.e., to enable browsing, creation of suitable mental models, interpretation of navigational cues, and formulation of browsing strategies through suited user interface design.

An overview of related research about navigation in mobile, wearable, embedded, 3D, and desktop systems has been provided by Vainio [190]. Accordingly, research topics in the 'desktop' category include navigation patterns, searching and browsing, filtering and recommending, multimodal interaction, user-related issues, social navigation, information visualization, usability evaluation, and user interface design. Research topics in the 'mobile' cateogory include navigation techniques, user interface design, (web) browsing, multimodal interaction, and specific contextual or user characteristics.

One branch of navigation research has examined navigation *between* documents. For example, in the context of hypertext environments, compare Chen et al. [39], Dillon et al. [51], and Nielsen

[144] and websites, compare Pilgrim [152] and Weinreich et al. [194]. Another example is when users try to find the right form to fill in an enterprise resource planning system, as investigated by Tomasic et al. [186].

In contrast, research on *within*-document navigation has investigated topics such as reading long documents, e.g., see Alexander et al. [5], Chang et al. [38], Cockburn et al. [42], and Guiard et al. [82]. Other works have investigated navigation in lists, compare Furnas [71], and tree-like structures, see Card et al. [36]. More akin to this work, Couper et al. [46] have investigated navigation in long form-based UIs, more specifically, button placement for navigation in online surveys.

Requirements for efficient navigation have been formulated by Furnas [72] based on a formal, graph-based model. In this model, the nodes of the graph represent views, and edges represent possible transitions. This allowed to formulate the following two requirements for efficient navigation. Firstly, the out-degree of each node must be relatively small because given limited display size, each view can only show a small number of outgoing navigation links. Consequently, navigation is likely to include multiple steps, which leads to the second requirement: the maximum length of all navigation paths should be short to make navigation efficient. Focus&Context techniques fulfill the first requirement by only showing contextually relevant information that users can navigate to, and the second requirement if the contextual information provides shortcuts that abbreviate navigation paths.

Various navigation design patterns (NDPs) exist, allowing users to navigate in applications, websites, and other, long UIs. For example, the patterns described in the two books by Neil [143] and Tidwell [184] include Scrolling, Tabs, Menus, Tables-of-Contents, Breadcrumb Trails, Pages, and Wizard Steps. These patterns can be categorized using concepts from information visualization, as described in the following section.

### 7.2.3 Information Visualization

A taxonomy of information visualization techniques used for navigation design has been put forth by Cockburn et al. [43]. The taxonomy includes Zooming, Overview&Detail (O&D), Focus&Context (F&C), as well as cue-based techniques. The first three techniques are discerned based on how overview and detailed views are combined. Thus Zooming corresponds to a temporal separation of the two views. O&D corresponds to a spatial separation. F&C techniques interweave the detailed (focal) and contextual views in order to minimize the seams. Lastly, cue-based techniques correspond to visual highlighting of specific UI elements.

The above concepts allow to classify existing navigation design patterns (NDPs) as follows. Tabs, Menus, Tables-of-Contents, and Breadcrumb Trails offer a spatially separated overview and detailed view. Zooming (not examined in this work) uses a temporal separation. Scrolling uses a single, static view instead of multiple views. Our novel "Collapsible Fieldsets" design encompasses the F&C principle and seeks to minimize the separation between views by combining overview and detail in a single, dynamic view.

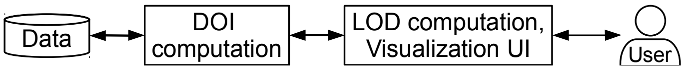



**Figure 7.2:** Architecture of Focus&Context systems, as described by Card et al. [36, Fig.1]. Graphic originally published by Harms et al. [92].

### 7.2.4 The Focus&Context Principle

The Focus&Context (F&C) principle, as formulated in the information visualization discipline by Card et al. [35, p.307], states that users simultaneously need detailed information (at the user's focus of interest) and overview (context). It suggests these two kinds of information to be combined into a single, dynamic display. As described by Furnas [71], this display should dynamically balance global overview and local detail as follows. Specific areas of interest need to be shown in great detail to make interaction feasible while other areas should be compacted to provide an overview of the global context that the user is operating in.

Amongst the above techniques, F&C is particularly relevant for navigation in long form-based UIs because existing navigation patterns hide most of the context either outside the scrolling viewport or behind other tabs or pages. A link between F&C techniques and navigation is also established by Furnas [71]: "Context is not only needed to interpret a static view of an item, providing meaning. It is also critical for moving around effectively".

### 7.2.5 Adaptive UIs

As a defining characteristic, adaptive systems modify their behavior based on models of user attributes and actions in order to improve the interaction with the user, compare Höök et al. [105] and Malinowski et al. [136]. To implement adaptation, software architectures of adaptive systems employ runtime models of the UI to reflect and manipulate the current state of the interactive system, see Blumendorf et al. [26].

The above understanding allows to describe Focus&Context in terms of adaptive systems, as follows. In F&C approaches, as characterized by Card et al. [36], a runtime model computes the users' degree of interest (DOI), which allows to adapt the level of detail (LOD) in which UI elements are shown. The corresponding software architecture of F&C systems is shown in Figure 7.2.

A taxonomy of adaptive UIs has been put forth by Malinowski et al. [136]. The taxonomy allows to classify the present work as shown in Table 7.2. Thus the overall goal of F&C form navigation is to make complex systems usable. To achieve this goal, the manner of presentation of specific form sections is switched upon user initiative, and upon system initiative when the UI is initially displayed.

Related work has used adaptive systems for various purposes. For example, Findlater et al. [67] and Scarr et al. [162] proposed "ephemeral adaptation", a technique for highlighting elements by varying the order in which they initially appear, and evaluated this technique for menu selection tasks. Anderson et al. [7] have adapted UIs not on current, but on predicted, future user behavior, aiming to improve web navigation. Malinowski [135] has employed adaptation to reduce visual clutter in form design.

Adaptive systems have been criticized for introducing additional complexity, in Woods's paper [202] about "the price of flexibility", i.e., about drawbacks of increasingly adaptive, intelligent UIs. It is therefore important to design simple interactions to avoid drawbacks in efficiency and

| Classification criteria | Classification of this work |
|---|---|
| Initiating agents | User, system. |
| Type of adaption | Manner of presentation. |
| UI-Level of adaptation | Visible |
| Scope of adaptation | User behavior, a-priori importance of form elements |
| Goals of adaptation | Make complex systems usable |
| Methods of adaptation | Switching. |
| Strategy of adaptation[1] | During use. |

[1] Strategy refers to the timing of adaptation: pre / post / during use.

**Table 7.2:** Classification of the proposed Focus&Context form navigation as an adaptive UI, based on the taxonomy put forth by Malinowski et al. [136]. Table originally published by Harms et al. [92].

satisfaction. In a similar way, Höök et al. [105] have stressed that evaluations of adaptive systems should not purely evaluate performance and efficiency, but that the users' emotional response and how much they learn from using the system are just as important.

### 7.2.6 Prior Studies on Desktop Devices

Scrolling has been described to be a popular method for within-document navigation by Alexander et al. [5]. But despite its popularity, a long term study on web navigation by Weinreich et al. [194] has described various problems with scrolling in long web pages. Consequently, related work has either suggested to avoid scrolling, or to improve it in various, innovative ways, see, e.g., Atterer et al. [14], Cockburn et al. [42, 44], and Mizoguchi et al. [141].

Tabbed form design has been recommended in linear form filling scenarios, often combined with progress indicators, compare, e.g., Jarrett et al. [112, p.106] and Wroblewski [205, p.70]. But given more scenarios involving non-linear form filling and subsequent revision, Jarrett et al. [112, p.111] gave the conflicting recommendation to rather avoid tabs.

Focus&Context form design, as proposed in this work, is a novel, alternative design. Its collapsing fieldsets allow to dynamically show various parts of the form in different levels of detail to save space and provide a better overview. Related work by Jarrett et al. [112, p.102] has likewise recommended to compact the form layout ("crush the fields onto as few pages as possible") in long forms-based UIs if they are frequently used by trained users.

### 7.2.7 Prior Studies on Mobile Devices

Related evaluations of mobile NDPs (navigation design patthers) have compared various usability measures, including effectiveness and efficiency, errors, simplicity, comprehensibility, learnability, memorability, and user satisfaction; albeit with conflicting results, see Zhang et al. [207] for a literature review.

Scrolling is a popular design pattern for navigation in mobile UIs. But a study by Gutwin et al. [83] revealed bad performance results for Scrolling in long, mobile UIs. Additionally, users clearly disapproved of this navigation pattern.

Tabs are a common way to organize navigation in both desktop and mobile interfaces. They have been suggested for splitting heterogeneous content in Tidwell [184, p.448], but also recommended against due to poor performance in very long form-based UIs by Jarrett et al. [112, p.111] and Tidwell [184, p.357].

Gutwin et al. [83] showed that F&C reduced task completion time when navigating websites on small-screen devices. Nonetheless, in studies by Cockburn et al. [43] and Gutwin et al. [83], the Fisheye distortion that is often – but not necessarily [43] – used in F&C UIs has been shown to decrease targeting performance. Hence related work has recommended to investigate new, non-traditional, possibly non-distorted F&C interaction techniques, e.g., as in Björk et al. [24]. The novel F&C design proposed in this section likewise is a non-distorted implementation of the F&C principle.

Menus and Tables-of-Contents are employed in many mobile apps to provide Overview&Detail (O&D) for the primary navigation. Despite the popularity of these patterns, related research has mostly investigated O&D in a different context, namely navigation in two-dimensional map views. Burigat et al. [31] reported benefits of using O&D on mobile devices. In contrast, Büring et al. [32] emphasized the drawback that an overview window (positioned next or on top of a larger, detailed view) occupies additional screen size. In summary, the above conflicting results indicate a need for further evaluation.

## 7.3 Design Space Analysis of Focus&Context Navigation in Long Form-based UIs

Based on the above findings summarized from related work, we suggest applying the Focus&Context principle to navigation in long form-based UIs. The user's focus of interest determines which part of the form is fully shown; the rest of the form is shown in a more compact, aggregated, read-only way. Since this can be designed in various ways, the method of design space analysis is apt to systematically describe design options and their implications.

Design spaces have been proposed by MacLean et al. [134] as a semi-formal notation of design questions (i.e., key issues to be addressed in a design project), design options (possible answers to design questions), and evaluation criteria (implications of design options, used for choosing between design options). In order to make our proposed design space reusable across multiple projects and domains, this chapter presents questions and options without evaluation criteria, as shown in Table 7.3. Project-specific evaluation criteria and corresponding design decisions are nonetheless discussed in the context of one specific case study in Section 7.4.

The overall structure of the proposed design space can be seen in Table 7.3, consisting of design questions and options for how to compute the user's degree of interest (DOI) and the levels of detail (LOD) with which UI elements are rendered, i.e., for the two essential components of F&C visualization as described by Card et al. [36] and Furnas [71]. Options for DOI computation

**Design Space: Design Questions and Corresponding Design Options**

**DOI: Degree of Interest Computation**
A-priori importance of form elements:
– Manually assigned by form author
– Automatically derived from form schema
Modelling the user's interest:
– Single focal point
(with spatial / structural / semantic distance calculation)
– Multiple foci of interest
– Discrete or continuous distributions of interest
Granularity of DOI computation:
– Per control, field, fieldset, section or page
Timing of DOI computation:
– During use, pre-use, post-use
Influencing factors:
– User characteristics, user behavior, context of use, domain

**LOD: Level of Detail Computation and Visualization**
Influencing factors:
– DOI values and (optionally) total available display space
The number of LODs:
– Multiple, discrete LODs vs. an infinite number of continuous LODs
Techniques for 'making space':
– Semantic approaches: Filtering, aggregation
– Visual approaches: Scaling, distortion, highlighting
– Layout: Block movement, deformation, overlay, outside allocation
Designing LODs by applying the above techniques to:
– Labels, values, form controls
– Hints, validation errors
– Selection fields and corresponding options
– Composite fields, fieldsets, form layout

**Table 7.3:** The proposed design space for Focus&Context form navigation. The above table shows design questions and corresponding design options for the two essential components of Focus&Context visualizations, i.e., continuous computation of the user's degree of interest and corresponding visualization of UI elements in varying levels of detail. Table originally published by Harms et al. [92].

describe possible algorithms for detecting which subset of information is most interesting to a user at any given moment. Options for LOD computation and visualization describe possible UI designs for visualizing form elements in varying levels of detail depending on previously computed DOI values and the available screen space.

### 7.3.1 DOI: Degree-of-Interest Computation

Degree of interest is used to model the instantaneous interest a user is likely to have in various parts of the UI. Furnas [71] described a generalized fisheye formalism to estimate a user's DOI in various features of large information structures based on current user activity, defined as

*DOI of feature = A-priori importance - Distance from focal point,*

where a-priori importance describes the static, intrinsic importance of the features of an information structure, and the focal point describes one specific point of heightened activity.

In form design, *a-priori importance* can be manually assigned by the form author based on the domain-specific importance of form fields. Alternatively, a-priori importance can be derived automatically from a given form schema, e.g., an algorithm may assign higher initial DOI values for fields that were marked as 'required' by the form author. Furthermore, the importance of specific fields may be adapted based on the characteristics of individual users or user groups, such as physical and cognitive abilities, preferences, expectations, and experience, compare Malinowski et al. [136]. E.g., user characteristics based on market segmentation in e-commerce could be used by an algorithm to adapt shopping forms.

Modeling a user's interest in various UI elements as a single *focal point* has been proposed by Card et al. [36] and Furnas [71] as a highly simplified but practical abstraction. In form design, distance from the focal point may be calculated spatially using a metric on the visualization space (e.g., pixel distance in the UI), structurally using a metric on the form schema (e.g., distance measured in number of fields or fieldsets), or semantically based on the domain-specific similarity or co-relevance of specific form sections. Björk et al. [24] also considered multiple, discrete focal points. Even more generally, DOI can be modeled as distribution of interest values over elements of a UI (or elements of the underlying data structure). In form design, DOI can be distributed with different granularity across form elements: per control, field (whereas one field may contain multiple controls), fieldset, section, tab or page.

Different *timings* have been proposed for adapting system behavior, as described in the taxonomy of adaptive systems by Malinowski et al. [136]. During-use adaptation is the most dynamic option, able to adapt the system while in use. This is required for DOI computation in F&C visualizations to adapt the system to the user's fluctuating focus of interest. Pre-use adaptation corresponds to the a-priori importance of features in the above formula for DOI computation. Post-use adaptation relates to adapting the system between usage sessions.

Many *factors* can be exploited to influence DOI computation. Related work in information visualization has mostly included user behavior such as mouse position and movement, mouse click and hover events, and keyboard input. Other input modalities include taps and gestures on touch devices and other means of interaction such as gestures or eye gaze. Form-specific factors that can be exploited for DOI computation include previously entered data (e.g., as in wizards steps), focus and blur events of input fields and fieldsets, validation errors, and unfilled but required fields. In a more advanced approach, Dörk et al. [57] considered the social behavior of multiple users for adaptation. Anderson et al. [7] sought to adapt a user interface based on predicted future user behavior. Malinowski et al. [136] proposed context of use as an additional, influencing factor. For example, form-based UIs may be designed to behave differently depending on mobile vs. stationary usage in private versus public environments.


**Figure 7.3:** Hiding of form controls to reduce visual clutter. Annotated screenshot from Youtube.com [W38] in the year 2014 where a dropdown form element for choosing the user interface language was initially hidden but revealed on mouse over. Graphic originally published by Harms et al. [92].

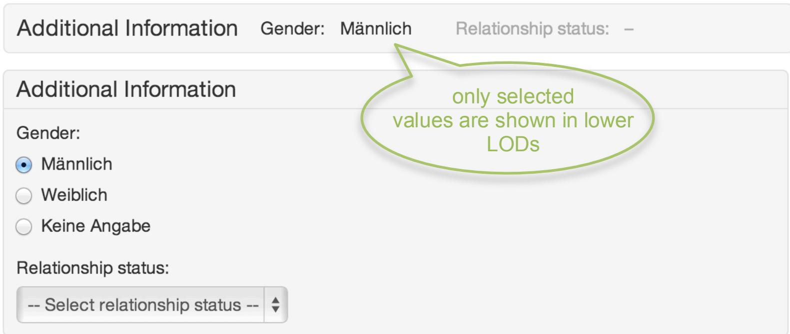



**Figure 7.4:** Hiding of deselected values in lower levels of detail (LODs). The above screenshot shows the same fieldset visualized in a low LOD and then visualized in full detail. As evident from the screenshot, the lower LOD intentionally hides de-selected values in favor of a more compact visualization. Graphic originally published by Harms et al. [92].

### 7.3.2 LOD: Level-of-Detail Computation and Visualization

The visualization component of F&C user interfaces must be able to display UI elements with different levels of detail (LOD). This computation of LOD values is a function of DOI values and available display space. Since DOI values change over time, the visualization component must continually recalculate the below formula, compare [36, 38] and Figure 7.2 for corresponding software architectures.

*LOD of feature = f (DOI of feature, total display space).*

The above formula for LOD calculation shows that in addition to DOI values, the available display space can be used to influence the LOD computation. For example, the visualization component may be designed to “squeeze” the entire UI into one screen, as proposed by Chang et al. [38]. Another possible aim is to fit a printable form on one sheet of paper, as recommended by Jarrett et al. [112, p.102].

Designing for lower LODs immediately raises the question what to omit in order to make space. Previous research in information visualization has explored a large variety of techniques for selective reduction of information based on the DOI formalism. According to Furnas [71], semantic approaches address *what* parts of a structure to display, visual approaches address *how* to display them. “What” corresponds to techniques for filtering and aggregating information. “How” corresponds to techniques for scaling, distorting and highlighting of visual representations. More specific techniques for ‘making space’ within textual documents have been described by Chang et al. [38] as follows. Block movement moves neighboring elements apart to make space. Deformation scales or deforms elements. Overlay allows elements to be rendered on top of others. And outside allocation creates an empty space outside the current view, such as a page margin, and uses it to display additional information.

A varying number of LODs may be used in F&C designs. Multiple, discrete LODs can be designed using filtering, aggregation and highlighting techniques. An infinite number of continuous levels of detail can be designed using distortion and scaling techniques. Note that in traditional form design, the whole form is rendered with just one LOD, but interactive form features such as tooltips and selection-dependent expanding of form sections, as described, e.g., by Wroblewski [205, ch.12], can be likened to additional levels of detail.

The design of form elements should result in a semantically meaningful progression of levels of detail. Many design options exist because all of the before-mentioned visualization techniques (filtering, scaling, highlighting, etc.) can be applied to the various form elements. For example, labels may be omitted for non-empty fields if the field's content is self-explanatory. Values may be truncated to save space, especially for text-areas with potentially long contents (compare LoD 2 and 3 in Figure 7.1). The type of form control may be hidden to reduce visual clutter, as shown in Figure 7.3. Hints and help may be hidden in lower LODs. Validation errors may be compacted in lower LODs, e.g., by only showing a warning icon. Deselected options in selection fields (such as unchosen radio buttons and check boxes) can be hidden, see Figure 7.4. Composite fields and fieldsets may be compacted by filtering the most important information (compare LoD 3 and 4 in Figure 7.1). The form layout may be adjusted to use less space, e.g., by decreasing whitespace, by removing line breaks, and by changing the labels' placement (compare LODs 2-4 in Figure 7.1).

The transition between different LODs should be smooth to avoid confusion. Scaling, distortion, and block movement techniques can be improved using spatial animations to avoid abrupt changes. Filtering and aggregation techniques can be improved by highlighting the focused element so the user does not lose sight of it during a transition. Highlighting may use graphic styles such as color and font weight to differentiate important from less important elements. Alternatively and additionally, highlighting may use the temporal dimension by showing important elements at once, but fading in less important elements with a delay; a method termed "ephemeral adaptation" by Findlater et al. [67].

### 7.3.3 Intended Use of the Design Space

The above design space can be employed as design tool for supporting usability engineering and UI design of navigation in form-based UIs.

Methodologically, the design space is best used in early to medium phases of usability engineering. Within Mayhew's Usability Engineering Lifecycle [139], the design space can be used in levels 1 and 2 for prototyping and UI design activities. Within Jarrett et al.'s form design process [112, ch.6], it can be used in the conversation layer of form design, seeking to "make the form flow easily".

In practice, to use the design space, designers should first define users, tasks, and the intended form schema, as described in Jarrett et al.'s relationship layer of form design [112]. Based on this knowledge, they can draft a concept for DOI computation using options from the DOI section of our design space as inspiration. Design decisions will depend on the specific project, e.g., different information may be available to influence DOI computation. Designers can then proceed to the more visual design of the different levels of detail, inspired by options in the LOD section of our design space. These activities can and should be iterated using prototyping and formative usability evaluations.

## 7.4 Case Study about Navigation in Social Network Profile Pages

To evaluate the design space's practical usefulness and applicability, it was employed in a case study on social network profile pages. This section describes the resulting design that employs the Focus&Context principle by use of collapsible fieldsets.

**Scenario: Social Network Profile Pages.** The social network profile page editing scenario comprises both initial filling and subsequent revising – it is in this respect similar to form-based UIs of productivity applications and different from, e.g., registration forms and questionnaires.

Task characteristics in the scenario can furthermore be characterized as follows. Form filling is sparse (i.e., irrelevant fields are left empty), navigation is non-linear and to some degree explorative, and thus not strictly goal-directed, compare Guiard et al. [82] for more on goal directedness.

In addition to popular use on desktop devices, many social networks allow users to edit their profile using a mobile app installed on their smartphone. These mobile profile pages, like their web-based desktop variants, employ long form-based user interfaces (e.g., Facebook's profile page with 88 form fields, LinkedIn's with 43 fields) to help users provide details about themselves.

In contrast to other domains, no special knowledge is required to answer the questions in a social network profile page. This makes the scenario suited for evaluating navigation performance without interference of the test users' varying domain-specific knowledge.

**Application of the Design Space within the Case Study.** Two designers (the author of this thesis with more than 5 years in UI design, as well as one student in HCI) employed the design space in order to redesign navigation in a social network profile page prototype. The prototype was designed to feature similar fields as in popular social networks (Facebook and Xing). It consisted of 75 form controls arranged in 27 fields and 6 fieldsets. The designers performed three iterations joined by two formative usability tests. Their design decisions are documented in the following paragraphs. The resulting visual design is shown in Figure 7.1.

**Resulting Navigation Design.** The resulting design is a novel application of the Focus&Context principle in the area of form design. More specifically, the design employs collapsible fieldsets that visualize data in varying levels of detail, depending on the user's current degree of interest.

Regarding DOI (degree of interest) computation, a constant a-priori importance was applied to all form elements. User interest was modeled using per-fieldset granularity and a single focal point, with linearly decreasing DOI values for neighboring fieldsets. DOI values are computed during use, based on focussing of form fields by clicking or tabbing.

LOD (level of detail) computation is performed by the prototype whenever a DOI value changes. The corresponding algorithm is similar to Chang et al. [38] in that it takes the available screen space into account. Thus the algorithm first assigns the maximum LOD to the focussed fieldset. It then tries to fit the remaining fieldsets into the available screen space and otherwise resorts to scrolling. Four levels of detail were designed as shown in Figure 7.1, using the visualization techniques of filtering, aggregation, highlighting, block movement, and overlay. Specifically, lower LODs use a more compact form layout, omit empty fields, truncate long textual values, omit non-chosen radio buttons and check boxes, and reduce visual clutter by hiding the type of form control (but reveal it on mouse over). The lowest LODs go even further, truncating an entire fieldset's representation to one line or even a single word. Switching between LODs is eased using animations and graphical highlighting.

**Lessons Learned from Using the Design Space.** The two designers summarized their experience in using the design space for the social networking case study as follows.

*Applicability and Usefulness:* The designers reported a mostly positive experience with the design space, stating they had successfully applied the design space and benefited from using it. They criticized they had not been able to choose some design options because of the generic nature of the prototype to be re-designed (e.g., specific user profiles would have opened additional options) – we conclude that the prototype's purposely generic nature was a trade-off in study design between realism and generalizability. The designers had very positive opinions on the general applicability of the F&C principle to form design, based on their experiences in the case study.

*Creativity*: The designers reported their biggest benefit while using the design space was that it fostered creativity by providing a list of design options, thus enabling them to discuss options they would otherwise not have considered. The amount of options was initially overwhelming, but later appreciated for inspiration. Additional options suggested by the designers were later added to the design space.

*Decision making*: The designers found the design space supported their making of design decisions. Its textual description particularly provided helpful details and explanations.

*Documenting design decisions*: The designers found the design space's structure (particularly its tabular representation) has helped documenting design decisions in a structured way.

**Conclusion and Outlook.** The above sections introduced a novel, generic design space for Focus&Context (F&C) navigation in long, form-based UIs. The structure of the design space reflects two important considerations that were elicited from literature. Firstly, the user's degree of interest (DOI) in specific UI elements can be continually computed based on various factors. Secondly, this information can be used for a subsequent visualization of form elements in varying levels of detail (LODs). For each of these considerations, the design space provides a systematic and comprehensive list of design options.

Qualitative results from an initial application of the design space within a case study on long form-based UIs in social network profile pages strongly support the applicability and usefulness of the design space. Firstly, the design space's applicability and the general feasibility of F&C form designs can clearly be seen from the prototype that resulted from the case study (compare Figure 7.1). Even novice users could easily work with the prototype with similar performance as in tabbed and scrolled designs, as evaluated in a preliminary usability test. Secondly, the designers' experience within the case study strongly supports both the applicability and usefulness of the design space: they found it fostered creativity and helped making and documenting design decisions.

The following sections describe evaluation results on desktop and mobile devices.

## 7.5 Evaluation on Desktop Devices

A comparative usability test of three prototypes designed for the case study, using scrolled, tabbed, and Focus&Context designs respectively, was performed with 30 participants in a between-subject test design.

### 7.5.1 Research Question

The primary goal of this evaluation was to investigate potential improvements or drawbacks in navigation performance and subjective satisfaction in order to check if F&C form design can safely be used without regrets concerning these two crucial measures. This is a relevant research question because flexible and dynamic user interfaces have in the past introduced additional complexity and burdens for the users in certain circumstances, see Woods [202] for a corresponding discussion. Note that other potential benefits and drawbacks, e.g., the benefit described by Furnas [71] that additional, contextual information improves the users's understanding, were not evaluated within the scope of this study, but a later evaluation on mobile devices (see Section 7.6) included such additional measures.

### 7.5.2 Study Design

Participants were randomly assigned to one of three test conditions, each featuring a different navigation design (Scrolling, Tabs, and Focus&Context). This between subject design was chosen to avoid the influence of learning effects.

The scrolled and tabbed designs that were used as control conditions are reasonable choices because these designs are popular in the 'social network profile page' scenario and generally in form design. Furthermore, F&C exploits an untapped potential of varying, fine-grained LODs absent in scrolling and tabs. In scrolled designs, all UI elements are displayed with one constant LOD and arranged linearly on the page; overview is only provided by the scrollbar's indication of overall size and current position. In tabbed designs, the active tab is shown in full detail but the contents of all other tabs are fully hidden; cursory overview is provided by the tabs but the overall size of the form is obscured. Other tabbed or paged designs (e.g., wizard steps) were not evaluated because they are similar to tabbed designs in that only one active tab or page is fully shown using a single LOD, whereas the contents of all other tabs or pages are hidden. In contrast to the above designs, F&C UIs typically use multiple, finer grained LODs, disperse LOD values more moderately, and thus provide an overview of the form's structure, size and content.

Note that scrolled, tabbed, and F&C designs could also be combined in future work. For example, the contents of each tab could employ the F&C principle to dynamically adapt the level of detail in reaction to the user's fluctuating focus of interest. But the study design chosen for this work compares the dynamic, adaptive, interactive nature of novel F&C form design to the rather static nature of the more established scrolled and tabbed designs and therefore does not evaluate such combinations of multiple design patterns.

**Prototypes and Test Materials.** In addition to the F&C prototype depicted in Figure 7.5, scrolled and tabbed prototypes were implemented to serve as control conditions, as shown in Figure 7.6. The prototypes were implemented using HTML and JavaScript, using the AngularJS [W3] framework for the form's interactive features. All prototypes share the same form schema (a social network profile page with 75 form controls arranged in 27 fields and 6 fieldsets), and the same visual design using the default appearance of the popular Bootstrap [W10] framework, but different navigation

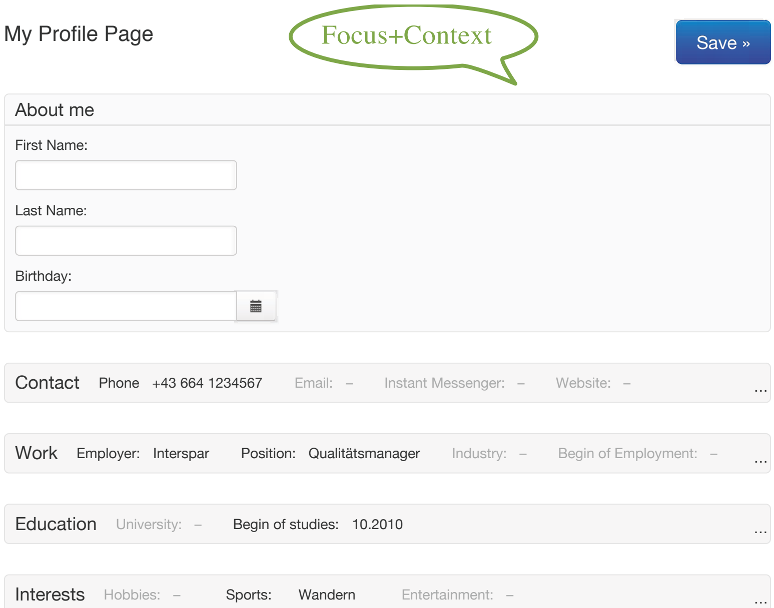



**Figure 7.5:** The proposed Focus&Context form design fitted the most form fields into the viewport by displaying contextual fields with a lower level of detail. Screenshot from the study originally published by Harms et al. [92].

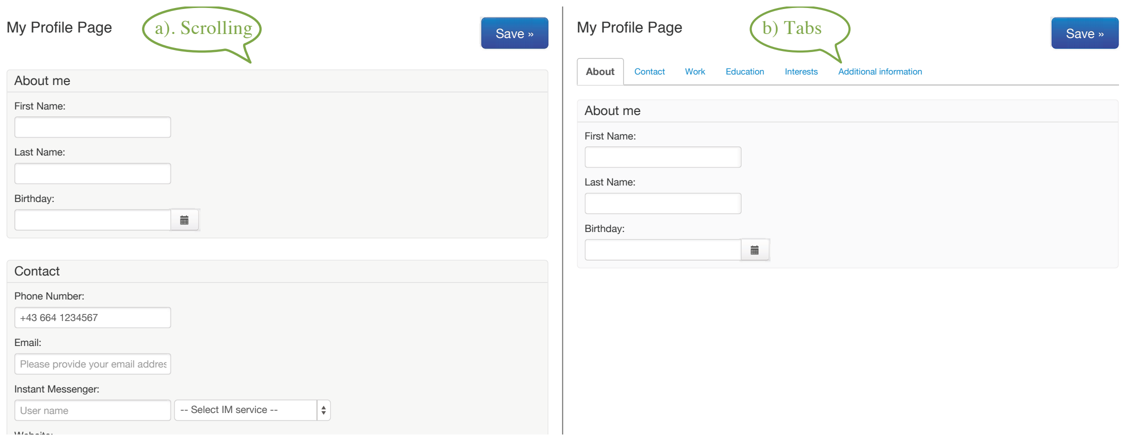



**Figure 7.6:** The two navigation designs used as control conditions. In the scrolled design (a), contextual form fields are cut off by the viewport. In the tabbed design (b), contextual form fields are hidden behind other tabs and the available space is not always used efficiently. Screenshot from the study originally published by Harms et al. [92].

designs. The scrolled prototype shows the entire form on one long page, about five times the available screen height. The tabbed prototype is split into six tabs based on the form's semantic structure, each tab's contents being small enough to avoid scrolling. The F&C prototype features collapsible fieldsets that visualize information in varying levels of detail, depending on the user's current focus of interest.

**Participants.** We clearly state user and task characteristics chosen for the evaluation because these factors have been shown to strongly influence the usability and navigation efficiency in hypertext systems, compare, for example Chen et al. [39] and Nielsen [144].

Amongst the 30 volunteer participants were 10 females and 20 males, aged between 13 and 62 years (M=31.27, SD=14.03). The users all shared a western cultural background and displayed no special mental or physical disabilities. Participants were chosen to have moderate to high experience with computers and online form filling. Computer experience was also included in a post-test questionnaire to allow checking for bias.

**Tasks and Procedure.** Usability tests were performed in a stationary home/office context. At the beginning of each test session, the test observer started the video recordings and opened the prototype in a maximized web browser window. All tests were conducted on 13" laptops with a screen size of 1280x800 pixels using the built-in touchpad and keyboard as input devices.

Participants were given a task sheet with a total number of 10 tasks. The test tasks consisted of filling and revising the form-based UI of a fictitious social network profile page; the task assignment was the same for all users and variants of the prototype. The tasks were selected to represent typical goals when editing a user profile and included filling, editing, and deleting of form values. E.g., tasks included "enter the following instant messenger address: schneesturm84 (skype)", and "delete the phone number from your profile". To allow comparison of navigation performance, the tasks had to be completed in the order specified on the task sheet, requiring users to visit all form sections.

All users could successfully complete the assigned tasks without major interference by the test observer. Upon completion, users were asked to fill a post-test questionnaire.

**Measures.** We primarily investigated navigation performance and user satisfaction as dependent variables because these are crucial measures for assessing new interface styles and interaction techniques.

Navigation performance was evaluated using time-based measures through an analysis of video-recorded test sessions. The recordings included the screen contents, mouse movements and clicks, keyboard activities, as well as audio and video of the participants. Recordings were analyzed by classifying the overall time for task completion into three categories: navigation time between the tasks, data entry time, and time needed to read and understand the task sheet.

User satisfaction was measured in a post-test questionnaire, using the German translation by Rummel [W29] of the System Usability Scale (SUS) that was originally developed by Brooke [28].

Qualitative observations were additionally made by taking notes on a logging sheet. These included navigation errors (as opposed to data entry errors or other types of errors) and utterances indicating a user's personal satisfaction or dissatisfaction.

### 7.5.3 Results

Analysis of performance (measured as time spent navigating) and user satisfaction (SUS score) revealed no significant effect of the variant of prototype, indicating that all three navigation designs performed equally well in the social network profile page scenario.

**Navigation Performance.** We calculated mean and median time for both total task completion time and navigation time per task for each different form design, as shown in Table 7.4 and Figures 7.7 and 7.8. Regarding overall task completion time, participants were fastest using our F&C design (M=5:27, SD=1:55), followed by the scrolled (M=5:37, SD=1:22) and tabbed (M=6:01, SD=2:31) designs. In line with these results, participants spent the least amount of time on navigation using our F&C design (M=1:31, SD=0:30), followed by the scrolled (M=1:37, SD=0:39) and tabbed (M=1:41, SD=0:50) designs.

| | | Scrolling | Tabs | F+C |
|---|---|---|---|---|
| **Total time** | M | 05:37 | 06:01 | 05:27 |
| | SD | 01:22 | 02:31 | 01:55 |
| | MD | 05:39 | 05:08 | 04:57 |
| **Navigation** | M | 01:37 | 01:41 | 01:31 |
| | SD | 00:39 | 00:50 | 00:30 |
| | MD | 01:44 | 01:18 | 01:25 |
| **Data entry** | M | 02:31 | 02:32 | 02:27 |
| | SD | 00:49 | 01:09 | 00:55 |
| | MD | 02:14 | 02:15 | 02:10 |
| **Task comprehension** | M | 01:28 | 01:47 | 01:31 |
| | SD | 00:17 | 00:51 | 00:43 |
| | MD | 01:28 | 01:22 | 01:26 |

**Table 7.4:** Time measurements. On average, users were fastest using the Focus&Context variant, but this observed difference proved to be statistically insignificant. Data originally published by Harms et al. [92].

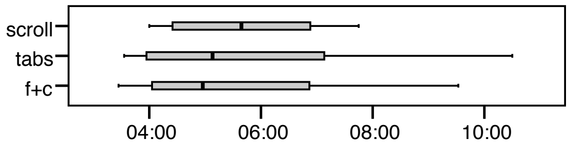



**Figure 7.7:** Boxplot: Total time for task completion in each test condition. Data originally published by Harms et al. [92].

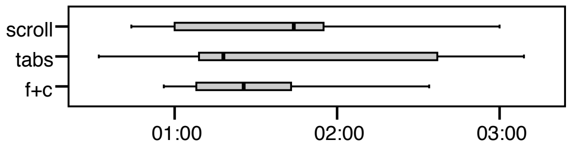



**Figure 7.8:** Boxplot: Navigation time in each test condition. Data originally published by Harms et al. [92].

Data satisfied the requirements (normality of residuals, absence of outliers, homogeneity of variances) for testing the significance of observed differences using one-way ANOVA. Contrary to our expectations, the ANOVA revealed no significant effect of form design on either task completion time or navigation time: $F(2, 27) = 0.213$, $p<0.809$ for total time and $F(2, 27) = 0.144$, $p<0.867$ for navigation time. A covariate analysis (ANCOVA) was able to explain some of the variance in navigation performance by age, gender, and computer experience, but not enough to make the effect of the variant of prototype significant.

**Subjective Satisfaction.** Subjective satisfaction results are shown in Figure 7.9 and Table 7.5. On the system usability scale (ranging from 0 to 100, the higher the better), the scrolled condition scored best (M=88.00, SD=6.65), followed by F&C (M=79.25, SD=17.00) and then tabs (M=76.00, SD=15.47), in this order. We used the Kruskal-Wallis H test to investigate the significance of these differences. The test failed to reject the null hypothesis at p=0.116, indicating that there was no significant effect of the variant of prototype on the SUS measures for subjective satisfaction.

**Covariates.** User characteristics were found to each have a strong influence on navigation performance, see Figures 7.10 and 7.11. We quantified the statistical significance of these findings using

| **SUS (System Usability Scale) Scores** | **Scrolling** | **Tabs** | **F+C** |
|---|---|---|---|
| Overall SUS Score | 88.00 (6.65) | 76.00 (15.47) | 79.25 (17.00) |
| I think that I would like to use this system frequently. | 3.60 (1.27) | 3.10 (0.99) | 3.70 (0.95) |
| I found the system unnecessarily complex. | 1.40 (0.70) | 1.90 (0.74) | 1.80 (0.42) |
| I thought the system was easy to use. | 4.70 (0.48) | 4.40 (0.70) | 4.00 (1.05) |
| I think that I would need the support of a technical person to be able to use this system. | 1.00 (0.00) | 1.40 (0.97) | 1.00 (0.00) |
| I found the various functions in this system were well integrated. | 4.20 (0.92) | 3.70 (0.95) | 3.70 (1.06) |
| I thought there was too much inconsistency in this system. | 1.60 (0.84) | 2.30 (1.16) | 1.80 (1.03) |
| I would imagine that most people would learn to use this system very quickly. | 4.50 (0.71) | 4.50 (0.71) | 4.10 (1.45) |
| I found the system very cumbersome to use. | 1.30 (0.95) | 2.10 (1.37) | 1.80 (0.92) |
| I felt very confident using the system. | 4.50 (0.53) | 3.70 (1.42) | 3.90 (1.20) |
| I needed to learn a lot of things before I could get going with this system. | 1.00 (0.00) | 1.30 (0.48) | 1.30 (0.48) |

**Table 7.5:** SUS scores for each test condition, shown as M (SD), i.e., means and standard deviations. Higher values indicate stronger agreement with the statement. Data originally published by Harms et al. [92].

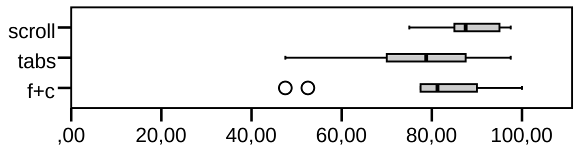



**Figure 7.9:** Boxplot: Overall SUS (System Usability Scale) scores of the three test conditions. The scale goes from 0-100, the more the better. Data originally published by Harms et al. [92].

ANOVA. Average navigation time increased with age, $F(5, 24) = 8.599$, $p<0.0005$, and decreased with computer experience, $F(3, 26) = 5.223$, $p=0.006$. Subjective satisfaction generally decreased with age, $F(2, 28) = 4.144$, $p=0.027$, but was not influenced by other factors.

**Qualitative Observations.** On a qualitative level, we observed no difficulties or objections to either one of the three variants of the prototype. Specifically, the F&C prototype did not introduce additional complexity since users intuitively and naturally worked with its interactive features – not a single user required help or explanations.

### 7.5.4 Discussion

This section discusses evaluation results from the above study in the light of related work and with regard to the aim of investigating navigation performance and user satisfaction of the novel Focus&Context (F&C) form design. The evaluation compared scrolled, tabbed, and F&C form designs in a usability test with a total of N=30 participants. Unfortunately, the absence of significant differences does not help to clear conflicting recommendations given in related literature.

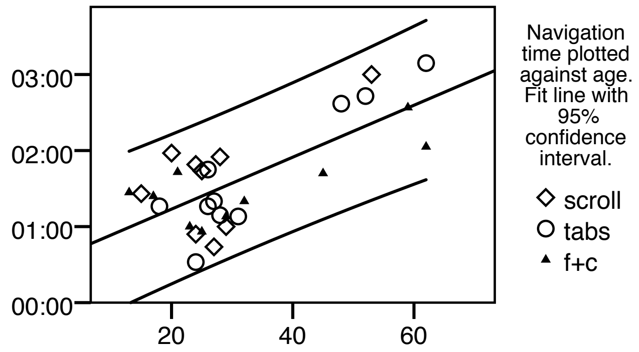



**Figure 7.10:** Covariates: The influence of age on navigation time. Older users took longer to navigate. Graphic originally published by Harms et al. [92].

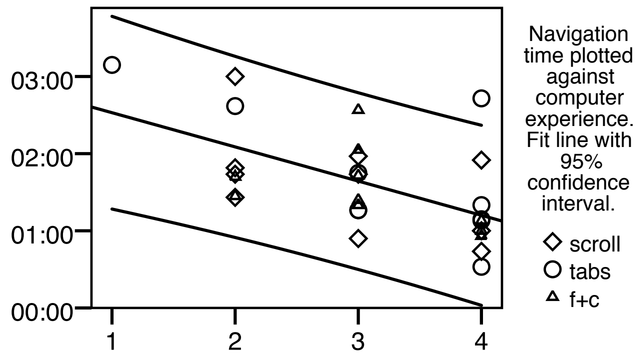



**Figure 7.11:** Covariates: The influence of computer experience on navigation time. More experienced users took less time to navigate. Graphic originally published by Harms et al. [92].

*Navigation performance:* Statistical analysis revealed no significant difference between navigation times measured in the F&C design versus the tabbed and scrolled control conditions. More surprisingly, there was no significant effect of form design on any one of our performance measurements. This suggests the three design variants to be equally suited for the profile page scenario.

*Subjective satisfaction:* Results show no clear user preference regarding the scrolled vs. tabbed vs. F&C prototypes. Quantitative satisfaction measures resulting from the post-test SUS (system usability scale) questionnaire showed no significant differences. This may be due to observed user problems in answering the rather unspecific SUS questions, but qualitative observations also revealed no clear preference.

*Influence of user and task characteristics:* Results showed a strong influence of the covariates age and computer experience on navigation performance. This circumstance is not unusual, compare related studies on hypertext navigation by Chen et al. [39] and Nielsen [144]. The influence of user and task characteristics limits the applicability of our results to scenarios with similar users and tasks and makes a one-size-fits-all solution unlikely to exist. Instead, form design decisions must be empirically grounded in the intended domain, users, and tasks.

*UI complexity:* We cannot confirm the drawback of additional complexity in our adaptive F&C design, as reported and criticized in related studies by Höök et al. [105] and Woods [202]. Quantitative results indicate same or similar performance and satisfaction and qualitative observations revealed that users could work with the F&C prototype intuitively and without any need for help or instructions.

### 7.5.5 Conclusion and Outlook

Three prototypes using scrolled, tabbed, and Focus&Context (F&C) designs were evaluated in a usability test with 30 participants. Results indicate that the novel F&C form design implied no drawbacks in usability. Even novice users worked with similar performance and satisfaction without needing any help or assistance. This confirms the new design to be a viable alternative. Nonetheless, the study did not produce the hoped-for improvements in performance and satisfaction. Future work is needed to further evaluate the F&C design on different devices and to develop measures that better capture the ability of Focus&Context UIs to provide a good overview.

## 7.6 Evaluation on Mobile Devices

Mobile applications provide increasingly complex functionality through form-based user interfaces, which requires effective solutions for navigation on small-screen devices. This section presents a comparative usability evaluation, originally published in Harms et al. [90], of four navigation design patterns: Scrolling, Tabs, Menus, and Collapsible Fieldsets. These patterns were evaluated in a case study on social network profile pages. Results show that memorability, usability, overview, and subjective preference were worse in Scrolling than in the other patterns. This indicates that designers of form-based user interfaces on small-screen devices should not rely on Scrolling to support navigation, but use other design patterns instead.

### 7.6.1 Introduction

Long forms cannot always be avoided – given the fact that increasingly complex functionality is offered on smartphones, this observation also holds for form-based UIs on mobile devices that are typically equipped with small screens only. Examples of mobile apps with long form-based UIs include adding a calendar entry on Android devices (28 form fields), editing a contact in the iOS address book (43 form fields), Facebook's mobile profile page (11 collapsible fieldsets for 88 form fields), and the Samsung Galaxy system settings (4 tabs for about 380 form fields). The length of these UIs clearly indicates a need for effective navigation.

### 7.6.2 Study Design

The evaluation presented in this section aimed to compare different navigation design patterns (NDPs) on mobile devices.

In comparison to the desktop evaluation presented in the previous Section 7.5, this study additionally evaluated Menus because they are a popular design pattern for providing a primary navigation in mobile apps. In summary, the following four NDPs served as test conditions: Scrolling, Tabs, Menu, and Collapsible Fieldsets (i.e., our novel design). The corresponding prototypes are shown in Figure 7.12a-d.

The study used a mixed within/between subject study design, as described in the following. Participants started working with one randomly assigned NDP. A subsequent first questionnaire assessed memorability (between-subject test design). They then performed three more test runs with the remaining three NDPs. The order in which NDPs were assigned was randomized to level out learning effects. This provided measures regarding efficiency and errors (within-subject test design). Lastly, participants ranked and qualitatively described the NDPs in a second post-test questionnaire and in a short, semi-structured interview (between-subject).

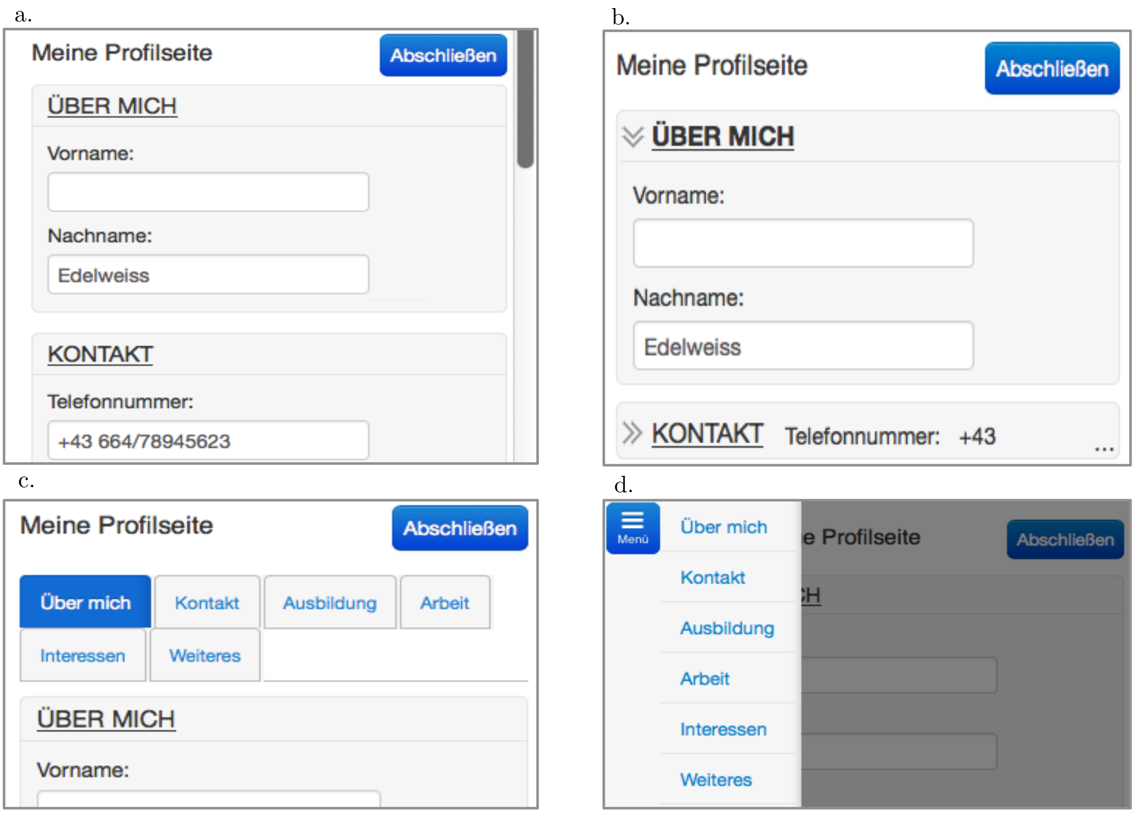



**Figure 7.12:** Screenshots of the four navigation design patterns (NDPs) that were evaluated on mobile devices: Scrolling (a) was used as control condition; it showed the entire form in a single, static view. Collapsible Fieldsets (b) were designed our novel Focus&Context design. They combined detailed information at the user's focus of interest with a contextual overview. Tabs (c) and Menus (d) also provided an overview of the form schema but showed details (for the selected tab or menu entry) in a spatially separated view. Graphic originally published by Harms et al. [90].

All tests took place in a home/office usage context. Users were allowed to sit or stand and used their own smartphones to access a website running the profile page. The tasks required entry, retrieval, editing, and deletion of fictitious form data. Screen recordings and log files supported further analysis.

This study design allowed to take measures regarding efficiency, errors, memorability, perceived usability, and subjective rankings of difficulty, overview, and preference.

| *Time needed for:* | *Navigation* | *Data Entry* | *Task comprehension* |
|---|---|---|---|
| Scrolling | 00:59.37 ± 00:18.56 | 01:25.63 ± 00:38.03 | 00:41.79 ± 00:15.28 |
| Tabs | 00:53.74 ± 00:30.14 | 01:18.93 ± 00:25.27 | 00:49.26 ± 00:17.77 |
| Menu | 01:05.50 ± 00:27.80 | 01:22.92 ± 00:32.79 | 00:45.04 ± 00:15.39 |
| Collapsible Fieldsets | 00:59.15 ± 00:25.00 | 01:18.40 ± 00:20.62 | 00:41.05 ± 00:13.23 |
| H-Value, p-Value | H(3)=4.967, p=0.170 | H(3)=0.83, p=0.994 | H(3)=3.144, p=0.377 |

**Table 7.6:** Efficiency (measured as time needed for navigation, data entry, and task comprehension) was insignificantly different depending on NDP. Data originally published by Harms et al. [90].

### 7.6.3 Results

This section presents quantitative and qualitative results regarding the usability and subjective user satisfaction of the four NDPs (navigation design patterns) shown in Figure 7.12, as assessed through a comparative usability test with N=24 participants (f=14, m=10).

The significance of observed differences was tested using two-sided Kruskal-Wallis H-Tests with a significance level of $p<0.05$. We used an Exact-Methods implementation of Kruskal-Wallis when computationally possible, otherwise Monte-Carlo with 10.000 samples. Post-hoc pairwise comparisons between groups were tested using Exact Mann-Whitney U-Tests. These test methods are well-suited for the lack of normality and the heteroscedasticity present in much of the data.

**Efficiency.** We measured the time needed for navigation by analyzing screen recordings, thus splitting total task completion time into navigation, data entry, and task comprehension. There were no significant influences of NDP on the time needed for navigation (p=0.170), data entry (p=0.994), and task comprehension (p=0.377), see Table 7.6.

To assert that these results are not biased by learning effects, we additionally conducted separate tests for each one of the test runs 1-4, but also found no significant differences. This indicates that our randomized study design worked well for eliminating learning effects.

To further quantify eventual learning effects on efficiency, we tested the influence of the sequential number of test run on the time needed for navigation. Navigation durations were significantly different ($p<0.001$); post-hoc comparisons between pairs of sequence numbers revealed that participants were significantly slower in the first test run (01:26±00:26) than in all of the following runs (e.g., 00:55±00:24 in run4). But there were no significant differences between any of those following runs.

**Navigation Errors.** Screen recordings were further analyzed in order to count navigation errors. This included Scrolling in the wrong direction as well as selecting the wrong Tab, Menu entry or Fieldset. We found no significant influence (p=0.094) of NDP on the number of errors, see Table 7.7.

Further investigations showed that errors were strongly influenced ($p<0.001$) by learning, i.e., that the sequential number of test run influenced the number of navigation errors. Post-hoc pairwise comparisons revealed that users made significantly more errors in the first run than in any other run ($p<0.001$ for run 2, p=0.030 for run 3, and p=0.010 for run 4, each in comparison to run 1). A surprising increase in the number of errors between runs 2 and 3 was significant as well (p=0.009).

**Memorability.** The first questionnaire allowed to measure three memorability scores. Mem1 (number of correctly remembered form sections) and Mem2 (number of correctly ordered form sec-

| *Navigation Errors* | *Scrolling* | *Tabs* | *Menu* | *Collapsible Fieldsets* | *H-Value, p-Value* |
|---|---|---|---|---|---|
| | 2.50 ± 1.719 | 1.75 ± 2.541 | 1.79 ± 2.553 | 2.00 ± 2.377 | H(3)=6.333, p=0.094 |

**Table 7.7:** Navigation errors were not significantly different depending on NDP. Data originally published by Harms et al. [90].

| *Memorability Scores:* | *Mem1* | *Mem2* | *Mem3* |
|---|---|---|---|
| Scrolling | 1.00 ± 1.265 | 3.17 ± 0.753 | 1.50 ± 0.548 |
| Tabs | 3.67 ± 1.966 | 3.67 ± 2.338 | 1.50 ± 0.837 |
| Menu | 4.50 ± 0.548 | 4.67 ± 1.633 | 1.83 ± 0.753 |
| Collapsible Fieldsets | 2.50 ± 1.225 | 4.83 ± 0.983 | 1.83 ± 1.169 |
| H-Value, p-Value | H(3)=13.071, **p=0.001** | H(3)=5.616, p=0.128 | H(3)=1.072, p=0.813 |

**Table 7.8:** Memorability scores depending on NDP. Mem1 (number of correctly remembered form sections) was significantly better for Menu, followed by Tabs, Collapsible Fieldsets and Scrolling, in this order. Mem2 (correctly ordered form sections) and Mem3 (correctly remembered labels in the "hobbies" section) showed no significant differences. Data originally published by Harms et al. [90].

| *SUS Scores:* | *Overall* | *SUS1* | *SUS5* | *SUS8* |
|---|---|---|---|---|
| Scrolling | 66.35 ± 23.751 | 2.33 ± 1.579 | 3.17 ± 1.551 | 3.08 ± 1.863 |
| Tabs | 83.13 ± 19.157 | 3.87 ± 1.191 | 4.29 ± 1.042 | 1.71 ± 1.197 |
| Menu | 80.94 ± 20.494 | 3.83 ± 1.167 | 4.25 ± 1.189 | 1.58 ± 1.213 |
| Collapsible Fieldsets | 78.75 ± 15.429 | 3.29 ± 1.429 | 4.17 ± 0.917 | 1.75 ± 0.897 |
| H-Value, p-Value | H(3)=9.544, **p=0.019** | H(3)=15.24, **p=0.001** | H(3)=10.378, **p=0.015** | H(3)=12.751, **p=0.004** |

**Table 7.9:** Perceived usability. Overall SUS (System Usability Scale) scores ranging from 0 to 100, the higher the better, were significantly different depending on navigation design pattern. Furthermore, three out of ten individual SUS questions (ranging from 1 to 5, the higher the more agreement) showed significant differences: SUS1 ("would like to use this frequently"), SUS5 ("well integrated"), and SUS8 ("cumbersome to use"). Data originally published by Harms et al. [90].

tions) relate to how well participants remembered an overview of the form schema, whereas Mem3 (number of correct labels from the "hobbies" section) measures how well they remembered details. Test results show a significant influence of NDP on Mem1 (p=0.001), but not on Mem2 (p=0.128) and Mem3 (p=0.813), see Table 7.8. Pairwise comparisons for Mem1 revealed that Menu worked significantly better than both Collapsible Fieldsets (p=0.009) and Scrolling (p=0.002), the latter of which performed worse than Tabs (p=0.041); all other differences were insignificant.

**Perceived Usability.** Participants comparatively rated the usability of the four NDPs by answering System Usability Scale (SUS) [28] questions in the second post-test questionnaire (handed out upon completion of all test runs 1-4). Overall SUS scores significantly differed (p=0.019) depending on NDP, see Table 7.9. Pairwise comparisons showed that Scrolling scored significantly worse than both Tabs (p=0.007) and Menu (p=0.024). We also evaluated each SUS question individually, revealing significant influences of NDP on three out of ten questions: SUS1 (p=0.001, "I think that I would like to use this design frequently"), SUS5 (p=0.015, "I found the various functions in this design were well integrated"), and SUS8 (p=0.004, "I found the design very cumbersome to use"), compare Table 7.9. In every one of these questions, pairwise comparisons showed that Scrolling performed significantly worse than all other NDPs (p-Values between 0.000 and 0.026); all other pairwise differences were not significant.

| *Ranking Scores:* | *Overview* | *Difficulty* | *Preference* |
|---|---|---|---|
| Scrolling | 3.63 ± 0.770 | 2.04 ± 1.334 | 3.29 ± 1.042 |
| Tabs | 1.96 ± 0.859 | 2.67 ± 0.917 | 2.29 ± 0.955 |
| Menu | 2.21 ± 1.021 | 2.58 ± 1.100 | 2.17 ± 1.049 |
| Collapsible Fieldsets | 2.21 ± 1.021 | 2.71 ± 1.042 | 2.25 ± 1.113 |
| H-Value, p-Value | H(3)=32.854, **p< 0.001** | H(3)=5.476, p=0.143 | H(3)=16.031, **p=0.001** |

**Table 7.10:** Subjective Rankings. Scores ranging from 1 to 4, with lower scores indicating a better overview, higher difficulty, and stronger preference. Data originally published by Harms et al. [90].

| *Feedback:* | *Scrolling* | *Tabs* | *Menu* | *Collapsible Fieldsets* |
|---|---|---|---|---|
| *Positive* | Usability (1) | Usability (11) | Usability (10) | Usability (10) |
| | | Overview (8) | Overview (8) | Overview (9) |
| *Negative* | Lack of Usability (17) | Lack of Usability (2) | Hidden UI Elements (4) | Visual Design (6) |
| | Lack of Overview (7) | Hidden UI Elements (2) | Unfamiliar Design (3) | Lack of Usability (3) |
| | | | | Unfamiliar Design (2) |

**Table 7.11:** Qualitative feedback from the post-test interviews. Transcriptions were coded into positive and negative statements and counted regarding the four NDPs. Data originally published by Harms et al. [90].

**Subjective Rankings.** Users ranked clarity of overview, perceived difficulty, and their individual preference of the four NDPs in the second post-test questionnaire. Results show a significant influence of NDP on overview ($p<0.001$) and preference ($p=0.001$), but not on difficulty ($p=0.143$), see Table 7.10. Pairwise comparisons for preference and overview revealed that Scrolling worked significantly worse than all of the other NDPs (all p-Values $\leq 0.001$); there were no significant differences in all other pairwise comparisons.

**Qualitative feedback.** Semi-structured post-test interviews asked participants to describe their experience and whether they had difficulties using the NDPs. The interviews were recorded, transcribed and analyzed using empirical codes, see Table 7.11. Scrolling garnered more negative comments than any other NDP. Users criticized a lack of usability in Scrolling (N=17 comments), stating they found it disorienting and cumbersome. In the same way, they criticized a lack of overview (N=7). In contrast, the other three NDPs received mostly positive comments regarding these topics. Tabs (N=2) and Menu (N=4) were criticized for hidden UI elements, i.e., the tab bar or menu button was hidden when users scrolled down. The visual design was only commented upon with regard to Collapsible Fieldsets (N=6); some users mentioned a lack of color, others were unable to articulate more specifically what they did not like. Users also complained that Collapsible Fieldsets (N=2) and Menu (N=3) lacked familiarity.

### 7.6.4 Discussion

The four navigation design patterns (NDPs) of Scrolling, Tabs, Menu, and Collapsible Fieldsets differed regarding memorability, perceived usability (SUS), subjectively ranked overview, and user preference. There were no significant differences in measures of efficiency (time needed for task completion) and navigation errors.

Scrolling performed worse than all other NDPs in every measure with significant differences. Memorability was lower in Scrolling, indicating that users remembered the form schema less well. One possible explanation is that Scrolling required no direct interaction with form section titles, never showed all section titles at once, and thus provided less overview. This lack of overview is confirmed by qualitative results and subjective rankings. Perceived usability and user preference were also significantly worse for Scrolling. The other three NDPs performed equally well with regard to most measures, the only significant pairwise difference being higher memorability of Menu than Collapsible Fieldsets.

Results indicate that designers should not rely on Scrolling alone, but should provide an additional high-level overview of the form schema, possibly using Tabs, Menus, or Collapsible Fieldsets. We expect the results to be generalizable from our case study about social network profile pages to other scenarios with similar characteristics: Long, form-based UIs filled on small-screen devices where tasks include initial filling and subsequent revision of form data in a non-linear, not strictly goal-directed manner. Examples are forms in productivity applications, mobile app settings, and system preferences. Future work should investigate further scenarios and other, not just form-based UIs. Also, the memorability of the various NDPs should be further examined in long-term studies.

### 7.6.5 Conclusion Regarding Navigation on Mobile Devices

A usability evaluation compared the four navigation design patterns of Scrolling, Tabs, Menus, and Collapsible Fieldsets on mobile devices. The Collapsible Fieldsets variant featured our novel Focus&Context form design. The evaluation was conducted with 24 participants in a case study on social network profile page editing. Results revealed no influence of navigation design pattern on efficiency and errors, but the following measures significantly differed: memorability, perceived usability, subjectively ranked overview, and user preference. Scrolling performed worst in all of these measures. The remaining three patterns worked equally well. Qualitative results and subjective rankings provided the explanation that the more interactive patterns (i.e., Tabs, Menus, and Collapsible Fieldsets) offer a better overview than Scrolling. We conclude that designers should avoid Scrolling in favor of the other patterns when designing navigation for long, form-based UIs that users fill and edit on small-screen devices.

## 7.7 Conclusion

The work presented in this chapter set out to improve navigation in long, form-based UIs by applying the Focus&Context principle from the information visualization discipline to form design. The resulting contributions are a design space analysis, an innovative design implemented in prototype for a case study, and results from usability evaluations on desktop and mobile devices.

The design space was shown to be useful and practically applicable in a case study on social network profile page editing. Designers found it fostered creativity and helped to clearly document design decisions. This indicates the design space to be a valuable support for designing navigation in long, form-based user interfaces.

The novel design, as created for the case study, employed the Focus&Context principle to provide usable navigation in a long, form-based UI. It implemented the Focus&Context principle through collapsible fieldsets that dynamically visualize information in varying levels of detail, depending on the user's current degree of interest.

Evaluations on desktop and mobile devices showed that even novice users could work with the new design without an increase in errors and without any need for help or assistance. There were no significant differences regarding navigation performance or subjective satisfaction. Scrolling performed far worse than the other navigation design patterns in the mobile evaluation.

In summary, results indicate that designers should not rely on Scrolling alone, especially on small-screen devices. Instead, they should seek to provide an additional, interactive overview of the form schema, possibly using Tabs, Menus, or Collapsible Fieldsets.

# 8 Collaboration: Design Space Analysis and Rapid Prototyping Tool for Real-Time Collaborative Web Forms

**Chapter Summary.** Form-based user interfaces are popular in cooperative work settings. But collaborative usage in general and synchronous collaboration in particular are poorly supported in many user interfaces (UIs) that are based on the 'form' UI metaphor. Consequently, there has been interest in improving form-based UIs of groupware systems. The specific topic addressed by the work presented in this chapter are the many design options available for collaborative, form-based UIs. The large number of options and current lack of best practices imply that designers must make, evaluate, and revise design decisions in multiple iterations – a process that is hindered by high implementation efforts and the current lack of rapid prototyping tools. To address these problems, the present work contributes a design space analysis and a rapid prototyping tool. The design space analysis systematically analyzes and describes available design options, as derived from related work and existing products. The rapid prototyping tool allows for quick configuration (instead of time-consuming implementation) of many design options identified in the design space analysis. In summary, the above contributions can inform and inspire the design of real-time collaborative form filling and support the corresponding design activities with a novel prototyping tool.

## 8.1 Introduction

The work presented in this chapter addresses designers' needs when creating collaborative user interfaces (UIs) based on the 'form' UI metaphor.

**Historical Forms and Today's Form-based UIs.** Historically, paper forms have supported collaboration for centuries, compare Chapter 3 for a more detailed, historical account. Corresponding collaboration took place between and within form authors and form fillers. For example, earliest, hand-written forms such as the hand-written, blank charters for issueing indulgence letters, compare Becker [20] and Eisermann [63], enabled collaboration within a single form authoring organization. In other words, writers prepared a blank charter with empty placeholders, which were later on filled by members of the same organization at the time of issuing. Another kind of collaboration, namely collaboration between different groups or organizations, can be found in questionnaire forms. One very early example are the questionnaires used by local officers in colonies of Philipp II of Spain since the late 16th century [20]. These questionnaires enabled communication and collaboration between a central government and remote colonies. The 'form' UI metaphor entails that today's form-based UIs should likewise support various kinds of collaboration.

**Background and General Motivation.** Collaboration between and within form authors and fillers can be found in many of today's form-based UIs – many of these UIs enable collaboration between different groups of people at and across different times and locations. Related definitions of form-based UIs have reflected this fact, compare Chapter 4 for a detailed review. For example, Frohlich et al. [70] stated, “What is common to most definitions is the notion that a form facilitates some kind of communication between an organization and an individual”. In a similar way, Axelsson et al. [15] defined form-based UIs in e-Government applications as “instruments for communication” and Bargas-Avila et al. [16] described web forms as “the main contact point between users and website owners”. Despite widespread support for collaboration between form authors and form fillers, collaborative filling (i.e., collaboration between multiple form fillers) is currently not well supported. For example, Gaubatz et al. [76] and Harms [88] described medical scenarios where form-based UIs did not provide enough awareness about concurrent editing and needed better ways of enforcing access control. If form-based UIs are employed in collaborative applications, then these UIs must provide corresponding interactive features (in the above examples: better awareness and access control) to aptly support collaborative use cases.

**Specific Problem Statement and Goals.** When designing collaborative form filling, one challenge for designers are the many available design options and thus the many decisions to be made. For example, how to provide awareness of concurrent activities in form-based UIs without distracting users from their actual tasks. Also how to sync, lock, or merge data in a way that scales for the intended number of users and how to track and visualize versions. Each of these options has been analyzed in the CSCW (computer-supported co-operative work) discipline, but no summary of design options from a UI design perspective exists. There also exist no clear guidelines or proven best practices about when to choose which option. Consequently, designers of collaborative, form-based UIs have to make, evaluate, and reconsider design decisions in multiple iterations. The corresponding design iterations are hindered by the current lack of rapid prototyping tools for collaborative form filling. Hence it is the goal of this work to systematically analyze and summarize the design space of collaborative, form-based UIs and to develop a rapid-prototyping tool.

**Summary of Contributions.** The work presented in this chapter contributes a design space analysis for designing collaborative form filling, as well as a rapid prototyping tool. The design space provides a systematic overview on relevant design questions and corresponding design options. The rapid prototyping tool allows designers to easily configure (instead of laboriously implement) many design options identified in the design space analysis. Designers can use the tool to quickly create prototypes by simply configuring the desired design options, allowing to comparatively evaluate design options and make empirically grounded design decisions.

**Structure of Work.** The following Section 8.2 describes three motivating scenarios where collaborative form filling is an important use case. Subsequent sections will repeatedly use these scenarios as examples. The design of collaborative, form-based UIs is an interdisciplinary undertaking – Section 8.3 correspondingly describes related work from the three disciplines of Form Design, Computer-Supported Co-Operative Work (CSCW), and Usability Engineering. Related work on contextual factors and design options is of particular importance for the goals of this work: To design form-based UIs, designers first analyze the contextual factors of a specific project or scenario. Based on this knowledge, they can make design decisions regarding many available design options. To support these design activities, Section 8.4 summarizes important contextual factors proposes to visualize them in a novel, grid-like structure. Section 8.5 presents one main contribution of the work described in this chapter, i.e., a systematic analysis of design options for collaborative form filling. The second contribution is a novel rapid-prototyping tool described in Section 8.6 where many options described in the design space analysis can quickly and easily be configured by designers.

## 8.2 Motivating Scenarios

The following exemplary scenarios motivate the need for collaborative form-based UIs in different domains and applications. All of the below scenarios correspond to situations experienced by the author of this thesis – as designer in a medical documentation project, as citizen in bureaucratic encounters, and as customer faced with administrative web forms. To further demonstrate the relevancy of each scenario, references to related work are provided as part of each scenario description. Later parts of this chapter will repeatedly refer to the scenarios to analyze contextual characteristics and discuss suited design options.

**Scenario 1: Medical Documentation.** Electronic medical records involve a large number of medical professionals working together. Many tasks require filling and subsequent revision of web forms. In one instance observed by the author and described in Harms [88], doctors and nurses shouted from one room to the other in order to find out who else was documenting the same patient at the same time because the forms did not update in real-time and did not provide enough awareness about concurrent usage. Related work by Gaubatz et al. [74–76] has described additional problems in a similar scenario. Form-based UIs in a medical application have lacked fine-grained access control to support collaboration between different medical roles such as doctors and nurses. Jacobs et al. [110] described a web-based solution where medical, form-based UIs were enhanced with real-time collaborative features.

**Scenario 2: Customer Support.** The fictional ACME Insurance Company described in an IBM technical report [W2] provides a web interface for customers to fill an insurance claim form. Since standard web forms provide no means for customer representatives to support the form filling process, an enhanced version of the form is put forth in order to enable customers to contact the support staff for help, to share their form data, and be assisted in a co-browsing and co-editing session. Additionally, an integrated voice-over-IP solution offers a "call customer support" button to open a verbal communication channel. The scenario is characterized by asymmetric collaboration, i.e., support staff influences the customer's actions, but customers may not influence the support staff's helpdesk environment. An early solution for a similar scenario implemented "What You See Is What I See" collaboration where the viewports of client and support staff were strictly synchronized, compare Kobayashi et al. [123]. In contrast, the solution described in the IBM technical report [W2] did not synchronize the viewports, but only the form contents.

**Scenario 3: Government Administration.** Filling and submitting administrative forms is typically a collaborative process where citizens and officers fill different form sections and assist each other by providing information and explanations. Typical e-government solutions support the process through distant, asynchronous workflows, compare, for example, the work by Axelsson et al. [15] on communication quality of e-government forms. In contrast, face-to-face collaboration between citizens and officers in a local government bureau setting is a poorly researched topic. Nonetheless, this scenario would benefit from electronic support to avoid the following, common problems. Verbally communicated data may easily be misunderstood – an electronic system could provide means for spontaneous, written communication in addition to verbal, face-to-face communication. Another source of error is that government officials scan or transcribe pre-filled paper forms into electronic documents. This problem could be circumvented if citizens could directly provide digital data or if they could check the government official's transcription in real time during their encounter. The more general goal of augmenting face-to-face collaboration through electronic devices has been addressed in related work, albeit without a focus on form-based interactions. For example, DiMicco et al. [52] investigated electronical support for group discussions. Specifically, they employed natural language processing to visualize speaker participation on a large screen. This allowed members of the group discussion to reflect on minority participation. Shen et al. [171] investigated interactive tabletop surfaces as a way for supporting face-to-face communication. This could be used to support interactions between citizens and officers around shared, form-based artifacts. Alternatively, the electronic form (or parts thereof) could be shown to citizens and officers on separate screens, with real-time propagation of updated form contents.

## 8.3 Related Work

Many disciplines, methods and tools are relevant for designing of collaborative web forms. The present work focuses on the intersection of the three disciplines of usability engineering, form design, and CSCW (computer-supported co-operative work).

Related work at the intersection of the above three disciplines is rare. An early paper by Bell et al. [22] described a form-based system for structured data entry of ultrasound results in a hospital setting. In this system, collaboration took place through a form-based UI and synchronization of form contents was performed using a distributed database system. But the paper left unclear how conflicts resulting from concurrent editing were handled at the UI level. Amongst a large set of further publications that investigated collaborative web browsing, a few dealt with collaborative filling of web forms. Within this context, the design considerations by Jacobs et al. [110] are highly relevant for this work. The paper describes various cooperation features and modes of operation that will be discussed in more detail in further sections of this work. Later papers employed proxy servers instead of java applets to implement collaboration, compare Aoki [11] and Cheng et al. [40]. Recent advances in web technology enabled more lightweight, javascript-based solutions, compare for example IBM's collaborative web forms [W2] and Gaubatz's CocoForms framework [W16]. These projects provide specific implementations (that will inform our design space analysis presented in Section 8.5), but they cannot be configured with other design options.

### 8.3.1 Groupware

The discipline of CSCW has investigated various types of collaborative software under the term groupware. Groupware has been defined by Ellis et al. [65] as "computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment". It is evident from this definition that a form-based UI that is collaboratively filled by multiple users qualifies as groupware: a group of users is engaged in a common task (form filling) using a shared, form-based editing environment. The term groupware comprises many further kinds of systems. For example, Ellis et al. [65] listed the following types of groupware: message systems, multiuser editors, group decision support systems, electronic meeting rooms, computer conferencing, intelligent agents (e.g., if not all participants in an electronic meeting are humans), and coordination systems.

To understand similarities and differences amongst the above, very heterogeneous systems, related research in CSCW has proposed various groupware taxonomies using different criteria for classification. These criteria are relevant for the purposes of this work because they highlight fundamental distinctions that either correspond to contextual factors (that designers should analyze prior to other design activities) or design options (that designers can choose from). We reviewed existing groupware taxonomies (a total of nine papers) to compile lists of contextual factors and design options, compare Tables 8.1 and 8.2. The specific contextual factors and design options are presented along with additional references in the following sections.

| Contextual Factors in Related Groupware Taxonomies | References |
|---|---|
| **Time:** | |
| – same / different | Andriessen [8], Ellis et al. [65], Johansen [116], and Penichet et al. [150] |
| – same / different but predictable / different and unpredictable | Grudin [81] |
| – short-term / mid-term / long-term | Schuster et al. [165] |
| **Space:** | |
| – same / different | Andriessen [8], Ellis et al. [65], Johansen [116], and Penichet et al. [150] |
| – face-to-face / dispersed | Desanctis et al. [48] |
| – same / different but predictable / different and unpredictable | Grudin [81] |
| – small scope / medium scope / anywhere | Schuster et al. [165] |
| **Group Size:** | |
| – smaller / larger | Desanctis et al. [48] |
| – individual / small group / project / organization | Grudin [81] |
| – individual / group / anonymous community | Schuster et al. [165] |
| **User Involvement:** | |
| – high / medium / low | Rama et al. [157] |
| **Task Characteristics, Group Processes:** | |
| – communication, information sharing, co-operation, coordination, social encounters | Andriessen [8] |
| – information sharing, communication, coordination | Penichet et al. [150] |
| – planning, creativity, intellective, preference, cognitive conflict, mixed motive | Desanctis et al. [48] |
| **Task Sharing:** | |
| – low (not many shared tasks, e.g., timesharing systems) / high (a lot of task sharing, e.g., software review system) | Ellis et al. [65] |

**Table 8.1:** Contextual factors that influence groupware design, as described in related groupware taxonomies.

| Place \ Time | Same | Different, but predictable | Different and unpredictable |
|---|---|---|---|
| Same | Meeting facilitation | Work shifts | Team rooms |
| Different, but predictable | Tele conferencing | E-Mail | Collaborative writing |
| Different and unpredictable | Interactive multicast seminars | Computer bulletin boards | Workflow |

**Figure 8.1:** Groupware taxonomy based on the same/different time and space distinction, also known as "time and space quadrant". The above graphic includes an additional distinction regarding the predictability of different times and locations where collaboration takes place. Graphic redrawn based on Grudin [81].

### 8.3.2 Contextual Factors

It is essential for designers to analyze contextual characteristics prior to starting with UI design. Relevant contextual factors have been described in all related disciplines of usability engineering, form design, and CSCW. This section seeks to combine prior findings to inform the design of collaborative web forms. Thus the contextual factors described in this section provide designers with an agenda of relevant research questions for analyzing the contextual characteristics of a particular project that involves collaborative form filling.

**Usability Engineering.** From a usability engineering perspective, Mayhew's "Usability Engineering Lifecycle" [139] recommends analyzing users, tasks, and other contextual factors beforehand in order to gather requirements and better understand the specific domain. In a similar way, Benyon's "PACT" (people, activities, context, technology) framework recommends to analyze the same factors, plus an additional factor related to technical constraints.

**Form Design.** In form design, Jarrett et al.'s "three layers of form design" [112] likewise recommend to conduct an initial analysis prior to other design activities. Accordingly, designers should first analyze the "relationship layer of form design", i.e., the relationship between form authors and fillers, before starting with conceptual and visual UI design activities described as "conversation" and "appearance" layers. In this regard, recommendations in form design are very similar to general usability engineering, but obviously have a more specific focus on form-based UIs.

**CSCW.** Co-operative work necessarily takes place between more than one person. Contextual factors consequently depend on who is using the system at which time and at what location. These differences are well-described in existing groupware taxonomies, compare Table 8.1 for an overview. The differences and distinctions put forth in these taxonomies can roughly be split into factors related to user and task characteristics, as described in the following.

**User Characteristics.** The related disciplines of CSCW, form design, and usability engineering have each described relevant user characteristics.

Usability engineering has formulated general purpose user characteristics that are relevant to a wide range of projects: knowledge and experience (e.g., typing skills, task experience), job responsibilities and frequency of use, psychological factors (e.g., attitute, motivation), and physical characteristics (e.g., color blindness), compare, for example Mayhew [139, ch.3].

The CSCW discipline has analyzed social and organizational user characteristics, with a focus on how these characteristics may be dispersed across multiple users. Desanctis et al. [48], Grudin [81], and Schuster et al. [165] accordingly included group sizes into their taxonomies, with scales ranging from individuals to small groups or projects, up to entire organizations or anonymous communities. Rama et al. [157] additionally distinguished between high, medium, or low user involvement.

From a form design perspective, users can be discerned as those who collect data (i.e., form authors, recipients of form data) and those who provide it (form fillers, users, respondents). Users may furthermore have different organizational or professional roles. As described by Gaubatz et al. [75], it is essential that collaborative, form-based UIs take such roles into account by modeling corresponding role-based access control.

**Task Characteristics.** Cooperative tasks have been classified based on their spatial and temporal distribution. Accordingly, one widely used groupware taxonomy by Johansen [116] distinguishes between same/different times and spaces where collaboration takes place. Same-time collaboration refers to people cooperating at the same time, whereas different-time collaboration refers to cooperation at different times, as typically encountered in asynchronous communication. Similarly, same-space collaboration refers to people co-operating in the same place, as opposed to nearby or remote places. The above distinction has been extended by Grudin [81] by discerning if times and spaces are predictable or not, as shown in Figure 8.1. Another extension has been proposed by Schuster et al. [165] who used continuous scales instead of binary or ternary distinctions. Specific examples of groupware systems where tasks are differently dispersed over time and space characteristics have been described by Grudin [81] and Penichet et al. [150].

One implication of the time-based task characteristics that is relevant for the design of collaborative web forms has been described by Ellis et al. [64]. Accordingly, 'same time' tasks are best supported by propagating changes instantaneously to all users involved, i.e., through "real-time" collaboration and synchronous communication. On the other hand, long-running workflows with only one (or few) active users at a time can be supported through asynchronous collaboration and communication.

Space-based task characteristics likewise have design implications. Since 'same space' tasks involve users working together in the same location, they can use informal communication channels (i.e., they can spontaneously talk to each other) to help them organize the group work. In contrast, users in 'different space' tasks are spatially dispersed. The system should therefore provide informal communication channels and means for group communication and organization.

The taxonomies by Andriessen [8], Desanctis et al. [48], and Penichet et al. [150] furthermore distinguished between different types of tasks. For example, Andriessen [8] described the following processes or activities: communication, information sharing, co-operation, co-ordination, and

| Design Options in Related Groupware Taxonomies | References |
|---|---|
| **Shared Environment:** | |
| – low (no common environment, e.g., electronic mail system) / high (shared UI, lot of awareness, e.g., electronic classroom system) | Ellis et al. [65] |
| **Type or “Focus” of UI:** | |
| – user centered / artifact centered / workspace centered | Rama et al. [157] |
| **Synchronization:** | |
| – synchronized collaboration / unsynchronized collaboration / mixed (synchronized and unsynchronized) collaboration / serial collaboration | Rama et al. [157] |
| **Functionality:** | |
| – informal interaction, information sharing and exchange, decision making, coordination and control protocols, domain directories | Schmidt et al. [163] |
| – communication medium only / group decision modelling / advanced group decision support including machine-induced communication patterns | Desanctis et al. [48] |
| – messaging, conferencing and electronic meetings, group decision support, document management, document collaboration, compound document management systems | Rama et al. [157] |
| **Architecture:** | |
| – central / replicated / hybrid | Rama et al. [157] |
| **Platform Support:** | |
| – mobile platforms / operating system based platform / browser based platform / platform independent (multi-platform) | Rama et al. [157] |

**Table 8.2:** Design options for groupware, as described in related groupware taxonomies.

social encounters. A subset of Andriessen’s task types has also been used in the taxonomy by Penichet et al. [150]. Another list of task types has been provided by Gutwin et al. [84] who put forth a list of “mechanics of collaboration” as essential and necessary functions of groupware: explicit communication, consequential communication (awareness provided as a side effect of other actions), coordination, planning, monitoring, assistance, and protection.

Form filling tasks have been analyzed by Frohlich et al. [70] to inform the design of administrative systems, resulting in the fundamental distinction that form fillers need to understand questions, answer questions, and navigate between questions. The process of understanding and answering questions has furthermore been detailed from a psychological perspective by Tourangeau et al. [188]. Corresponding steps include comprehension, information retrieval, judgment (deciding what to answer), and response (filling the form field). Navigation between questions has been investigated by Harms et al. [90, 92], also compare Chapter 7 of this work. One important distinction is that tasks may require linear navigation (e.g., as in surveys), as opposed to non-linear navigation (e.g., when revising existing form contents). Non-linear navigation may furthermore be characterized by different degrees of goal directedness, as described in the author’s work on navigation, compare Harms et al. [92] and Chapter 7 of this work.

### 8.3.3 Design Options

Related work has described various groupware implementations, but there exists no comprehensive, systematic analysis of user interface design options for collaborative form filling.

Closest to the goal of this work of analyzing design options for form-based, collaborative UIs is a publication by Jacobs et al. [110] about collaborative web browsing. The forms implemented in Jacobs et al.'s publication enabled collaborative editing of form fields. The system furthermore allowed users to point out parts of images to each other. A chat function provided an additional communication channel. The paper provided a systematic analysis of four "cooperation modes" for how navigation can be synchronized across multiple users. Further, recent work by Gaubatz et al. [75, 76] described additional design options for how input fields may be masked or hidden depending on a user's access permissions.

Groupware taxonomies put forth in the CSCW discipline have used various additional design options as criteria for distinguishing between different types of groupware, compare Table 8.2 for an overview. It is evident from the table that many of these design options are concerned with other topics than UI design, for example, the functional scope and system architecture. Given the goals of this work, we will not discuss these issues at length but instead focus on UI design.

One important distinction described by Ellis et al. [65] is the degree to which a UI or environment is shared amongst users. Taking the examples described by Ellis et al., electronic mail systems allow users to connect with various mail clients of their choice and therefore do not provide a shared environment. In contrast, electronic classroom systems typically provide web-based workspaces that provide awareness about past and current activities. The concept of workspaces leads to another distinction concerning the type or "focus" of a UI. According to Rama et al. [157], a groupware UI may be user-centered, artifact-centered, or workspace-centered. User centered groupware creates communication channels between collaborating users – disregarding what users do with that channel. Artifact centered groupware enables collaboration on a specific type of artifact; the UI typically reflects the artifact's specific structure. Workspace centered groupware enables communication between users, but in contrast to the volatility of communication sessions, workspaces can exist without users, or with a changing group of users. Since forms and form-based UIs are essentially artifacts (compare the definition provided in Chapter 4), collaboration through these artifacts is first and foremost artifact-centered.

Concurrent editing of artifacts necessitates some kind of synchronization. Corresponding design options have been described in the groupware taxonomy by Rama et al. [157]. The most basic distinction is that groupware may synchronize artifacts, or not synchronize them at all – in which case each person works on their own set of artifacts. Serial collaboration is a special case where the same artifact is sequentially edited by multiple users. For example, a form-based workflow system may not synchronize form contents until the form is submitted and subsequently processed by the next user. The first two options (unsynchronized artifacts and serial, form-based workflows) are well-researched and widely employed in industry. In contrast, synchronized co-operation by multiple form fillers using the same form-based UI, i.e., collaborative form filling, requires further investigations.

In summary, related work has described many relevant options for the design of collaborative, form-based UIs. A comprehensive list of design options with a specific focus on form-based UIs has not yet been published, but is needed to understand the available design options and to inspire collaborative form designs.

### 8.3.4 Rapid Prototyping

Prototyping is a widely used and recommended method for user interface and interaction design. According to Buxton [34], prototypes as well as sketches can both be characterized as "instantiations of a design concept" [34, p.139]. Nonetheless, they correspond to different design methods that do not serve the same purpose. Sketching, as a distinct form of drawing, historically developed as a means whereby designers could explore and communicate ideas [34, p.105ff]. In the same way, sketches today explore ideas rather than confirm or refine them. Sketches are quick, inexpensive, and disposable. They are intentionally ambiguous and vague. Prototypes, in contrast, are more detailed and refined [34, p.139ff]. They consequently require a higher investment, take longer to create, and are less disposable. Prototypes elaborate a design concept in detail, allowing to evaluate the concept and detect errors. Thus prototypes allow to "fail early and fail often" – and hopefully learn from previous failure.

Rapid prototyping, i.e., the ability to quickly implement (and subsequently evaluate) prototypes, is important to reduce the effort required for multiple design iterations. Consequently, related work has proposed rapid prototyping tools for various kinds of systems. For example, Klemmer et al. [122] proposed a rapid prototyping tool for speech-based applications and Weis et al. [196] proposed a programming language to enable rapid prototyping of pervasive, context-aware applications. The authors motivated the need for such tools by arguing that the respective applications are difficult to implement and that iterative design is hindered by high implementation efforts. The same is true for collaborative form filling, but few tools exist to support rapid prototyping of corresponding UIs. The remainder of this section describes tools and libraries that can be used to implement – and thus prototype and evaluate – collaborative form filling.

Various synchronization libraries exist that enable shared editing in web-based applications, compare Koren et al. [124] for a recent overview of available products. These libraries provide web-based (mostly JavaScript) implementations of algorithms that synchronize changes across multiple clients. There furthermore exist multiple real-time web development frameworks built upon such libraries. Wilson et al. [200] described advantages of such frameworks for implementing distributed web applications. A recent book by Mardan [137] provides practical advice and programming tutorials. Popular frameworks described in the above works include Derby.js [W12], Loopback [W21], Meteor.js [W22], and Sails.js [W30]. Collaborative, form-based UIs can be implemented using any of these libraries and frameworks. But implementation efforts are high because all user interface elements and design options have to be programmed by hand.

Another possibility for prototyping collaborative, form-based UIs is by using (and potentially modifying) co-browsing tools. For example, Mozilla's TogetherJS [W34] project provides a general-purpose tool, allowing multiple users to collaboratively browse the web. The tool can be configured with multiple design options (including facilities for pointing and highlighting) and also supports collaborative form filling. Despite these useful features, many other design options cannot be configured. Furthermore, the broad purpose of the tool has resulted in a rather complex UI design.

Lastly, related projects have provided implementations of collaborative web forms that may be adapted and used for the purpose of prototyping. Compare, for example, IBM's solution for live customer support [W2] and Gaubatz's CocoForms framework [W16] with a focus on access constraints in medical documentation systems. These projects have made design decisions specific to their respective usage scenarios. Hence these projects are suited for prototyping similar scenarios, but designers cannot expect to be able to configure other design options that may be needed for different scenarios.

In contrast and addition to the above prior works, the rapid prototyping tool proposed in this chapter provides implementations of UI elements (in contrast to existing synchronization libraries), focusses specifically on form-based UIs (as opposed to general-purpose co-browsing tools), and allows designers to configure various design options that are relevant for a wide range of usage scenarios.

### 8.3.5 Discussion and Outlook

The above discussion of related work showed that publications about collaborative form filling – at the intersection of CSCW, usability engineering, and form design – are rare. Nonetheless, related work on contextual factors that influence groupware design appeared systematic and complete. We will integrate these contextual factors in a novel, grid-like visualization in Section 8.4. Related work has also pointed out several relevant design options, but a comprehensive overview has not been provided. This indicates a need for a systematic design space analysis, as put forth in Section 8.5. Lastly, we discussed how prototyping of collaborative, form-based applications can be achieved using various libraries and tools. But in addition to existing tools, designers would benefit from a rapid prototyping tool, as shall be put forth in Section 8.6. The tool should allow designers to easily configure various design options in order to evaluate and compare their suitability for specific scenarios.

## 8.4 Analysis of Contextual Factors

To summarize the contextual factors discussed in the above review of related work (Section 8.3.2) and to integrate them into a coherent framework, this section proposes a novel, grid-like visualization, as shown in Table 8.3. Accordingly, the primary contextual factors are people, activities, context, and technology, as put forth in Benyon's "PACT" framework [23]. Many detailed characteristics correspond to each of these factors, including user characteristics for the 'people' factor, task characteristics for the 'activities' factor, and characteristics of context and technology. The corresponding characteristics are well-documented in related work and have been summarized in the previous Section 8.3.

Each factor and its corresponding characteristics may be temporally, spatially, and organizationally (or otherwise socio-culturally) dispersed, i.e., they may depend on time, space, and organizational context. The table cells in Table 8.3 describe if, to which degree, and in which specific way the contextual factors related to people, activities, context, and technology are distributed across time, space, and organizations.

To analyze contextual factors for a given project, designers will typically employ qualitative methods such as observations and interviews. An overview on relevant methods has been provided, for example, by Seffah et al. [170]. A more in-depth introduction to ethnographic methods in CSCW has been provided by Harper [94]. Detailed methodological advice is furthermore given in related textbooks, compare for example Holtzblatt et al. [101] for ethnographic methods in usability engineering and Mayhew [139] for in-depth descriptions of a broad range of usability engineering methods.

The grid-like visualization can support the analysis of contextual factors in two ways. Firstly, the tabular grid provides an overview on relevant research questions that designers should address in their analysis of contextual factors – compare the questions formulated in each table cell of Table 8.3. Secondly, the tabular grid provides structure for documenting the results of corresponding contextual analyses. For example, the contextual factors of the three motivational scenarios described in the previous section have been documented as shown in Table 8.4 and as described in the following.

| Contextual Factors | Dispersal | | |
|---|---|---|---|
| | Temporal | Spatial | Organizational |
| **People** | Do users vary over time? | Are users spatially dispersed? | Are users part of different organizations? |
| **Activities** | Are collaborative tasks performed at same or different times? | Are collaborative tasks performed at same or different locations? | Are collaborative tasks performed by users in different organizations? |
| **Context** | Do usage contexts vary over time, e.g., as in ubiquitous collaboration? | Do usage contexts depend on different locations? | Do usage contexts depend on different organizations? |
| **Technology** | Does use of technology vary over time? | Does use of technology depend on different locations? | Does use of technology depend on different organizations? |

**Table 8.3:** Overview of contextual factors, understood as temporally, spatially, and organizationally dispersed characteristics related to people, activities, context, and technology.

**Characteristics of the Medical Documentation Scenario.** In the medical documentation scenario (see Table 8.4a), collaboration is largely time-invariant. The same doctors and nurses worked together at the same time; their tasks, context, and use of technology did not vary over time. Collaboration was spatially dispersed across two rooms, requiring staff to communicate across rooms (i.e., the observed shouting and lack of awareness). There was no fixed assignment of users and rooms. Instead, the same activities were performed in both rooms using the same, technical equipment. Although the medical staff was part of the same organization, their specific roles and activities heavily depended on their organizational roles of doctors and nurses. Doctors primarily documented their diagnosis and the prescribed treatment. Nurses performed the actual treatment on the patient and documented that treatment. Despite these differences, both user groups worked together using the same system and same documentation schema and therefore had to co-ordinate their concurrent work.

**Characteristics of the Customer Support Scenario.** In the customer support scenario (see Table 8.4b), collaboration may be asynchronous (e.g., correspondence via E-Mail) as well as synchronous (e.g., live assistance during form filling). Users of the system are strictly split into two organizational groups. Support staff works at callcenters whereas customers may be at arbitrary locations. Support staff provides support, whereas customers are in need of support. The corresponding usage contexts and technology use are also very different. In contrast to the support staff's fixed working conditions, the customers' location and usage context (e.g., mobile vs. desk-bound) and use of technology (e.g., smartphone vs. personal computer) may change over time.

**Characteristics of the Government Administration Scenario.** In the e-government scenario (see Table 8.4c), collaboration takes place face-to-face over a shared desk or counter and across sharp organizational boundaries. This implies different activities, context, and use of technology by citizens (in front of the desk) and officers (behind the desk). Citizens primarily provide form data,

| **a) Medical Documentation Scenario** | Dispersion | | |
|---|---|---|---|
| | Temporal | Spatial | Organizational |
| People | Constant | Two rooms | Doctors and Nurses |
| Activities | Same-Time Collab. | Two rooms | Doctors and Nurses |
| Context | Constant | Constant | Constant |
| Technology | Constant | Constant | Constant |

<table>
<tr><th rowspan="2">b) Customer Support Scenario</th><th colspan="3">Dispersion</th></tr>
<tr><th>Temporal</th><th>Spatial</th><th>Organizational</th></tr>
<tr><td>People</td><td>Constant</td><td rowspan="4">Callcenter vs. arbitrary client locations</td><td rowspan="4">Customers requiring support, vs. Callcenter staff providing support</td></tr>
<tr><td>Activities</td><td>Both Same-Time and Asynchr. Collab.</td></tr>
<tr><td>Context</td><td rowspan="2">Customers' usage context may change.</td></tr>
<tr><td>Technology</td></tr>
</table>

<table>
<tr><th rowspan="2">c) Face-to-Face e-Government Scenario</th><th colspan="3">Dispersion</th></tr>
<tr><th>Temporal</th><th>Spatial</th><th>Organizational</th></tr>
<tr><td>People</td><td>Constant</td><td rowspan="4">In front of vs. behind the desk</td><td rowspan="4">Citizens vs. Officers</td></tr>
<tr><td>Activities</td><td>Same-Time Collab.</td></tr>
<tr><td>Context</td><td>Constant</td></tr>
<tr><td>Technology</td><td>Constant</td></tr>
</table>

**Table 8.4:** Contextual factors of the three motivational scenarios, documented using the novel framework proposed in this work and shown in Table 8.3. The above table shows how contextual characteristics related to people, activities, usage context, and technology are different for each scenario (a-c) and are differently dispersed across time, space, and organizations.

but officers may also enter data that has been verbally communicated to them by a citizen. Officers not only assist citizens, but may also question and correct their data, as typical for authoritative communication in bureaucratic settings.

In summary, the above textual scenario descriptions provided systematic summaries of relevant contextual characteristics. The tabular overviews in (Table 8.4) demonstrate that the proposed grid-like structure is well-suited for visualizing and summarizing the contextual characteristics of different collaborative scenarios. Note that specific design implications of the above scenario characteristics will be discussed in Section 8.6.3.

| Functionality | Temporal Dispersal | Products reviewed |
|---|---|---|
| Communication | Different time | Email Clients: Apple Mail, Gmail. |
| Communication | Same time | Instant Messengers: Skype, Adium. |
| Communication & Sharing | Different time | Web-based forum: PhpBB. Wiki: MediaWiki |
| Communication & Sharing | Same time | Video telephony: Skype. |
| Communication & Sharing | Same & different time | Documents: Google Docs, Etherpad. |
| Coordination | Different time | Calendars: iCal. Meeting planner: Doodle. |
| Coordination & Sharing | Different time | Software project management: Redmine, Trac. |
| Sharing | Same & different time | File Sharing: Dropbox. |

**Table 8.5:** Review of groupware products. Two designers used and reviewed the above 14 popular groupware products with different collaborative features and different temporal characteristics. This allowed to identify practicable and relevant design options.

## 8.5 Design Space Analysis

Since collaborative form-based UIs can been designed in various ways, it is important to shed light on available design options. This section provides a structured list of UI design options derived from related work and from a review of collaborative products. The list of UI design options can inspire designers of collaborative web forms to create a large variety of multi-user form filling experiences. Corresponding design decisions should be informed by an analysis of contextual factors, as described in the previous section. The distinctions made in the following list of options can also provide concepts and vocabulary for analyzing existing solutions.

### 8.5.1 Methodology

Design space analysis is a systematic method for exploring and describing possible designs, as well as for documenting the design rationale why a certain design was chosen. MacLean et al. [133] proposed a semi-formal notation for design spaces, consisting of questions, options, and decision criteria. Questions group design options into coherent topics, e.g., "how can I provide awareness about concurrent activities?", or "should individual characters or entire form fields be synchronized amongst users?". Options provide possible answers to these questions. Decision criteria assess and evaluate options regarding specific requirements and contextual factors of a given project. The design space analysis presented in this work can be described in MacLean et al.'s terms as consisting of questions and options – decision criteria were intentionally omitted because they depend on specific projects, whereas the design space analysis is intended for general use.

Methodologically, an initial list of design options was derived from related literature and by reviewing popular groupware products. The list of options was iteratively refined, completed, and re-structured. The following text details the methodological steps; the resulting options are presented in the next subsections.

*Literature survey:* A literature review of existing groupware taxonomies (compare Section 8.3) provided a good starting point because the taxonomies provide major decision points for designers of collaborative web forms. The resulting list of design options was extended by reviewing system papers about collaborative web forms. Systematic, rigorous analyses of design options were particularly found in Gaubatz et al. [75] and Jacobs et al. [110].

| Design Question | Design Options |
|---|---|
| Awareness and Notifications | Online status, notifications of concurrent activities, additional communication channels, pointing facilities, metadata. |
| Granularity | Individual characters or keystrokes, words or sentences, form fields, form sections, entire form contents. |
| Locking | Automatic locking, manual locking, avoid locking |
| Merging | Transparent merging, expose merging to the user |
| Access Control | Constraining access to data, metadata, and functionality. Form fields may be fully shown, locked, masked, or hidden. |
| History, Versioning and Undo | Time-based, user-based, object-based histories. |
| Co-Browsing and Navigation | "What You See is What I See" vs. independent navigation. |

**Table 8.6:** Summary of the proposed design space, consisting of 7 design questions and 28 design options for UI and interaction design in collaborative form filling.

*Review of existing products:* To further complement the list with practicable, industrially relevant design options, we reviewed the UIs of 14 existing products of 8 types of groupware, see Table 8.5 for an overview. We purposely did not review form-based applications at this stage in order to be able to transfer design options from other groupware to the design of collaborative web forms. The taxonomy by Penichet et al. [150] provided a way to systematically choose products with diverse collaborative features (i.e., information sharing, communication, and coordination) and diverse usage contexts (synchronous vs. asynchronous collaboration); compare Table 8.5 for the list of chosen products. Note that we did not separately review products with different spatial usage contexts because most products could be used in both 'same space' and 'different space' usage contexts. We aimed at choosing popular products for each product type because we wanted to find well-established and practicable design options. Popularity was informally assessed by searching the internet for recommendations. To review the chosen products, two designers (the author of this thesis and a student in HCI) walked through the UIs of each product, taking notes about UI design options. For example, to review a synchronous communication tool, the popular product Skype was chosen. Designers used those features advertised as main use cases on the product's website and took notes regarding UI design options, e.g., regarding different ways of visualizing a user's online status.

*Towards design options for collaborative web forms:* The designers then creatively sought solutions for how (if at all) the previously identified design options could be applied to form design. The list of design options was complemented by considering opposite designs and by relating options to existing literature. The list was restructured in several iterations to improve clarity, eliminate duplicates, and balance the grouping of design options. As stated in the introduction, many of the below considerations and UI design options are not new from a CSCW perspective, but related work has not provided a systematic and comprehensive overview and the specific application of design options to form design has so far been unclear.

The resulting list of options for UI and interaction design of collaborative, form-based UIs (see Table 8.6 for a summary) can inspire designers to create a large variety of multi-user form filling experiences. Corresponding design decisions should be informed by an analysis of contextual factors as described in the previous section. The distinctions made in the following list of options can also provide concepts and vocabulary for analyzing existing solutions.

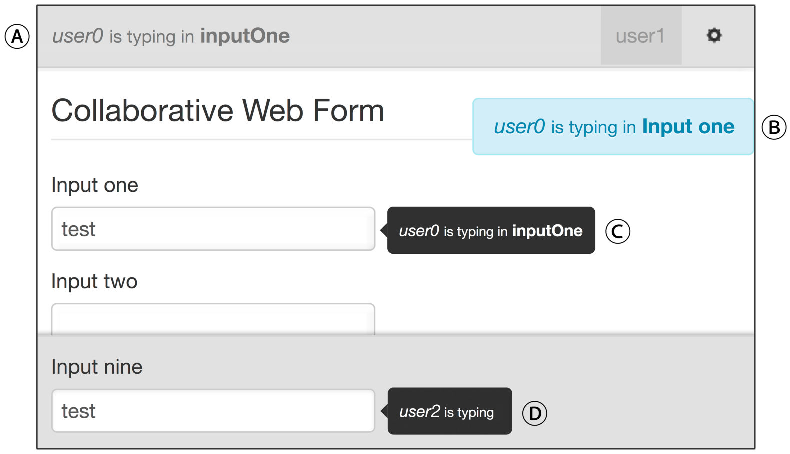



**Figure 8.2:** Design options for providing awareness about concurrent activities: (A) notification bar and (B) notification bubbles, (C) notifications attached to form fields, and (D) special top and bottom notification bars for when changes happen outside the scrolling viewport.

### 8.5.2 Options for Awareness and Notifications

Awareness has been defined by Dourish et al. [59] as "an understanding of the activities of others, which provides a context for your own activity". Related work by Steinfield et al. [175] has distinguished various aspects that users need to be aware of: activities (current and past), availability of other users, progress of workflows, other team member's knowledge and beliefs, and the outside environment. The user need for awareness is evident in all three motivational scenarios. The medical scenario described staff shouting across rooms due to lack of awareness of concurrent activities. In the customer support scenario, support staff needs to be aware of user activities to be able to help. In the e-government scenario, citizens and officers need to be aware of the data that each can contribute for filling a government form. Design options for providing awareness in collaborative form filling include the following.

*a) Online status* is one of the most basic options for providing awareness information. For example, users may set their status to 'online', 'available', 'not to be disturbed' or 'invisible'. The online status may additionally display the device a user is currently using (e.g., 'mobile' or 'desk-bound') and the user's availability status, compare Hincapié-Ramos et al. [99]. Online status may furthermore be integrated with or derived from social networks, as proposed by Schuster et al. [165] using the concept of "pervasive social context".

*b) Notifications of concurrent activities* may display editing operations performed by other users and remote cursor events (i.e., mouse or text cursor positions of other users). Beware that from a technical point of view, not all synchronization libraries provide such information, compare Koren et al. [124]. Notifications may be displayed in a single notification area or next to each affected form field. Additionally, notifications for form fields that are outside a user's scrolling viewport may be displayed in notification bars to draw attention to those other areas of the form. See Figure 8.2 for examples.

*c) Additional communication channels* such as chat, comments, and messaging, as well as user-configurable notification systems can also foster awareness by enabling meta-communication without directly affecting the primary artifact that users work on.

*d) Pointing facilities* such as the ability to highlight regions in the user interface can provide additional awareness about what a collaboration partner is currently working on.

*e) Metadata* such as last-edited-by information or locked artifacts can provide awareness in both synchronous and asynchronous usage contexts.

### 8.5.3 Options for Granularity

The granularity of collaboration is the size of the smallest units of content that users can collaboratively edit. In collaborative web forms, the granularity can be designed as follows.

*a) Individual characters* or keystrokes are the finest granularity. This is often encountered in synchronous collaboration and 'same time' task characteristics.

Larger granularities include *b) words or sentences* and *c) form fields*. The 'form field' granularity means that a form field is only synced when a user leaves the field.

Even larger granularities include *d) form sections*, *e) and entire form's contents*, as typical for conventional web forms.

Note that form-based collaboration may also designed with *e) multiple granularities*. For example, users and support staff in the customer support scenario collaborate in real-time using a fine 'character' or 'form field' granularity until the entire form is submitted to the insurance company using the coarsest 'entire form' granularity.

### 8.5.4 Options for Locking

Concurrent editing conflicts can be avoided by locking artifacts so only one user can edit them at any given time.

Amongst the design options, *a) automatic locking* allows to prevent editing conflicts by automatic placement of locks. One positive side effect is that locked artifacts can provide awareness about other user's activities. But this option has also been criticized for use in synchronous collaboration because it is difficult to determine when locks should be placed and released, compare Ellis et al. [64].

*b) Manual locking* allows users to explicitly place locks on artifacts. This option can be useful to avoid large merges after asynchronous or offline editing. Nonetheless, editing conflicts may still occur should users forget to place locks, in which case either the system or the user would have to revert or merge changes. Also, non-compliant users may refuse to remove locks, thus blocking other users, as described by Ellis et al. [64].

Lastly, designers may choose to *c) avoid locking* and allow concurrent editing of the same artifact. As with the previous options, some sort of merging will be required. This option has been recommended for synchronous collaboration by Ellis et al. [64].

Note that concurrency control is not the sole purpose of locking. Instead, form-based UIs may be designed to use *d) locking for access control*, i.e., to lock certain form fields that a user is not entitled to edit, as suggested by Gaubatz et al. [75] in a medical context and by Jiang et al. [115] in the context of business administration.

### 8.5.5 Options for Merging

To resolve editing conflicts, collaborative web forms need to merge changes.

From a user interface and interaction design perspective, designers may choose *a) transparent merging* to hide the complexity of manual merging from the users. The system will then have to resolve editing conflicts automatically, e.g., by using operational transformation[1]. Transparent merging has been recommended for real-time collaboration by Ellis et al. [64]. Since transparent merging is performed automatically by the system, it may be important for users to see who authored which form data. This may be achieved by visualizing authorship, e.g., using different text colors for each author.

Given other contextual characteristics, it may however be necessary or desirable for designers to *b) expose merging* to the users, thus making the underlying mechanisms for concurrent editing visible. For instance, users may be shown conflicting versions and be allowed to resolve editing conflicts as needed. Corresponding functionality is, for example, typically provided in source code revision control systems.

### 8.5.6 Options for Access Control

Role-based access control has emerged as a standard solution to model permissions and scopes of duty in information systems, compare Sandhu et al. [160] for an introduction. This principle has recently been applied to collaborative web forms by Gaubatz et al. [74–76]. Previous papers have taken a conceptual and software architecture point of view; in contrast and addition, this work focuses on UI design options.

Constrainable elements (i.e., UI elements or actions requiring certain roles and permissions) in collaborative, form-based UIs include: *data* contained in specific form fields or sections, *metadata* such as awareness information and editing histories, and *functionality* such as the ability to read and edit form fields and to click a button or otherwise trigger an action.

In order to constrain access to these elements in the UI, designers may choose to *a) hide* the respective element for unauthorized users, to *b) mask* the contents of a form field, e.g., by replacing characters with asterisks as in password fields, to *c) lock* a form field to enable reading but prevent editing, lock a button to disable triggering the underlying action, or, lastly, *d) fully show* a UI element, see Table 8.7 for visual examples.

The above UI design options are relevant in all three case studies. For example, form-based UIs in the medical documentation scenario very likely require customized views for different user groups, as well as constraints regarding who is allowed to sign form contents.

### 8.5.7 Options for the Editing History, for Versioning and Undo

The editing history of a collaborative web form can be characterized using time-related terms and concepts described by Aigner et al. [4]. Thus a history visualization consists of a linear time axis where time points correspond to actions triggered by a certain user and time intervals correspond to versions that each reflect the web form's state.

[1] The operational transformation (OT) algorithm, originally proposed by Ellis et al. [64], is now widely established to enable concurrent editing in groupware. Alternative algorithms such as CRDT have been proposed to better support decentralized system architectures, compare Ahmed-Nacer et al. [3]. But otherwise, OT-based algorithms have matured and have been shown to be formally correct regarding consistency, convergence, and undo semantics by Sun et al. [178]. An overview on available software libraries is given in Koren et al. [124].

| Option | Example UI Elements | |
|---|---|---|
| Fully Shown | text | Action |
| Locked | text | Action |
| Masked | •••• | *n/a* |
| Hidden | | |

**Table 8.7:** Design options for enforcing access control to form elements. Designers may choose to either fully show, lock, mask, or hide UI elements, as shown in the above graphics.

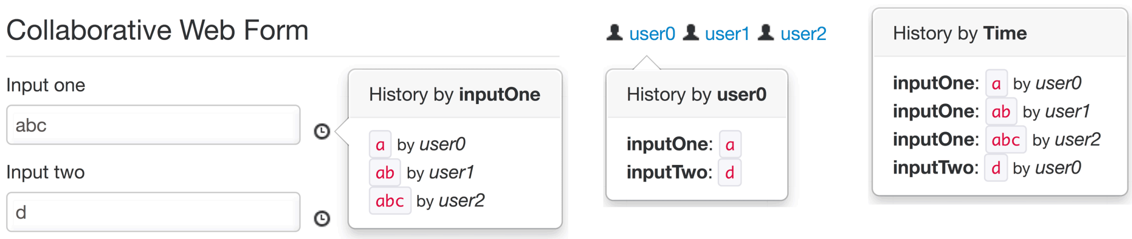



**Figure 8.3:** Design options for visualizing editing histories. A collaborative web form's editing history may be structured by time, user, or object, as shown in the above graphics.

From a UI design perspective, designers have many visualization options. Designers can structure the visualization based on three important dimensions: time, user, and object. *a) Time-based histories* sort actions or versions by time, as typical for providing undo functionality. *b) User-based histories* split time-based history into separate lists for each user, thus providing a way to keep users accountable. *c) Object-based histories* attach separate time-based histories to each artifact, e.g., to each field or section in a collaborative web form. These options are not mutually exclusive but can be combined. See Figure 8.3 for examples of different history visualizations.

Note that keeping track of a collaborative web form's editing history may also be required from a security perspective in order to keep users accountable for actions they perform in the system, compare Sandhu et al. [160] for a discussion of corresponding, security-relevant topics.

Keeping track of the editing history is furthermore a necessary condition for providing versioning and undo functionality. Note however that undo functionality in distributed systems is a complicated topic, compare Bueno et al. [30] and Weiss et al. [197] for recent discussions of distributed undo semantics and Koren et al. [124] for an analysis of undo support in technical collaboration libraries.

### 8.5.8 Options for Co-Browsing and Navigation

Long, form-based UIs require users to navigate. This can be achieved using various design patterns for navigation, including scrolling, tabs, menus, and collapsible fieldsets; compare Harms et al. [90, 92] and Chapter 7 of this work for corresponding studies. Hence collaboration in long, form-based UIs requires effective ways for multiple users to navigate. Related work has investigated this topic under the term "collaborative browsing", or shortly, "co-browsing". Jacobs et al. [110] has described four corresponding modes of interaction. Two modes distinguish between different granularities for the synchronization of form form contents, as previously discussed in Section 8.5.3. The other two modes describe the following two options for how navigation in long, collaborative, form-based UIs may be synchronized across users.

*a) "What You See Is What I See"* (WYSIWIS) corresponds to strictly synchronized navigation. All users see the same viewport, and the same form field is focused for all users at a time.

*b) An "independent document" mode* allows users to navigate independently – only the filled-out form contents are synchronized across users.

According to Jacobs et al. [110], independent navigation is usually preferred by users, "Empirical studies show that pure WYSIWIS sometimes is cumbersome. Users want to edit the same text but be more independent in navigation". Nonetheless, tightly synchronized navigation may prove useful in scenarios were only few users co-operate closely on a single artifact.

### 8.5.9 Discussion and Outlook

This section provided a systematic and comprehensive overview on options for UI and interaction design for collaborative form filling. The resulting design space consists of 7 topics with a total of 28 design options, see Table 8.6 for an overview.

The above section provides detailed descriptions of each option, as well as references to related work because many design options have been discussed in previous literature. The novel contribution (in contrast and addition to these prior works) is the design space's comprehensiveness, its focus on UI and interaction design, as well as application of many design options to form design.

The suitability of the various design options for specific projects with their respective characteristics must be investigated in future work – current research lacks corresponding guidelines and established best practices. Thus, to find out which design options are suited for a specific project, designers must evaluate and compare various design options. The next section addresses this need for iterative evaluation and comparison by proposing a rapid prototyping tool.

## 8.6 Rapid Prototyping Tool for Designing Collaborative Form Filling

One challenge for designers of collaborative web forms are the many design options available, as evident from the design space analysis presented in the previous section. Since there exist no clear guidelines or proven best practices regarding the respective benefits and implications of these design options within various usage contexts, designers must iteratively make, evaluate, and reconsider design decisions. One difficulty is that many of the available design options are time-consuming to implement. Efforts are even higher if iterative usability evaluations necessitate revisions of prior design decisions and thus re-implementations using other design options.

To better support iterative design and reduce prototyping efforts, this section puts forth a novel rapid prototyping tool that can easily be configured to support a large variety of design options. Figure 8.4 shows the tool from a user perspective. Figure 8.5 shows how designers can configure the tool with various design options.

### 8.6.1 Requirements

In order to allow designers to prototype and evaluate collaborative form filling in rapid design iterations, a corresponding prototyping tool should fulfill the following requirements.

*R1 – Collaborative Form Filling:* The rapid prototyping tool should allow multiple users to collaboratively fill the same form-based UI.

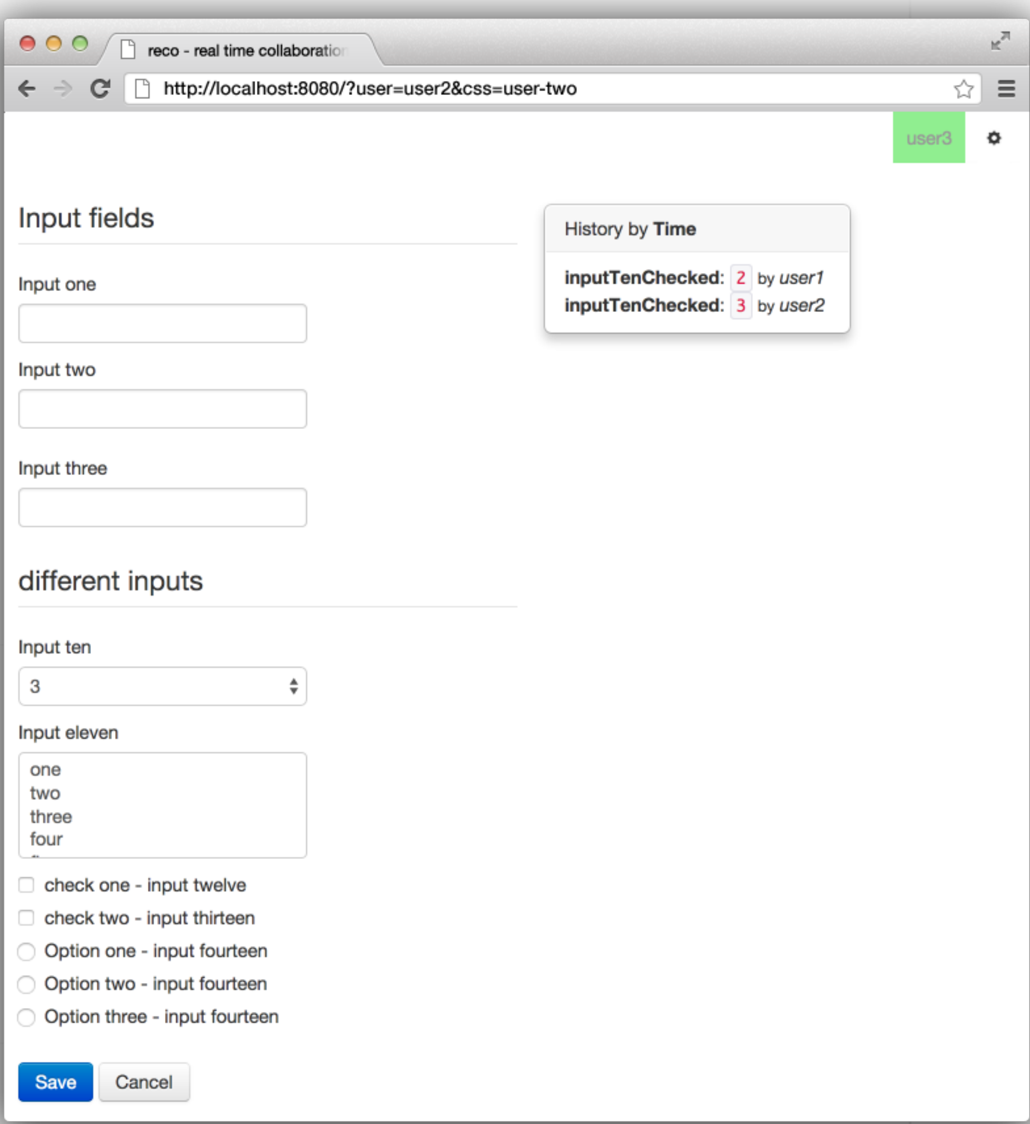



**Figure 8.4:** Screenshot of the rapid prototyping tool from a user perspective. As evident from the screenshot, the prototyping tool supports various kinds of form fields, including text inputs, dropdown lists, checkboxes, and radio buttons. The above screenshot also shows one option for history visualization, i.e., "history by time". The history shows that form field labelled "input ten" was edited by both "user 1" and "user 2".

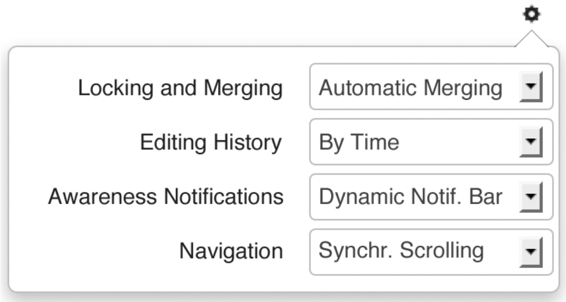



**Figure 8.5:** Screenshot of the configuration options offered by the rapid prototyping tool, as seen by designers. The configuration menu allows designers to easily configure options for four design questions, resulting in a total number of 72 possible configurations.

*R2 –* *Customizable Form Schema:* The tool should allow designers to implement arbitrary form schemas, as needed for the application they wish to prototype.

*R3 –* *Easy Configuration of Design Options:* The tool should support easy configuration of design options, i.e., it should provide implementations for the design options described in the design space analysis in Section 8.5.

*R4 –* *Abstraction and Modularization:* To enable dynamic configuration of design options, the rapid prototyping tool should use modular, exchangeable implementations for each customizable aspect.

*R5 –* *Web Technology:* To make the rapid prototyping tool usable on a wide range of desktop and mobile devices, it should be implemented using web technology.

*R6 –* *Neutral, Customizable Appearance:* The tool should have a state-of-the-art visual appearance, but should be rather neutrally styled (as opposed to unusual or eye-catching designs). It should be easy for designers to modify the prototype's visual appearance, as needed for a specific project or application.

### 8.6.2 Implementation

A rapid prototyping tool that meets the above requirements has been implemented. The tool is publicly available [W19] under the MIT open source license. In its current implementation, it fulfills all of the above requirements, but only implements a subset of design options.

The prototyping tool allows multiple users to collaborate in real time through a form-based UI (Requirement 1). Designers can customize the form schema (Requirement 2) by adapting HTML code, allowing them to implement arbitrary form schemas.

Various design options for collaborative form filling can easily be configured through the tool (Requirement 3). For this purpose, the tool provides a drop-down menu where designers can choose amongst multiple design options, see Figure 8.5 for a screenshot. Not all design options described in the design space analysis have been implemented yet. The UI for configuring those options that have been implemented has been structured to allow any combination of $4 \times 3 \times 3 \times 2$ options, resulting in a total of 72 possible configurations. The specific options implemented in the rapid prototyping tool include three options for merging and locking, three types of history visualizations, four types of notifications to provide awareness about concurrent editing, and two options for navigation, as summarized in Table 8.8.

| Design Question | Implemented Options | N |
|---|---|---|
| Awareness and Notifications | Online status. Notifications of concurrent activity through one of four options: a static notification bar, a dynamic notification bar that visualizes changes outside a user's current viewport, global notification bubbles, or notification bubbles attached to specific form fields. | 4 |
| Granularity | Individual characters. | – |
| Locking and Merging | automatic locking, automatic merging, or automatic merging with color-coded visualization of authorship. | 3 |
| Access Control | Not yet implemented. | – |
| History, Versioning and Undo | Time-based, user-based, or object-based history. | 3 |
| Co-Browsing and Navigation | Independent navigation or synchronized scrolling. | 2 |

**Table 8.8:** Configuration options implemented in the rapid prototyping tool. The above design options can be configured by designers to quickly prototype and evaluate $4 \times 3 \times 3 \times 2 = 72$ possible configurations for collaborative form filling.

All design options were implemented in a modular way (Requirement 4). This allows designers to dynamically re-configure the prototyping tool with the desired design options. This furthermore provides the basis for future work to extend the tool with additional design options.

The tool is implemented using web technology (Requirement 5), i.e., it uses HTML, JavaScript, and CSS for the user interfaces, program logic, and styling, respectively. The specific JavaScript frameworks that were used in the tool are Require.js [W27] for modularization of program code, Socket.io [W32] for synchronizing changes across clients, and Knockout.js [W20] for binding the user interface to a data model. The visual appearance of the user interface was created using the Bootstrap [W10] CSS framework. The framework's default theme has a modern, but rather neutral, grayish appearance. Designers can easily modify this default appearance (Requirement 6) by either choosing another Bootstrap theme – for example, see the Bootswatch.com website [W11] for a list of free themes – or by using custom CSS code.

### 8.6.3 Intended Use

To use the rapid prototyping tool, designers should first analyze the contextual characteristics of their project or scenario. They can use the tabular overview presented in Section 8.4 for this purpose. The tabular overview firstly provides a systematic research agenda and secondly provides structure for documenting corresponding findings.

Designers can then use the design space analysis presented in Section 8.5 for inspiration. The design space contains important design questions to be considered. Designers can decide easy and un-ambiguous design questions based on contextual knowledge. Other questions may be difficult to answer and may thus require further investigation through empirical evaluations.

Methodological advice for planning and conducting such evaluations has been provided in related work. Pinelle et al. [153] reviewed prior evaluations and provided a good overview. Antunes et al. [10], Hamadache et al. [85], and Herskovic et al. [97] gave advice for when to choose which available method for groupware evaluation. Most importantly for the purposes of this work, the above authors uniformly recommended to start the design process with formative evaluations in a controlled environment. These early stages of the design process are where the rapid prototyping tool can be helpful.

The rapid prototyping enables designers to quickly create prototypes of real-time, collaborative form filling applications. Designers can use these prototypes to evaluate and compare various design options in early, formative evaluations. From a practical perspective, designers should first modify the form schema and styling to suit their specific project. They can then configure and comparatively evaluate various design options, allowing to gather empirical data based on which they can make well-grounded design decisions. As the prototype is refined throughout the design process, evaluations in more natural settings with users from the target group can provide more realistic feedback.

The remainder of this section provides examples how the rapid prototyping tool can be used in the three motivating scenarios described in Sections 8.2 and 8.4.

**Application in the Medical Documentation Scenario.** The contextual characteristics of the medical documentation scenario imply some easy-to-make design decisions. But other design questions are more difficult to answer. Designers can use the rapid prototyping tool to empirically evaluate the usability of corresponding design options.

Design questions regarding awareness and navigation are easy to answer based on knowledge about the scenario's contextual characteristics. The scenario description clearly indicates a need for more awareness and suggests that users would benefit from notifications about concurrent activities. But since the users collaborate at close locations and do not typically fill the same set of form fields, additional design options for providing awareness (e.g., online status, additional communication channels, or pointing facilities) are unlikely to be needed. Regarding navigation, the fact that doctors and nurses independently document different parts of the form schema clearly suggests to enable independent navigation (as opposed to the "What You See Is What I See" design option).

The rapid prototyping tool can help designers to answer other, more difficult design questions. For example, it is unclear if editing conflicts should rather be prevented using locking or resolved using merging. Also, requirements regarding fine-grained access control are likely to exist, but should be investigated in more detail. Furthermore, different history visualizations could prove beneficial for different use cases, for example a history of a patient's diagnoses and treatments versus a history of a staff members' editing actions. The rapid prototyping tool allows to investigate the above design questions as follows. Designers can configure design options in the tool, allowing to evaluate their respective benefits and demonstrate and discuss the functionality with users of the medical documentation scenario.

**Application in the Customer Support Scenario.** Contextual characteristics of the customer support scenario suggest the following design decisions. Regarding awareness, a visualization of online status is needed to make users aware that live support is available and to make support staff aware of users who may currently need help. Given that users and support staff are at different locations, an additional communication channel is essential to enable clarification of customer questions and potential misunderstandings. Since support sessions are typically short-lived, a small, keystroke-level granularity and automatic merging of changes are suitable design options for supporting quick, real-time cooperation. For the same reason, visualizations of editing histories are unlikely to be needed.

The design question how navigation should be realized is more difficult to answer. The "What You See Is What I See" principle has the benefit that both customers and support staff see the same form fields at any given time. But independent navigation would allow them to quickly navigate to other form sections (e.g., to look up a value) without disturbing the collaboration partner. The rapid prototyping tool can support corresponding investigations about how navigation should be realized in this scenario.

Furthermore, access control is very likely needed in the customer support scenario to prevent the support staff from seeing passwords or other sensitive information. The prototyping tool could be extended to support configuration of corresponding design options, including masked text, disabled actions, and hidden form elements.

**Application in the Government Administration Scenario.** Contextual characteristics of the e-government scenario and particularly the fact that collaboration takes place as part of face-to-face communication implies the following design decisions. Regarding awareness, a visualization of online status and additional communication channels are not required since the two collaboration partners can easily talk to each other. The speed and spontaneity of face-to-face communication suggests that small granularities and transparent merging should be used so that form data is instantaneously synchronized between citizen and officer. Regarding access control, the officer should see all data entered by the citizen, but certain form fields (typically labelled "for office use only" on paper forms) should be hidden from the citizen. Visualizing the editing history is not necessary because both users watch closely as they collaborate on the same artifact.

The rapid prototyping tool can be used to clarify other design questions in the government administration scenario. For example, the system could strictly synchronize navigation between the two users. This would ensure that both users see the same form data and thus provides additional awareness. In contrast, enabling independent navigation would offer unconstrained navigation to collaborating users but would require additional means of providing awareness, e.g., through pointing facilities.

## 8.7 Discussion and Future Work

The work presented in this chapter aims at supporting the design of collaborative, form-based UIs. Towards this goal, it contributed a design space analysis and a rapid prototyping tool.

The design space analysis describes relevant design questions and corresponding design options. In contrast and addition to prior work, it provides a comprehensive overview, focusses on aspects related to UI and interaction design, and describes design options that are relevant for form-based UIs. Designers can use the options described in the design space for inspiration. Future work should seek to identify best practices, i.e., specific combinations of design options that work well for scenarios with certain contextual characteristics. In the present situation, it remains unclear which design options work best in which contexts, and which combinations of design options work well together. Designers can circumvent the current lack of best practices by using the proposed rapid prototyping tool.

The rapid prototyping tool allows designers to quickly configure various options for four design questions, resulting in total number of 72 possible configurations. The intended use of the rapid prototyping tool is for comparative evaluation of the configured design options. Such evaluations provide designers with empirical data based on which they can make well-grounded design decisions. To illustrate the intended use of the rapid prototyping tool, the above sections provided three examples for how the tool can be used in three scenarios that involve collaborative form filling.

Future work in co-operation with Sütcü [179] is planned in order to practically employ the rapid prototyping tool in a case study. The case study will investigate face-to-face collaboration between citizens and officers, similar to the government administration scenario described in this chapter. This will allow to gather practical experience and to formulate qualitative lessons learned regarding the applicability and usefulness of the rapid prototyping tool. Future work could also extend the tool with additional design options described in our design space analysis.

## 8.8 Conclusion

The work presented in this chapter addresses designers' needs for creating collaborative form filling experiences. Specifically, a comprehensive overview on available design options is needed by designers, as well as tools to enable rapid prototyping. The design space analysis contributed in this chapter provides one such systematic and comprehensive overview. It describes many important design options that can be chosen by designers of collaborative, form-based user interfaces. Corresponding design decisions are supported by the second contribution of this chapter, i.e., a novel rapid-prototyping tool. The tool allows for quick configuration (instead of time-consuming implementation) of many design options described in the design space analysis. The benefit for designers is that they can quickly create and evaluate prototypes in order to make empirically grounded design decisions.

In summary, the design space analysis can inspire innovative, collaborative, form-based UI designs and the proposed rapid prototyping tool supports iterative design and firmly grounded design decisions. Future work should extend the prototyping tool with additional design options and evaluate its usefulness and applicability in real-world case studies.

# 9 Gamification: A Novel Design Process and Empirical Evaluation Results for Gamifying Online Surveys

**Chapter Summary.** The work presented in this chapter seeks to improve the hedonic qualities of form-based user interfaces – specifically of those employed in online surveys. Online surveys are an important means of data collection in marketing and research, but conventional survey designs have been perceived as dull and unengaging. In consequence, survey results have been afflicted by negative respondent behavior. Gamification has therefore been proposed for making online surveys more pleasant to fill and, consequently, for improving the quality of survey results. Related studies on gamified online surveys have primarily sought to demonstrate beneficial psychological and behavioral outcomes. While these are worthwhile goals, prior work has been unclear about methodological aspects and suitable design processes.

This chapter discusses conceptual foundations of gamified online surveys in terms of relevant design dimensions as well as critical issues concerning validity. It then contributes a design process for survey gamification based on the MDA (mechanics, dynamics, aesthetics) framework. The process was employed and evaluated in two case studies. Firstly, to gamify an existing survey about sports and leisure activities amongst teenagers and young adults. Secondly, gamifying the same survey using a low-cost variant of our process resulted in lower efforts and a higher return-on-investment.

## 9.1 Introduction

The use of forms for surveying information from a large population has a long historical tradition dating back to the 16th century when officers in Spanish provinces were equipped with questionnaires to standardize interviewing and observations, as described by Eisermann [63]. These questionnaires enabled bureaucratic processes by abstracting individual life experiences into consistent, standardized representations, compare Becker [20] and Chapter 3 of this work for detailed explanations. Historical forms share these characteristics, i.e., their common use for surveying standardized information, with today's online surveys.

Understanding the history of online surveys provides ample opportunity for innovation. Form-based user interfaces in general have been criticized by Harms [88] for being reminiscent of static paper forms instead of using the interactive possibilities of software. The specific form-based UIs that are typically used in online surveys have been criticized by Downes-Le Guin et al. [60] and Puleston [156] for being dull to fill – hence the motivation for gamification.

Research about gamified online surveys can be described using a historical perspective and using our metaphoric understanding of form-based UIs (compare Chapter 4) as follows: Gamification of online surveys seeks to avoid negative historical entailments of the 'form' UI metaphor, in particular the connotations that forms are bureaucratic and dull, by employing game elements in the non-game context of web surveys.

**Motivation.** Gamification of online surveys has been proposed to make questionnaire filling a less boring and more enjoyable experience. This is an important goal because online surveys have been criticized for their dullness resulting in negative respondent behavior such as speeding, random responding, premature termination, and lack of attention, compare Downes-Le Guin et al. [60] and Puleston [156]. In contrast to these negative effects, evaluations of gamified surveys by Cechanowicz et al. [37], Dolnicar et al. [56], Downes-Le Guin et al. [60], and Puleston [156] have reported diverse psychological and behavioral benefits regarding user experience, motivation, participation, amount and quality of data. These prior studies largely confirm the usefulness of gamified surveys but have remained unclear about suitable design methods and best practices.

**Summary of Contributions.** The work presented in this chapter provides methodological support for designers who wish to employ gamification in survey design. More specifically, it contributes a novel design process for survey gamification that was successfully employed and evaluated in two case studies.

**Structure of Work.** The remainder of this chapter is structured as follows. Sections 9.2 and 9.3 summarize prior work on gamified online surveys and analyze conceptual foundations from a design perspective. This provided the basis for proposing a design process for gamifying online surveys in Section 9.4. The process was first published by Harms et al. [93] and was subsequently evaluated in two case studies. In the first case study, the process was employed to gamify an existing online survey about sports and leisure activities of teenagers and young adults, see Section 9.5, originally published by Harms et al. [89]. In the second case study, we proposed and evaluated a low-cost variant of the same process and were thus able to reduce the required effort and improve the return-on-investment, see Section 9.6, originally published by Harms et al. [91].

## 9.2 Related Work

The past decades have seen a rise of the digital game medium in large parts of western societies, including entertainment, industry, and research, compare Seaborn et al. [167] for a corresponding introduction. This has motivated research and industry to adopt gameful and playful design for other purposes beyond entertainment. Gamification is an important strategy in this direction. Its industrial relevancy is evidenced, e.g., by Gartner's annual "Hype Cycle" ratings of current technology where gamification was placed on the very top of the hype curve in 2013 [W15]. Related research in the area of gamification has recently been summarized by Seaborn et al. [167]. This section also provides an overview on gamification literature, but with a more specific focus on gamified online surveys.

### 9.2.1 Gamification

Gamification has been defined by Deterding et al. [49] as "the use of design elements characteristic for games in non-game contexts". This definition provides two important distinctions, allowing to contrast gamification against other approaches, as shown in Figure 9.1. Accordingly, gamification may be distinguished from playful approaches because gamification and games involve rules and goals. This is in contrast to playful design and toys that afford a more free-form type of behavior. The second distinction allows to distinguish gamified systems from full-fledged games. Gamified systems only selectively employ design elements characteristic for games, but otherwise maintain their non-game context and purpose. Non-game contexts have included commerce, education, health, business, government, many more listed by Hamari et al. [87] and Seaborn et al. [167], and – of primary interest for this work – online surveys.

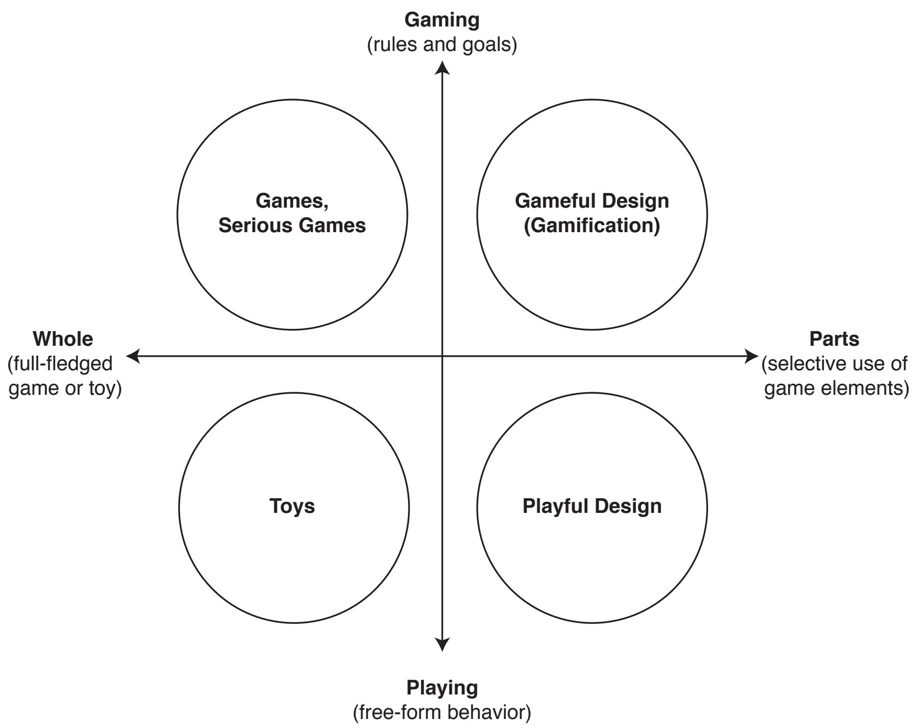



**Figure 9.1:** Definition of gamification. Deterding et al.'s definition of gamification [49] as "the use of design elements characteristic for games in non-game contexts" allows to contrast gamification against playful approaches and against full-fledged games or toys. Figure adapted based on [49].

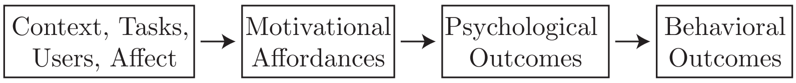



**Figure 9.2:** Outcomes of gamification may be understood as psychological and behavioral effects of game elements provided as motivational affordances, as described by Hamari et al. [87]. These outcomes are potentially influenced by a-priori factors such as context, tasks, user characteristics, and affect. Figure adapted based on Harms et al. [89].

Potential outcomes of gamification have been studied in Hamari et al. [87]'s excellent literature review. Outcomes can thus be classified into psychological (e.g., user experience, emotion, fun) and behavioral (e.g., participation, performance) effects of providing game elements as motivational affordances. In Figure 9.2, we additionally included a-priori factors such as context of use, user characteristics, and affect because these factors have been shown to significantly influence the outcomes of gamification in Hamari's literature review.

### 9.2.2 Influence of Contextual Factors

Hamari et al.'s literature review [87] has shown that benefits of gamification have been strongly influenced by contextual factors. This general observation is particularly true for online surveys. For example, Mavletova [138] found a significant influence of childrens' age on how they respond to a gamified survey. Further extraneous factors have been shown to influence non-gamified surveys; they will most likely influence gamified surveys as well. For example, Christensen et al. [41] and Paraschiv [149] found that the day of week when the invitation to participate in a survey was sent influenced the response rate. Kaminska et al. [119] found a correlation between the participants' cognitive ability and satisficing[1], whereby lower ability increased satisficing and subsequent negative respondent behavior. Keusch [121] investigated effects of gender and found that invitations sent by females increased the response rate amongst a pre-dominantly male target population. In summary, the above findings call for future studies to clearly state characteristics of the usage context, of the target user group(s), of the users' affect or emotional state (e.g., feeling happy, skillfull).

### 9.2.3 Statistical Error in Online Surveys

Innovative survey design should pay careful attention to data quality – this recommendation has applied to the time when telephone surveys were newly developed as well as to the more recent rise of web surveys, compare Dillman et al. [50]. The same recommendation also applies to current innovations where surveys are enhanced through gameful or playful design elements. Given that gamification can improve but also worsen data quality, the topic of statistical error is of primary importance for gamified online surveys.

A systematic conceptual framework for understanding and analyzing statistical error and data quality in surveys is Groves et al. [80]'s "total error framework". It provides an overview on all components of statistical error that may afflict survey results, see Figure 9.3. A survey's total statistical error is thus composed of two chains of error components, measurement error and representation error, visualized in the left and right side of Figure 9.3, respectively. Measurement error stems

[1] The term 'satisficing' is a portmanteau referring to a survey respondent's attitude and consequent behavior to just about *satisfy* what *suffices* to fill the survey, compare Kaminska et al. [119]. For example, a respondent may provide thoughtless answers that suffice to satisfy the requirements for being able to proceed to the next survey page.

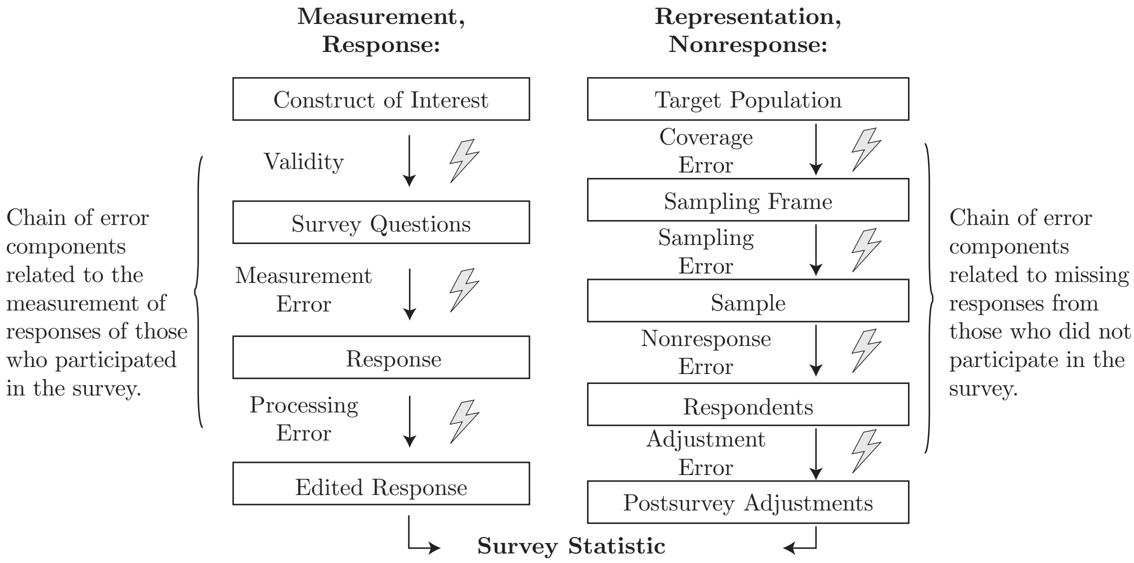



**Figure 9.3:** The total error framework by Groves et al. [80] decomposes a survey's total statistical error into various error components (visualized as gray errors) related to either measurement or representation. Concept based on Groves et al. [80], graphic modified based on Harms et al. [93].

from wrong answers; representation error stems from missing answers or answers by the wrong persons. The following paragraphs will briefly summarize all error components. Please refer to the excellent books by Groves et al. [80] and Tourangeau et al. [187] for more detailed descriptions and mathematical definitions of each error component.

**Measurement.** One chain of error components relates to measurement; it encompasses all statistical error introduced during the collection of answers. To collect answers through a survey, researchers first define the construct of interest that they want to measure, then formulate corresponding survey questions, gather survey responses, process the data, and finally compute a survey statistic. The 'measurement' chain of error components is composed of mismatches along these activities, i.e., mismatches between the construct of interest that researchers aim to investigate, the questions asked in the survey, the responses obtained from survey participants, and the data used for calculating the survey statistic, see the left side of Figure 9.3.

*Validity*, or lack thereof, refers to a mismatch between the construct of interest that researchers aim to investigate and the questions asked in the survey. One example of a lack of validity is when researchers badly formulate a question that, even if truthfully answered by respondents, does not provide valid data about the researcher's construct of interest.

*Measurement error*, the second error component in the cain, refers to a mismatch between ideal and actual answers. Such a mismatch may be the consequence of a respondent's mis-interpretation of a question, but may also result from a satisficing attitude and consequent negative respondent behavior. For example, respondents may provide quick, mindless, possibly contradictory answers or deliberately provide false information.

Lastly, *processing error* refers to a mismatch between the answer provided by respondents and the data used for estimation of the survey statistic. For example, researchers may mis-interpret a free-text answer or mistakenly correct an outlier.

**Representation.** A second chain of error components relates to representation, i.e., to how well the data obtained from the survey represents the target population. When conducting a survey, researchers first define the target population (about whom they want to investigate a certain construct of interest), then choose a sampling frame (e.g., every household), choose a sample (e.g., every tenth household), collect responses (some households may not respond at all), and perform post-survey adjustments prior to calculating the survey statistic. The chain of 'representation' error components is composed of mismatches along these activities, i.e., mismatches between the target population, the sampling frame chosen by researchers, the sample of people invited to participate in the survey, the subset of people who responded to the survey, and error introduced through post-survey adjustments, see the right side of Figure 9.3.

*Coverage error* results from a badly chosen sampling frame. For example, if a survey's target population are all adults living in a specific country, the choice of households as a sampling frame systematically neglects people who do not live in households, e.g., the homeless and unregistered immigrants.

*Sampling error* results from a badly chosen sample. For example, if every tenth household were to be included in the sample, then this random sample may well be unbalanced regarding certain characteristics such as household size, average age, and income. Balancing many such factors by stratifying the sample typically requires a large sample size.

*Nonresponse error* results from the possibility that specific groups of respondents may be systematically more inclined to respond to a survey, in contrast to other groups who are consequently under-represented. Suppose for example a survey about annual income, and further suppose high-income households to be less likely to respond to a survey, then the resulting survey statistic would under-estimate the average household income.

Lastly, *adjustment error* may result from the researchers' attempts to correct any of the above error components. For example, researchers may seek to compensate the low response rate of high-income households by adding more weight to the corresponding responses. While these adjustments may reduce nonresponse error, they may also introduce adjustment error.

Taken together, the error components of the above two chains of statistical error sum up to constitute the 'total error' that afflicts a survey's result (as implied by the total error framework's name). Subsequent parts of this work will analyze the potential influence of survey gamification on the individual error components, see Section 9.3.5.

### 9.2.4 Theoretical Framings of Gamified Online Surveys

Related research about innovative online surveys has used various concepts to frame their work, compare Table 9.1 for a summary. The studies by Brownell et al. [29], Cechanowicz et al. [37], Downes-Le Guin et al. [60], Harms et al. [89, 91], and Mavletova [138] are framed using the concept of gamification. In contrast, Hebecker et al. [96] described their playful, multimedial survey in terms of "games with a purpose". Delavande et al. [47] and Dolnicar et al. [56] portrayed their works in terms of visual enhancements and interactive questions. Despite the different theoretical framings, the enhancements were quite similar, ranging from visual and interactive decorations to design characteristics more strictly associated with games, compare the column "enhancements" in Table 9.1.

| **Study** | **Theoretical Framing** | **Enhancements** (Design or Game Elements) |
|---|---|---|
| Brownell et al. [29] | Gamification | Autonomy of the participant, Fantastical scenario, Feedback, Immersive Experience, Novelty, Points, Progress, Time pressure |
| Cechanowicz et al. [37] | Gamification | Challenge, Drag'n'drop interactions, Fantasy, Freedom, Mystery, Points, Progress, Reward, Sound Effects, Time Pressure, Visual decoration |
| Delavande et al. [47] | Visual representation | Unusual interactions for answering questions (placing balls into bins) |
| Dolnicar et al. [56] | Interactive Questions | Drag'n'drop interations, Visual decoration |
| Downes-Le Guin et al. [60] | Gamification | Assets (weapons), Avatar, Drag'n'drop interactions, Fantasy, Narrative, Quest, Rewards, Visual decoration |
| Harms et al. [89] | Gamification | Avatar, Challenge, Coins, Drag'n'drop interactions, Exploration, Feedback, Medal ceremony, Progress, Rewards, Sensation, Shop, Time pressure |
| Harms et al. [91] | Gamification | Achievement Badges, Challenge, Collection, Possession, Reward |
| Hebecker et al. [96] | Purposeful Games | Hand-Drawing, Multiplayer, Points, Pre-recorded games as stand-ins for human game partners, Randomness, Scores, Skill levels, Time limits |
| Mavletova [138] | Gamification | Challenge, Narrative, Points, Reward, Time limit, Visual decoration |

**Table 9.1:** Theoretical framing and survey enhancements employed in related studies. Not all studies used the concept of gamification to theoretically frame their work – but their design elements and enhancements are nonetheless similar to game elements in gamified online surveys.

### 9.2.5 Outcomes of Gamified Online Surveys

Outcomes achieved in related work are summarized in Table 9.2. The table categorizes outcomes of gamified online surveys using Hamari et al. [87]'s distinction into psychological and behavioral effects of gamification. Behavioral effects were further categorized using Groves et al. [80]'s framework into measurement and representation. Measurement refers to how answers are obtained ("measured") from respondents, whereas representation refers to how well those those people correspond to ("represent") the survey's target population; see Section 9.2.3 for more detailed explanations. Note that the summary of outcomes also includes the author's own studies that were originally published in Harms et al. [89, 91] and that are also presented in Sections 9.5 and 9.6 of this dissertation.

Most studies on gamified online surveys were able to achieve beneficial psychological outcomes. As summarized in Table 9.2, the study by Mavletova [138] reported positive effects on enjoyment and on the respondents' interest in receiving further invitations. Increased ease of use was reported by Dolnicar et al. [56]. Increased fun was reported by Dolnicar et al. [56] and Harms et al. [89]. Higher user preference by Dolnicar et al. [56] and Harms et al. [91]. A better user experience

| Measures | | | Outcomes | | | |
|---|---|---|---|---|---|---|
| Name | Type | Source | positive | negative | mixed | no influence |
| **Psychological** | | | | | | |
| - affect | quant. | self-r. | – | – | – | [91, 96] |
| - cognitive test results | quant. | tested | – | – | – | [138] |
| - ease of use | quant. | self-r. | [56] | – | – | [138] |
| - enjoyment | quant. | self-r. | [138] | – | – | [29] |
| - fun | quant. | self-r. | [56, 89] | – | – | [91] |
| - interest | quant. | self-r. | – | [29] | – | – |
| - interest in further invitations | quant. | self-r. | [138] | – | – | – |
| - motivation | quant. | self-r. | – | – | – | [29] |
| - perceived duration | quant. | self-r. | – | – | – | [91, 138] |
| - preference | quant. | self-r. | [56, 91] | – | – | [96] |
| - qualitative feedback | qual. | self-r. | [91] | – | [29, 89] | – |
| - time spent | quant. | self-r. | – | – | [60] | – |
| - user experience | quant. | self-r. | [60, 89, 91] | – | – | – |
| - willingness to recommend | quant. | self-r. | [89] | – | – | – |
| **Behavioral (measurement)** | | | | | | |
| - anchoring or primacy effects | quant. | obs. | – | [138] | – | [47] |
| - consistency of answers within the survey | quant. | obs. | [47, 56] | – | – | [60, 138] |
| - correctness of answers | quant. | obs. | [37] | – | – | – |
| - dont-know answers | quant. | obs. | – | – | – | [138] |
| - length of free-text answers | quant. | obs. | – | [37] | – | [89, 91, 138] |
| - socially undesirable answers | quant. | obs. | – | – | – | [138] |
| - speeding | quant. | obs. | – | – | – | [91] |
| - straightlining | quant. | obs. | [138] | – | – | [60, 91] |
| **Behavioral (representation)** | | | | | | |
| - demographic bias | quant. | obs. | – | – | – | [60] |
| - number of completed questions | quant. | obs. | [37] | [29] | – | [29, 89] |
| - number of empty answers | quant. | obs. | – | – | – | [91] |
| - number of free-text answers | quant. | obs. | – | [138] | – | – |
| - response rate | quant. | obs. | – | [60, 89, 138] | – | [29, 47, 91, 138] |
| **Behavioral (survey statistic)** | | | | | | |
| - central tendency | quant. | obs. | – | – | [60, 89] | [29, 47, 91] |
| - dispersion | quant. | obs. | [47] | – | – | – |
| - extreme responses | quant. | obs. | – | – | – | [138] |
| - middle responses | quant. | obs. | – | – | [47, 138] | – |
| - symmetry of distribution | quant. | obs. | [47] | – | – | – |
| - validity compared to an external source | quant. | obs. | – | – | – | [60] |
| **Behavioral (other)** | | | | | | |
| - number of requests for help | quant. | obs. | [138] | – | – | – |
| - time spent | quant. | obs. | – | – | [89, 138] | [29, 47, 91, 96] |
| - time when participants quit | quant. | obs. | – | – | – | [89] |

**Table 9.2:** Measures and outcomes of gamified online surveys. The above table classifies measures by type (quantitative or qualitative) and source (observed, self-reported, or tested). Outcomes are classified into psychological and behavioral effects of gamification as in Hamari et al. [87]. Behavioral outcomes are further classified using Groves et al. [80]'s Total Error Framework into positive or negative effects on measurement and representation. In 'mixed' outcomes, the study remained unclear on whether the observed influence of gamification was beneficial. 'No influence' means there was no statistically significant influence.

in the studies by Downes-Le Guin et al. [60] and Harms et al. [89, 91]. A higher willingness to recommend the survey in Harms et al. [89] and better qualitative feedback in Harms et al. [89, 91]. Most studies also reported psychological measures where they found no significant effect of gamification. Few studies included negative or unclear psychological outcomes, see Table 9.2 for a summary.

In contrast to widespread success in producing psychological benefits, only very few gamified online surveys achieved beneficial behavioral outcomes. Regarding measurement of response data, Mavletova [138] reported reduced straightlining, Delavande et al. [47] and Dolnicar et al. [56] reported improved within-survey data consistency and Cechanowicz et al. [37] reported improved correctness of answers. Regarding representation, Cechanowicz et al. [37] reported a higher number of completed questions. Other, positive, behavioral outcomes have included a lower number of requests for help, as reported by Mavletova [138]. Also, in the (rather specific) context of a study by Delavande et al. [47], lower dispersion of the survey statistic and more symmetrical distributions were further positive outcomes.

Despite the above promising results, many studies also revealed negative effects of gamification. Most notably, a lower response rate was reported in the three studies by Downes-Le Guin et al. [60], Harms et al. [89], and Mavletova [138]. In another study by Brownell et al. [29], respondents found the gamified survey less interesting (!) and completed less questions. Further negative outcomes included stronger primacy effects[2] and a lower amount of free-text answers, as reported by Mavletova [138]. In a similar way, Cechanowicz et al. [37] reported shorter free-text answers by respondents of the gamified survey. A further critical issue is the potential bias that gamification may introduce in the answers given by respondents. Two studies by Downes-Le Guin et al. [60] and Harms et al. [89] revealed an influence of gamification on the central tendency of the survey statistic. But both studies remained unclear whether this was due to biased answers or due to reduced negative respondent behavior.

In summary, related outcomes confirm survey gamification to be a promising means for improving psychological outcomes such as the subjective user experience. But the circumstances and conditions for psychological effects to translate into beneficial respondent behavior remain unclear.

### 9.2.6 Effects of Individual Game Elements

Hamari et al. [87]'s literature review revealed that current research in gamification lacks comparisons of the required effort and subsequent benefits of individual game elements. The author found that this general observation also holds for the specific domain of gamified online surveys, as previously stated in Harms et al. [91]. Prior studies evaluated combinations of multiple game elements, but the effect of individual game elements is unknown. Future studies are therefore needed to rigorously evaluate the respective benefits of individual game elements in isolation from each other. Regarding this need, Section 9.6 contributes an evaluation of a single game element, i.e., of achievement badges.

[2] Primacy effects refer to the degree to which participants simply select the first response item.

### 9.2.7 Methods and Processes for Gamifying Online Surveys

Related work on gamified online surveys (prior to the author's own publication in Harms et al. [93]) did not discuss methods or processes for how to proceed with a survey gamification project. General-purpose methodological advice is given by Werbach et al. [198] who recommend careful planning and goal-setting, a design process similar to the MDA (mechanics - dynamics - aesthetics) game design framework by Hunicke et al. [106], and iterative evaluation. We will extend and specialize the advice given in these works to more specifically address survey gamification, see Section 9.4.

### 9.2.8 Low-Cost Methods and Return-on-Investment

Outcomes and efforts of gamified surveys have varied greatly in related work. Some of the more ambitious designs have achieved better results, but also required a lot more time and effort. For example, in a study by Cechanowicz et al. [37] a "full game" survey design produced higher motivation compared to "partial game" and conventional designs, but the study did not report the invested amount of effort. In Downes-Le Guin et al. [60]'s study, simple decorations did not improve outcomes whereas more advanced "functionally visual" or "fully gamified" designs produced a better user experience – but required more than twice the amount of working hours, plus additional costs for subcontracted artwork. The study presented in Section 9.5 of this work required over 200 working hours for the design and implementation of a highly gamified, almost game-like survey. The primary outcomes were an improved user experience (more perceived fun, higher willingness to use and recommend the survey) but a lower response rate.

Return-on-Investment (ROI) is well-suited for discussing the ambivalence between outcome and effort of survey gamifications. Methodological advice for how to measure the ROI of gamification in commercial projects has been provided by Conley et al. [45]. ROI can thus be measured as the effect of gamification on key performance indicators (KPIs), put in relation to the cost or effort invested into gamification. With regard to online surveys, KPIs translate to beneficial psychological and behavioral outcomes such as a better user experience and a higher response rate. ROI can improved by two strategies: firstly by improving outcomes, and secondly by lowering efforts. The first strategy is examined in Section 9.5 of this work where a lot of time and effort was invested to create a highly gamified online surveys. The second strategy is examined in Section 9.6 where a low-cost approach was chosen to reduce efforts and increase ROI.

Low-cost methods are a popular approach for increasing ROI in usability engineering; compare, for example, Nielsen's "discount" usability engineering methods [145] and Holtzblatt et al.'s "rapid" ethnography [101]. These low-cost methods promise to produce good results without requiring a lot of effort. Despite their potential for increasing ROI, low-cost approaches to gamification have been subject to harsh criticism. For example, Werbach et al. [198] warned about "the lure of pointsification". Pointsification, a term coined by Robertson [W28], describes the approach of mindlessly using features that are least essential to games (e.g., points) in non-game contexts. In line with the above critique, Jacobs [109] proposed to understand gamification not as simple addition of game elements, but as a complex task that requires a holistic process. In a similar way, Werbach et al. [198] recommend careful planning, iterative design, and evaluations to avoid pitfalls.

The author agrees with the above warnings and recommendations and affirms the need for iteration and evaluation. Section 9.4 of this work correspondingly proposes a design process that includes iterative design and evaluation. Nevertheless, it is also important to keep efforts low – Section 9.6 will thus investigate and employ a low-cost variant of the proposed process.

## 9.3 Conceptual Foundations

This section contributes a summary and selection of relevant conceptual foundations for designing gamified online surveys. Survey gamification builds on many disciplines including form design, usability engineering, user interface and experience design, market research, game design, and gamification. This section takes a practical design perspective by discussing select concepts from the above disciplines, putting them forth as relevant foundations for designing gamified online surveys. These foundations also firmly ground the design process for gamifying online surveys that is subsequently proposed in Section 9.4.

Since gamified online surveys have been designed in various ways, it is important to shed light on possible designs and on the underlying design dimensions. Towards this goal, Downes-Le Guin et al. [60] classified possible survey designs based on the style of presentation: text-only, decoratively visual, functionally visual, and fully gamified. In a similar way, Cechanowicz et al. [37] contrasted plain surveys with partial game and full game design variants. In contrast to the above distinctions, the conceptual foundations discussed in this work (originally put forth in Harms et al. [93]) do not represent qualities of gamified surveys. Instead, they relate to the following three important methodological questions to be considered when designing gamified surveys.

- Firstly, regarding gamification: How can game elements be used in a survey to produce psychological and behavioral benefits?
- Secondly, since online surveys typically employ form-based user interfaces: Which aspects relevant to form design need to be considered in survey gamification?
- And thirdly, concerning the survey's structure: Which survey areas can gamification be applied to?

Answers to the above questions are largely independent from each other; the questions can thus be described (using a spatial metaphor) as dimensions spanning up a design space of possible survey gamifications, see Figure 9.4 for a visualization. Each of the three dimensions is discussed in more detail in the following sections.

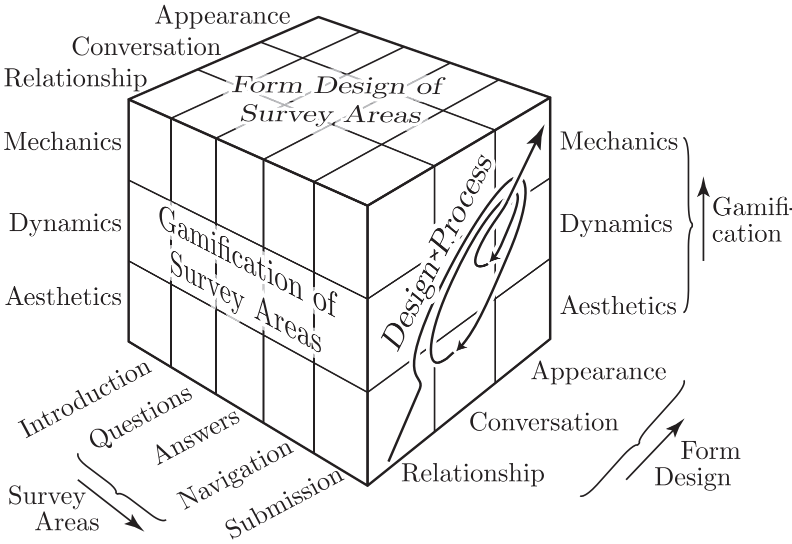



**Figure 9.4:** Three design dimensions in the gamification of online surveys: Gamification, visualized as the three MDA (mechanics, dynamics, aesthetics) types of game elements, compare Hunicke et al. [106]. Form design, visualized as three layers of form design, as proposed in Jarrett et al. [112]. And, as third dimension in the cube, the survey areas to be gamified, specifically: introduction, questions, answers, navigation, and form submission. Graphic originally published by Harms et al. [93].

### 9.3.1 Gamification using the MDA Framework

The use of "design elements characteristic for games", more shortly termed game elements, is constitutive for gamification according to Deterding et al.'s definition. Game elements have been collected in related work and may be used by designers for inspiration. E.g., see the "gamification toolkit" by Werbach et al. [198], the "ingredients of great games" by Reeves et al. [158], various game mechanics listed in Aparicio et al. [12], the "motivational game design patterns" by Lewis et al. [129], the "game flow criteria" by Sweetser et al. [180], and elements suited for gamified surveys described by Puleston [156] and Wlaschits [201]. Resulting user experiences have also been listed, compare the "playful experiences" by Korhonen et al. [125] and the aesthetics described by Hunicke et al. [106].

Gamification processes have been understood as adding game elements into a non-game context- This understanding corresponds with Deterding et al.'s definition of gamification [49]. But Jacobs [109] argued against this naive understanding, claiming that gamification requires a more holistic, creative, and structured design process. In a similar way, Werbach et al. [198, ch.5-6] held that gamification requires careful planning, execution, and assessment in order to avoid potential failure.

The MDA (mechanics, dynamics, aesthetics) framework by Hunicke et al. [106] provides one such holistic, structured process. Although originally intended for game design, a modified variant of the framework has also been proposed by Werbach et al. [198] for gamification and is suggested for survey gamification in this work, compare the 'gamification' dimension in Figure 9.4.

The MDA framework distinguishes three types of game elements, as visualized in Figure 9.5. Mechanics describe the data representations, algorithms and rules that make up a game. Dynamics refer to the resulting run-time behavior over time. Aesthetics characterize the player's emotional response or experience.

One practical utility of the MDA framework, as described by Hunicke et al. [106], is that it allows designers to reason about which game mechanics will produce suitable dynamics that can produce

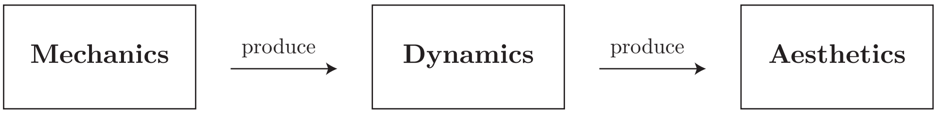



**Figure 9.5:** The MDA (mechanics-dynamics-aesthetics) framework by Hunicke et al. [106] explains how interaction with game mechanics (i.e., the rules and basic building blocks of a game) leads to specific game dynamics (run-time behavior over time) which produce a certain aesthetic (a certain user or player experience). The framework allows designers to reason about which dynamics and mechanics can produce intended aesthetics. Graphic based on Hunicke et al. [106].

a user experience characterized by target aesthetics. Thus designers first define the aesthetics they wish to create, e.g., based on business requirements or target user characteristics, compare Aparicio et al. [12]. They then think about game dynamics suited for producing these aesthetics, and about game mechanics that will in turn produce these dynamics.

### 9.3.2 Form Design using Jarret's Three Layer Model

The discipline of form design is highly relevant to survey gamification because online surveys typically employ form-based UIs to enable data entry. Related work has captured best practices for form design in international standards such as DIN EN ISO 9241-143 [54], guidelines such as those by Bargas-Avila et al. [16], and books including those by Barnett [17], Jarrett et al. [112], and Wroblewski [205]; compare Section 1.2 for a more detailed overview on state-of-the-art practices in form design.

A process for form design has been proposed as 'three layers of form design' by Jarrett et al. [112]. In the relationship layer, designers analyze the relationship with users, their tasks, and the usage context. In the conversation layer, designers seek to create interactions that make the conversations between users and the survey flow easily. The appearance layer describes detailed UI and graphical design. In Jarret's design process, activities focus on the above three layers in a roughly sequential order, joined by usability evaluations and iterations where necessary. As a side note, other, general-purpose process models for usability engineering share a similar structure. E.g., Mayhew's "usability engineering lifecycle" [139] also starts with an analysis of users, tasks and context, followed by iterative and increasingly specific design. We adopted Jarret's three layers of form design for the purposes of the survey gamification process, see the 'form design' dimension in Figure 9.4.

### 9.3.3 Survey Areas to be Gamified

The overall structure of online surveys typically consists of an introduction page, a form-based questionnaire, and a thank-you page to be displayed after submission. Related work has provided further distinctions regarding the inner structure of the form-based questionnaire. Five areas of form-based user interfaces have been distinguished by Bargas-Avila et al. [16] as follows: form content, layout, input types, error handling, and submission. Another distinction by Frohlich et al. [70] puts an emphasis on form filling tasks, which consist of understanding questions, answering questions, and navigation between questions. To identify major areas in a survey's structure that each can be gamified, we subsumed 'form content' under questions, 'error handling' under answers, and identified 'layout' with the appearance layer of form design. This resulted in the following five survey areas: introduction, questions, answers, navigation, and submission, as visualized in the 'survey areas' dimension in Figure 9.4.

### 9.3.4 Intersections Between the Three Design Dimensions

The above three design dimensions for survey gamification, i.e., gamification using the MDA framework, form design using Jarret's "Three Layers of Form Design", and the five survey areas to be gamified intersect and overlap in different ways. These intersections and overlaps are visualized as surface areas of the cube in Figure 9.4.

Firstly, the intersection between form design and the survey areas, labelled as "form design of survey areas" in the cube shown in Figure 9.4, simply corresponds to applying Jarret's "three layers" process as well as the recommendations given in her book to the design of the various survey areas.

Secondly, the intersection between gamification and the survey areas, labelled as "gamification of survey areas" in the cube, corresponds to applying gamification to the various parts of the survey. It is important to note that each survey area may be gamified in a different way and with different goals. For example, gamification of the introduction page may aim at arousing interest amongst respondents. Gamification of questions and answers may seek to encourage truthful answers. Gamification of the navigation between questions may seek to motivate respondents to continue in the survey. Gamification of the submission page may try to persuade people to invite more respondents. Despite the different goals formulated in the above examples, designers should seek to provide a coherent user experience.

Thirdly and lastly, the intersection between form design and gamification reveals interesting overlaps because both Jarret's layers of form design and Hunicke's MDA framework each describe a design process. These processes should be unified to take recommendations from both disciplines (form design and gamification) into account. We will put forth one such unified design process in Section 9.4.

In summary, the above three design dimensions of gamification form design and survey areas provide important conceptual foundations for proceeding with a survey gamification project. Prior to suggesting a process that unifies these three dimensions (Section 9.4), the next section discusses critical issues regarding the statistical validity of results obtained from gamified surveys.

### 9.3.5 Critical Issues regarding Statistical Error

This section provides a detailed analysis which specific statistical error components are potentially influenced by a survey's gamification. The analysis was originally published by the author of this dissertation in Harms et al. [93].

Designers of gamified online surveys should carefully avoid introducing statistical error into the survey's results. This warning is relevant for any type of online survey – e.g., Tourangeau et al. [187, ch.4] describe many factors related to a survey's visual appearance, navigation, and input controls that have a potential influence on the answers given. Nonetheless, the topic of statistical error is of particular importance for gamified surveys where designers intentionally employ unusual interface and interaction styles that may reduce but also increase various error components. For example, a gamified survey's improved user experience may lessens negative respondent behavior such as speeding or straightlining, resulting in lower measurement error. On the other hand, a gamified survey's unusual appearance may put off a certain group of people, which may result in higher non-response error.

As a result of analyzing the error components in Groves' total error framework (described in Section 9.2.3) with regard to a survey's gamification, this section puts forth that only three error components are potentially influenced (increased or diminished) by a survey's gamification. These three error components have been marked with red arrows and circled numbers in Figure 9.6.

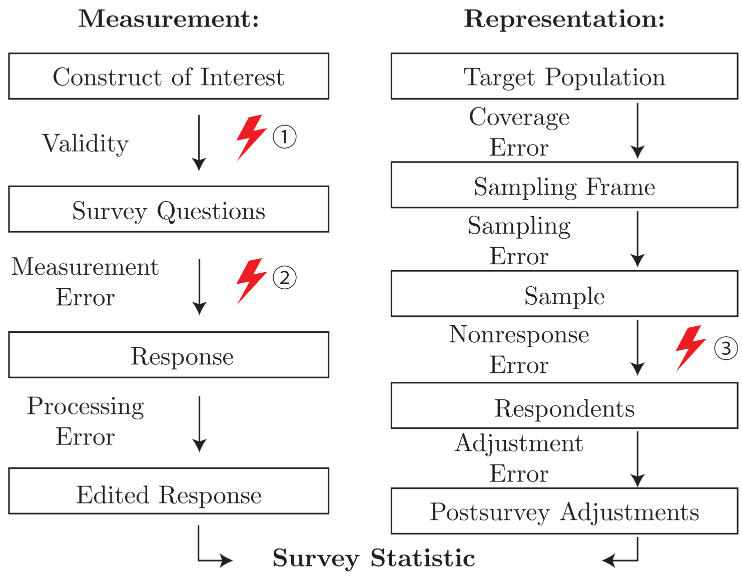



**Figure 9.6:** Critical error components that are potentially influenced by a survey's gamification. Gamification can only potentially influence (increase or diminish) those three error components marked with red arrows. Graphic originally published by Harms et al. [93].

Firstly, ①, gamification influences construct validity if the gamified questions correspond to a higher or lesser degree with the construct to be measured. Construct validity is difficult to assess on a quantitative level, but researchers may evaluate the validity of gamified survey questions using qualitative methods, e.g., through expert reviews, usability tests and interviews, see Groves et al. [80, ch.8] for a summary of suited methods.

Secondly ②, measurement error is introduced if gamified questions bias the answers given by respondents, and reduced if gamification succeeds in reducing detrimental user behavior such as speeding, random responding, and lack of attention. Researchers may evaluate measurement error using similar qualitative methods and using split-ballot experiments where groups of participants are presented with multiple versions of the survey, as described in Groves et al. [80, ch.8] and as conducted as part of this work, see Sections 9.5 and 9.6.

Thirdly ③, non-response error is influenced if a different group of people systematically responds (or does not respond) to gamified surveys. Researchers may investigate the presence of non-response error by comparing response rates and user characteristics of gamified versus non-gamified survey versions.

The other error components are the same for gamified and non-gamified surveys. Specifically, sampling frame and sampling, post-survey adjustments, and data processing remain the same whether a survey is gamified or not.

Researchers and designers of gamified surveys should seek to reduce the three, critical error components using the above recommendations. Future research should seek to quantify how gamification influences the individual error components.

## 9.4 A Unified Design Process for Gamifying Online Surveys

A novel design process for survey gamification (originally published in Harms et al. [93]) is described in this Section. The process is based on the MDA (mechanics, dynamics, aesthetics) framework and on the conceptual foundations described in the above section 9.3. It is put forth in the CHI community for further discussion, evaluation, and application that will hopefully lead to more entertaining and engaging online surveys. The applicability and usefulness of the process has been evaluated in follow-up studies, see Sections 9.5 and 9.6.

Note that the process focuses on design activities – one implication is that it does not cover certain steps required from an empirical research and survey methodology perspective. Empirical researchers start by defining their research objective (the construct of interest that they wish to measure using a survey). Then they design the survey (possibly using a gamification process, as put forth in this section). Lastly, they choose a sampling method, select a sample, collect data, and analyze the data. Regarding most of these steps, we kindly refer to the excellent textbooks on survey methodology by Groves et al. [80] and Tourangeau et al. [187] since the remainder of this section focuses on design. In other words, the process put forth in this section is a design process; it describes the specific steps that designers should perform when gamifying an online survey.

### Step 1 – Collecting Game Elements for Inspiration

Prior to starting with the gamification process, designers should collect game elements that can inspire their further design activities. All members of the design team should familiarize themselves with the catalogue of game elements so it can fulfill its purpose of inspiring design in the next steps of the process.

**Examples.** As a quick and easy starting point, designeres can use the pre-compiled catalogues of game elements suited for survey gamification, as described by Puleston [156] and Wlaschits [201]. Further game elements (not all of them necessarily suited for surveys) have been provided in the “gamification toolkit” by Werbach et al. [198], the “ingredients of great games” by Reeves

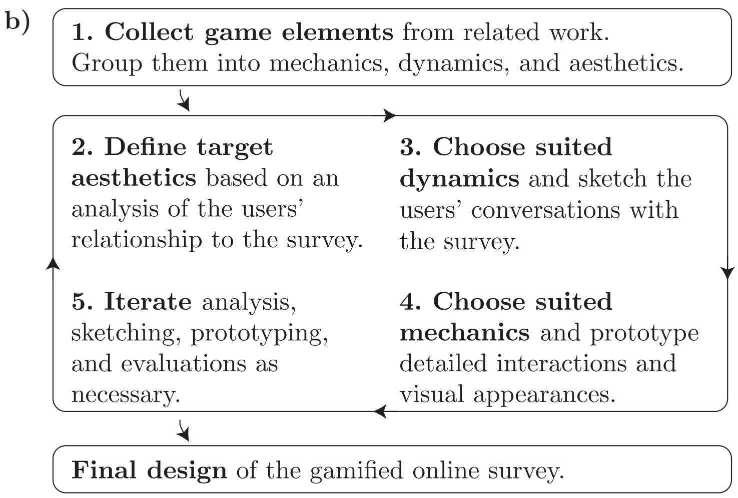



**Figure 9.7:** Design process for gamifying online surveys. Its iterations combine the steps proposed in Hunicke et al. [106]'s MDA framework and in Jarret's “three layers of form design” [112]. Graphic originally published by Harms et al. [89].

et al. [158], the game mechanics by Aparicio et al. [12], the "motivational game design patterns" by Lewis et al. [129], the "game flow criteria" by Sweetser et al. [180], the "playful experiences" by Korhonen et al. [125], and the aesthetics described by Hunicke et al. [106].

### Step 2 – Aesthetics and the Relationship Layer of Form Design

As a second step of the proposed process, designers should analyze the intended users (i.e., the survey's target population), tasks (the form schema to be filled), and context, as described in Jarrett et al.'s *relationship layer* of form design [112]. Based on this knowledge, they can set goals regarding intended *aesthetics*, i.e., the intended emotional responses and user experiences that shall be elicited by the survey.

Designers may set different aesthetic goals for different survey areas (introduction, questions, answers, navigation, and submission). Nonetheless, gamification should result in one coherent design, and a single design process is proposed for all survey areas, see Figure 9.7. Aesthetics from the previously compiled catalogue of MDAs can serve as inspiration during these design activities. Thus designers can rank and choose aesthetics found in related work and judge whether they seem suitable for the various survey areas.

**Examples.** Designers may consider the aesthetics of challenge and sensation to be suited for the target users, but may deem the fellowship aesthetic unsuited for an intended single-user experience. Regarding the various survey areas, they could aim at arousing curiosity and interest in a survey's introduction page. They could seek to provide visual and auditory sensation to enhance questions and answers, but refrain from making questions challenging to answer because perceived intellectual difficulty has been shown to adversely influence respondent behavior by Kaminska et al. [119]. They could decide to design navigation with a target aesthetic of gameful exploration. The submission page could be designed to reward users for their effort. Note that the above aesthetics are provided as illustrative examples – other target aesthetics are of course possible.

### Step 3 – Dynamics and the Conversation Layer of Form Design

Designers can use the MDA framework to reason about which game dynamics are suited for producing the intended aesthetics. This creative thinking can be inspired by game dynamics from the catalogue of MDAs. Note that since game dynamics refer to the run-time behavior of a game or gamified system, the designer's considerations in this step of the process correspond to the the conversation layer of form design, i.e., the flow of interactions that a user is going to have with the survey.

**Examples.** The game dynamic of time pressure has been recommended for motivating users to provide lengthy free-text answers by Puleston [156]. Nonetheless, designers should avoid creating time pressure throughout the entire survey because this could motivate users to speed. Designers may also implement feedback loops, i.e., dynamics wherein user actions affect the overall state of gameplay, as described by Hunicke et al. [106]. Feedback loops may visualize concepts such as a user's progress, status, wealth or health of a game character, points, etc.

### Step 4 – Mechanics and the Conversation and Appearance Layers of Form Design

To produce the intended dynamics and aesthetics, designers can employ suitable game mechanics and playful elements. Again, they can use the catalogue of MDAs for inspiration. Since game mechanics are the detailed building blocks and rules that make up a game [106], this step relates to detailed design activities in the conversation and appearance layers of form design. As an overall goal, re-designed questions should still represent the construct of interest and the interactive UI elements should not bias the answers given by respondents.

**Examples.** Designers may choose to employ the mechanics of points and badges to implement the dynamic of feedback, which in turn can produce the aesthetic of challenge. They may further choose to visualize a stopwatch next to free-text fields to implement the dynamic of time pressure and the same aesthetic of challenge. They may choose to employ the avatar mechanic and allow users to freely move their avatar throughout the survey and thus produce an aesthetic of exploration.

### Step 5 – Prototyping, Evaluation, Iteration

As typical for creative design processes, compare for example the processes put forth by Buxton [34] and Mayhew [139], designers should work in a team, explore multiple designs in parallel, prototype, and evaluate prototypes. The overall gamification process will typically progress from deliberate vagueness during brainstorming, ideation, and sketching (primarily in steps 2–3) to increasing detail and specifity during prototyping and evaluation (primarily in step 4).

Designers of gamified surveys should seek to reduce the three critical error components described in Section 9.3.5. This can be achieved if gamification helps to avoid negative user behavior that has been observed in conventional (non-gamified) surveys. Non-response error is reduced if users are generally more willing to respond to the survey. It is also important that gamification should appeal to all users in the target population; not just a specific sub-group. Measurement error is reduced if a survey's gamification reduces negative respondent behavior such as speeding and random responding, and if it increases the users' engagement and attention.

Evaluations should consider both intended outcomes for the user (e.g., a pleasant user experience) and outcomes for those who create the survey (e.g., a high completion rate and truthful answers). Formative evaluations can be performed with relatively few users, using test observation methods such as thinking-aloud, as described by Nielsen [145].

**Examples.** In the authors' experience, paper prototyping and digital mockups have worked well in the first iteration, whereas later iterations have required digital, interactive prototypes. Three iterations have sufficed to create a pleasant design with good usability.

### Conclusion and Outlook

The previous sections discussed related work and conceptual foundations for survey gamification. Based on these foundations, a novel design process for gamifying online surveys was put forth. The following sections describe how the process was employed and evaluated in two case studies.

## 9.5 Case Study 1: Sports and Leisure Activities amongst Young Adults

We evaluated the design process for gamifying online surveys presented in Section 9.4 in a case study where two designers gamified a survey about sports and leisure activities amongst teenagers and young adults.

The goals and contributions made by conducting this case study are firstly, to document an application of the design process for survey gamification. This provided qualitative results regarding the process's applicability and usefulness, see Section 9.5.4. And secondly, to evaluate the psychological and behavioral outcomes of the gamified design, through an empirical study, see Sections 9.5.5–9.5.7.

Results indicate that gamification successfully increased the users' perceived fun, the average time spent, as well as their willingness to recommend the survey, without introducing a strong bias in the survey results, albeit with a lower overall response rate.

### 9.5.1 Characterization of the Case Study

An existing online survey about sports and leisure activities amongst teenagers and young adults [W9] was chosen as a case study because of its following beneficial characteristics. The survey's questions are easy to understand and answer; therefore domain-specific knowledge amongst test users is unlikely to bias evaluation results. It employs state-of-the art survey design using the default style and functionality of the popular SurveyMonkey [W33] platform for online surveys. Furthermore, the survey addresses children and teenagers as target population; related work has shown this target group to react well to gamification [138].

### 9.5.2 Application of the Gamification Process

Methodologically, two designers (the author of this thesis, as well as one student in HCI) employed the design process presented in this work to gamify the sports survey. The designers held three workshops. They took an overall number of three iterations (each including prototyping and evaluation) to work through the different phases of the process, thus converting the conventionally-designed sports survey into a gamified one.

Through their choice of game elements, the designers aimed at producing a design that elicits a rich *visual sensation* (in contrast to typical, text-only surveys), that includes small *challenges* in the form of micro-games (albeit without making questions too difficult to answer because this could potentially bias results), and that allows users to freely *explore and discover* the various survey areas.

The remainder of this section describes how the designers followed each step of the survey gamification process (described in Section 9.4) to gamify the case study's online survey.

**1. Collection of Suitable Game Elements.** In the first workshop, the two designers discussed the game elements available in the catalogue by Wlaschits [201]. The catalogue not only provides a list of game elements, but also a classification of those elements into mechanics, dynamics, and aesthetics. The designers discussed each element in the catalogue to familiarize themselves with each game element.

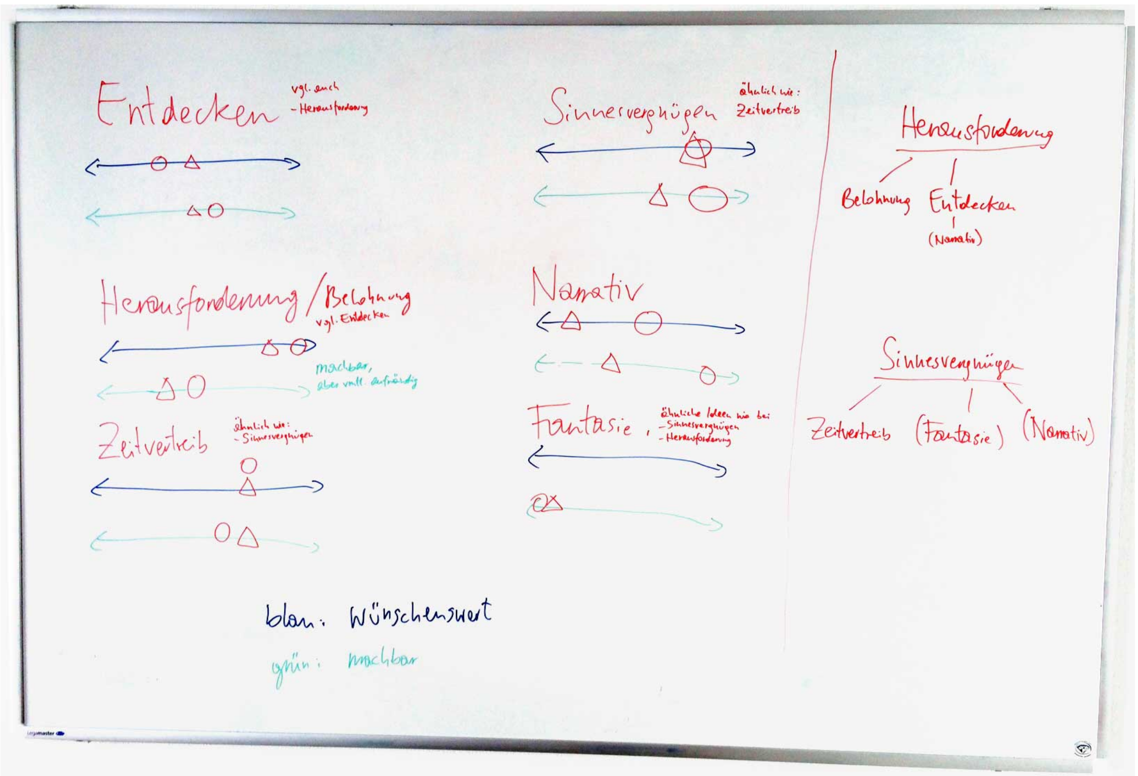



**Figure 9.8:** Photograph of the whiteboard in the first workshop where the designers rated aesthetics by estimating their usefulness and feasibility – the further right the mark, the better the designer's rating. Ratings on the upper, blue scales are about usefulness, whereas the lower, green scales concern feasibility (the further right, the better). The rated aesthetics include discovery ("Entdecken"), challenge ("Herausforderung"), pasttime ("Zeitvertreib"), visual or otherwise sensual pleasure ("Sinnesvergnügen"), narration ("Narrativ"), and fantasy ("Fantasie"). The designers finally chose a combination of sensation, challenge, and exploration as target aesthetics for gamifying the sports survey. Photograph taken by Harms et al. [89].

**2. Choice of Target Aesthetics.** The catalogue of aesthetics was further narrowed down in the first workshop meeting. Designers estimated and rated the perceived usefulness and feasibility of aesthetics on a white board, see Figure 9.8. They finally chose sensation, challenge, and exploration as aesthetic goals for the intended user experience.

**3. Choice of Suited Dynamics.** In the second workshop, the designers brainstormed possible designs using the catalogue of MDAs from [201] as inspiration. Their design activities iterated rapidly between explorative, abstract thinking (i.e., which dynamics and mechanics can produce the intended aesthetics) and specific, increasingly detailed design (i.e., sketching ideas and elaborating the conversation and appearance layers of form design).

More specifically, the designers chose to implement the following dynamics. They decided to employ the dynamic of 'feedback' in order produce an aesthetic of challenge. Feedback can inform about the respondent's progress and thus challenge respondents towards beneficial actions. In a similar way, the dynamic of time pressure can produce an aesthetic of challenge when users enter free-text answers. The designers further sought to produce the aesthetic of free exploration through the users' ability to steer an avatar through various survey areas.

**4. Choice of Suited Mechanics.** Based on their previous design decisions, the designers sketched a design with the following mechanics. Graphical and unusual design should afford visual sensation. Users should interact with an avatar, resulting in the dynamic of moving around and the aesthetic of free exploration. Feedback should be given using progress indicators and using coins as rewards for beneficial actions.

**5. Prototyping, Evaluation, and Iteration.** To work on detailed UI design and the appearance layer of form design, the designers held a third workshop where they produced sketches, which were then refined into detailed mockups. An initial paper prototype was employed in an early, formative usability test and was subsequently replaced by a web-based prototype and a final implementation.

The paper-typed prototype proved useful because it was simple to create without any coding. More detailed mockups were created in wireframe style using the Balsamiq [W8] mockup software. A quick, formative usability test was conducted with five users who tested the mockup's functionality on a computer and communicated feedback as well as any problems they had detected. Issues were noted by test observers and fixed by the designers.

To enable a more realistic evaluation, a high-fidelity prototype was implemented using web technology. The prototype was implemented in multiple modules for each survey area. This allowed to conduct quick, informal usability tests for each individual module. Then the different modules were integrated and tested again, resulting in the final design and implementation of the gamified survey.

### 9.5.3 Resulting Gamified Design

The resulting gamified survey contains the same questions as the original sports survey, but features a novel design, as shown in Figures 9.9 and 9.10. This section describes characteristics of the gamified survey design.

**Visual Design.** The overall *theme* of the gamified survey was designed to reflect the survey's topic of sports. The *graphical appearance* was designed to remind of jump'n'run games (such as Super Mario) that members of the target population are likely to be familiar with from their childhood. Survey elements such as input controls were graphically decorated in order to produce the intended aesthetic of sensation. For example, radio buttons were re-designed to include the respondent's avatar along with pictures that each represent one possible answer, as shown in Figure 9.10. The intended benefit of the new input types is that the participant's avatar is included in the design, which can help participants to personally identify with the question. All survey areas maintained a similar, "hand-drawn" visual appearance but featured different interactions, as explained in the following subsections.

**Avatar.** In the first survey area, an avatar was automatically assigned to each respondent. The avatar's visual appearance depended on the demographic data (age, gender, etc.) that respondents provided about themselves, see Figure 9.9a for an example.

**Free Exploration.** The survey allowed respondents to navigate freely between four sports disciplines that each represented a different survey area. Navigation was implemented through a map shown in the second survey area, see Figure 9.9b. When respondents clicked on a sports discipline, their avatar walked to the specified place on the map and the according survey area was subsequently shown. Once they completed a survey area, they returned back to the map.

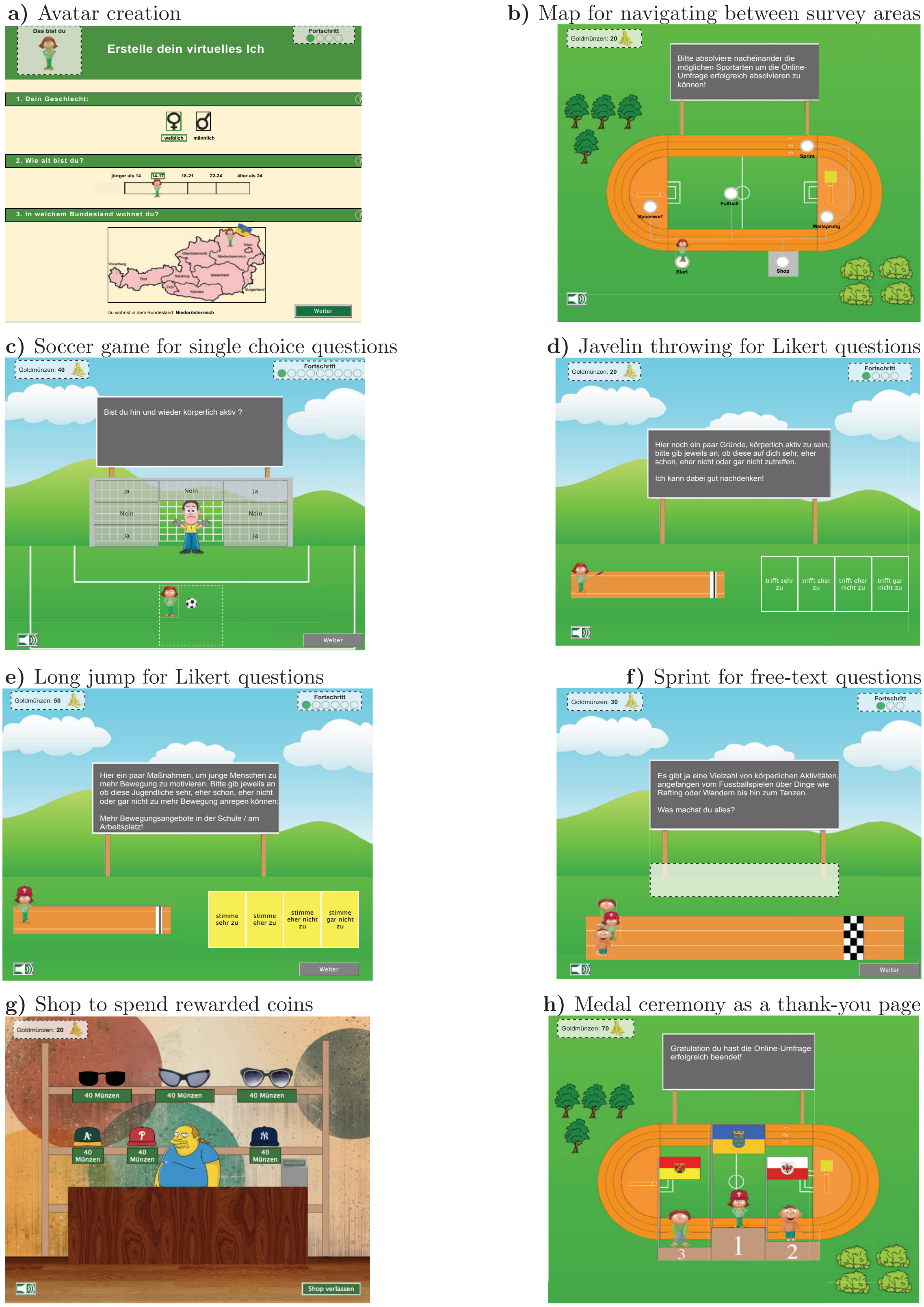



**Figure 9.9:** Areas in the gamified survey. Respondents could (a) create an avatar, (b) freely navigate between survey areas, (c-f) play mini-games to answer questions, and (g) may buy accessories for their avatar in a shop using rewarded coins. Upon completion, they win the sports competition and are (h) rewarded a gold medal. Graphic modified based on Harms et al. [89].

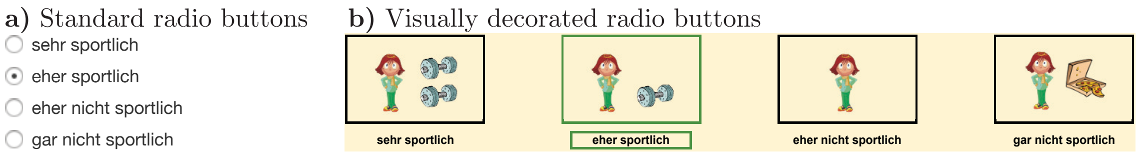



**Figure 9.10:** Visual decoration of input controls. The above screenshots show the (a) conventional and (b) gamified design of form controls for choosing amongst a given set of options. The gamified form controls were visually decorated but otherwise had the same functionality. Graphic originally published by Harms et al. [89].

**Questions and Answers.** The survey areas of soccer, javelin throwing, long jump, and sprint, see Figure 9.9c-f, were designed as micro-games that each afforded and required different interactions through which respondents could answer questions. For example, the soccer game (Figure 9.9c) instructed respondents to perform a penalty kick by dragging and then releasing their avatar. When released, the avatar kicked the ball in the specified direction into the goal and thus selected an answer. The other survey areas are designed in similar ways. The javelin throwing and long jump games (Figure 9.9d-e) mapped length (of jump or throw) unto answers. The sprint game (Figure 9.9f) created time pressure by visualizing a decreasing amount of time during which respondents were asked to provide a maximum of free-text answers. To avoid bias through unintentionally wrong answers, each survey area provided instructions about the required interactions. Furthermore, respondents were asked to practice and demonstrate their skill by providing a pre-specified answer before they could start answering real questions. Respondents could correct every answer before confirming it by clicking a “next”-button that lead to the next question.

**Feedback mechanisms.** Various mechanisms provided positive feedback about the respondents’ progress. While filling the survey, they were awarded *coins*. The map allowed respondents to enter a *shop* (Figure 9.9g) where they could buy accessories such as sunglasses and hats for their avatar. The shop had no other purpose than to strengthen positive reward. The last survey area – shown upon completion of the entire survey – was designed as a *medal ceremony* (Figure 9.9h) where each respondent was honored as winner of a sports competition.

### 9.5.4 Lessons Learned about the Process

The two designers reported qualitative feedback regarding the applicability and usefulness of the gamification process, as experienced by them in the case study.

**Overall Usefulness and Applicability.** The designers’ overall opinion was positive. They both found the process served them as a helpful guideline about how to proceed with the gamification.

**Structure of the Process.** Both designers liked the structure provided by the process. They could follow its steps (i.e., initial collection of game elements, then three steps plus iterations) and found no need to deviate from its structure. They confirmed that “aesthetics” of the MDA framework fit very well with the relationship layer because both were related to setting design goals. One of the designers experienced the combinations of dynamics and mechanics with the conversation and appearance layers to be rather intermingled, but stated that this did not hinder the design process.

| Activity | Working hours: | Gamified | Conventional |
|---|---|---|---|
| Design & Meetings | | 57 | 1 |
| Prototyping & Implementation | | 83 | 4 |
| Testing | | 107 | 1 |
| Total | | 247 | 6 |

**Table 9.3:** Working time needed for design and implementation of the gamified vs. conventional survey. Note that since the designers gamified an already existing survey, the numbers do not include the time needed to plan and formulate survey questions. Data originally published by Harms et al. [89].

**Catalogue of MDAs.** Regarding the first step of the process, they found that using a catalogue of MDAs provided ideas and useful inspiration. They often consulted it during their design activities and wished for a more extensive catalogue. The game elements for survey gamification by Wlaschits [201] proved useful for the designer's purposes, although they did not agree with every aspect. For instance, the use of an avatar has been considered to be unsuited for gamified surveys by Wlaschits [201], but the designers did employ an avatar in a meaningful way by personalizing the avatar based on demographic answers.

**Designing to Avoid Bias.** Regarding the subsequent steps of the process, the designers highlighted the need to carefully avoid bias. For example, they were aware that their chosen target aesthetic of challenge – although suited for the target population – should not result in overly complex interactions that could bias answers. They had therefore decided to make questions easy to answer but to produce the aesthetic of challenge by designing a narration of sports competition. In a similar way, the designers reflected on their decision to include an avatar in the gamified survey. They expressed concerns about users taking on foreign roles since this can bias survey results. They had therefore personalized the avatars based on respondent characteristics, thus communicating that the avatar represents the actual respondent, and not a fictitious role.

**Implementation and Iteration.** Both designers stated that iterative design and implementation of the gamified survey took a lot of time and effort – more than they had anticipated, and significantly more than the non-gamified variant, see Table 9.3 for a quantitative comparison. They found that – in addition to the gamification process – they could have used technical guidance and better development tools for their prototyping and implementation activities. They further suggested that future work should examine methods for reducing the implementation effort. The designers stressed the need for formative evaluations and said they had discovered and fixed many usability problems through formative usability testing and subsequent design iterations.

### 9.5.5 Study Design

The gamified survey's psychological and behavioral outcomes were evaluated in a remote, comparative, between-subject usability test. Invitations were sent and potentially forwarded via Email and Facebook, asking to participate in a survey about sports activities. The invitations did not promise any extrinsic reward and did not disclose the study's true purpose of evaluating a gamified design. Participants were unaware of the existence of two different survey designs and were automatically assigned to one of two test conditions (gamified vs. conventional design) using a round-robin algorithm upon arriving at the survey's web page. Duplicate responses were prevented through technical measures, i.e., by setting a browser cookie. After completing the survey, respondents were asked to also fill out a post-test questionnaire. Respondent behavior and answers were logged into a database. The survey was closed after 60 participants because participation had almost ceased at that time, resulting in an equal distribution of 30 participants in both the conventional and gamified survey.

### 9.5.6 Results

A total of N=60 participants accessed the sports survey and were randomly assigned to one of the variants of prototype (gamified vs. non-gamified, conventional survey). The survey was completed by 47 respondents (24 female, 23 male). A test session was considered complete if participants completed the sports survey, no matter if they also filled the subsequent post-test questionnaire (N=40 out of 47). Results are shown in Tables 9.4–9.7, including means (M), medians (MD) and standard deviations (SD). Significant differences ($p<0.05$), as tested using Mann-Whitney U-Tests, are highlighted in a bold font.

**Respondent Behavior.** Respondent behavior was automatically logged during use. We logged data regarding the amount of participation, engagement, and negative behavior.

The gamified survey had a lower *response rate* of 70% (21 out of 30 persons), as opposed to the conventional survey with a response rate of 86% (26 out of 30 persons).

We also measured the amount of time spent in the survey and the question where participants cancelled the survey. Amongst respondents who completed the survey, those working with the gamified design spent about *twice as much time* (19:20 ± 04:42) in comparison to those working with the conventional design (09:18 ± 04:39), see Table 9.4c. Amongst those who cancelled the survey, we found no significant differences regarding the *question after which participants cancelled* and the *time after which they quit*, as shown in Table 9.4a and b.

Besides response rate and time spent, we took an additional measure of engagement by evaluating the *amount of plain-text answers* that respondents were willing to provide, but found no significant difference between the gamified and conventional survey, see Table 9.4d.

We additionally investigated if respondent behavior was influenced by the following *demographic factors*: gender, age, self-rated health and sportiness, county, size of city, highest education and profession, relationship status, has children, living condition (i.e., lives with parents / friends / own family). None of the above factors proved to have a statistically significant influence.

**Answers Given.** We compared the answers given in response to the gamified versus non-gamified survey. For this purpose, all answers to the survey's 61 closed questions were numerically coded.

The answers to 4 of 61 questions were significantly different between the gamified and conventional survey (Table 9.5); all other questions revealed no such difference. Interestingly, all four of these questions were negatively worded Likert questions, part of large blocks of radiobuttons in the text-only survey and part of the javelin-throwing survey area in the gamified design. All four questions got higher answers (i.e., "agree more fully") in the conventional survey, as compared to the gamified variant.

We further investigated the possibility of answers being systematically influenced by the gamified survey's microgames. The javelin-throwing micro game did produce significantly different answers, as compared between the gamified (2.50 ± 1.072) vs. conventional (2.65 ± 1.130) design. There were no significant differences in any of the other micro-games.

We also compared the overall answers given, but found no significant difference between the gamified (2.42 ± 1.250) versus conventional (2.52 ± 1.310) design, see Table 9.5a.

| | N | M | MD | SD | Test statistic |
|---|---|---|---|---|---|
| a.) Amongst respondents who cancelled the survey: After how much time did they cancel? | | | | | |
| Gamified | 9 | 02:22 | 02:23 | 02:05 | U=70 |
| Conventional | 4 | 01:00 | 01:06 | 00:38 | p=0.330 |
| Total | 13 | 01:57 | 01:41 | 01:51 | |
| b.) Amongst respondents who cancelled the survey: After how many questions did they cancel? | | | | | |
| Gamified | 9 | 7.56 | 6.00 | 6.54 | U=110 |
| Conventional | 4 | 7.75 | 7.50 | 4.27 | p=0.956 |
| Total | 13 | 7.62 | 6.00 | 5.75 | |
| c.) Amongst respondents who completed the survey: How long did respondents take to complete it? | | | | | |
| Gamified | 21 | 19:20 | 18:20 | 04:42 | U=115 |
| Conventional | 26 | 09:18 | 07:52 | 04:39 | **p=0.000** |
| Total | 47 | 13:47 | 13:20 | 06:50 | |
| d.) Amongst respondents who completed the survey: Did gamification increase the word counts of the plain text answers? | | | | | |
| Gamified | 21 | 17.76 | 16.00 | 6.71 | U=115 |
| Conventional | 26 | 15.46 | 15.00 | 10.40 | p=0.120 |
| Total | 47 | 16.49 | 15.00 | 8.92 | |

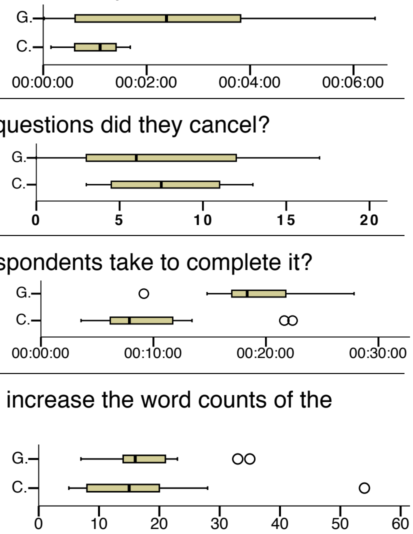



**Table 9.4:** Respondent behavior. The gamified survey took significantly longer to complete. All other differences were insignificant. Data originally published by Harms et al. [89].

As a sidenote, we also tried to compare the answers (of both the gamified and non-gamified survey) with those of the original survey [W9] that our case study is based on. But many demographic respondent characteristics (i.e., age, living condition, education, children) were significantly different in our sample, indicating that results cannot be directly compared.

**Self-Rated User Experience.** The perceived usability and user experience of the gamified survey, in comparison to the conventional version, was assessed through a post-test questionnaire shown immediately upon completion of the survey. The post-test questionnaire also included the System Usability Scale (SUS) [28]. It was filled out by an overall number of 40 respondents (21 gamified, 19 conventional).

Pair-wise comparison of *individual SUS questions* (see Table 9.6) revealed that respondents were significantly more inclined to frequently use the gamified survey (2.81 $\pm$ 0.75), compared to the conventional version (1.16 $\pm$ 1.02). However, respondents felt significantly less confident using the gamified survey (3.1 $\pm$ 0.7), compared to the conventional version (3.79 $\pm$ 0.42). There was no significant effect of survey design on any other SUS question. *Overall SUS scores* for both survey versions were comparable as well (p=0.851), with the gamified survey scoring 77.98 $\pm$ 11.10 points and the conventional survey scoring 79.08 $\pm$ 10.67 points.

Answers to further questions in the post-test questionnaire (Table 9.7) showed that respondents found the gamified survey (3.29 $\pm$ 0.56) significantly more *fun to use* than the conventional survey (2.32 $\pm$ 1.01). They were also significantly more inclined to *recommend* the gamified survey (3.38 $\pm$ 0.67), compared to the conventional survey (2.42 $\pm$ 0.96).

**Qualitative Results.** Qualitative comments were collected from respondents using open-ended questions in the post-test questionnaire. The comments were analyzed and grouped into structured categories (see Table 9.8). Of 21 respondents that finished the gamified survey, every single one answered the post-test questionnaire, while only 19 of 26 respondents that finished the conven-

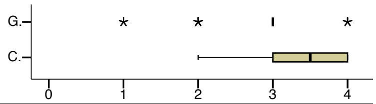
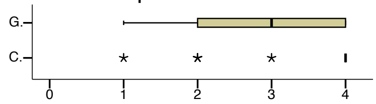
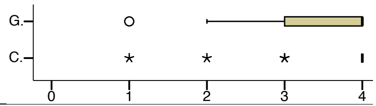
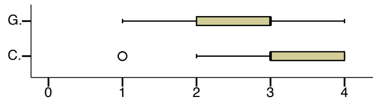
| | N | M | MD | SD | Test statistic | 0: disagree ⇔ 4: fully agree |
|---|---|---|---|---|---|---|
| a.) Reasons for being physically active: My friends push me to do sports: | | | | | | |
| Gamified | 21 | 2.76 | 3.00 | 0.768 | U=172.5 |  |
| Conventional | 26 | 3.31 | 3.50 | 0.788 | **p=0.020** | |
| Total | 47 | 3.06 | 3.00 | 0.818 | | |
| b.) Reasons for not being physically active: I do not like when others watch me do sports: | | | | | | |
| Gamified | 21 | 2.86 | 3.00 | 1.014 | U=151.5 |  |
| Conventional | 26 | 3.62 | 4.00 | 0.852 | **p= 0.003** | |
| Total | 47 | 3.28 | 4.00 | 0.994 | | |
| c.) Reasons for not being physically active: I have made bad experiences: | | | | | | |
| Gamified | 21 | 3.33 | 4.00 | 0.913 | U=200 |  |
| Conventional | 26 | 3.73 | 4.00 | 0.724 | **p=0.047** | |
| Total | 47 | 3.55 | 4.00 | 0.829 | | |
| d.) Sports is being taken far too serious in our society: | | | | | | |
| Gamified | 21 | 2.57 | 3.00 | 1.076 | U=178 |  |
| Conventional | 26 | 3.23 | 3.00 | 0.765 | **p=0.029** | |
| Total | 47 | 2.94 | 3.00 | 0.965 | | |

**Table 9.5:** Answers given. Amongst the survey's 61 closed questions, answers to the above four questions were significantly influenced by the survey's gamified vs. conventional design. All other questions showed no such influence. Data originally published by Harms et al. [89].

tional survey answered the post-test questionnaire. Respondents were also much more inclined to provide comments (both positive and negative) for the gamified survey (100%) compared to the conventional survey (37%).

Regarding the gamified survey, respondents positively commented on its novelty (N=9), variety (4) and interactivity (2). They found it playful (4) and fun (3). Graphics and animation also garnered positive comments (5), as well as the personalized and customizable avatar (4).

Some respondents complained that the gamified survey took much longer to answer than a conventional survey might have taken (4). There also were complaints about the controls (4) and responsiveness of individual mini games (3). Several respondents also commented that they would have liked to continue playing after finishing the survey (4), which is an interesting complaint insofar as it highlights the heightened level of engagement and joy compared to a conventional survey.

Comments regarding the conventional survey were less varied: Respondents found the survey easy to use (5) and easy to answer (3), while complaining about vague or ambigious questions (4) and boredom (3).

| | N | M | MD | SD | Test statistic |
|---|---|---|---|---|---|
| Overall SUS Score: | | | | | |
| Gamified | 21 | 78.21 | 77.50 | 11.10 | |
| Conventional | 19 | 79.20 | 77.50 | 10.67 | U=112 |
| Total | 40 | 78.69 | 77.50 | 10.77 | p=0.851 |
| SUS 1: I think that I would like to use this system frequently. | | | | | |
| Gamified | 21 | 2.81 | 3.00 | 0.75 | |
| Conventional | 19 | 1.16 | 1.00 | 1.02 | U=140 |
| Total | 40 | 2.03 | 2.00 | 1.21 | **p=0.000** |
| SUS 2: I found the system unnecessarily complex. | | | | | |
| Gamified | 21 | 1.14 | 1.00 | 0.96 | |
| Conventional | 19 | 0.84 | 1.00 | 0.96 | U=220 |
| Total | 40 | 0.84 | 1.00 | 0.96 | p=0.333 |
| SUS 3: I thought the system was easy to use. | | | | | |
| Gamified | 21 | 3.05 | 3.00 | 0.81 | |
| Conventional | 19 | 3.53 | 4.00 | 0.51 | U=230 |
| Total | 40 | 3.28 | 3.00 | 0.72 | p=0.078 |
| SUS 4: I think that I would need the support of a technical person to be able to use this system. | | | | | |
| Gamified | 21 | 0.52 | 0.00 | 0.81 | |
| Conventional | 19 | 0.11 | 0.00 | 0.32 | U=110 |
| Total | 40 | 0.33 | 0.00 | 0.66 | p=0.124 |
| SUS 5: I found the various functions in this system were well integrated. | | | | | |
| Gamified | 21 | 3.29 | 3.00 | 0.56 | |
| Conventional | 19 | 2.68 | 3.00 | 1.16 | U=110 |
| Total | 40 | 3.00 | 3.00 | 0.87 | p=0.124 |
| SUS 6: I thought there was too much inconsistency in this system. | | | | | |
| Gamified | 21 | 0.86 | 1.00 | 0.73 | |
| Conventional | 19 | 1.16 | 1.00 | 1.12 | U=230 |
| Total | 40 | 1.00 | 1.00 | 0.93 | p=0.469 |
| SUS 7: I would imagine that most people would learn to use this system very quickly. | | | | | |
| Gamified | 21 | 3.14 | 3.00 | 0.66 | |
| Conventional | 19 | 3.32 | 4.00 | 1.15 | U=110 |
| Total | 19 | 0.11 | 0.00 | 0.32 | p=0.117 |
| SUS 8: I found the system very cumbersome to use. | | | | | |
| Gamified | 21 | 1.00 | 1.00 | 0.84 | |
| Conventional | 19 | 0.53 | 0.00 | 0.91 | U=55 |
| Total | 40 | 0.78 | 1.00 | 0.90 | p=0.054 |
| SUS 9: I felt very confident using the system. | | | | | |
| Gamified | 21 | 3.10 | 3.00 | 0.70 | |
| Conventional | 19 | 3.79 | 4.00 | 0.42 | U=145 |
| Total | 40 | 3.43 | 4.00 | 0.68 | **p=0.003** |
| SUS 10: I needed to learn a lot of things before I could get going with this system. | | | | | |
| Gamified | 21 | 0.57 | 0.00 | 0.75 | |
| Conventional | 19 | 0.16 | 0.00 | 0.38 | U=230 |
| Total | 40 | 0.38 | 0.00 | 0.63 | p=0.078 |

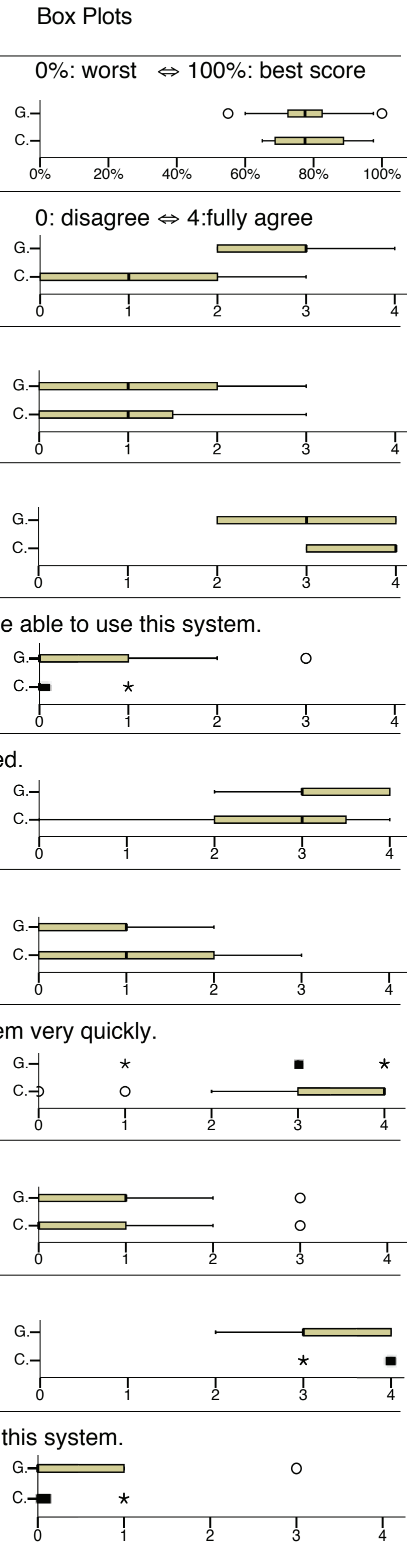



**Table 9.6:** System Usability Scale (SUS) scores from the post-test questionnaire. The overall SUS score was insignificantly different between the conventional and gamified surveys, but the answers to questions 1 and 9 significantly differed in favor of the gamified design. Data originally published by Harms et al. [89].

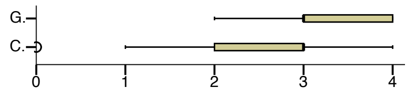
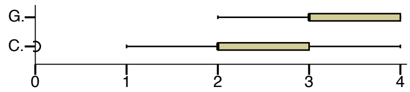
| | N | M | MD | SD | Test statistic | 0: disagree ⇔ 4:fully agree |
|---|---|---|---|---|---|---|
| a.) It was fun to answer this survey. | | | | | | |
| Gamified | 21 | 3.29 | 3.00 | 0.56 | |  |
| Conventional | 19 | 2.32 | 3.00 | 1.01 | U=54 | |
| Total | 40 | 2.83 | 3.00 | 0.96 | **p=0.002** | |
| b.) I would recommend this survey to other people. | | | | | | |
| Gamified | 21 | 3.38 | 3.00 | 0.67 | |  |
| Conventional | 19 | 2.42 | 2.00 | 0.96 | U=55 | |
| Total | 40 | 2.93 | 3.00 | 0.94 | **p=0.001** | |

**Table 9.7:** Self-rated fun and willingness of recommending the survey were significantly higher in the gamified variant. Data originally published by Harms et al. [89].

| ***Gamified:*** *Positive comments* | *N* | *Negative comments* | *N* |
|---|---|---|---|
| Novelty | 9 | Duration | 4 |
| Graphics & animation | 5 | Inability to continue playing after survey | 4 |
| Playfulness | 4 | Controls | 4 |
| Rich in variety | 4 | Responsiveness of individual games | 3 |
| Customizable avatar | 4 | Complexity | 1 |
| Fun | 3 | Sound | 1 |
| Interactivity | 2 | Amount of textual instructions | 1 |
| Ease of use | 1 | | |
| Anonymity | 1 | | |
| Suitability for children | 1 | | |
| No comment | 0 | No comment | 6 |

| ***Conventional:*** *Positive comments* | *N* | *Negative comments* | *N* |
|---|---|---|---|
| Ease of use | 5 | Vague or ambigious questions | 4 |
| Clarity and ease of answering | 3 | Boring | 3 |
| Broad theme | 1 | Missing progress indicator | 1 |
| No comment | 12 | No comment | 12 |

**Table 9.8:** Qualitative results. The table shows answers given to open-ended questions in the post-test questionnaire, structured into coded categories. Participants provided more, and more positive qualitative feedback regarding the gamified survey. Data originally published by Harms et al. [89].

### 9.5.7 Discussion

The above case study confirmed the applicability and usefulness of the design process. Evaluation results furthermore revealed that the gamified design successfully improved subjective user experience and engagement.

**Applicability and Usefulness of the Design Process.** The designers' overall opinion regarding the usefulness and applicability of the design process for survey gamification was very positive. They found the structure provided by the process a helpful guideline and appreciated the recommendation to use a catalogue of game elements for inspiration.

The overall required effort was high. Future work should investigate ways of lowering the required effort.

**Summary of Evaluation Results.** Quantitative results showed that respondents found the gamified survey more fun and spent significantly more time. This may prove beneficial for marketing surveys that aim at exposing users to a certain brand in a pleasant way. Furthermore, the respondents' higher willingness to recommend the gamified survey can be useful for viral marketing.

**Response Rate.** Given these positive outcomes, the lower overall *response rate* for the gamified survey was surprising and warrants further examination. Results provide two possible explanations. Firstly, the longer duration of the gamified survey may have caused participants to cancel. Secondly, higher engagement and positive feedback from those who did finish the gamified survey suggest that the gamified design may have caused polarized reactions among participants, turning those away who did not approve of the chosen design.

**Answers Given.** The observed influence of the gamified design on answers given requires further examination. On the one hand, if results were the same for both the gamified and conventional survey, this would question the ability of gamification to improve respondent behavior. On the other hand, diverging answers could not only be caused by improved respondent behavior (primarily expected in the gamified survey), but also by new bias introduced by the gamified design. To clarify the issue, we suggest that future work should develop automated measures of speeding, straightlining, random responding, lack of attention, conflicting, and empty answers and use these measures in case studies to compare gamified and conventional surveys. Future work may additionally examine the influence of the chosen theme (e.g., sports competition, but possibly other themes such as medieval games, hacker competition, ...).

**Qualitative Feedback.** The qualitative comments given by respondents reaffirm our initial expectations and motivation: That conventional surveys are often perceived as somewhat dull and boring, and that gamification is a suitable approach to make surveys more fun and engaging. Some of the comments validated specific design decisions made during the gamification process, such as the use of a customizable avatar to represent survey respondents, as well as implementation details such as graphics and animation. However, other comments demonstrated the difficulty of getting every design detail right, as evident from scattered complaints about the use of form controls and the responsiveness of individual micro-games. Additionally, the abrupt ending of the game after survey completion drew a large number of complaints. While an abrupt ending might be appropriate for a conventional survey, it seems inappropriate for more playful, open-ended experiences, as in our gamified survey. Comparing the comments between the gamified versus conventional survey, it becomes apparent that the gamified survey garnered both a larger number of comments, as well as more varied comments. One possible explanation for this difference in quantity and quality of respondent's comments is that the novelty of the gamified survey may have raised awareness of specific survey design aspects, in contrast to the dull familiarity of a conventional survey that spurred less reflection.

### 9.5.8 Conclusion

In summary, the case study presented in this section extended prior research by making the following two contributions.

Firstly, it allowed to document the successful application of a recently proposed design process for gamifying online surveys and to describe the resulting design. Specifically, the process was applied in a case study where two designers gamified a survey about sports and leisure activities amongst teenagers and young adults. The designers reported qualitative results that support the practical usefulness and applicability of the process. This indicates that other survey gamification projects can benefit from the same or a similar process.

As a second contribution, the resulting gamified design was evaluated in a remote online study with 60 participants. The gamified survey achieved better psychological outcomes (respondents found the gamified survey more fun, they were more inclined to use and recommend the gamified design, and provided more, and more positive, qualitative feedback) and better behavioral outcomes (respondents spent more time in the gamified survey and were more willing to fill the post-test questionnaire). These positive results are, however, accompanied by critical issues including a lower response rate in the gamified survey and possibly biased answers in one specific survey area. These issues warrant further empirical investigation.

Our future work in this area will continue in the following direction. Since a survey's gamification takes a lot of effort, we intend to examine ways of increasing benefits (e.g., by identifying best practices) and of reducing effort (e.g., by creating re-usable design patterns and component libraries) in order to improve the return on investment of future survey gamifications.

## 9.6 Case Study 2: Low-Cost Gamification by using Badges as one and only Game Element

The work described in this section (originally published in Harms et al. [91]) addresses two problems within the context of gamified online surveys. Firstly, the benefits of individual game elements are unclear to date. Prior work has evaluated combinations of multiple game elements; this study evaluates a single game element (i.e., the popular element of achievement badges) in isolation. Secondly, survey gamification requires a lot of effort. This study examines the use of just one game element as a novel low-cost method.

Methodologically, we used the design process for survey gamification from Section 9.4 to gamify an existing survey about sports and leisure activities among teenagers and young adults (i.e., the same survey as in the previous Section 9.5). The resulting design is shown in Figure 9.11. Our low-cost approach consisted of using just one game element – in this case study, the popular game element of achievement badges. This allowed to evaluate the benefits of a single game element in comparison to a regular survey serving as control condition, as well as to formulate lessons learned regarding our low-cost approach.

Results show that the badges improved the user experience but did not influence the respondents' behavior. These benefits are similar to related work but have been achieved with a lower effort. In summary, this indicates the proposed low-cost approach to be a viable and efficient solution for survey gamification, and achievement badges to be well-suited for gamified online surveys.

### 9.6.1 Achievement Badges in Gamified Online Surveys

Achievement badges are a common design pattern in games and gamification, compare Hamari et al. [86] and Werbach et al. [198]. According to Hamari et al.'s analysis [86], the design pattern is composed of a signifier (often visualized as a badge that displays name and description of the achievement), completion logic, and rewards. Antin et al. [9] have furthermore analyzed five social and psychological functions of achievements: setting goals for users, instructing about possible further activities, visualizing past activity, providing status symbols, and supporting group identification. The first three functions are apt for single-user experiences, as typically intended for survey


**Figure 9.11:** Gamified survey with achievement badges. The collection of badges in the top part of the screen showed awarded badges and challenged to complete further, yet unachieved (hence grayed-out) badges. Graphic originally published by Harms et al. [91].


**Figure 9.12:** The ten achievement badges that were designed for the gamified survey. Graphic originally published by Harms et al. [91].

filling. In contrast, the other two functions are based on social interactions; they are therefore less suited during survey filling, but may be employed before and after a survey to motivate members of a survey panel.

Despite the general popularity of badges in gamification, compare Hamari et al. [86] and Werbach et al. [198], their effect in the specific domain of gamified online surveys has not yet been evaluated. Related work by Puleston [155] suggests likely benefits of using badges in online surveys. His work described benefits of employing challenges and rewards in gamified online surveys. Badges provide both challenges and rewards by first challenging users to complete a task, and then rewarding them for their achievements. Nonetheless Puleston's work did not explicitly discuss badges and unfortunately did not report the statistical significance of findings.

### 9.6.2 Characteristics of the Case Study

An existing, publicly available online survey about sports and leisure activities among teenagers and young adults [W9] was chosen as a case study because of the following, beneficial characteristics: The survey's questions are easy to understand; therefore domain-specific knowledge amongst participants is unlikely to bias evaluation results. It employs state-of-the art survey design using the default style and functionality of the popular SurveyMonkey [W33] platform and thus provides a good control condition. Furthermore, our prior study in Section 9.5 gamified the same survey using an ambitious, labor-intensive, design, so it is interesting to see how these prior results compare to the new low-cost approach.

### 9.6.3 Design Process

Two designers, the author of this work and one HCI student, gamified the sports survey using achievement badges as one and only game element. They employed the design process for survey gamification put forth in Section 9.4 to design the achievement badges. Specifically, they chose target aesthetics of challenge, collection, and possession because they hoped that challenges would motivate users to engage in the survey, and considered collection and possession of badges to be suitable rewards.

They designed a total number of 10 achievement badges, see Figure 9.12, aiming to encourage positive behavior without motivating biased answers. In line with Hamari et al. [86]'s framework, each achievement consisted of a badge serving as signifier (designed to fit the survey's sports theme), a completion logic, and, as reward, possession of the badge in a collection of personal achievements. A collection of badges was placed in the topmost part of the screen, as shown in Figure 9.11. It visualized both past achievements (i.e., completed badges) and new challenges (further badges yet to be achieved, shown in a grayed-out visual style). The completion logic of an achievement was displayed when the user moved the mouse cursor above the badge. The achievement badges were evaluated through formative usability testing and improved in two subsequent design iterations.

The total effort invested into the gamification was 68 working hours, see Table 9.9. Much of this effort can be re-used to gamify other surveys since only the visual design of the badges (20 hours) was specific to the sports survey, in contrast to the reward and completion logic that may be re-used in future surveys. Note that installation activities did not include conceptualizing text-only questions because these were adopted from the existing sports survey. We did not outsource any activities.

| **Effort** (hours) | **Low-Cost Approach** | | Σ | **Prior work** | | Σ |
|---|---|---|---|---|---|---|
| **Conventional Survey** | Installation: | 4 | | Design: | 1 | |
| | Implementation: | 8 | | Implementation: | 4 | |
| | Testing: | 4 | 16 | Testing: | 1 | 6 |
| **Re-usable Gamification** | Design: | 14 | | – | | – |
| | Implementation: | 28 | | | | |
| | Testing: | 6 | 48 | | | |
| **Survey-specific Gamification** | Concept: | 4 | | Design: | 57 | |
| | Visual Design: | 16 | 20 | Implementation: | 83 | |
| | | | | Testing: | 107 | 247 |

**Table 9.9:** Effor in working hours required for the conventional survey and its gamification, compared between our low-cost approach and the prior study described in Section 9.5. Table originally published by Harms et al. [91].

### 9.6.4 Study Design and Test Procedure

The gamified survey was evaluated in a remote, comparative, between-subject usability test. Invitations were sent and potentially forwarded to teenagers and young adults (14 - 26 year old) via Email and Facebook, without promising extrinsic rewards and without disclosing the goal of evaluating a gamified design. Respondents filled a pre-test questionnaire, were randomly assigned to the gamified or conventional sports survey, and then completed a post-test questionnaire. The randomization algorithm balanced the assignment of test conditions as well as the participant's prior experience with computer games (as assessed in the pre-test questionnaire) using Efron's method of biased coins [61]. Duplicate responses were prevented through technical measures, i.e., by setting a browser cookie. The survey was stopped when participation ceased after two weeks.

We measured *psychological* outcomes of gamification (affect, user experience, and ratings of fun, duration, and preference) as well as *behavioral* outcomes (completion, duration, speeding, straightlining, and answers given).

The significance of observed differences was tested using non-parametric tests, more specifically, an Exact-Methods implementation of the Mann-Whitney U-test when computationally possible, otherwise Monte-Carlo with 10.000 samples. This method is well-suited for the lack of normality and the heteroscedasticity present in much of the data. Differences in dichotomous data were tested using Chi-Square tests. The significance level of all tests was $p<0.05$.

### 9.6.5 Results

In reaction to invitations sent via Email and Facebook, 139 persons clicked the invitation link, 126 of whom completed the pre-test questionnaire and were randomly assigned to either the gamified (N=66 participants) or conventional (N=60) sports survey. See Table 9.10 for a summary of the participants' demographic characteristics.

**Affect.** The participant's affect was measured using the I-PANAS-SF questionnaire. This is a 10-item, standardized, psychometric questionnaire that has been put forth by Thompson [183] to measure positive and negative affect. Answers to the questionnaire allow to compute two scores for positive and negative affect, each ranging from 0 to 50 with higher scores indicating a stronger

| **Demographic characteristics** | | **Gamified** | | **Convent.** | |
|---|---|---|---|---|---|
| | | **N** | **%** | **N** | **%** |
| **Gender** | Female | 27 | 40.9% | 24 | 40.0% |
| | Male | 36 | 54.6% | 36 | 60.0% |
| | N/A | 3 | 4.5% | 0 | 0.0% |
| **Agegroup** | ≤19 | 6 | 10.0% | 6 | 9.1% |
| | 20-29 | 41 | 68.3% | 46 | 69.7% |
| | ≥30 | 8 | 13.4% | 7 | 10.6% |
| | N/A | 5 | 8.3% | 7 | 10.6% |
| **"Do you play computer games?"** | Yes | 51 | 77.3% | 45 | 75.0% |
| | No | 15 | 22.7% | 15 | 25.0% |
| **"Are you familiar with game achievement badges?"** | Yes | 41 | 62.1% | 38 | 63.3% |
| | No | 25 | 37.9% | 22 | 36.7% |

**Table 9.10:** Demographic characteristics of the participants. Data originally published by Harms et al. [91].

emotion. We measured the respondent's affect in pre- and post-test questionnaire. Differential affect scores were calculated as post-test minus pre-test scores. None of the scores differed significantly depending on survey design, see Table 9.11a.

**User Experience.** We assessed the respondents' user experience using the AttrakDiff2 questionnaire that was developed by Hassenzahl et al. [95]. AttrakDiff2 allows to assess four qualities of user experience. These include the pragmatic quality of a product, its perceived attractiveness, as well as two hedonic qualities, the first one related to how well a product's design supports the user's self-expression of his or her identity, the second one related to a product's ability to stimulate a rich, sensual experience. We included the AttrakDiff2 questions in the post-test questionnaire. Results are summarized in Table 9.11b. The "pragmatic quality" and "hedonic quality - identity" scores were insignificantly different between the gamified and conventional survey. In contrast, the scores for "hedonic quality - stimulation" and "attractiveness" were significantly higher (i.e., better) in the gamified survey.

**Subjective Ratings.** The post-test questionnaire included three Likert-type questions where participants rated fun ("The survey was fun"), perceived duration ("The survey took a lot of time"), and subjective preference ("I liked the survey better than other surveys"). The available answers were coded as "strongly disagree" (1), "disagree" (2), "agree" (3) and "strongly agree" (4). Evaluation results (Table 9.11c) show no significant differences regarding the first two questions, but preference was higher (better) in the gamified survey.

**Completion Rate.** The gamified survey's completion rate of 86% (N=57 out of 66) was only insignificantly higher than the conventional survey's completion rate of 83% (N=50 out of 60), see Table 9.11d.

**Engagement.** The time that participants spent on the survey and the number of words they answered in response to free-text questions provided measures of how much respondents engaged with the survey. Results showed no significant difference between the two survey designs, see Table 9.11d. Respondents of the gamified survey collected an average of 7.04 badges (N=57, M=7.04, SD=1.636).

| | Gamified | | | Conventional | | | | |
|---|---|---|---|---|---|---|---|---|
| | N | M | SD | N | M | SD | Test Statistic | p-Value |
| **a) Affect** (I-PANAS-SF [183] questionnaire) | | | | | | | | |
| Pre-Test Positive Affect | 58 | 14.66 | 3.354 | 56 | 14.70 | 3.264 | U=1581.0 | 0.808 |
| Pre-Test Negative Affect | 60 | 6.15 | 1.858 | 58 | 6.29 | 2.392 | U=1728.0 | 0.945 |
| Post-Test Positive Affect | 55 | 14.42 | 3.521 | 47 | 14.49 | 3.406 | U=1257.0 | 0.813 |
| Post-Test Negative Affect | 55 | 5.67 | 1.001 | 48 | 5.73 | 1.976 | U=1163.5 | 0.220 |
| Differential Positive Affect | 53 | -0.45 | 2.081 | 44 | -0.50 | 2.029 | U=1127.5 | 0.779 |
| Differential Negative Affect | 55 | -0.29 | 1.133 | 46 | -0.22 | 0.696 | U=1238.5 | 0.827 |
| **b) User Experience** (AttrakDiff2 [95] questionnaire) | | | | | | | | |
| Pragmatic Quality | 48 | 1.38 | 0.634 | 42 | 1.31 | 0.735 | U=948.5 | 0.851 |
| Hedonic Quality - Identity | 43 | 0.74 | 0.721 | 38 | 0.72 | 0.749 | U=787.0 | 0.779 |
| Hedonic Quality - Stimulation | 48 | 0.90 | 1.000 | 41 | 0.23 | 0.885 | U=536.5 | $<$**0.001** |
| Attractiveness | 48 | 1.43 | 1.429 | 41 | 1.09 | 0.852 | U=746.0 | **0.049** |
| **c) Subjective Ratings** (4-item Likert-type questions in post-test questionnaire) | | | | | | | | |
| Fun | 55 | 2.98 | 0.828 | 48 | 2.83 | 0.975 | U=1233.5 | 0.545 |
| Time consuming | 56 | 1.66 | 0.837 | 48 | 1.69 | 0.689 | U=1261.5 | 0.557 |
| Preferred over other surveys | 53 | 3.09 | 0.714 | 42 | 2.64 | 0.958 | U=821.5 | **0.019** |
| **d) Respondent Behavior** (Quantitative observations) | | | | | | | | |
| Completion of the survey | 66 | 0.86 | 0.346 | 60 | 0.83 | 0.376 | $\chi^2(1)$=0.229 | 0.632 |
| Time spent in the survey | 57 | 08:04 | 03:12 | 50 | 08:19 | 04:50 | U=1366.0 | 0.713 |
| Words in free-text answers | 57 | 19.96 | 14.874 | 50 | 20.24 | 18.083 | U=1268.5 | 0.724 |
| Speeding | 64 | 0.58 | 1.307 | 59 | 0.59 | 0.949 | U=1714.5 | 0.292 |
| Straightlining | 61 | 0.38 | 0.553 | 57 | 0.26 | 0.552 | U=1535.0 | 0.182 |
| Empty Answers | 57 | 2.28 | 8.474 | 50 | 3.16 | 7.614 | U=1134.0 | 0.057 |

**Table 9.11:** Psychological (a-c) and behavioral (d) outcomes of using achievement badges in a gamified online survey. Data originally published by Harms et al. [91].

**Negative Respondent Behavior.** Speeding, straightlining, and empty answers were used as measures of negative respondent behavior. Speeding was measured in a similar way to Zhang et al. [206]. A threshold of 200 ms multiplied by the number of words in each survey page was set, allowing to count the number of pages where a participant was faster than the speeding threshold. Straightlining was assessed by counting the number of question groups with only identical answers. We also counted the number of questions with empty answers. None of the measures significantly differed between the gamified and conventional survey, see Table 9.11d.

**Answers Given.** We investigated the influence of gamification on the central tendency of answers given by respondents using separate tests for each individual survey question (Mann-Whitney U-tests for ordinal questions, Chi-Square tests for boolean questions; Dunn-Sidak adjusted p-Values for avoiding type I errors in multiple comparisons). None of the questions revealed a significant influence, the smallest adjusted p-Value being p=0.861.

**Qualitative Feedback.** The post-test questionnaire included three plain-text questions: “What did you like about the survey”, “What didn’t you like?”, and “What would you change or improve?”. Answers were coded into positive and negative statements made about the gamified and conventional survey, see Table 9.12. Participants of the gamified survey provided more, and more positive feedback. The majority of comments referred to the achievement badges, and did so in a positive way (22 positive and 4 negative statements). Participants commented, for example, “These badges are a great idea”, and “The badges were fun”. Among the four negative statements about the badges, one found them to be too pushy and obtrusive, one stated the opposite and suggested more visibility and interaction, and the other two negative statements concerned details of specific badges. Other

| Code | Gamified | | Conventional | |
|---|---|---|---|---|
| | Pos | Neg | Pos | Neg |
| **Achievement Badges** | 22 | 4 | n/a | n/a |
| **Questions and Wording** | 4 | 7 | 15 | 5 |
| **Usability** | 3 | 1 | 3 | 3 |
| **Survey Duration** | 2 | 1 | 2 | 1 |

**Table 9.12:** Qualitative feedback, as obtained from post-test questionnaires. Data originally published by Harms et al. [91].

feedback referred to the wording of questions (which we had adopted from the existing sports survey), usability (mostly visual design, e.g., “nice graphical design”, font size too small), and the survey’s duration (both positive and negative comments).

### 9.6.6 Discussion

Achievement badges were employed as the one and only game element in a gamified online survey. This allowed to evaluate their effect in isolation from other game elements, as well as to try a low-cost variant of the design process for survey gamification from Section 9.4.

**Outcomes of Employing Achievement Badges.** Evaluation results revealed improved psychological outcomes but no behavioral changes. Respondents found the gamified design to be more attractive and stimulating, preferred it over other surveys, and provided positive feedback about the badges. Respondent behavior showed no influence of gamification – as a positive aspect of this result, the gamification did not produce biased answers. In summary, results indicate achievement badges to be suitable and safe to use.

**Low-cost Approach.** We proposed and evaluated the use of a single game element (achievement badges in our case study) as a low-cost design method for gamifying online surveys. The outcome of improved user experience without behavioral change is similar to related work by Cechanowicz et al. [37], Downes-Le Guin et al. [60], and Harms et al. [89], but was achieved with a lower effort, much of which can be re-used for further surveys (see Table 9.9), which indicates a higher return on investment (ROI). This supports our hypothesis that using just one game element is a well-suited low-cost method for survey gamification.

**Future Work.** Practitioners interested in using badges to gamify an online survey may ask if it is worth the effort. The answer depends on how highly they value the monetary worth of the benefits and working hours reported in this paper. Future research may wish to challenge, strengthen, or generalize our results in further contexts using different game elements. It would also be interesting to evaluate long-term panelist behavior across multiple surveys, as well as viral distribution of invitations. Follow-up research may also seek to further increase ROI. This will require more formal measures of ROI to enable comparisons across multiple versions of a gamified survey. One strategy will then be to reduce efforts, e.g., through re-usable implementations and gamification frameworks as proposed by Herzig et al. [98]; another strategy will be to improve outcomes, e.g., by fine-tuning achievement badges or through other game elements.

### 9.6.7 Conclusion

The use of a single game element was investigated in the case study presented in this section as a low-cost method for gamifying online surveys. In the case study, the popular game element of achievement badges was employed to gamify an existing online survey about sports and leisure activities among teenagers and young adults (i.e., the same survey as in Section 9.5). Results show that the gamified survey did not change user behavior, but produced better psychological outcomes (better user experience, higher preference, positive qualitative feedback). These results are similar to related, more laborious studies, but were achieved using a simpler, low-cost approach, thus indicating a higher return on investment. In summary, the case study suggests the use of just one game element to be a useful and applicable low-cost approach and achievement badges to be well-suited for increasing the user experience in gamified online surveys.

## 9.7 Conclusion and Future Work

Form-based user interfaces, as typically employed in online surveys, have a strong connotation of being dull and boring to fill. The work presented in this chapter addressed this problem through gamification, i.e., by employing design elements characteristic for games. The prior sections of this chapter contributed a novel design process for gamifying online surveys and evaluation results from two empirical studies.

The design process unifies concepts and methods from the related disciplines of gamification, form design, survey methodology, and usability engineering. Qualitative feedback from the two case studies strongly supports the process's applicability and usefulness, both for ambitious, laborious gamification projects as well as for rapid, low-cost approaches.

The first case study employed the design process to turn an existing survey about sports and leisure activities among teenagers and young adults into a highly gamified survey composed of multiple micro-games. The gamified survey achieved better psychological and behavioral outcomes that were, however, accompanied by a lower response rate and possibly biased answers in one specific survey area.

The second case study gamified the same survey using a low-cost variant of the design process, i.e., by using achievement badges as one and only game element. Evaluation results were similar to the first case study, but were achieved with a lower effort. These results indicate achievement badges to be suitable and safe to use and the low-cost approach to be applicable and useful for achieving good results with a relatively low effort.

Future work in survey gamification will have to address the difficulty of turning positive, psychological outcomes of survey gamification into positive respondent behavior, e.g., to encourage thoughtful, truthful answers and to reduce undesired behavior such as pre-mature termination, empty answers, speeding, and straightlining. From a practical, industrial perspective, the required effort for survey gamification is still high; it will be essential to re-use efforts through gamification frameworks. Also, the outcomes that can be achieved with various game elements are still unclear. In addition to the second study presented in this chapter, future work should evaluate the outcomes of further game elements in the context of gamified online surveys.

Future work in form design should further seek to explicitely address and improve hedonic qualities of form-based user interfaces. Towards this goal, gamification, playful design, schema-free form filling, and unbureaucratic communication may provide useful approaches for designing pleasant user experiences with and around form-based user interfaces.

# 10 Overall Discussion

This dissertation set out to provide a firm, theoretical understanding of form-based user interfaces (UIs) and to evolve the current design practice. The corresponding contributions are visualized in Table 10.1 and discussed in this chapter.

The goals of this dissertation are focussed on the design of modern form-based UIs, as understood from an HCI perspective. Beyond this specific focus, other artifacts from other time periods, possibly using other media and technology, may be researched from the perspectives of a large variety of disciplines. Some of these other possibilities of conducting research about forms were not only discussed, but actively used in this thesis. This includes, for example, the historical perspective taken in Chapter 3 and the use of Semiotics and Cognitive Science in Chapter 4. Despite the broad use of concepts and methods in this thesis, it is important to stress that its primary goal is to design more efficient and pleasant form-based interactions in today's software applications.

The overall relevancy of the goals of this dissertation stems from widespread use of form-based UIs in many of today's software applications, as well as from widespread criticism of these UIs regarding dullness, bureaucratic connotations, and bad usability. The introduction of this work described two possible reactions to this situation, both of which can be found in related human-computer interaction (HCI) literature. One reaction is to interpret the criticized characteristics as being constitutive for form-based UIs and to consequently recommend that designers should avoid them. Another reaction is found in related work that proposed remedies and improvements and thus interpreted the same, criticized characteristics as contingent design practices that should rather be changed. Thus the very practical design question if designers should avoid or improve form-based UIs is tightly linked to a deep, theoretical confusion regarding the defining characteristics of form-based UIs.

The *theoretical part* of the dissertation addressed the current confusion over the defining characteristics of form-based UIs. It contributed an investigation of historical forms, a novel definition of today's form-based UIs, and a systematic analysis of goals for future research. The novel definition understands form-based UIs through the concept of UI metaphor. According to the definition, form-based UIs are user interfaces that include a metaphoric reference to other (e.g., paper, historical, electronic, or any other kinds of) forms. We elaborated the definition using Semiotic theory of UI metaphor. This allowed to describe the interpretation of the 'form' UI metaphor from the perspectives of designers and users, as well as the metaphor's current habituation and conventionalization. Habituation and conventionalization imply that there exist conventionally fulfilled characteristics of form-based UIs. We interpreted those characteristics that have time-invariantly applied and that have uniformly been suggested in related work as being constitutive. We put them forth as three, further, necessary, defining characteristics of form-based UIs, as follows. Firstly, form-based UIs have a specific appearance characterized by the use of placeholders. Secondly, form-based UIs have a specific structure composed of fields, which in turn are composed of fixed and variable parts, i.e., labels and placeholders. Thirdly, form-based UIs have a specific socio-cultural function because they are used to abstract and categorize individual human experiences into standardized representations.

Many other characteristics are not necessary or defining for form-based UIs. In particular, the criticized dullness, bureaucracy, and lack of usability have been shown to be contingent characteristics and thus nothing more than a design practice that should rather be changed. The theory provided in

| | | |
|---|---|---|
| **Part I: Theoretical Part** | | |
| **Analysis and Evolution of Form-based UIs** (Chapter 2)<br>A comprehensive literature review of prior definitions of form-based UIs. | | |
| **Past** (Chapter 3)<br>A summary and overview of the historical development of forms. Identification of historically time-invariant characteristics. Comparison with today's form-based UIs. | **Present** (Chapter 4)<br>A novel definition of form-based UIs. Explication and elaboration of this definition to explain the interpretation of the 'form' UI metaphor by designers and users. | **Future** (Chapter 5)<br>A systematic and comprehensive analysis of fourteen goals for future research in form design. Each goal is described along with related work. |
| **Part II: Practical Part** | | |
| **Navigation** (Chapter 7)<br>Design space analysis and specific solution for applying the Focus&Context principle from information visualization to form design. Evaluations of the novel design on desktop and mobile devices with promising results. | **Collaboration** (Chapter 8)<br>Design space analysis for real-time collaborative form-filling. Implementation of a novel rapid prototyping tool, allowing for easy configuration instead of time-consuming implementation of the available design options. | **Gamification** (Chapter 9)<br>A novel design process for gamifying online surveys. Application of the design process in two case studies. Empirical evaluations of the gamified survey designs revealed several beneficial outcomes of gamification. |

**Table 10.1:** Summary of contributions made in this dissertation. The theoretical part spans a large narration that covers the past, present, and future of form-based user interfaces and thus provides useful understanding about form-based UIs. The practical part contributes research in three specific areas related to navigation, collaboration, and gamification in the context of form-based UIs and thus seeks to advance the current design practice towards more efficient and pleasant interactions.

this dissertation allowed to formulate detailed directions for how such change can take place. Accordingly, re-interpretation of the 'form' UI metaphor by designers allows to break away from the current, habituated, criticized design practice and to produce new meaning and innovative designs. The dissertation provided one such re-interpretation which allowed to systematically analyze and propose fourteen goals for future research in form design.

The *practical part* of this dissertation sought to improve the current design practice by proposing innovative form designs for three of the fourteen proposed research goals; two of them related to utilitarian qualities of form-based UIs (i.e., efficient navigation and easy collaboration) and one of them related to hedonic qualities (i.e., pleasant, game-like user experiences in online surveys). Corresponding contributions included analyses of available design options, proposals of innovative designs, and evaluations of these designs with promising results, as described in the following paragraphs.

*Navigation* is required for applications in various domains where users edit large amounts of form data. To support efficient navigation and provide a good overview of the form schema, the work presented in Chapter 7 proposed to apply the Focus&Context principle from information visualization to form design. It contributed a design space analysis and comparative usability evaluations on desktop and mobile devices. Results confirmed that even novice users could work with the novel design efficiently. The evaluation on mobile devices revealed that scrolling should be avoided in favor of other design patterns that provide a better overview.

*Collaboration* through form-based UIs by multiple form fillers working together to edit shared form data is not typically supported in many of today's applications. The work presented in Chapter 8 contributed a design space analysis to inform designers about available design options. It furthermore presented a novel rapid-prototyping tool to support rapid design iterations and empirically grounded design decisions.

*Gamification* of form-based UIs in online surveys is a promising means for improving the user experience and for stimulating positive respondent behavior. Chapter 9 put forth a novel design process for gamifying online surveys. Applications of the proposed process in two case studies confirmed its usefulness and applicability. Empirical evaluations of the gamified survey designs revealed significant improvements in user experience.

In summary, the contributions of this dissertation have provided theoretical foundations for form design, a clear definition of form-based UIs, practical improvements, corresponding evaluations, and a systematic analysis of future research goals, compare Table 10.1.

Future research is much needed in many areas of the above contributions, e.g., to further improve the proposed designs, to apply and evaluate these improvements in further domains and applications, and to enable easy implementation of the improvements through re-usable software components. Also, many of the fourteen research goals could not be addressed in this thesis, but should be addressed in future work. In view of these limitations, the present dissertation must be seen as a starting point and as a first impulse in a much needed direction – towards a deeper understanding and a new design practice characterized by efficient and pleasant interactions in form-based UIs.

# 11 Conclusion

The present dissertation seeks to provide theoretical understanding for form design and to practically evolve form-based user interfaces (UIs) towards more efficiency and a better user experience.

The primary theoretical contributions of this dissertation are a novel definition of form-based UIs and a systematic analysis of goals for future research in form design. These contributions are firmly grounded in a comprehensive review of prior definitions found in related work and in historical investigations regarding past and present characteristics of forms and form-based UIs.

The practical contributions include analyses of available design options, proposals of innovative designs for specific case studies, and corresponding evaluations. These contributions were made in three areas of form design, i.e., regarding navigation in long form-based UIs, real-time collaboration, and gamification of online surveys. Evaluation results largely confirmed the usefulness and applicability of the proposed concepts and quantified the improvements that were achieved through novel, innovative form designs.

In summary, the contributions of this dissertation provide designers with firm, theoretical foundations and specific goals that can inspire future, innovative form design. The practical research that is presented in this dissertation addressed three of these goals and can be seen as first steps in a much-needed direction, i.e., to evolve form-based UIs away from their static, document-like, bureaucratic heritage towards more efficient, interactive, and pleasant user interfaces.

# Bibliography

The following bibliography provides references to scientific literature, including peer reviewed journal articles and conference papers, as well as books. An additional list of web references is printed in the next subsection.

## References


[1] Y. Abdelrahman, T. Kubitza, K. Wolf, N. Pohl, and A. Schmidt. „Tick that box: interactive paper documents“. In: *Human-Computer Interaction – INTERACT'15*. Ed. by J. Abascal, S. Barbosa, M. Fetter, T. Gross, P. Palanque, and M. Winckler. Vol. 9298. Lecture Notes in Computer Science. Springer, 2015, pp. 376–383.

[2] R. Abdullah and K. Henze. *Formulare. Von der Wiege bis zu Bahre...: Formulare im Corporate Design*. Stiebner, 2007.

[3] M. Ahmed-Nacer, P. Urso, V. Balegas, and N. Preguica. „Concurrency control and awareness support for multi-synchronous collaborative editing“. In: *Collaborative Computing: Networking, Applications and Worksharing. 2013 9th International Conference on*. Collaborate.com '13. 2013, pp. 148–157.

[4] W. Aigner, S. Miksch, W. Müller, H. Schumann, and C. Tominski. „Visualizing time-oriented data – a systematic view“. *Computers & Graphics* 31.3 (2007), pp. 401–409.

[5] J. Alexander and A. Cockburn. „An empirical characterisation of electronic document navigation“. In: *Proceedings of Graphics Interface 2008*. GI '08. Canadian Information Processing Society, 2008, pp. 123–130.

[6] S. Allen, G. Barnett, and P. Castleman. „Use of a time-shared general-purpose file-handling system in hospital research“. *Proceedings of the IEEE* 54.12 (1966), pp. 1641–1648.

[7] C. R. Anderson, P. Domingos, and D. S. Weld. „Relational markov models and their application to adaptive web navigation“. In: *Proceedings of the eighth ACM SIGKDD international conference on Knowledge Discovery and Data Mining*. KDD '02. ACM, 2002, pp. 143–152.

[8] J. H. E. Andriessen. *Working with groupware: understanding and evaluating collaboration technology*. Computer Supported Cooperative Work. Springer, 2003.

[9] J. Antin and E. F. Churchill. „Badges in social media: a social psychological perspective“. In: *CHI 2011 Gamification Workshop Proceedings*. 2011.

[10] P. Antunes, V. Herskovic, S. F. Ochoa, and J. A. Pino. „Structuring dimensions for collaborative systems evaluation“. *ACM Computing Surveys* 44.2 (2008), 8:1–8:28.

[11] Y. Aoki. „Collaborative environment for supporting web users“. In: *Systems, Man, and Cybernetics, 2001 IEEE International Conference on*. Vol. 4. 2001, pp. 2309–2316.

[12] A. F. Aparicio, F. L. G. Vela, J. L. G. Sánchez, and J. L. I. Montes. „Analysis and application of gamification“. In: *Proceedings of the 13th International Conference on Interacción Persona-Ordenador*. INTERACCION '12. ACM, 2012, 17:1–17:2.

[13] D. L. Atkins, T. Ball, G. Bruns, and K. Cox. „Mawl: a domain-specific language for form-based services“. *IEEE Transactions on Software Engineering* 25.3 (1999), pp. 334–346.

[14] R. Atterer and P. Lorenzi. „A heatmap-based visualization for navigation within large web pages“. In: *Proceedings of the 5th Nordic conference on Human-Computer Interaction: Building Bridges*. NordiCHI '08. ACM, 2008, pp. 407–410.

[15] K. Axelsson and S. Ventura. „Reaching communication quality in public e-forms – a communicative perspective on e-form design“. In: *Electronic Government*. Ed. by M. Wimmer, J. Scholl, and Å. Grönlund. Vol. 4656. Lecture Notes in Computer Science. Springer, 2007, pp. 342–353.

[16] J. Bargas-Avila, O. Brenzikofer, S. Roth, A. Tuch, S. Orsini, and K. Opwis. „Simple but crucial user interfaces in the world wide web: introducing 20 guidelines for usable web form design“. In: *User Interfaces*. Ed. by R. Matrai. InTech, 2010. Chap. 1.

[17] R. B. Barnett. *Forms for People: Designing Forms that People Can Use*. Robert Barnett & Associates, 2005.

[18] R. B. Barnett. *Managing Business Forms*. 5th. Robert Barnett & Associates, 2008.

[19] P. Barr, R. Biddle, and J. Noble. „A Semiotic model of user-interface metaphor“. In: *Virtual, Distributed and Flexible Organisations*. Ed. by K. Liu. Springer, 2005, pp. 189–215.

[20] P. Becker. „Formulare als “Fließband” der Verwaltung? Zur Rationalisierung und Standardisierung von Kommunikationsbeziehungen“. In: *Eine intelligente Maschine? Handlungsorientierungen moderner Verwaltung (19./20. Jh.)* Ed. by P. Collin and K.-G. Lutterbeck. Nomos, 2009.

[21] P. Becker. „Le charme discret du formulaire. De la communication entre administration et citoyen dans l'aprés-guerre“. In: *Politiques et usages de la langue en Europe*. Ed. by M. Werner. Éditions de la MSH, 2007, pp. 217–240.

[22] D. S. Bell and R. A. Greenes. „Evaluation of UltraSTAR: performance of a collaborative structured data entry system“. In: *Proceedings of the Annual Symposium on Computer Application in Medical Care*. American Medical Informatics Association, 1994, pp. 216–222.

[23] D. Benyon. *Designing Interactive Systems: A Comprehensive Guide to HCI, UX and Interaction Design*. 3rd. Pearson, 2013.

[24] S. Björk and J. Redström. „Redefining the focus and context of focus+context visualizations“. In: *Proceedings of the IEEE Symposium on Information Vizualization 2000*. INFOVIS '00. IEEE Computer Society, 2000, pp. 85–90.

[25] A. F. Blackwell. „The reification of metaphor as a design tool“. *ACM Transactions on Computer-Human Interaction (TOCHI)* 13.4 (2006), pp. 490–530.

[26] M. Blumendorf, G. Lehmann, and S. Albayrak. „Bridging models and systems at runtime to build adaptive user interfaces“. In: *Proceedings of the 2Nd ACM SIGCHI Symposium on Engineering Interactive Computing Systems*. EICS '10. ACM, 2010, pp. 9–18.

[27] J. M. Boyer, C. Wiecha, and R. P. Akolkar. „A REST protocol and composite format for interactive web documents“. In: *ACM Symposium on Document Engineering*. Ed. by U. M. Borghoff and B. Chidlovskii. ACM, 2009, pp. 139–148.

[28] J. Brooke. „SUS - a quick and dirty usability scale“. *Usability evaluation in industry* 189 (1996), p. 194.

[29] B. Brownell, J. Cechanowicz, and C. Gutwin. „Gamification of survey research: empirical results from gamifying a conjoint experiment“. In: *Gamification in Education and Business*. Ed. by T. Reiners and L. C. Wood. Springer, 2015, pp. 569–591.

[30] C. Bueno, S. Crossland, C. Lutteroth, and G. Weber. „Rewriting history: more power to creative people“. In: *Proceedings of the 23rd Australian Computer-Human Interaction Conference*. OzCHI '11. ACM, 2011, pp. 62–71.

[31] S. Burigat and L. Chittaro. „On the effectiveness of overview+ detail visualization on mobile devices“. *Personal and ubiquitous computing* 17.2 (2013), pp. 371–385.

[32] T. Büring, J. Gerken, and H. Reiterer. „Usability of overview-supported zooming on small screens with regard to individual differences in spatial ability“. In: *Proceedings of the Working Conference on Advanced Visual Interfaces*. AVI '06. ACM, 2006, pp. 233–240.

[33] B. Burkhard. „Liste, Vordruck, Bildschirmmaske. Eine kleine Geschichte des Formulars“. *Das Archiv, Magazin für Kommunikationsgeschichte* 2010.1 (2010), pp. 6–13.

[34] B. Buxton. *Sketching User Experiences: Getting the Design Right and the Right Design*. Morgan Kaufmann, 2007.

[35] S. Card, J. Mackinlay, and B. Shneiderman. *Readings in Information Visualization: Using Vision to Think*. Morgan Kaufmann Series in Interactive Technologies. Morgan Kaufmann, 1999.

[36] S. K. Card and D. Nation. „Degree-of-interest trees: a component of an attention-reactive user interface“. In: *Proceedings of the Working Conference on Advanced Visual Interfaces*. AVI '02. ACM, 2002, pp. 231–245.

[37] J. Cechanowicz, C. Gutwin, B. Brownell, and L. Goodfellow. „Effects of gamification on participation and data quality in a real-world market research domain“. In: *Gamification 2013: Proceedings of the First International Conference on Gameful Design, Research, and Applications*. ACM, 2013, pp. 66–73.

[38] B.-W. Chang, J. D. Mackinlay, P. T. Zellweger, and T. Igarashi. „A negotiation architecture for fluid documents“. In: *Proceedings of the 11th annual ACM symposium on User interface software and technology*. UIST '98. ACM, 1998, pp. 123–132.

[39] C. Chen and R. Rada. „Interacting with hypertext: a meta-analysis of experimental studies“. *Human-Computer Interaction* 11.2 (1996), pp. 125–156.

[40] B. Cheng, S. Agarwal, and D. Abbadessa. „Enabling co-browsing service across different browsers and devices“. In: *Service-Oriented and Cloud Computing*. Ed. by F. Paoli, E. Pimentel, and G. Zavattaro. Vol. 7592. Lecture Notes in Computer Science. Springer, 2012, pp. 214–229.

[41] L. Christensen and J. Martinsson. „Field work, survey completion times and data quality in citizen panel 4 - 2012“. *LORE Methodological Notes* 2013.1 (2013).

[42] A. Cockburn, C. Gutwin, and J. Alexander. „Faster document navigation with space-filling thumbnails“. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '06. ACM, 2006, pp. 1–10.

[43] A. Cockburn, A. Karlson, and B. B. Bederson. „A review of overview+detail, zooming, and focus+context interfaces“. *ACM Computing Surveys* 41.1 (2009), 2:1–2:31.

[44] A. Cockburn, P. Quinn, C. Gutwin, and S. Fitchett. „Improving scrolling devices with document length dependent gain“. In: *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*. CHI '12. ACM, 2012, pp. 267–276.

[45] K. Conley and C. Donaldson. „Gamification: the measurement of benefits“. In: *Gamification in Education and Business*. Ed. by T. Reiners and L. C. Wood. Springer, 2015, pp. 673–688.

[46] M. P. Couper, R. Baker, and J. Mechling. „Placement and design of navigation buttons in web surveys“. *Survey Practice* 4.1 (2013).

[47] A. Delavande and S. Rohwedder. „Eliciting subjective probabilities in internet surveys“. *Public opinion quarterly* 72.5 (2008), pp. 866–891.

[48] G. Desanctis and R. B. Gallupe. „A foundation for the study of group decision support systems“. *Management science* 33.5 (1987), pp. 589–609.

[49] S. Deterding, D. Dixon, R. Khaled, and L. Nacke. „From game design elements to gamefulness: defining "gamification"“. In: *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*. MindTrek '11. ACM, 2011, pp. 9–15.

[50] D. A. Dillman and J. D. Smyth. „Design effects in the transition to web-based surveys“. *American Journal of Preventive Medicine* 32.5, Supplement (2007), S90–S96.

[51] A. Dillon, C. McKnight, and J. Richardson. „Navigation in hypertext: a critical review of the concept“. In: *Human-Computer Interaction – INTERACT'90*. Ed. by D.Diaper, D.Gilmore, G.Cockton, and B. Shackel. North-Holland, 1990, pp. 587–592.

[52] J. M. DiMicco, K. J. Hollenbach, A. Pandolfo, and W. Bender. „The impact of increased awareness while face-to-face“. *Human–Computer Interaction* 22.1-2 (2007), pp. 47–96.

[53] DIN EN ISO 9241-11. *Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability*. 1998.

[54] DIN EN ISO 9241-143. *Ergonomics of human-computer interaction – Part 143: Forms*. 2012.

[55] A. Dix, J. Finlay, G. D. Abowd, and R. Beale. *Human-Computer Interaction*. 3rd. Vol. 3. Prentice Hall, 2004, p. 834.

[56] S. Dolnicar, B. Grün, and V. Yanamandram. „Dynamic, interactive survey questions can increase survey data quality“. *Journal of Travel & Tourism Marketing* 30.7 (2013), pp. 690–699.

[57] M. Dörk, H. Lam, and O. Benjelloun. „Accentuating visualization parameters to guide exploration“. In: *CHI '13 Extended Abstracts on Human Factors in Computing Systems*. CHI EA '13. ACM, 2013, pp. 1755–1760.

[58] K. Dørum and K. Garland. „Efficient electronic navigation: a metaphorical question?“ *Interacting with Computers* 23.2 (2011), pp. 129–136.

[59] P. Dourish and V. Bellotti. „Awareness and coordination in shared workspaces“. In: *Proceedings of the 1992 ACM Conference on Computer-supported Cooperative Work*. CSCW '92. ACM, 1992, pp. 107–114.

[60] T. Downes-Le Guin, R. Baker, J. Mechling, and E. Ruyle. „Myths and realities of respondent engagement in online surveys“. *International Journal of Market Research* 54.5 (2012), pp. 1–21.

[61] B. Efron. „Forcing a sequential experiment to be balanced“. *Biometrika* 58.3 (1971), pp. 403–417.

[62] F. Eisermann. „The indulgence as a media event: Developments in communication through broadsides in the fifteenth century“. In: *Promissory Notes on the Treasury of Merits. Indulgences in Late Medieval Europe*. Ed. by R. N. Swanson. Vol. 5. Brill Academic, 2006, pp. 309–330.

[63] F. Eisermann. „Zu den Anfängen des gedruckten Formulars (Gastbeitrag)“. In: *Formulare. Von der Wiege bis zu Bahre...: Formulare im Corporate Design*. Stiebner, 2007.

[64] C. A. Ellis and S. J. Gibbs. „Concurrency control in groupware systems“. In: *Proceedings of the 1989 ACM SIGMOD International Conference on Management of Data*. SIGMOD ’89. ACM, 1989, pp. 399–407.

[65] C. A. Ellis, S. J. Gibbs, and G. Rein. „Groupware: some issues and experiences“. *Communications of the ACM* 34.1 (1991), pp. 39–58.

[66] G. Fauconnier and M. Turner. „Rethinking metaphor“. In: *The Cambridge Handbook of Metaphor and Thought*. Ed. by J. Raymond W. Gibbs. Cambridge Books Online. Cambridge University Press, 2008, pp. 53–66.

[67] L. Findlater, K. Moffatt, J. McGrenere, and J. Dawson. „Ephemeral adaptation: the use of gradual onset to improve menu selection performance“. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI ’09. ACM, 2009, pp. 1655–1664.

[68] S. Firmenich, V. Gaits, S. Gordillo, G. Rossi, and M. Winckler. „Supporting users tasks with personal information management and web forms augmentation“. In: *Web Engineering*. Ed. by M. Brambilla, T. Tokuda, and R. Tolksdorf. Vol. 7387. Lecture Notes in Computer Science. Springer, 2012, pp. 268–282.

[69] M. R. Frank and P. Szekely. „Adaptive forms: an interaction technique for entering structured data“. *Knowledge-Based Systems* 11 (1998), pp. 37–45.

[70] D. M. Frohlich, L. Crossfield, and G. Gilbert. „Requirements for an intelligent form-filling interface“. *People and computers: Designing the interface* (1985), pp. 102–116.

[71] G. Furnas. „A fisheye follow-up: further reflections on focus + context“. In: *Proceedings of the SIGCHI conference on Human Factors in computing systems*. ACM. 2006, pp. 999–1008.

[72] G. W. Furnas. „Effective view navigation“. In: *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*. CHI ’97. ACM, 1997, pp. 367–374.

[73] F. Gantner. *Theorie der juristischen Formulare: Ein Beitrag zur Methodenlehre der Rechtsanwendung*. Vol. 252. Schriften zur Rechtstheorie. Duncker & Humblot, 2010, p. 166.

[74] P. Gaubatz, W. Hummer, U. Zdun, and M. Strembeck. „Enforcing entailment constraints in offline editing scenarios for real-time collaborative web documents“. In: *29th Symposium On Applied Computing*. ACM, 2014.

[75] P. Gaubatz, W. Hummer, U. Zdun, and M. Strembeck. „Supporting customized views for enforcing access control constraints in real-time collaborative web applications“. In: *Web Engineering*. Ed. by F. Daniel, P. Dolog, and Q. Li. Vol. 7977. Lecture Notes in Computer Science. Springer, 2013, pp. 201–215.

[76] P. Gaubatz and U. Zdun. „Supporting entailment constraints in the context of collaborative web applications“. In: *Proceedings of the 28th Annual ACM Symposium on Applied Computing*. SAC ’13. ACM, 2013, pp. 736–741.

[77] N. Gehani. „The potential of forms in office automation“. *IEEE Transactions on Communications* 30.1 (1982), pp. 120–125.

[78] J. Goody. *The Domestication of the Savage Mind*. Themes in the Social Sciences. Cambridge University Press, 1977.

[79] S. Grosse and W. Mentrup, eds. *Bürger, Formulare, Behörde*. Vol. 51. Forschungsberichte des Instituts für Deutsche Sprache, Institut für Deutsche Sprache. G. Narr, 1980.

[80] R. M. Groves, E. Singer, J. M. Lepkowski, S. G. Heeringa, D. F. Alwin, J. S. House, F. T. Juster, R. L. Kahn, H. Schuman, and E. Singer. *Survey Methodology*. 1st. John Wiley & Sons, 2004.

[81] J. Grudin. „Computer-supported cooperative work: history and focus". *Computer* 27.5 (1994), pp. 19–26.

[82] Y. Guiard, Y. Du, and O. Chapuis. „Quantifying degree of goal directedness in document navigation: application to the evaluation of the perspective-drag technique". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '07. ACM, 2007, pp. 327–336.

[83] C. Gutwin and C. Fedak. „Interacting with big interfaces on small screens: a comparison of fisheye, zoom, and panning techniques". In: *Proceedings of the 2004 Graphics Interface Conference*. GI '04. Canadian Human-Computer Communications Society, 2004, pp. 145–152.

[84] C. Gutwin and S. Greenberg. „The mechanics of collaboration: developing low cost usability evaluation methods for shared workspaces". In: *Enabling Technologies: Infrastructure for Collaborative Enterprises, 2000. (WET ICE 2000). Proceedings. IEEE 9th International Workshops on*. 2000, pp. 98–103.

[85] K. Hamadache and L. Lancieri. „Strategies and taxonomy, tailoring your CSCW evaluation". In: *Groupware: Design, Implementation, and Use*. Vol. 5784. Lecture Notes in Computer Science. 2009, pp. 206–221.

[86] J. Hamari and V. Eranti. „Framework for designing and evaluating game achievements". *Proceedings of the Digra 2011 Conference: Think Design Play* 115 (2011), pp. 122–134.

[87] J. Hamari, J. Koivisto, and H. Sarsa. „Does gamification work? – a literature review of empirical studies on gamification". In: *System Sciences (HICSS), 2014 47th Hawaii International Conference on*. 2014, pp. 3025–3034.

[88] J. Harms. „Research goals for evolving the 'form' user interface metaphor towards more interactivity". In: *Human Factors in Computing and Informatics*. Ed. by A. Holzinger, M. Ziefle, M. Hitz, and M. Debevc. Vol. 7946. Lecture Notes in Computer Science. Springer, 2013, pp. 819–822.

[89] J. Harms, S. Biegler, C. Wimmer, K. Kappel, and T. Grechenig. „Gamification of online surveys: design process, case study, and evaluation". In: *Proceedings of the 15th IFIP TC 13 International Conference Human-Computer Interaction – INTERACT'15*. Ed. by J. Abascal, S. D. J. Barbosa, M. Fetter, T. Gross, P. Palanque, and M. Winckler. Vol. 9296. Lecture Notes in Computer Science. Springer, 2015, pp. 214–231.

[90] J. Harms, M. Kratky, C. Wimmer, K. Kappel, and T. Grechenig. „Navigation in long forms on smartphones: scrolling worse than tabs, menus, and collapsible fieldsets". In: *Proceedings of the 15th IFIP TC 13 International Conference Human-Computer Interaction – INTERACT'15*. Ed. by J. Abascal, S. D. J. Barbosa, M. Fetter, T. Gross, P. Palanque, and M. Winckler. Vol. 9296. Lecture Notes in Computer Science. Springer, 2015.

[91] J. Harms, D. Seitz, C. Wimmer, K. Kappel, and T. Grechenig. „Low-cost gamification of online surveys: improving the user experience through achievement badges". In: *Proceedings of the 2nd ACM SIGCHI annual symposium on Computer-Human Interaction in Play*. CHI PLAY '15. ACM, 2015.

[92] J. Harms, C. Wimmer, K. Kappel, and T. Grechenig. „Design space for focus+context navigation in web forms". In: *Proceedings of the 2014 ACM SIGCHI Symposium on Engineering Interactive Computing Systems*. EICS '14. ACM, 2014, pp. 39–44.

[93] J. Harms, C. Wimmer, K. Kappel, and T. Grechenig. „Gamification of online surveys: conceptual foundations and a design process based on the MDA framework". In: *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*. NORDICHI '14. ACM. 2014, pp. 565–568.

[94] R. H. R. Harper. „The organisation in ethnography–a discussion of ethnographic fieldwork programs in cscw". *Computer Supported Cooperative Work (CSCW)* 9.2 (2000), pp. 239–264.

[95] M. Hassenzahl, M. Burmester, and F. Koller. „Attrakdiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität". In: *Mensch & Computer 2003*. Ed. by G. Szwillus and J. Ziegler. Vol. 57. Berichte des German Chapter of the ACM. Vieweg+Teubner Verlag, 2003, pp. 187–196.

[96] R. Hebecker and H. Regenbrecht. „Visual surveys with purposeful games". *Information Design Journal (IDJ)* 19.3 (2011), pp. 259–271.

[97] V. Herskovic, J. A. Pino, S. F. Ochoa, and P. Antunes. „Evaluation methods for groupware systems". In: *Groupware: Design, Implementation, and Use*. Vol. 4715. Lecture Notes in Computer Science. 2007, pp. 328–336.

[98] P. Herzig, M. Ameling, B. Wolf, and A. Schill. „Implementing gamification: requirements and gamification platforms". In: *Gamification in Education and Business*. Ed. by T. Reiners and L. C. Wood. Springer, 2015, pp. 431–450.

[99] J. D. Hincapié-Ramos, S. Voida, and G. Mark. „A design space analysis of availability-sharing systems". In: *Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology*. UIST '11. ACM, 2011, pp. 85–96.

[100] D. E. Hoffmann, S. I. Zimmerman, and C. J. Tompkins. „The dangers of directives or the false security of forms". *The Journal of Law, Medicine & Ethics* 24.1 (1996), pp. 5–17.

[101] K. Holtzblatt, J. Wendell, and S. Wood. *Rapid Contextual Design: A How-To Guide to Key Techniques for User-Centered Design*. Morgan Kaufmann, 2005.

[102] M. Honkala and M. Pohja. „Multimodal interaction with XForms". In: *Proceedings of the 6th International Conference on Web Engineering*. ICWE '06. ACM, 2006, pp. 201–208.

[103] M. Honkala and P. Vuorimaa. „Secure web forms with client-side signatures". In: *Web Engineering*. Ed. by D. Lowe and M. Gaedke. Vol. 3579. Lecture Notes in Computer Science. Springer, 2005, pp. 340–351.

[104] S. Hoober and E. Berkman. *Designing Mobile Interfaces*. O'Reilly, 2011.

[105] K. Höök and M. Svensson. „Evaluating adaptive navigation support". In: *Social Navigation of Information Space*. Ed. by A. Munro, K. Höök, and D. Benyon. Computer Supported Cooperative Work. Springer, 1999, pp. 237–249.

[106] R. Hunicke, M. LeBlanc, and R. Zubek. „MDA: a formal approach to game design and game research“. In: *Proceedings of the AAAI-04 Workshop on Challenges in Game AI*. 2004, pp. 1–5.

[107] Z. Idrus, N. Razak, N. Talib, and T. Tajuddin. „Using three layer model (TLM) in web form design: WeFDeC checklist development“. In: *Computer Engineering and Applications (ICCEA), 2010 Second International Conference on*. Vol. 1. 2010, pp. 385–389.

[108] M. Imaz and D. Benyon. *Designing with Blends: Conceptual Foundations of Human-Computer Interaction and Software Engineering*. The MIT Press, 2007.

[109] M. Jacobs. „Gamification: moving from ‘addition’ to ‘creation’“. In: *CHI 2013 Workshop Designing Gamification: Creating Gameful and Playful Experiences*. 2013.

[110] S. Jacobs, M. Gebhardt, S. Kethers, and W. Rzasa. „Filling HTML forms simultaneously: CoWeb – architecture and functionality“. *Computer Networks and ISDN Systems* 28.7-11 (1996). Proceedings of the Fifth International World Wide Web Conference 6-10 May 1996, pp. 1385–1395.

[111] A. Jaimes and N. Sebe. „Multimodal human-computer interaction: a survey“. *Computer Vision and Image Understanding* 108.1-2 (2007), pp. 116–134.

[112] C. Jarrett and G. Gaffney. *Forms that work: designing web forms for usability*. Morgan Kaufmann, 2008.

[113] C. Jarrett and W. Quesenbery. „How to look at a form-in a hurry“. In: *Proceedings of the Usability Professionals’ Association Conference. Minneapolis, Minnesota*. 2006.

[114] H.-C. Jetter, H. Reiterer, and F. Geyer. „Blended interaction: understanding natural human–computer interaction in post-wimp interactive spaces“. *Personal and Ubiquitous Computing* 18.5 (2014), pp. 1139–1158.

[115] G. Jiang, B. Cao, J. Wang, and J. Yin. „Using business rule engine to integrate electronic form with workflow management system“. In: *Internet Technology and Applications (iTAP), 2011 International Conference on*. 2011, pp. 1–6.

[116] R. Johansen. *GroupWare: Computer Support for Business Teams*. The Free Press, 1988.

[117] S. B. Johnson, S. Bakken, D. Dine, S. Hyun, E. Mendonça, F. Morrison, T. Bright, T. Van Vleck, J. Wrenn, and P. Stetson. „An electronic health record based on structured narrative“. *Journal of the American Medical Informatics Association* 15.1 (2008), pp. 54–64.

[118] A. Jøsang, D. Povey, and A. Ho. „What you see is not always what you sign“. In: *Proceedings of the Australian UNIX and Open Systems Users Group Conference (AUUG2002)*. 2002.

[119] O. Kaminska, A. L. McCutcheon, and J. Billiet. „Satisficing among reluctant respondents in a cross-national context“. *Public Opinion Quarterly* 74.5 (2010), pp. 956–984.

[120] G. Z. Kantorski, V. P. Moreira, and C. A. Heuser. „Automatic filling of hidden web forms: a survey“. *SIGMOD RECORD* 44.1 (2015), pp. 24–35.

[121] F. Keusch. „How to increase response rates in list-based web survey samples“. *Social Science Computer Review* 30.3 (2012), pp. 380–388.

[122] S. R. Klemmer, A. K. Sinha, J. Chen, J. A. Landay, N. Aboobaker, and A. Wang. „Suede: a wizard of oz prototyping tool for speech user interfaces“. In: *Proceedings of the 13th Annual ACM Symposium on User Interface Software and Technology*. UIST ’00. ACM, 2000, pp. 1–10.

[123] M. Kobayashi, M. Shinozaki, T. Sakairi, M. Touma, S. Daijavad, and C. Wolf. „Collaborative customer services using synchronous web browser sharing“. In: *Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work*. CSCW ’98. ACM, 1998, pp. 99–109.

[124] I. Koren, A. Guth, and R. Klamma. „Shared editing on the web: a classification of developer support libraries“. In: *Collaborative Computing: Networking, Applications and Worksharing (Collaboratecom), 2013 9th International Conference on*. 2013, pp. 468–477.

[125] H. Korhonen, M. Montola, and J. Arrasvuori. „Understanding playful user experience through digital games“. In: *International Conference on Designing Pleasurable Products and Interfaces*. 2009, pp. 274–285.

[126] J. A. Krosnick. „Response strategies for coping with the cognitive demands of attitude measures in surveys“. *Applied Cognitive Psychology* 5.3 (1991), pp. 213–236.

[127] G. Lakoff and M. Johnson. *Metaphors we live by*. 2003 with a new afterword. University of Chicago, 1980.

[128] C. Lattmann. „Icons of novel thought: a new perspective on peirce’s definition of metaphor (cp 2.277)“. *Semiotica* 2012.192 (2012).

[129] C. Lewis, N. Wardrip-Fruin, and J. Whitehead. „Motivational game design patterns of ’ville games“. In: *Proceedings of the International Conference on the Foundations of Digital Games*. FDG ’12. ACM, 2012, pp. 172–179.

[130] K. Liu. *Semiotics in Information Systems Engineering*. Cambridge University Press, 2000.

[131] C. Lutteroth and G. Weber. „Going paperless - on the evaluation of electronic form technologies“. In: *Database and Expert Systems Applications (DEXA), 2011 22nd International Workshop on*. 2011, pp. 14–18.

[132] I. MacKenzie. *Human-Computer Interaction: An Empirical Research Perspective*. Elsevier Science, 2012.

[133] A. MacLean, R. M. Young, V. M. E. Bellotti, and T. P. Moran. „Questions, options, and criteria: elements of design space analysis“. In: *Design rationale*. Ed. by T. P. Moran and J. M. Carroll. L. Erlbaum Associates Inc., 1996, pp. 53–105.

[134] A. MacLean, R. M. Young, and T. P. Moran. „Design rationale: the argument behind the artifact“. *SIGCHI Bull.* 20.SI (1989), pp. 247–252.

[135] U. Malinowski. „Adjusting the presentation of forms to users’ behavior“. In: *Proceedings of the 1st international conference on Intelligent User Interfaces*. IUI ’93. ACM, 1993, pp. 247–249.

[136] U. Malinowski, T. Kühme, H. Dieterich, and M. Schneider-Hufschmidt. „A taxonomy of adaptive user interfaces“. In: *Proceedings of the conference on People and computers VII*. HCI’92. Cambridge University Press, 1993, pp. 391–414.

[137] A. Mardan. „Sails.js, derbyjs, loopback, and other frameworks“. In: *Pro Express.js: Master Express.js: The Node.js Framework For Your Web Development*. Expert’s voice in Web development. Apress, 2014. Chap. 18, pp. 205–214.

[138] A. Mavletova. „Web surveys among children and adolescents: is there a gamification effect?“ *Social Science Computer Review* (2014).

[139] D. J. Mayhew. *The Usability engineering lifecycle: A practitioner’s handbook for user interface design*. Morgan Kaufmann, 1999.

[140] F. Meng. „A natural language interface for information retrieval from forms on the world wide web“. In: *Proceedings of the 20th international conference on Information Systems*. ICIS ’99. Association for Information Systems, 1999, pp. 540–545.

[141] K. Mizoguchi, D. Sakamoto, and T. Igarashi. „Overview scrollbar: a scrollbar showing an entire document as an overview“. In: *Human-Computer Interaction – INTERACT’13*. Ed. by P. Kotzé, G. Marsden, G. Lindgaard, J. Wesson, and M. Winckler. Vol. 8120. Lecture Notes in Computer Science. Springer, 2013, pp. 603–610.

[142] A. Money, L. Lines, S. Fernando, and A. Elliman. „E-government online forms: design guidelines for older adults in europe“. *Universal Access in the Information Society* 10 (1 2011), pp. 1–16.

[143] T. Neil. *Mobile Design Pattern Gallery: UI Patterns for Smartphone Apps*. 2nd. O’Reilly, 2014.

[144] J. Nielsen. „The matters that really matter for hypertext usability“. In: *Proceedings of the second annual ACM conference on Hypertext*. HYPERTEXT ’89. ACM, 1989, pp. 239–248.

[145] J. Nielsen. *Usability engineering*. Morgan Kaufmann, 1993.

[146] E. G. Nilsson. „Design patterns for user interface for mobile applications“. *Advances in Engineering Software* 40.12 (2009), pp. 1318–1328.

[147] N. Niraula, A. Stent, H. Jung, G. Di Fabbrizio, I. Dan Melamed, and V. Rus. „Forms2dialog: automatic dialog generation for web tasks“. In: *Spoken Language Technology Workshop (SLT), 2014 IEEE*. 2014, pp. 608–613.

[148] T. Nomura and Y. Mitsukura. „Evaluation approach for web form usability“. *Journal of Signal Processing* 18.4 (2014), pp. 193–196.

[149] D.-C. Paraschiv. „Timing in a web based survey: an influential factor of the response rate“. *Marketing From Information to Decision* 6 (2013), pp. 200–209.

[150] V. Penichet, I. Marin, J. Gallud, M. Lozano, and R. Tesoriero. „A classification method for CSCW systems“. *Electronic Notes in Theoretical Computer Science* 168 (2007), pp. 237–247.

[151] E. Philippot, K. C. Santosh, A. Belaid, and Y. Belaid. „Bayesian networks for incomplete data analysis in form processing“. *International Journal of Machine Learning and Cybernetics* 6.3 (2015), pp. 347–363.

[152] C. J. Pilgrim. „Website navigation tools – a decade of design trends 2002 to 2011“. In: *Australasian User Interface Conference (AUIC 2012)*. Ed. by H. Shen and R. T. Smith. Vol. 126. CRPIT. ACS, 2012, pp. 3–10.

[153] D. Pinelle and C. Gutwin. „A review of groupware evaluations“. In: *Proceedings of the 9th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises*. WETICE ’00. IEEE Computer Society, 2000, pp. 86–91.

[154] A. Pirhonen. „To simulate or to stimulate? in search of the power of metaphor in design“. In: *Future Interaction Design*. Ed. by A. Pirhonen, P. Saariluoma, H. Isomäki, and C. Roast. Springer, 2005, pp. 105–123.

[155] J. Puleston. „Gamification of market research“. In: *Social Media, Sociality, and Survey Research*. Ed. by C. A. Hill, E. Dean, and J. Murphy. John Wiley & Sons, Inc., 2013. Chap. 11, pp. 253–293.

[156] J. Puleston. „Online research–game on!: a look at how gaming techniques can transform your online research“. *Shifting the Boundaries of Research* (2011), p. 20.

[157] J. Rama and J. Bishop. „A survey and comparison of CSCW groupware applications“. In: *Proceedings of the 2006 annual research conference of the South African institute of computer scientists and information technologists on IT research in developing countries*. SAICSIT '06. South African Institute for Computer Scientists and Information Technologists, 2006, pp. 198–205.

[158] B. Reeves and J. L. Read. *Total Engagement: Using Games and Virtual Worlds to Change the Way People Work and Businesses Compete*. 1st. Harvard Business Review Press, 2009.

[159] J. Riegelsberger, M. A. Sasse, and J. D. McCarthy. „The mechanics of trust: a framework for research and design“. *International Journal of Human-Computer Studies* 62.3 (2005), pp. 381–422.

[160] R. Sandhu and V. Year. „The ASCAA principles for next-generation role-based access control“. *Engineer* 1 (2008), E1.

[161] S. Sarangi and S. Slembrouck. *Language, Bureaucracy and Social Control*. Real Language Series. Taylor & Francis, 2014.

[162] J. Scarr, C. Gutwin, A. Cockburn, and A. Bunt. „Stencilmaps and ephemeralmaps: spatially stable interfaces that highlight command subsets“. *Behaviour & Information Technology* (2015), pp. 1–15.

[163] K. Schmidt and T. Rodden. „Putting it all together: requirements for a CSCW platform“. *Human Factors in Information Technology* 12 (1996), pp. 157–176.

[164] J. L. Schnipper, J. A. Linder, M. B. Palchuk, J. S. Einbinder, Q. Li, A. Postilnik, and B. Middleton. „“Smart Forms” in an electronic medical record: documentation-based clinical decision support to improve disease management“. *Journal of the American Medical Informatics Association* 15.4 (2008), pp. 513–523.

[165] D. Schuster, A. Rosi, M. Mamei, T. Springer, M. Endler, and F. Zambonelli. „Pervasive social context: taxonomy and survey“. *ACM Transactions on Intelligent Systems and Technology* 4.3 (2013), 46:1–46:22.

[166] B. Schwesinger. *The Form Book: Creating Forms for Printed and Online Use*. Thames & Hudson, 2010.

[167] K. Seaborn and D. I. Fels. „Gamification in theory and action: a survey“. *International Journal of Human-Computer Studies* 74 (2015), pp. 14–31.

[168] M. Seckler, S. Heinz, J. A. Bargas-Avila, K. Opwis, and A. N. Tuch. „Designing usable web forms – empirical evaluation of web form improvement guidelines“. In: *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems*. CHI '14. ACM, 2014, pp. 1275–1284.

[169] M. Seckler, S. Heinz, J. A. Bargas-Avila, K. Opwis, and A. N. Tuch. „Empirical evaluation of 20 web form optimization guidelines“. In: *CHI '13 Extended Abstracts on Human Factors in Computing Systems*. CHI EA '13. ACM, 2013, pp. 1893–1898.

[170] A. Seffah and E. Metzker. „Usability engineering methods plethora“. *Adoption-centric Usability Engineering* (2009), pp. 15–33.

[171] C. Shen, K. Everitt, and K. Ryall. „Ubitable: impromptu face-to-face collaboration on horizontal interactive surfaces“. In: *UbiComp 2003: Ubiquitous Computing*. Ed. by A. Dey, A. Schmidt, and J. McCarthy. Vol. 2864. Lecture Notes in Computer Science. Springer, 2003, pp. 281–288.

[172] N. Shu, V. Lum, F. Tung, and C. Chang. „Specification of forms processing and business procedures for office automation“. *IEEE Transactions on Software Engineering* SE-8.5 (1982), pp. 499–512.

[173] C. S. de Souza. „Semiotic engineering: bringing designers and users together at interaction time“. *Interacting with Computers* 17.3 (2005), pp. 317–341.

[174] R. Spence. „A framework for navigation“. *International Journal of Human-Computer Studies* 51.5 (1999), pp. 919–945.

[175] C. Steinfield, C.-Y. Jang, and B. Pfaff. „Supporting virtual team collaboration: the teamscope system“. In: *Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work*. GROUP '99. ACM, 1999, pp. 81–90.

[176] J. Strohl, C. Gonzalez, J. Sauser, S. Montazeri, and B. Griepentrog. „Creating forms and disclosures that work: using eye tracking to improve the user experience“. In: *Universal Access in Human-Computer Interaction. Access to Today's Technologies*. Ed. by M. Antona and C. Stephanidis. Vol. 9175. Lecture Notes in Computer Science. Springer, 2015, pp. 121–131.

[177] J. Sturm and L. Boves. „Effective error recovery strategies for multimodal form-filling applications“. *Speech Communication* 45.3 (2005), pp. 289–303.

[178] C. Sun, Y. Xu, and A. Agustina. „Exhaustive search of puzzles in operational transformation“. In: *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*. CSCW '14. ACM, 2014, pp. 519–529.

[179] S. Sütcü. *Smart forms for supporting face-2-face citizen-officer collaboration: design space & usability evaluation*. Master's thesis at Vienna University of Technology, supervised by Thomas Grechenig and Johannes Harms. To be published in 2016.

[180] P. Sweetser and P. Wyeth. „Gameflow: a model for evaluating player enjoyment in games“. *Computers in Entertainment* 3.3 (2005), pp. 3–3.

[181] H. J. Tange, A. Hasman, P. F. de Vries Robbé, and H. C. Schouten. „Medical narratives in electronic medical records“. *International Journal of Medical Informatics* 46.1 (1997), pp. 7–29.

[182] M. Tedre and J. Pajunen. „An easy approach to epistemology and ontology in computing theses“. In: *Proceedings of the 13th Koli Calling International Conference on Computing Education Research*. Koli Calling '13. ACM, 2013, pp. 97–104.

[183] E. R. Thompson. „Development and validation of an internationally reliable short-form of the positive and negative affect schedule (panas)“. *Journal of Cross-Cultural Psychology* 38.2 (2007), pp. 227–242.

[184] J. Tidwell. *Designing interfaces*. 2nd. O'Reilly, 2010.

[185] K. Tjin-Kam-Jet, D. Trieschnigg, and D. Hiemstra. „Free-text search over complex web forms“. In: *Multidisciplinary Information Retrieval*. Vol. 6653. Lecture Notes in Computer Science. Springer, 2011, pp. 94–107.

[186] A. Tomasic, W. Cohen, S. Fussell, J. Zimmerman, M. Kobayashi, E. Minkov, N. Halstead, R. Mosur, and J. Hum. „Learning to Navigate Web Forms“. In: *Workshop on Information Integration on the Web*. 2004.

[187] R. Tourangeau, F. Conrad, and M. Couper. *The Science of Web Surveys*. Oxford University Press, 2013.

[188] R. Tourangeau, L. Rips, and K. Rasinski. *The Psychology of Survey Response*. Cambridge University Press, 2000.

[189] D. Tsichritzis. „Form management“. *Communications of the ACM* 25.7 (1982), pp. 453–478.

[190] T. Vainio. „A review of the navigation HCI research during the 2000's.“ *International Journal of Interactive Mobile Technologies* 4.3 (2010), pp. 36–42.

[191] D. Vaskevitch. „Dialogue: providing total terminal independence“. *Managing Requirements Knowledge, International Workshop on* (1982), p. 509.

[192] Q. Wang, C. Nass, and J. Hu. „Natural language query vs. keyword search: effects of task complexity on search performance, participant perceptions, and preferences“. In: *Human-Computer Interaction – INTERACT'05*. Vol. 3585. Lecture Notes in Computer Science. Springer, 2005, pp. 106–116.

[193] S. Wang, Y. Zou, B. Upadhyaya, I. Keivanloo, and J. Ng. „An empirical study on categorizing user input parameters for user inputs reuse“. In: *Web Engineering*. Ed. by S. Casteleyn, G. Rossi, and M. Winckler. Vol. 8541. Lecture Notes in Computer Science. Springer, 2014, pp. 21–39.

[194] H. Weinreich, H. Obendorf, E. Herder, and M. Mayer. „Off the beaten tracks: exploring three aspects of web navigation“. In: *Proceedings of the 15th international conference on World Wide Web*. WWW '06. ACM, 2006, pp. 133–142.

[195] C. S. Weir, J. N. Anderson, and M. A. Jack. „On the role of metaphor and language in design of third party payments in ebanking: usability and quality“. *International Journal of Human-Computer Studies* 64.8 (2006), pp. 770–784.

[196] T. Weis, M. Knoll, A. Ulbrich, G. Muhl, and A. Brandle. „Rapid prototyping for pervasive applications“. *Pervasive Computing, IEEE* 6.2 (2007), pp. 76–84.

[197] S. Weiss, P. Urso, and P. Molli. „Logoot-undo: distributed collaborative editing system on p2p networks“. *Parallel and Distributed Systems, IEEE Transactions on* 21.8 (2010), pp. 1162–1174.

[198] K. Werbach and D. Hunter. *For the Win: How Game Thinking Can Revolutionize Your Business*. Wharton Digital Press, 2012.

[199] A. Whitten and J. D. Tygar. „Why Johnny can't encrypt: a usability evaluation of PGP 5.0“. In: *Usenix Security*. Vol. 1999. 1999.

[200] J. Wilson, J. M. Brown, and R. Biddle. „Distributed data and displays via SVG and HTML5.“ In: *DUI@EICS*. Ed. by M. D. Lozano, A. S. Mashat, H. M. Fardoun, J. A. Gallud, V. M. R. Penichet, R. Tesoriero, and J. Vanderdonckt. 2013, pp. 67–70.

[201] B. Wlaschits. *Gamifizierung von elektronischen Umfrageformularen: Design und Experten-Evaluierung*. Master's thesis at Vienna University of Technology, supervised by Thomas Grechenig and Johannes Harms. 2014.

[202] D. D. Woods. „The price of flexibility“. In: *Proceedings of the 1st international conference on Intelligent User Interfaces*. IUI '93. ACM, 1993, pp. 19–25.

[203] P. Wright. „Strategy and tactics in the design of forms“. *Visible language* 14.2 (1980), pp. 151–93.

[204] L. Wroblewski. *Mobile & Multi-Device Design: Lessons Learned Building Polar*. Luke Wroblewski, 2014.

[205] L. Wroblewski. *Web Form Design. Filling the Blanks*. Louis Rosenfeld, 2008.

[206] C. Zhang and F. Conrad. „Speeding in web surveys: the tendency to answer very fast and its association with straightlining“. *Journal of the European Survey Research Association* 8.2 (2014).

[207] D. Zhang and B. Adipat. „Challenges, methodologies, and issues in the usability testing of mobile applications“. *International Journal of Human-Computer Interaction* 18.3 (2005), pp. 293–308.

[208] G. Zimmermann, A. Stratmann, D. Reeß, and T. Glaser. „Patterns for user interface adaptations“. In: *Human Aspects of IT for the Aged Population. Design for Aging*. Ed. by J. Zhou and G. Salvendy. Vol. 9193. Lecture Notes in Computer Science. Springer, 2015, pp. 426–436.

## Web References

[W1] *Adobe business catalyst website. integrated customer database and web forms*. http://businesscatalyst.com/features/crm-database. Last visited Sept. 9, 2015.

[W2] D. Amrhein and A. Ivory. *Enable a collaborative experience for HTML forms*. Tech. rep. IBM. http://ibm.co/TIIc9w. Last visited Sept. 25, 2015.

[W3] *Angularjs website*. http://angularjs.org. Last visited Sept. 27, 2012.

[W4] Apple Inc. *OS X human interface guidelines*. https://developer.apple.com/library/mac/documentation/UserExperience/Conceptual/OSXHIGuidelines/. Last visited Sept. 7, 2015.

[W5] Apple Inc. *OS X mavericks: mouse & trackpad pane of accessibility preferences*. https://support.apple.com/kb/PH14427. Last visited Sept. 7, 2015.

[W6] Apple Inc. *Xcode interface builder built-in*. https://developer.apple.com/xcode/interface-builder/. Last visited Sept. 9, 2015.

[W7] *Badforms.com website*. http://badforms.com/. Last visited Sept. 3, 2015.

[W8] *Balsamiq mockups website*. http://balsamiq.com/products/mockups. Last visited Sept. 23, 2015.

[W9] *Bewegung und Sport. Eine Umfrage des Österreichischen Jugendportals*. http://jugendportal.at/befragung/bewegung-und-sport. Last visited Sept. 23, 2015.

[W10] *Bootstrap website*. http://getbootstrap.com/. Last visited Aug. 26, 2015.

[W11] *Bootswatch website*. https://bootswatch.com/. Last visited Sept. 1, 2015.

[W12] *Derby.js website*. http://derbyjs.com/. Last visited Sept. 3, 2015.

[W13] *European accident statement*. http://cartraveldocs.com/european-accident-statement. Last visited Sept. 7, 2015.

[W14] *Garlic.js website*. http://garlicjs.org/. Last visited Sept. 23, 2015.

[W15] *Gartner's 2013 Hype Cycle for Emerging Technologies Maps Out Evolving Relationship Between Humans and Machines*. Tech. rep. Gartner, Inc. http://www.gartner.com/newsroom/id/2575515.

[W16] P. Gaubatz. *Cocoform - constrainable collaborative form*. https://demo.swa.univie.ac.at/cocoform/. Last visited May 21, 2014.

[W17] *Google forms website*. https://docs.google.com/forms/. Last visited Sept. 7, 2015.

[W18] Google Inc. *'material design' guidelines*. http://www.google.com/design/spec/material-design/introduction.html. Last visited Sept. 7, 2015.

[W19] J. Harms and R. Stary. *Reco source code repository – a rapid prototyping tool for real-time collaboration with web forms*. https://github.com/johannesjh/form-collaboration-reco. Last visited Aug. 26, 2015.

[W20] *Knockout.js website*. http://knockoutjs.com. Last visited July 30, 2012.

[W21] *Loopback website*. http://loopback.io/. Last visited Sept. 3, 2015.

[W22] *Meteor.js website*. http://www.meteor.com/. Last visited 2015.

[W23] Microsoft Corporation. *Design applications for the windows desktop*. https://dev.windows.com/en-us/desktop/design. Last visited Sept. 7, 2015.

[W24] *Microsoft infopath forms services in sharepoint server 2010*. https://msdn.microsoft.com/en-us/library/office/aa701145(v=office.14).aspx. Last visited Sept. 7, 2015.

[W25] J. Nielsen. *Forms vs. applications*. Blogpost. http://www.useit.com/alertbox/forms.html. Last visited May 30, 2011.

[W26] *Orbeon forms website*. http://www.orbeon.com/. Last visited Sept. 9, 2015.

[W27] *Require.js website*. http://requirejs.org/. Last visited Aug. 26, 2015.

[W28] M. Robertson. *Can't play, won't play*. Blogpost. http://www.hideandseek.net/2010/10/06/cant-play-wont-play/. Last visited June 24, 2015.

[W29] B. Rummel. *System Usability Scale – jetzt auch auf Deutsch*. https://experience.sap.com/skillup/system-usability-scale-jetzt-auch-auf-deutsch/. Last visited Sept. 23, 2015.

[W30] *Sails.js website*. http://sailsjs.org/. Last visited Sept. 3, 2015.

[W31] *Sisyphus.js website*. http://simsalabim.github.com/sisyphus/. Last visited Sept. 23, 2015.

[W32] *Socket.io*. http://socket.io/. Last visited Aug. 26, 2015.

[W33] *Surveymonkey.com website*. http://surveymonkey.com/. Last visited Sept. 23, 2015.

[W34] *Togetherjs website*. https://togetherjs.com/. Last visited Aug. 26, 2015.

[W35] *United states census 2000 long form questionnaire*. https://www.census.gov/dmd/www/pdf/d02p.pdf. Last visited Sept. 7, 2015.

[W36] *Usability.gov guidelines*. http://guidelines.usability.gov/. Last visited Sept. 7, 2015.

[W37] *Wufoo.com website. create and share your forms*. http://www.wufoo.com/. Last visited Sept. 9, 2015.

[W38] *Youtube.com website*. http://www.youtube.com/. Last visited Apr. 19, 2014.

[W39] *Zoho.com website. forms for mobile teams*. https://www.zoho.com/forms/. Last visited Sept. 9, 2015.