Thesis for the degree of Doctor of Philosophy

Beyond Gadgetry

Reflections on Tech- and User-Driven Research in Human-Computer Interaction

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Abstract

This compilation thesis builds on a number of research projects within the domain of Human-Computer Interaction (HCI).

Firstly, the thesis includes papers in the area of multi-device spatially-aware interactions. Prototypes of future interaction environments were built and evaluated in anticipation of technical developments in mobile sensing. The thesis shows that spatially-aware mobile devices can be effective in supporting information retrieval from information visualisations and facilitating sensemaking. Secondly, an accurate account of an industrial case study on designing interfaces for big data in the automotive domain is presented. The work contributes a proposed process for building user-oriented big data applications. Finally, the thesis undertakes efforts in supporting sports activities with interactive technology in order to explore the design space of HCI and sports. The papers explore the needs of amateur sportsmen and show examples of technology that fits into the social setting of running and group exercise. All of the activities were conducted using design-based research.

The theoretical part of this thesis focuses on a structured reflection on past research work. Based on the appended papers and a literature review, the Contribution Type Family (CTF) model is presented. The model characterises the different types of intermediate-level knowledge that design-based research may generate. The published papers contained in this thesis serve as examples of contribution types. A distinction between user- and technology-driven research emerges from the analysis.

The thesis also features a set of lessons learnt aimed at researchers with an engineering background who endeavour to practice design-based research. These lessons showcase the pragmatic differences between user- and technology-driven inquiry and explicate the necessary choices that a researcher needs to make. Together, the CTF model and the presented lessons serve as a tool for reflection and may help planning future design-based research inquiries and inform research strategy.

Keywords: mobile interaction; multi-device environments; spatial awareness; big data; HCI for sports; designing for motivation; design-based research; HCI as a field

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Referat

Den här sammanläggningsavhandlingen sammanställer ett antal olika forskningsprojekt inom ämnet människa-datorinteraktion (MDI).

I avhandlingen finns publicerat ett antal artiklar som rör interaktion och spatialt medvetna mobila enheter. För att skapa en förståelse för framtida utveckling av mobila sensorer byggdes ett antal interaktionsmiljöer som simulerade denna utveckling. Avhandlingen demonstrerar att spatialt medvetna enheter kan stödja informationsinhämtning och förenkla förståelse i samband med visualisering. Utöver detta inkluderas en industriell fallstudie inom bilindustrin, som medföljer som exempel på hur man kan skapa nya gränssnitt för så kallad ”big data”. Arbetet bidrar även med en process för att skapa användarorienterade ”big data”-applikationer. Slutligen finns det inkluderat tre artiklar som rör hur interaktiv teknologi kan hjälpa idrottande; med stöd av designbaserad forskning runt löpares behov visar de på hur teknologi kan anpassas till sociala miljöerna runt löpning och gruppträning.

Den teoretiska delen av avhandlingen är en strukturerad analys av forskningsarbetet i de inkluderade artiklarna. Tillsammans med en litteraturanalys ligger de till grund för en presenterad modell, Contibution Type Family (CTF), som beskriver olika typer av kunskap som designbaserad forskning kan generera. Publicerade paper är exempel av typ av bidrag. En skillnad mellan användare- och teknologidriven forskning står upp från analysen.

Avhandlingen innehåller även en serie av lektioner som kan hjälpa teknikorienterade forskare som vill bidra till designorienterad forskning. Dessa lektioner visar pragmatiska skillnader mellan användar- och teknologidriven forskning, beskriver ett antal val som forskare behöver ta. CTF-modellen samt lektionerna är avsedda att fungera som ett verktyg för att planera designbaserade undersökningar och forskningsstrategier.

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Streszczenie

Niniejsza rozprawa kumulatywna jest oparta na kilku projektach badawczych w dziedzinie interakcji człowiek-komputer (HCI).

Rozprawa zawiera artykuły na temat urządzeń mobilnych wyposażonych w świadomość przestrzeni. Zbudowano i zbadano szereg systemów symulujących przyszłe środowiska interakcji. Rozprawa wykazuje, że urządzenia mobilne ze świadomością przestrzeni mogą być efektywnie użyte do pozyskiwania informacji z wizualizacji oraz wspierać proces tworzenia zrozumienia (ang. sensemaking).

W dalszej części rozprawa zawiera opis studium przypadku, w którym projektowano interfejsy użytkownika dla systemów typu big data. Zaprezentowano propozycje procesu budowania systemów big data zorientowanych na użytkownika. Następnie, rozprawa podejmuje tematykę wspierania aktywności sportowej za pomocą interaktywnych technologii. Zawarte w rozprawie publikacje podejmującatematykę potrzeb sportowców-amatorów. Są tu również przywołane przykłady technologii, które dopasowują się do środowiska społecznego biegaczy i grup sportowych. Całość prac wykorzystuje metody badań opartych na designie.

Część teoretyczna rozprawy koncentruje się na metodycznej refleksji nad osiągniętymi wynikami prac badawczych. Na podstawie zawartych publikacji oraz przeglądu literatury, przedstawiono model Contibution Type Family (CTF). Model ten określa rodzaje wiedzy poziomu pośredniego, która może być tworzona za pomocą badań opartych na designie. Publikacje autora służą jako przykłady różnych typów wkładu w stan wiedzy. Wynikiem analizy jest różnica między badaniami inspirowanymi przez użytkowników i technologię.

Rozprawa zawiera również zestaw lekcji, które mają za zadanie pomóc naukowcom, wywodzącym się z dziedzin ścisłych, prowadzić badania oparte na designie. Lekcje te pokazują praktyczne różnice między badaniami inspirowanymi przez użytkowników i technologię i ukazują niezbędne decyzje, które badacze muszą podejmować. Model CTF i zestaw lekcji mogą pomóc w planowaniu przyszłych badań opartych na designie oraz być istotne dla strategii badawczych.

Third Whicker: Father Pierre, why did you stay on in this colonial Campari-land where the clink of glasses mingles with the murmur of a million mosquitoes, where waterfalls of whisky wash away the worries of a world-weary Whicker, where gin and tonic jingle in a gyroscopic jubilee of something beginning With J?

Monty Python's Flying Circus Series Three, Episode One (Twenty Seven).
Originally aired 19 October 1972.

To my parents.

Acknowledgements

I was happy to have had a fabulous support team during my doctoral studies. I cannot thank you enough and I am sure to forget to mention some names, but I will make a feeble attempt.

First and foremost, I would like to thank the two people who gave me the opportunity to start my research career and trusted me not to negatively affect theirs — Morten Fjeld and Andrzej Romanowski. Thank you for believing in me and supporting even the bizarre decisions. Special thanks goes to my co-supervisors — Staffan Björk for well-timed intellectual challenges and stoicism in crisis, Mohammad Obaid for always knowing when I *really* need help. I have also had many ad-hoc mentors who cared to listen and comment throughout my PhD. Thank you. You probably do not realise how helpful you were. I would not be able to complete this work without the companionship of fellow doctoral students at the t2i lab — Zlatko Franjcic, Tomasz Kosiński, Khanh-Duy Lê and Jesper Molin.

I cannot thank my colleagues at the division of interaction design enough — among others, my best friend in Sweden and partner in crime Kristina Knaving, next door colleague turned research school director Pär Meiling and the thoughtful boss Jonas Landgren. I thank Marco Fratarcangeli, Dimitios Gkouskos, Maria Håkansson and Arvid Karsvall for many inspiring impromptu talks that provided loads of inspiration. I am grateful to the wonderful people in Kuggen who care to smile in the kitchen, even when it is two days to the CHI deadline and I look rather dreadful. I thank the brilliant support staff at Visual Arena Lindholmen who helped with many of our experiments — Thomas Hansson and Åsa Andblad. I would also like to mention all of the study participants made our work meaningful and engaging. My life would be different if not for the personnel at L's Kitchen who fuelled my work with food throughout my doctoral education.

I sincerely thank all my co-authors for coping with my idiosyncrasies. Special thanks go to Lars Lischke for keeping me sane, Nitesh Goyal for constructive argument and

Sven Mayer for his unmatchable proficiency in creating graphs. I am indebted to the CHI student volunteer community which enabled me to meet brilliant people who love HCI as much as I do. Bobby, Anna, Victoria, Chris, Michael et al. — you made this PhD an amazing experience. Furthermore, I am proud I was able to supervise many student theses and I thank my students for their wonderful work.

Finally, and most importantly, the biggest thanks go to my nearest and dearest at home. I am sorry I cannot be with you when I should be there. I thank my parents for their love, support and friendship and Mikołaj for not hating me for being a brother via FaceTime. I am indebted to Piotr and Przemek for around-the-clock remote support and to Agnieszka and Tomek for making me a part of their family despite the distance. I am very thankful to all of you who make me want to go back home each an every day.

On an official note, I would like to thank the Research Executive Agency and the Adlerbertska Research Foundation for supporting my research financially.

Paweł W. Woźniak
Göteborg, March 2016

Preface

Welcome to this doctoral thesis in Human-Computer Interaction (HCI) written by a random computer engineering graduate from central Poland. I have no idea how I got here. I would never expect that reflecting on all the research I conducted in Gothenburg would require so many sleepless nights and make me doubt myself so many times. They say that the imposter syndrome is common with doctoral students and it can be even more severe with those studying interdisciplinary fields. While I do not feel that I am suffering from the condition, I am certain that a large amount of luck was required in order for me to be able to write these words. This thesis reflects that to a large extent. After all, my research activities were determined by a number of external factors (e.g. research funding or the availability of colleagues who were willing to bear with me). Of course, one strives for elaborate plans, but reality wins at the end of the day. However diverse the papers included in this thesis may be, I can guarantee I was fully engaged in all of them and spent most of my day brooding about the research projects. As a consequence, this thesis represents a retrospective of not only my research, but also most of the thoughts that occupied my brain from August 2012 to March 2016.

The scariest and most exciting remark I can make in hindsight is that I feel even more clueless than I was when I started my doctoral studies. It was foolish to expect that things would become clear, but I anticipated that at least some notions would be set in stone. Even when writing this manuscript, I realised how many books I still need to read and how many notions in the *little* field of research I love so much will always be outside of my reach. Perhaps me getting a PhD was mainly about realising how vast one's ignorance really is? But, I would hate to end this preface on a negative note. However dumb some of the notions presented on the following pages may seem to you, however far-fetched the conclusions may appear and no matter how frivolous the style of writing in this thesis is, I still believe that my work confirms that HCI as an academic pursuit is worthwhile. HCI researchers are here to give meaning to technologies and make sure the marvellous engineering achievements in IT are a force for good in the

world. I have always been drawn to HCI owing to its humanistic side I do hope that this thesis reflects that fact.

Contents

Works included in this thesis

Paper 1:
Morten Fjeld, Paweł W. Woźniak, Josh Cowls, and Bonnie Nardi. 2015. Ad hoc encounters with big data: Engaging citizens in conversations around tabletops. First Monday 20, 2.

Paper 2:
Paweł W. Woźniak, Benjamin Schmidt, Lars Lischke, Zlatko Franjcic, Asim Evren Yantaç, and Morten Fjeld. 2014. MochaTop: building ad-hoc data spaces with multiple devices. CHI'14 Extended Abstracts on Human Factors in Computing Systems, 2329–2334.

Paper 3:
Paweł W. Woźniak, Lars Lischke, Benjamin Schmidt, Shengdong Zhao, and Morten Fjeld. 2014. Thaddeus: A Dual Device Interaction Space for Exploring Information Visualisation. Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational, ACM, 41–50.

Paper 4:
Paweł W. Woźniak, Nitesh Goyal, Przemysław Kucharski, Lars Lischke, Sven Mayer, and Morten Fjeld. 2016. RAMPARTS: Supporting Sensemaking with Spatially-Aware Mobile Interactions. Accepted for publication in the 34th Annual ACM Conference on Human Factors in Computing Systems — CHI '16.

Paper 5:
Paweł W. Woźniak, Robert Valton, and Morten Fjeld. 2015. Volvo Single View of Vehicle: Building a Big Data Service from Scratch in the Automotive Industry. Proceedings of the 33rd Annual ACM Conference Extended Abstracts son Human Factors in Computing Systems — CHI EA '15, ACM Press, 671–678.

Paper 6:
Kristina Knaving, Paweł W. Woźniak, Morten Fjeld, and Staffan Björk. 2015. Flow is Not Enough: Understanding the Needs of Advanced Amateur Runners to Design Motivation Technology. Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems — CHI '15, ACM Press, 2013–2022.

Paper 7:
Paweł W. Woźniak, Kristina Knaving, Staffan Björk, and Morten Fjeld. 2015. RUFUS: Remote Supporter Feedback for Long-Distance Runners. Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services, 115-–124

Paper 8:
Kristina Knaving, Paweł W. Woźniak, Morten Fjeld, and Staffan Björk. 2016. The Boar Board: Understanding Grassroots Sports Gamification in the Wild. Submitted for review to the 9th Nordic Conference on Human-Computer Interaction — NordiCHI 2016

Distribution of work

The following academics were appointed to supervise my doctoral studies.
Main supervisor: Morten Fjeld
Co-supervisors: Staffan Björk and Mohammad Obaid
Examiner: Fang Chen

Paper 1:
This purely conceptual vision paper did not require any experimental or design work. The concept of the paper was created jointly by me and Morten Fjeld as part of research proposal preparation and we worked together revising the core of the paper. Additional content relating the content to the social sciences was then provided by Josh Cowls and Bonnie Nardi.

Paper 2:
The paper includes content generated by designing and implementing two systems, which I conducted jointly with Lars Lischke and Benjamin Schmidt. I am the primary author of the text of the paper.

Paper 3:
This work focuses on the design and evaluation of Thaddeus, which constituted the content of Benjamin Schmidt's diploma thesis. I participated in the development of the system, designed the study, performed data analysis and wrote the paper.

Paper 4:
RAMPARTS was a system I developed jointly with Przemysław Kucharski. I was responsible for the study design and the study was conducted by authors in Sweden, Germany and Poland. Nitesh Goyal and I are the primary authors of the text of the paper. The content of the paper is also the main theme of Przemysław Kucharski's bachelor's dissertation.

Paper 5:
The paper contains experiences from my work at Volvo Group Telematics (VGT) which can be made publicly available. I was an independent consultant at VGT where I worked primarily with Robert Valton who also helped obtain publication permission from Volvo AB. I am the sole author of the manuscript.

Paper 6: Kristina Knaving and I are joint first authors of this paper. We jointly conceptualised the work and conducted the various data gathering activities required for the work. We also performed qualitative analysis for the purposes of the publication.

Paper 7:
RUFUS was a system I designed together with Kristina Knaving. I was responsible for the electronics design, the casing and the mobile application. We are joint first authors of the paper.

Paper 8:
In this user study paper, I was responsible for most of the data gathering while we conducted the analysis and wrote the paper jointly with Kristina Knaving. We also co-authored the text of the paper as joint first authors.

Other publications by the author

1. Vamsi Kiran Adhikarla, Paweł W. Woźniak, Attila Barsi, Dave Singhal, Péter Tamás Kovács, and Tibor Balogh. 2014. Freehand interaction with large-scale 3D map data. 3DTV-Conference: The True Vision-Capture, Transmission and Display of 3D Video (3DTV-CON), 1–4.

2. Vamsi Kiran Adihikarla, Paweł W. Woźniak, and Robert Teather. 2014. HoloLeap: towards efficient 3D object manipulation on light field displays. Proceedings of the 2nd ACM symposium on Spatial user interaction, 158.

3. Chen Chen, Paweł W. Woźniak, Andrzej Romanowski, Mohammad Obaid, Tomasz Jaworski, Jacek Kucharski, Krzysztof Grudzień, Shengdong Zhao, and Morten Fjeld. 2016. Using Crowdsourcing for Scientific Analysis of Tomographic Images. ACM Transactions on Intelligent Systems and Technology (TIST) (in print).

4. Zlatko Franjcic and Paweł W. Woźniak. 2014. QualiWand: Towards Optimising Feedback for Motion Capture System Calibration. Graphics Interface 2014 Poster Session Proceedings: 5—6.

5. Marta González Carcedo, Soon Hau Chua, Simon T. Perrault, Paweł W. Woźniak, Raj Joshi, Mohammad Obaid, Morten Fjeld, and Shengdong Zhao. 2016. HaptiColor: Interpolating Color Information as Haptic Feedback to Assist the Color Blind. Accepted for publication in the 34th Annual ACM Conference on Human Factors in Computing Systems — CHI '16.

6. Pradthana Jarusriboonchai, Sus Lundgren, Thomas Olsson, Joel Fischer, Nemanja Memarovic, Stuart Reeves, Paweł W. Woźniak, and Olof Torgersson. 2014. Personal or social?: designing mobile interactions for co-located interaction. Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational, 829–832.

7. Kristina Knaving and Paweł W. Woźniak. 2013. The extra mile: Augmenting the experiences of runners and their supporters. Proceedings of the International Conference on Multimedia, Interaction, Design and Innovation 2013.

8. Kristina Knaving and Paweł W. Woźniak. 2016. TickTockRun: Towards Enhancing Communication in Runner Families. Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion (CSCW'16 Companion). ACM, 309–312.

9. Andreas Kunz, Ali Alavi, Jonas Landgren, Asim Evren Yantaç, Paweł W. Woźniak, Zoltán Sárosi, and Morten Fjeld. 2013. Tangible tabletops for emergency response: an exploratory study. Proceedings of the International Conference on Multimedia, Interaction, Design and Innovation 2013, Paper 10.

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11. Andrzej Romanowski, Zbigniew Chaniecki, Krzysztof Grudzień, Hela Garbaa, Lidia Jackowska-Strumiłło, Dominik Sankowski and Paweł W. Woźniak. 2013. Design and implementation of a pervasive occupancy displaying system in an academic environment. Hybrid Intelligent Systems (HIS), 2013 13th International Conference on, 298—304.

12. Andrzej Romanowski, Krzysztof Grudzień, Zbigniew Chaniecki, and Paweł W. Woźniak. 2013. Contextual processing of ECT measurement information towards detection of process emergency states. Hybrid Intelligent Systems (HIS), 2013 13th International Conference on, 291—297.

13. Andrzej Romanowski, Paweł W. Woźniak, and Juliusz Gonera. 2012. Simplified Centralized Operational Transformation Algorithm For Concurrent Collaborative Systems. International Journal of Computer Science and Applications, 47–60.

14. Andrzej Romanowski, Paweł W. Woźniak, Tomasz Jaworski, Pawel Fiderek, and Jacek Kucharski. 2013. Modelling interpersonal relations in surgical teams with fuzzy logic. In Advances in Artificial Intelligence. Springer Berlin Heidelberg, 469–479.

15. Benjamin Schmidt, Paweł W. Woźniak, Kristina Knaving, Chen Chen, and Mohammad Obaid. 2014. ParkPal: Towards Ad-Hoc Route Planning for Runners. 2nd International Workshop on Cultures of Participation in the Digital Age.

16. Paweł W. Woźniak, Kristina Knaving, Staffan Björk, and Morten Fjeld. 2015. Untangling running: designing for real-life runner experiences. interactions 22, 2: 40—43.

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18. Paweł W. Woźniak, Bartosz Koczorowicz, Morten Fjeld, and Andrzej Romanowski. 2014. SubRosa: Supporting a Proper Learning Atmosphere through Subtle Cues with Immediate Feedback. In Persuasive Technology. Springer International Publishing, 279–290.

19. Paweł W. Woźniak, Margareta Lützhöft, Thomas Porathe, Asim Evren Yantaç, and Morten Fjeld. 2013. Examining interactive surfaces for maritime operations. Proceedings of the 2013 ACM international conference on Interactive tabletops and surfaces, 341—344.

20. Paweł W. Woźniak, Andrzej Romanowski, Filip Proborszcz, Martyna Borkowska, Dominik Stozek, and Bartosz Koczorowicz. 2012. Maintaining proper conditions in quiet study rooms with ambient influence. Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design, 787—788.

21. Paweł W. Woźniak, Andrzej Romanowski, Asim Evren Yantaç, and Morten Fjeld. 2014. Notes from the front lines: lessons learnt from designing for improving medical imaging data sharing. Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational, 381—390.

22. Paweł W. Woźniak and Andrzej Romanowski. 2012. Everyday problems vs. ubicomp: a case study. Proceedings of the 2nd International Conference on Web Intelligence, Mining and Semantics, 57.

23. Paweł W. Woźniak. 2013. Everyday encounters with data: Exploring engaging and collaborative interactive technologies. Licentiate Thesis, Chalmers University of Technology.

24. Paweł W. Woźniak, Morten Fjeld, and Shengdong Zhao. 2014. Limiting trial and error: Introducing a systematic approach to designing clutching. Proceedings of the Second International Symposium of Chinese CHI, 35—39.

25. Paweł W. Woźniak, Tomasz Jaworski, Pawel Fiderek, Jacek Kucharski, and Andrzej Romanowski. 2013. Clinical activity and schedule management with a fuzzy social preference system. In Advanced Methods for Computational Collective Intelligence. Springer Berlin Heidelberg, 345—354.

26. Paweł W. Woźniak and Andrzej Romanowski. 2013. Vertoid: Exploring the persuasive potential of location-aware mobile cues. Computer Science and Information Systems (FedCSIS), 2013 Federated Conference on, 1339—1342.

Part I.

Setting the scene

Disclaimer

> Granted I am a babbler, a harmless vexatious babbler, like all of us. But what is to be done if the direct and sole vocation of every intelligent man is babble, that is, the intentional pouring of water through a sieve?
>
> Fyodor Dostoyevsky,
> Notes from Underground, 1864

I endeavoured to structure this thesis so that it can fulfil a number of purposes and appeal to a wide readership, which I try to explicate in this introductory chapter. I hope that this thesis is usable and easy to navigate.

My work as a doctoral student was rather eclectic. I was engaged in a variety of projects during my doctoral studies and I concluded research projects started while being a Master's Student. There is a high probability that, looking at the table of contents, the reader will see a number of papers that do not fit together. Indeed, they are parts of several inquiries and I hope this thesis will clarify some of the connections. However, the goals of this work are to accurately report on my research activities and reflect on the finished research using the lens of what kind of contribution the work presents. Additionally, I will attempt to compare the different kinds of work that I performed and look for lessons for the future. My reflections are not only based on the included papers themselves, but they also include design notes, intermediate artefacts, photos, videos and anecdotal evidence that I collected during working on the research projects included in this thesis. As a consequence, this thesis explores the pragmatic conceptual challenge of how to make sense of all the research activities described in the published papers included in the thesis.

My aim was to make this thesis read as a concise story that is actually borderline enjoyable. I begin my story with a number of introductory remarks (part I) where I try to explain why it is important to try to reflect on my academic work. I then introduce the eight peer-reviewed papers included in this thesis and categorise them into three parts (listed as parts II, III and IV). The text of the papers is preceded by detailed publication information. I also added some extra words that put the papers in the context of this thesis before each part in chapters I dubbed *prologues*[*]. These are intended to offer a smoother reading experience, although the abstracts and related work sections still contain a significant amount of overlap as many of the papers address the same general topic. While the introductory part of this thesis operates on a meta-research level, the prologues also offer a summary of more specific findings in the particular application area. The thesis concludes with an extended summary (part V), which reflects on the included papers using the theory developed in the introductory part.

The papers are organised into three parts. Two of them reflect the dissonance reflected in the title of this work[†] — technology- and user-driven inquiry. I also included an in-between part where I discuss my experiences of working with industry partners. There is a final part of this thesis after the paper parts which includes some final reflections.

The structure of this thesis is somehow unorthodox as it does not feature an extensive literature review in the specific areas addressed by the included papers. I believe the reader should not have to endure the same experience twice — I and my co-authors already included a fair amount of related work in the papers and I provide a comprehensive list of all cited sources at the end of this work. Instead, this thesis offers some methodological and meta-research insights base on a different set of references. Instead of providing a repetitive and uninspiring review of the work which I have already cited in the appended papers, I offer a comprehensive review of papers about the nature of design-based research in HCI. If the reader is looking for the classic 'Literature review' chapter, please refer to chapters one and two[‡]. Furthermore, at times when I could not resist to include a less rigorous, non-essential comment in the text, I made use of footnotes as illustrated in this short introductory piece.

If you are looking to simply review the papers included in the thesis, the helpful thicker divider pages will guide you there. These eight numberless guardians of bibliographical order point you to the eight papers which constitute the main part of this thesis, which is also peer-reviewed material. These parts contain little reflection and, hopefully, a fair amount of academic contribution.

Thank you for reading this far. I wish you a pleasant journey as you plough through the subsequent pages.

---

[*]This also hints at the authors affinity for road cycling and the surprising commonalities between the mindsets required to practice full-time research and endurance sports. Or, at least *perceived* commonalities.

[†]I do hope that this is not the first page your are reading. If so, please contact the author immediately at pawelw@chalmers.se as a printing error needs to be urgently corrected.

[‡]They do have other (and hopefully more interesting) names.

1 Design in HCI inquiry

> Spontaneous creation is the reason there is something rather than nothing.
>
> Stephen Hawking
> The Grand Design, 2010

In this thesis, I attempt to take a critical and reflective look at the eight papers on which it is based. The main purpose of these introductory chapters is to introduce the reader to the critical lens I will apply to the papers (in each of the *prologues*) and then summarise after I present the eight published works. However, as this analysis is still set within an academic context, a number of assumptions is required to sufficiently narrow its scope. Consequently, I will begin by elaborating briefly on those so that the starting point of this thesis is clear.

1.1. The starting point

With the thirty fourth Annual ACM Conference on Human Factors in Computing Systems happening in 2016, it can be safely assumed that Human-Computer Interaction is an established field of inquiry (Zimmerman *et al.* , 2007) with a large and active research community. According to academic traditions (and noting that HCI's publication model is mostly borrowed and then augmented from computer science) the community is active in a number of publication venues. While we, as the HCI research community, are still unsure about HCI's relation to other fields of research and its many purposes (Rogers, 2012), we know without a doubt that HCI makes regular significant contributions to our (as the humanity) understanding of the world. Consequently, ignoring the intricate

issues of the suitability and usefulness of the peer review process*, one can safely assume that whatever the community deems acceptable for publication is likely to present a contribution.

And this is the key premise under which this thesis operates. As the eight papers included here constitute acceptable work in HCI, I will try to reflect and decipher what that means. I will attempt to look back on the methodology applied, results obtained and analyses conducted in order to find commonalities, contrasts and oddities. In this process, I will hope to learn more about what I did during my doctoral studies and gain a deeper understanding. Given how academic publishing works and the fact that researchers often present their work in forms prescribed by publishing venues, I will try to recreate what was lost between the lines of the eight papers in order to know more about the research practice, in which I was involved.

A quick glance at the list of papers in the beginning of this thesis is highly likely to produce an impression of an arbitrary selection of writing. The organisation of work in my course of studies enabled me to explore different directions in research. This, however, makes producing a uniform and comprehensive thesis more of a challenge. On one hand, this may be a nuisance. On the other hand, I can safely explore the differences between the different projects, in which I was involved.

The research activities described in the work in the thesis clearly have on thing in common — they all included design-based research (i.e. they empolyed interaction design methodologies in order to gain new insights), although in different forms. Work on all of the projects in the eight papers included elements of design practice. Taking the assumption that the papers constitute contributions to the field, I will first explore the role of design-based research in HCI. This will establish an theoretical and epistemological baseline, which will hopefully enable me to later re-evaluate the papers included in this thesis. This will be done through synthesising the expected knwoledge contributions from design-based research through a literature review. There is key assumption that I make in order to render my reflective analysis possible. I will assume that HCI is a design-oriented discipline and most research activities in HCI include smaller or larger parts of design activities. I consider the design activities we conduct in HCI (or the 'HCI design process' as described in e.g. (Harper, 2008)) the most important tool in our toolbox. I am fully aware that this is not a universally accepted assumption, but,

* I do not endeavour to dispute academic publishing traditions here, but I will quote Winston Churchill.

> Many forms of Government have been tried and will be tried in this world of sin and woe. No one pretends that democracy is perfect or all-wise. Indeed, it has been said that democracy is the worst form of government except all those other forms that have been tried from time to time.
> Speech in the House of Commons (11 November 1947)

I believe that substituting the word 'Government' with 'academic publishing' and 'democracy' by 'peer review' illustrates the current state of affairs well. That is why I believe that trusting the community that most published work is worth publishing is the logical choice.

given the flux in which the HCI field constantly finds itself (Bødker, 2015), I believe it is acceptable to make that assumption for the purposes of the intellectual experiment that this thesis constitutes acceptable academic work. As a consequence, much in the spirit of reflective design (Sengers *et al.* , 2005), I will attempt to look critically at my work and draw new conclusions.

1.1.1. Is this really needed?

A reasonable question to ask at this point would if such a meta-level analysis as I introduced above is strictly needed or whether it may lead to any deeper understanding of the work the HCI community performs. I am quite certain that charting the meaning of design-based research and the kinds of knowledge it may contribute bears little to no relevance to the everyday operations of an HCI lab. So, why do I find this activity worthwhile? Many of the findings presented here are thoughts I wish I had expressed at the beginning of my doctoral education. However, given my then heavily limited experience in conducting studies and a skeleton knowledge of the topical literature[†], I do not think I would have been able to formulate these reflections even if I had taken the time to conduct a proper literature survey.

In a way, I am attempting to step back into the position of a clueless engineering-educated wannabe design researcher and build some elementary bits of structure that, while not comprehensive, can aid immersing oneself in the field. As it can be observed that prominent HCI researchers often reflect to find that HCI is in a constant flux (e.g. (Bødker, 2015; Rogers, 2012)) looking for shreds of alignment in what constitutes commendable work is somehow difficult. A similar concern, along with a very positivist attitude, was recently presented by TOCHI's new editor-in-chief (Hinckley, 2016) Personally, I have often referred to work by esteemed researcher whose work seemed intuitively valuable and insightful. However, once immersed in academia, following role models cannot be the sole motivation.

There are multiple emerging questions that provoked me conducting the analysis in this thesis. Some have pointed that the strength and uniqueness of our discipline is connected to its relevance to practice. As Gray et al. suggest (Gray *et al.* , 2014), one of the key purposes of academic research in HCI is to produce refined and theoretically-grounded methods and tools. However, the authors also note that most practitioners learn methods through interacting with their more experienced colleagues. This paradox illustrates a clear challenge for the HCI research community — how to communicate our work in forms that are later reusable in application contexts. In other words, one may wonder if HCI research can be presented in ways that affect the day-to-day operations of commercial enterprises that develop interactive products.

[†]Not that I would find my experience or knowledge substantially improved, but I do hope there is a certain observable evolutionary growth in this department.

Another reason for pursuing the analysis presented in this thesis is the wish to understand the internal debate within HCI. In the beginnings of my doctoral education, I would often be annoyed by the apparent antinomies involved in HCI research. Only later did I learn that these 'conflicts' effectively stimulate discourse and provide new topics for research. For example, Greenberg and Buxton (Greenberg & Buxton, 2008) famously opposed to the hegemony of usability evaluation in HCI research. They expressed their dissatisfaction with systems too often being evaluated outside of the context in everyday practice. However, the purpose of Greenberg and Buxton's work was not to criticise or invalidate past experiments, but to call for more consideration in the choice of evaluation methods. They feared that obsessively trying to avoid subjective measures may eventually result in a field with outdated methodologies and little impact on everyday life. While Greenberg and Buxton propose sketches as alternatives to extensive quantitative measure, I attempted to gather forms that can communicate the qualities of research work that go beyond numbers.

Finally, it is worth mentioning that none of my motivations for conducting this analysis are of a negative nature. While the world of HCI seems difficult to navigate and I have to confess that I was once overwhelmed with the multitude of approaches and methodologies involved, the constant flux is thrilling. HCI is a field that accommodates thinkers with different backgrounds and scientific goals, but the diversity must be its strength given that the HCI community has developed into a vibrant and stimulating forum. The little shards of structure that I attempt to provide in this thesis are not a call for less diversity.

1.2. Getting the terminology straight

Yet, the previous section may seem a bit controversial to some readers. After all, there is no widely accepted consensus on what is the role of design in HCI or, more generally, an accurate definition of design per se. As I do not aspire to contribute to design theory in this thesis and my work did not aspire to answer these kinds of questions, I will take the liberty of clarifying some terms based on sources I find most relevant and by which I was most inspired in my work.

1.2.1. Inherent limits of this literature review

There are many definitions of design and the understanding concept is constantly evolving is some fields. It is also a linguistic conundrum as the word is understood differently in different languages. For example, in Polish, *design* (Słownik Języka Polskiego, 2016) is usually understood as the concept known as *kunstindustri* (Den Store Danske, 2016) or even *brugskunst* in the Scandinavian languages, which is closer to *industrial design* for the English-speaking reader. Instead, the term *design thinking* is preferred for a describing a wider set of approaches to identifying and solving problems together with knowledge

generation. On the other side of the spectrum, German offers *Ingenieurskunst* (GmbH, 2016), which refers chiefly to the flair and mastery involved in engineering achievements usually attributed to large-scale objects such as bridges or stadiums. This apparent lack of well-defined terminology indicates it is worthwhile to explicate the understanding of *design* in this thesis. There is no consensus on what how the term *interaction design* can be understood either[‡]. As a consequence, this section cites past work in the HCI field that addresses the understanding of design, but refrains from providing definite answers leaving interpretation to the reader.

It is important to state the limits of the analysis I will present here as setting boundaries seems to be required to make this thesis a manageable read[§]. First and foremost, my work is embedded within the HCI community. I decided to limit the scope of inquiry to what members of the community have expressed or deemed relevant. In other words, I did not dare to step outside of my domain of expertise (i.e. HCI) and proceeded to browse mainly HCI-related publications. Consequently, I primarily reflect on the views about design-based research presented in the HCI community. Such an inquiry is missing and a systematic account of what the expected contributions from design-oriented work are is needed. Consequently, for the purposes of this thesis, I decided to abstain from importing new knowledge from design theory into HCI and focus on what design-educated members of the community have already expressed. This can be meaningful as I am personally coming into HCI from the opposite end of the tech vs. user spectrum — I was educated as an engineer and started adopting design-oriented approaches later in my career.

Moreover, it is vital that this thesis does not attempt to build a model for conducting research in HCI or categorise past work in any way. This is what makes this work different from Prestopnik's (Prestopnik, 2013) writings which aimed to generalise multiple research inquiries into an actionable meta-construct for HCI inquiry. In contrast, this thesis aims to chart what kinds of knowledge we can create with design-based research and how the experience of designing digital artefacts can drive future research in HCI[¶]. Similarly to Prestopnik, the starting point here is understanding the relation between HCI and design and the ways HCI research can be viewed as a designerly endeavour.

Another past work that also attempted at providing structure to contributions looked specifically at UX frameworks. Law et al. endeavoured to investigates how theories and UX frameworks interact and influence design instances (Law *et al.* , 2014b). While their analysis does provide a structure, it only investigates three contribution types and does not relate these to research practice.

[‡]Hallnäs and Redström provide a comprehensive collection of definitions, but refrain from providing a conclusive interpretation (Hallnäs & Redström, 2006).

[§]The alternative being aspiring to possibly cover all interpretations and relevant fields of inquiry thus creating an incomplete thesis. While this seems like an exciting intellectual challenge, it also looks like one that requires not one PhD, but a life's work of study and engagement with multiple communities in academia and design practice.

[¶]Sadly, I have to report that this thesis does not provide simple answers to these questions. It does include a starting point based on a literature review, however.

1.2.2. Multiple perspectives on design in HCI

Having concluded the introductory remarks, it is high time we bulged into the intricacies of the relationship between HCI and design. It is worth mentioning the embracing design approaches is a rather new phenomenon in the HCI community and it is likely to be limited to a subgroup of researchers. Back in 2002, Bill Gaver still argued strongly for understanding the design aspects of work in interaction design (Druin *et al.* , 2002). This way was contrasted with several 'more traditional' understandings of what may constitute a contribution within the field. Thirteen years later (in 2005), Pierce et al. (Pierce *et al.* , 2015) note that a wide acceptance of design methodology is taken for granted by noting that doubts regarding the validity of design methodologies are a 'thing of the past". I believe that such an epistemological evolution[‖] in the HCI field requires extended analysis.

Back in 2003, Daniel Fallman made a strong point about how HCI has outgrown the boundaries of an academic discipline and began to encompass not only researchers, but a large group of consultants and designers from industry (Fallman, 2003). Consequently, Fallman sees HCI as a design-oriented field of inquiry and explores the meaning of design for HCI as well as the implications of such a framing of the field. He proposes three understandings (or 'accounts") of design that offer an increased understanding of the concept and illustrate the lack of consensus on the exact nature of design. The conservative, romantic and pragmatic accounts are presented. I will now briefly present these accounts and relate them to published work in HCI.

1.2.3. The conservative account

The conservative account focuses on describing design as structured intervention. Designers are seen as problem finders that use a variety of methods that lead to creating a reality that is more desirable than the status quo. In other words, design is a process that offers a structured transition from identifying constraints (or requirements) into developing artefacts. This means that the entire activity is primary concerned with problem solving. Such an approach also allows for a clear division of the design process into phases. Analysis leads to understanding the problem. Synthesis allows for creating conceptual solutions based on the analysis. Prototyping allows for communicating ideas and getting feedback. Although this process-oriented understanding of design is very stringent and it rejects many of the finer details of design, it does resonate in practical considerations. The three phases are known to be a good way to understand design methods for practitioners (Kolko, 2010). In fact, the conservative approach's focus on the process can be highly beneficial in situations when the multitude of design constraints and stakeholders is overwhelming. Trusting that a well-conducted design process will

[‖] It seems that this change can be considered evolutionary (rather than revolutionary) given that 13 years is a rather long period of time given the history of the HCI field.

lead to actionable results despite the many difficulties involved was recommended as a key principle for interaction designers (Kolko, 2013).

The clear division into phases proposed by the conservative account also makes design resemble more traditional methods of inquiry. Consequently, traces of the conservative approach can be seen in many HCI papers. Some work focuses on problem analysis and claims this as the main contribution. A very tangible example is the work on supporting Walking School Buses (Winstanley *et al.* , 2014) where the authors identified the needs of a very specific user group and showed how their reality could be improved through technology using a scenario-based approach. Most system** papers contain a design section, which often focuses on showing how analysis led to a synthesis of concrete prototype features††. One of the best papers from Ubicomp 2012 (Kay *et al.* , 2012) provides a good example of how the community appreciates a clear connection between requirements and features. In Lullaby, Kay et al. provided a well-defined set of needs based on past work in sleep management and showed how an effective design synthesis process can lead to designing an effective artefact supporting the user in sleep monitoring.

1.2.4. The romantic account

In contrast, the romantic account emphasises the qualitative and unstructured aspects of the design process. This interpretation of design centres around the designer and their skills as the sole source of change. Creativity is embraced as a core value and structure, methodology and control should be traded for the focus on the individual qualities of the designer. Designers are seen as feature-generating creatures and thus their individuality and imagination are to be cherished. Thus, abstract reasoning and problem solving become less important. There is a certain amount of mysticism involved in this approach as the designer's creative process is assumed to be a mystery. Consequently, the intricacies of what actions and decisions lead to a particular design are rarely shared and the output of design work focuses on the artefact produced and the designer themselves. Fallman remarks that this can be considered as a more art-oriented understanding of design‡‡. While it is somehow harder to find relevant examples of appreciating the designer in a romantic way compared to finding examples for the conservative account, it is far from impossible. One way that of this approach was manifested at the CHI conference is through articles that focus on interviews with designers. Notably, Bardzell and Bardzell (Bardzell & Bardzell, 2011) conducted a series of interviews with designers of sex toys to show how design practice in this domain can inform the HCI community. Through embracing the craft and skills of the designers, the authors showed how theoretical

**i.e. papers focusing on the design, implementation and evaluation of a single system

††I have noticed a strong focus on explicit design decisions and explaining each and every feature in the American HCI tradition, which seems to be an interesting discussion point when contrasted with European design culture.

‡‡I will comment on the art/science balance in understanding design later in this thesis.

developments in HCI in terms of embodiment, emotion and experience need more work to gain more relevance for design practice. They also illustrated how critical immersion can be an effective tool for designers — this highly subjective method strengthens their focus on the individual qualities of the designer and their intrinsic ability to successfully design products based on personal experience.

We can see traces of the romantic account further away in the history of the HCI field. Looking back the the seminal work performed at the XEROX PARC in the late 80s and early 90s, the Dangling String by Natalie Jeremijenko (Weiser & Brown reported this as part of their recollections of activities at the PARC (Weiser & Brown, 1997).) emerges as a romantic example that influenced future work. One could argue that romantic explorations that rely solely on the creativity of the designer and provide little explanation of the design process are the way to advance the discipline and inspire more structured research. Developments in informative art offer a good example here. Van Mensvoort's Data Fountain (Eggen & Van Mensvoort, 2009) shows an example of an artefact designed to be aesthetically pleasing and well integrated with the surrounding environment. This was achieved by solely relying on the designer's expertise and an informative element was added as an additional feature. While the design considerations of the Data Fountain remain rather fuzzy and cannot be interpreted as a contribution to HCI, the work has inspired research that led to more concrete results. The successful exploration of ambient information led to reapplying similar methods in persuasive systems e.g. in Nakajima's and Lehdonvirta's work on ambient mirrors (Nakajima & Lehdonvirta, 2013). Work that relies on individual creativity can also be effective in putting HCI at work in social roles, where adapting technology to communicate socially important messages is the key contribution. This was exemplified in Egg's Journey (Samanci *et al.* , 2007) where off-the-shelf interaction techniques were carefully crafted to tell an interactive story of how a sperm reaches an egg to produce children.

HCI papers can also use design methods that clearly draw on the romantic, but then try to hide the romanticism in the actual writing. The Clouds (Rogers *et al.* , 2010) is an example of a system description where functionality and the practical aspects were the focus, while the romantic element must have played an important role. In this description of an introspective installation that persuades users to use the stairs instead of the lift, the authors focused on the practical and persuasive aspects of the design. Little attention was given to the design of the visualisations that influenced the users and the designer of their physical and visual forms. This may suggest that researchers feel that romantic accounts may be less appreciated by the reviewers and thus harder to publish. This is confirmed by the fact that much exploratory work is often published outside of the main proceedings with the Drift Table (Gaver *et al.* , 2004) being a prime example.

1.2.5. The pragmatic account

The pragmatic account emphasises that all design is heavily contextualised, interpreting the designer as the reflective practice-oriented unit that strives to produce the best results

from the available means. Consequently, designers are seen as those highly skilled at defining the boundaries of a problem (or design constraints), ascertaining how many and what kinds of resources are accessible and optimising the outcome of their work based on the conditions in a particular setting. This is heavily related to the *bricoleur* concept coined by Lévi-Strauss (Lévi-Strauss, 1966). Furthermore, the designer is considered to be in constant dialogue with the world and the outcomes of the design process are the result of a rational compromise between the needs and the means available. It is the role of the designer to redefine and reinterpret resources into order to manage the heterogeneity of the particular design setting. This standpoint results in two consequences. Firstly, the reflectivity of the designer takes a crucial role. The ability to reflect on actions taken and outcomes observed builds the core understanding of the designer and becomes the essence of the design process. Embracing reflection was famously stressed by Schön to show how generalisable insights can be derived from understanding practice (Schön, 1983). Secondly, the pragmatic account stresses how directly engaging in a design activity enables the practitioner to gain tacit knowledge i.e. the kind of knowledge that escapes the definitions used in science and art. This implies that uncertainty and a lack of definition (related to the concept of *wicked problems*[§§]) is central to the understanding of the design activity. Consequently, the designer is a creature with exceptional constructive and reflective skills, operating in a 'build, reflect, repeat' cycle.

Elements of the pragmatic account can be found in parts of HCI literature. Surprisingly, *bricolage* seems to be a word to which researchers like to relate even in more technical contexts. For example, *bricolage* was used in a positive way to name a new algorithm (Kumar *et al.* , 2011) and negatively to contrast design work with an analytical approach (Casiez & Roussel, 2011). While these examples may be incidental, they showcase that the HCI community is toying with the idea of heavily contextualised design and it is hard to be indifferent to it.

There are works which addressed the pragmatic account more directly. The Clouds (also described in the previous section) included many bricolage elements and the authors decided to publish a more context-oriented account of their work as well (Hazlewood *et al.* , 2010). Not only does this particular work illustrate that HCI practice can be interpreted from many design angles, but it also shows the different roles HCI researchers need to take in their work. Hazlewood et al. offer a detailed pragmatic account of their, even though it is never stated explicitly in the paper. They provide a detailed description of how they designed multipe artefacts so that they fit well with the building. The researchers describe the activities required for deployment as well as the technical choices they made. The authors suggest that their approach was 'technology-centric', but it can as well be interpreted as bricolage. Their full understanding of the constraints involved and means available, perhaps best illustrated by the fact they even backup plans were present, allowed for successful deployment. Even more in line with Fallman's pragmatic

[§§]The author chooses not to attempt to define or discuss wicked problems in this thesis for the sake of the reader. This does not mean that I do not acknowledge my co-supervisors particular affinity for that term.

account, Hazlewood et al. underline the importance of dialogue and consultation in their work. It was important to be in constant dialogue with the outside world and within the design team. Consequently, they suggest rethinking some of the established design process models in interaction design, especially where designs that affect many users on a large scale are considered. Going 'beyond the computer' seems to requirte much more design considerations and, perhaps, a new framing for design per se. Vallgårda and Fernaeus explore the bricolage concept even further by suggesting it as a way to assure the advancement of the HCI field (Vallgårda & Fernaeus, 2015). In an exploration of how objects and materials can inspire designers and foster creativity (heavily based on prior work on materiality in interaction design (Vallgårda, 2014)) they propose reframing design as a conversations with materials and cultural connotations. While Vallgårda and Ferneaus claim to go beyond Fallman's understanding of the pragmatic account, bricolage and dialogue are still the central notions of their approach. They emphasise the importance of cultural defences and design as finding new connections between well-known, defined elements. Consequently, bricolage becomes an alternative approach to designing interactive artefacts.

1.2.6. A fourth way to understand design

It is worth noting that Fallman presents the three accounts of design as analogous to three ways of knowing widely accepted in human practice. The conservative account is analoguous to life sciences, the romantic to art and the pragmatic to the social sciences. One can also observe that the three accounts are somewhat complementary and design efforts can be interpreted from all three angles. Different accounts can be used to stimulate creativity in different contexts and the contributions of the work can be showcased particularly well when viewed with one of the accounts in mind. A somewhat more comprehensive way of framing design in HCI seems to be required. While not loosing the particular insights of the conservative, romantic and pragmatic, one naturally seeks a more overarching model that could fit all three. There is another interpretation of the tripartite division that may be helpful to understand the role of design in HCI inquiry — design as a new form of knowing separate from art and science, as postulated in *The Design Way* (Nelson & Stolterman, 2003).

While Nelson and Stolterman's attempt to address all aspects of understanding design, their framing of design as the third way of knowing is key in the scope of this thesis. The Design Way presents design as a practice that does not 'lend itself to simple answers". The authors acknowledge the hegemony of the scientific method as the only way of knowing and present design as a device to know things that are *real* in contrast to knowing things that are *true* which is done by means of science. They also emphasise the crucial role of systems thinking in the design process, thus stressing that designers should have an understanding of the complex processes and dependencies that are omnipresent in the real world. A sharp critique of this reductionist approach follows and Nelson and Stolterman believe that reductionism not only yields bad design, but it also limits design's

potential as an intellectual device. The notion that the context of an inquiry lies at the core of design makes one reconsider many contributions in HCI which examine designed artefacts in simplified contexts so that the evaluation is manageable[¶¶]. Furthermore, Nelson and Stolterman recognise that not all aspects of design can be rationally explained. While there is a fair amount of rational thinking involved in design, it is not a fully logical process. Consequently, not all design decisions can be explicated and communicated to fellow designers. This certainly poses a challenge to those using design within HCI as sharing design experiences in publications is considered the core of academic work in this domain.

1.2.7. Design-based research

However, Nelson and Stolterman's conceptual understanding of design addresses design as a whole and not specifically design work in HCI. Consequently, instead of trying to reinterpret or reapply their concepts to HCI work, I believe it is more convenient to recognise design as third way of knowing, but use a simpler understanding of it that works within the narrower context of the HCI community[***]. Obrenović presents a simplified account of design research that is easier to operationalise in an HCI context (Obrenović, 2011) — three categories of generalisation that attempt to explain how knowledge can be generated in design-based research. Instead of trying to fully comprehend and analyse the role of design as the third way of knowing, he proposes *to focus on what design can produce and how we can exploit the process to generate knowledge* by introducing three categories of generalisation for design-based research.

This thesis adopts Obrenović's understanding of design based research.

> In the rest of this work, I use the term *design-based research* as the overall set of design activities in interaction design that allow those involved in the design process and those observing it to generate new insights about the world. These activities are accompanied with a reflection process that allows for result communication.[¶¶¶]

I purposely avoid the word 'knowledge' in the definition. Koskinen et al. pointed that discussing knowledge in the context of design is counter-productive. Instead, I assume a pragmatic point of view and leave epistemology to philosophers and address solely design techniques and processes and the way people interact with them (Koskinen *et al.* , 2011, p. 168).

[¶¶] I will not provide examples as this is a large trend and simply picking a single paper would be unfair. Any CHI paper that contains more than two bar charts could serve as an example here.

[***] This is slightly reductionist, but this trick enables putting the papers in this thesis in context.

[¶¶¶] This is the one and only definition of this thesis. Reliable sources (Schmidt, 2016) claim that these should aim to have a largely limited number of definitions.

It is necessary to mention the difference between design-based research (i.e. using design as a tool to generate knowledge) and design research as studying the nature of design processes per se. Hallnäs and Redström (Hallnäs & Redström, 2006) have explicated the difference and my notion of design-based research in HCI is very close to their term *interaction design research*. They also note that such a lens may be considered controversial, especially if one assumes a 'knowledge production' point of view due to little structure compared to the scientific method. This thesis is written from a point of view that assumes that not all researchers consider HCI science (Churchill, 2015) and thus this inquiry is free from the constraints of such a framing. On the other hand, one needs to remember that design cannot pretend to be in an intellectual void and it is only meaningful if properly embedded in technical, scientific and social developments (Moholy-Nagy, 1969)[†††].

The HCI community is still not fully in agreement on what is the exact role of design-based research in answering the research questions that the discipline endeavours to address[‡‡‡](Zimmerman *et al.* , 2007). However, as design-based research has been successful in a variety of other domains and applied to, inter alia, systems, organisations and urban planning (Koskinen *et al.* , 2011, p. 165) it is interesting to take a structured look at how it can contribute to HCI. Furthermore, the proponents of design-based research often emphasise its transdisciplinarity (Koskinen *et al.* , 2011, p. 166), which is similar to where HCI researchers see the strength of the field (Rogers, 2009).

Obrenović structures activities and contributions in design-based research in three levels. Firstly, design procedures specify processes and stakeholders involved in particular design contexts. They can be generalised to *design methodologies*, which provide specifications on what processes are applicable given specific design goals. They also show what experts are required and what roles designers will need to take. Secondly, problem analyses present the understanding of a given problem and include specifics of user needs. A problem analysis shows how designers chart the design constraints and how their problem understanding evolved in the design process. These understandings can be generalised into *domain theories* that help designers know users or technologies thus being a source of knowledge about the world and not design. Finally, design-based research can result in design solutions. Solutions are descriptions of design artefacts that are outcomes of a process. They are the final point of a process that involves decision, trade off and understanding. Design solutions are necessary to build more general *design frameworks* that specify the features of a design required in a particular context given a set of user goals. They usually consists of design guidelines applicable for a set of users in a set of situations.

Through this structuring of contributions, Obrenović emphasises how design-based research enables systematic inquiry in complex, real-world contexts, especially if one is unsure which variables are involved (which contrasts strongly with the scientific

[†††]I follow the advice of Koskinen et al. and refrain from theoretical discussions on the notion of form in modern design-based research (Koskinen *et al.* , 2011, p. 166).

[‡‡‡]And, as noted before, there is little consensus on what the questions should be.

method). He further suggests using design-based research and controlled experiments as complementary tools what may result in a better understanding of the world if used in tandem. Lastly, and perhaps, most importantly, Obrenović stressed the contrast between design-based research and the social sciences. Instead of charting, documenting, and trying to characterise relationships in the world (e.g. as in ethnography), design-based research takes an active part in changing the world and documenting the experiences of the process. He sees that as an opportunity for many issues addressed in the field of HCI where strong theories or laws are not present and the scientific method is hard to apply[§§§].

Having established how design-based research can be interpreted and how different past works in HCI reflected those understandings, I will now look at what contributions the HCI field claims to deliver and how they related to our understanding of design.

[§§§]Or, it is applied, but its validity is limited.

2

Design-generated types of contribution in HCI

Hugh: And by demagoguery you mean ...?
Stephen: I mean demagoguery, I mean highly-charged oratory, persuasive whipping up rhetoric.

From A Bit Of Fry & Laurie Series 1, Episode 3, originally broadcast on January 27th 1989

This chapter integrates different types of contribution from design-based research from a variety of literature sources. I then juxtapose these constructs and aim to describe how they relate to each other by means of the Contribution Type Family model. Obrenović's proposed framing of design-based research serves as a frame of reference for the inquiry.

One could interpret Obrenović's three categories of generalisation (see section 1.2.7) as a set of broad categories that can be used to classify the contributions produced through design-based research* and described in academic work. However, these terms (design methodology, domain theory and design framework) are understood in multiple ways and that particular terminology is and not universally adopted in HCI literature. These categories enable us to interpret many types of contributions on a meta level, but a more explicit indication of what kind of results may be created in interaction design and inspire researchers to reflect on their design activities is needed. In this chapter, I will show some other kinds of contributions proposed in literature and attempt to relate them in a concise manner to later use them as a lens to interpret the core work presented in this thesis.

*Please observe that the terminology I apply here is as follows: 'design-based research generates design-generated knowledge', i.e. I will refer to the intellectual products of design-based research as 'design-generated knowledge'.

It is worth noting that I will not attempt to answer the question of what kind of work can constitute HCI work or work acceptable in the HCI community. I will also not comment the fact that my work included later in this thesis is presented in ways that are heavily affected by academic convention and the ways a typical academic paper written by a doctoral student in HCI should look like. Instead, I will focus on ways we can communicate the experiences of an HCI design process in order to share insights with other designers. Consequently, this chapter will not discuss all the kinds of contributions that go in line with HCI's trend for scientism such as, inter alia, technical specifications, validated laboratory experiments, programmer toolkits or purely theoretical developments. While reflecting on these more rigorous kinds of contributions is worthwhile, it is more relevant for this thesis to begin with looking at what the HCI research community perceives as topics that need to be studied.

A look at the CHI[†] conference submission form seems to give some clues. Here are the contribution types listed as possible answers to the question 'What is the primary contribution type of this paper?':

- Artefact or System
- Dataset
- Empirical study that tells us about how people use a system
- Empirical study that tells us about people
- Essay/Argument
- Meta-Analysis/Literature Survey
- Method
- Theory

This illustrates what kinds of categories an academic paper is expected to fit into in HCI's largest conference. A quick look at the contribution types reveals that these terms clearly operate at different levels of abstraction and are open to interpretation. Despite my best efforts, I was unable to determine how these categories were determined to be the most appropriate. However, the trend for scientism is evident in those categories. They appear to emphasise rigour, clear structure and a view of HCI as a well-defined field of inquiry. While it is true that some questions in HCI can be answered by pure scientific inquiry or theoretical work, if one takes Fallman's standpoint of HCI being a design-oriented discipline, the categories above emerge as a way to formalise inquires and give them a more academic view. In Gaver and Bower's words, many of these categories are about 'mutating design to become more like ' "real" research' (Gaver & Bowers, 2012). The work in this thesis was also affected by this process where the intricacies of the design process

[†]These contribution types are taken from CHI 2016 and this is the first time authors need to declare at least one contribution type when submitting their work. The contribution types are not currently publicly available on the internet — I extracted them from the submission form before the deadline.

were not reported in favour of more 'scientific' measures and descriptions. However, it has to be noted that this set of contribution types was never claimed to be comprehensive or necessarily correct[‡]. Yet, these categories are used to help assign reviewers and then affect the reviews. As the CHI conference is a major element of the social practice in the HCI domain and CHI publications are often the most desired output of research activities[§], it is hard to ignore the proposed set of categories. But, leaving funding and publication concerns aside, it is possible to derive a more theoretically founded set of contributions and even attempt to link them to the types listed in the form. In the remainder of this chapter, I propose to take a conceptual standpoint here and look for a more exhaustive and descriptive set of terms that could characterise design-generated knowledge.

2.1. Conceptual contributions from design

Gaver criticised the idea of scientism in research through design while attempting to describe possible contributions of the research approach. He focuses on theoretical developments that can offer generalisable insights as input to HCI's body of knowledge (Gaver, 2012). First, Gaver proposes *conceptual work* as a core theoretical contribution of design-based research. He understands concepts as the providing of rationales, reasons for decisions and grounds for assessment involved in the design process. In other words, Gaver sees the conceptual descriptions of design processes as contributions especially if the same or similar principles can be applied to multiple design instances.

The next theoretical development that can be achieved through design is the *'borrowing' of theory* from other disciplines. As designers usually require design empathy and a considerable amount of understanding of the design constraints in a particular context, they often employ methods known from other disciplines. It is quite illustrative that the now fundamental notions of affordances, context and situatedness were imported into HCI from other fields (Rogers, 2004) e.g. the ecological approach in psychology. Consequently, translating work form other disciplines into a form that is actionable for designers can be a way to generate knowledge. Borrowing theory can have an analytical purpose (understanding design constraints or building concepts) or a generative one (inspiring design and leading to new understandings of design artefacts). However, design is rather unlikely to contribute back to the disciplines that it employs for increased understanding of the design space. Koskinen et al. suggest that such contibutions are only reserved for very experienced researchers and still carry a lot of risk even for the most skilled (Koskinen *et al.* , 2011, p. 168).

Design-based research is also likely to produce *manifestos*, which are similar to *visions* which also appear in HCI literature. Manifestos focus on describing a desirable and

[‡]Especially as this seems to have been created by the CHI committee and by no means represents community consensus.

[§]Especially in the case of doctoral students.

correct future practice that may go beyond reflecting on current practice and additional theoretical reference. They can draw on a number of examples to illustrate the desired practice and employ theories to inform them, but it is the vision of future practice that constitutes the core of a manifesto. This resonates the idea expressed by Koskinen et al. that design-based research is a useful way contibute to the exploration of imagined worlds and notions that go beyond the everyday (Koskinen *et al.* , 2011, p. 168). An often-cited example is the Drift Table (Gaver *et al.* , 2004) where a design case was used to illustrate the concept of ludic design. They goal of the authors was not to showcase the particular artefact or describe its design process. Instead, they aimed to use the table as an example of how future inquiries should explore design for ludic engagement. Manifestos are closely connected to visions. The role of visioning in HCI is disputed and the community is unsure how exactly future research can benefit from visions (Quigley *et al.* , 2013). Weiser's seminal work on ubiquitous computing (Weiser, 1991) is a great example of how a vision can influence entire fields of research and produce many tangible artefacts. The verification of how accurate a vision was can trigger much needed reflection and stimulate criticality. The HCI field has contributed works pondering how to prepare for a Ubicomp reality (Weiser, 1993), analysing what to do once Ubicomp is there (Bell & Dourish, 2007) and realising that the dream is over (Aylett & Quigley, 2015). While this is not the place to discuss the impact of visioning and Ubicomp on the field[¶], this example shows that visioning is an effective and stimulating intellectual device. Another example is Ishii's work and tangible bits (Ishii *et al.* , 2012), which continues to inspire generations of researchers in tangible interaction. Recently, an alt.CHI paper encouraged the community to image how will HCI research look like in 2039 (Baumer *et al.* , 2014).

A somewhat lighter type of contribution proposed by (Gaver, 2012) is a framework for design. While the word 'framework' certainly rings a bell if one is familiar with Obrenović's hierarchy, Gaver's understanding of a framework is different. There is also a subtle difference between 'design framework' and 'framework for design'. Instead of treating frameworks as generalisations, Gaver defines a framework as tool for design research planning and identifying opportunities, which does not endeavour to provide designers with a set of applicable methods. It constitutes a way of conceptualising design constraints in a given situation although with less rigour and less focus on well-defined design goals than in a manifesto. A framework is heavily contextualised and only depicts an subset of design situations. While this is similar to Obrenović's framing, Gaver's framework is less rigorous and does not call for a coherent set of crisp guidelines with well-defined goals.

Finally, Gaver sees research about design-based research (meta design based research) as an emerging topic and possible contribution type. As design-based research begins to be an established research method in HCI (this is particularly evident in (Pierce *et al.* , 2015) where the authors state: 'There was a time when one had to argue for including designerly

[¶]While the author finds this question very interesting, that would require at least one more chapter. This, in turn, would render this thesis unbearably long. There seems to be no consensus on that issue at all at present.

ways of knowing in human-computer interaction (HCI) research'. This enables one to assume that this time is over — there is enough consensus in the community to establish that design-based research is a worthwhile pursuit), methodological developments will be required. This would be a reply to recent calls for establishing standards for design-based research in terms of evaluation and types of contribution such as those postulated by Zimmerman er al. (Zimmerman *et al.* , 2010). In a a way, Gaver suggests that more reflection on design-based research in written work may increase its legitimacy and reduce the trends for scientism.

Gaver's types of contribution build a mode. which is a significant theoretical development. While these categories can be seen as ways to create knowledge, they face the risk of being too abstract to effectively inspire more design and serve as generative examples for more research. It is worth noting that Gaver's list is not claimed to be exhaustive. Next, I describe an alternative, or complementary, set of contribution types.

2.2. Intermediate-level knowledge

A recent body of work postulates a number of different contribution categories under the name *intermediate-level knowledge* (Löwgren, 2013) or *intermediary knowledge forms* (Höök *et al.* , 2015b). This approach builds on the premise that the key difference between research and design is that knowledge creation is the primary goal in research and may be a secondary goal in design. In other words, the final product of correct research is knowledge, while design strives to produce artefacts (or ultimate particulars (Nelson & Stolterman, 2003)). Consequently, the two approaches operate on different levels of abstraction and design-based research is the way to explore the grey area between them. Intermediate-level knowledge can add an additional layer of understanding to particular design artefacts in the form abstraction. This makes it relevant as a generative factor for design compared to general theory that originates from pure research, which is often too abstract to be relevant in heavily contextualised design activities. Löwgren names several kinds of contributions that may constitute intermediate-level knowledge (Löwgren, 2013).

Firstly, Löwgren mentions *design methods and tools* as a meta-category of contributions that address the design process instead of the ultimate particular. They are the kind of insights that emerge from design practice and tell how things need to be designed. Design methods and tools are built through abstracting multiple design activities and enable other designers to increase their capabilities thanks to a widened activity repertoire. Future Technology Workshops (FTWs) (Vavoula *et al.* , 2002) are one example of an often-used design tool. They are discussed later in this thesis as they were applied as part of paper five.

Design guidelines are next on Löwgren's list. Guidelines provide operationalisations of theories thus translating them to a form that is useful in hands-on design. In a

way, they are the practical interpretation of Gaver's *'theory borrowing'* — guidelines usually come in the form of prescriptions of how designers should act when dealing with particular constraints, encountering specific difficulties or dealing with users in a given context. It is worthwhile to distinguish two types of guidelines here — some guidelines are intermediate-level insights that spawn form design practice as discussed by Löwgren, but HCI papers may also feature guidelines as a product of work in the 'scientism' vein or purely technical or theoretical considerations. Contributions that use the word 'guideline' range from works that study systems in context (e.g. Quintana et al.'s work on scaffolded software environments (Quintana *et al.* , 2002)), through ethnomethodological design empathy studies (like the work on helping older adults remember things by Giorgi et al. (Giorgi *et al.* , 2011)) to technical contributions such as OmniVib (Alvina *et al.* , 2015) This shows that the term is rather broadly interpreted in the community and may refer not only to contributions with a substantial design element.

Heuristics are tightly connected with guidelines. Perhaps best known from the introductory HCI class that discussed the work of Jakob Nielsen on usability (Nielsen, 2005), heuristics offer advice that focus on evaluation. While guidelines provide generative input, often in the form of help on design decisions in particular contexts, heuristics are evaluative and help assess design choices again higher-level principles. They can also provide a manifestation of a general consensus in the research community based on multiple examples such as Mankoff et al.'s work on heuristics for ambient displays (Mankoff *et al.* , 2003).

Next, Löwgren introduces the well-established notion of *design patterns*. Patterns attempt to abstract the qualities of single or multiple artefacts to provide a more general description limited to a certain class of design problems. Patterns also serve a vehicle to communicate best practices and provide a repertoire of possible intermediate-level solutions that a designer may consider in a particular context. They are a well-known concept that is also featured prominently in Zimmerman et al.'s view of design-based research (Zimmerman *et al.* , 2007) and strongly based on Alexander's work on pattern languages (Alexander *et al.* , 1977). An often-cited example is the constantly updated list of patterns for game design by Björk and Holopainen, which continues to function as a source of generative knowledge for developing innovative computer games (Björk & Holopainen, 2004). *Experiential qualities* represent a related contribution type — they are very much like patterns, but they provide commonalities in terms of user experience.

The next contribution type is *concepts*. While the name may sound ephemeral, this contribution type offers a well-defined intellectual construct that is generative in nature. Löwgren names the Dynabook (an early conceptual design of a future computer supporting creative thought by Alan Kay (Kay & Goldberg, 1988)) as a canonical example of a design concept. It is worth noting that while the Dynabook did inspire generations of researchers and contribute to a number of related inquires, it was never built or evaluated. This illustrates how a purely conceptual contribution derived mainly from the creators past design experience and expertise can significantly impact HCI research. Höök and Löwgren propose a more refined related contribution type — *strong concepts* (Höök &

Löwgren, 2012). They represent a form of communication used to describe the tacit knowledge of a design practitioner — the partial solutions the designer experienced in the past. A strong concept is heavily contextualised and far from being universal. Höök and Löwgren propose four qualities that characterise a strong concept: (1) it addresses interaction, not appearance, (2) it is related to the practical use of technology, (3) it is applicable to multiple interaction contexts or application domains and (4) it can be interpreted and implemented in many different ways. These qualities identify a strong concept as a core intellectual asset for the designer that can be used to identify the tacit lessons that spawn from a design process and can possibly be reused in further inquiries. Höök and Löwgren mention seamfulness (i.e. making infrastructure transitions visible to the user in meaningful ways instead of hiding it from them) as an example of a strong concept. This shows how a strong concept derived from design experience can influence numerous designs and provide a frame of reference. Originating in Weiser's writing in the early 90s (Weiser, 1993) seamfulness influenced several major contributions such as Feeding Yoshi (Bell *et al.* , 2006). Another example of work that focuses on concepts is the Metaphone (Šimbelis *et al.* , 2014). The authors explicitly used an interactive art installation to investigate how an art style can form a reusable concept.

Löwgren also proposes *design criticism* as an important contribution type. While criticism is valued in art and architecture, it is not fully established in interaction design. It is suggested that a critic can create new frames of reference and reinterpret design artefacts in order to reach a certain level of abstraction. This way, a critical perspective may lead to generating intermediate-level knowledge. Finally, Löwgren embraces Gaver's notion of annotated portfolios (Gaver & Bowers, 2012) and suggests that they can be often interpreted similarly to patterns or experiential qualities.

2.3. Putting it all together — the CTF model

In this section, I attempt to juxtapose and relate the different types of contribution coming from the multiple literature sources presented above. While this list is not exhaustive, I believe it may constitute a reasonable frame of reference. It is also worth noting the the focus of this analysis is to integrate the proposed contributions in terms of using design as tool for inquiry in HCI and it is unlikely that any of the suggestions presented here extend beyond this scope. Furthermore, I warn the reader that the structure presented here is inherently biased by the fact that I am about to present a theoretical framing that will accommodate the papers included in this thesis.

In Figure 2.2, I present the proposed framework[‖] (the CTF model) for relating the different contribution types in the aforementioned literature. The main goal of the model is to promote discussion about the contributions from design-based research and enable relating different design instances. The model may be helpful is explicating why

[‖]I would actually call this contribution a 'framework' and not a 'model'. However, as the CTF model uses a different meaning of 'framework' as one if its parts, it will remain a 'model'.

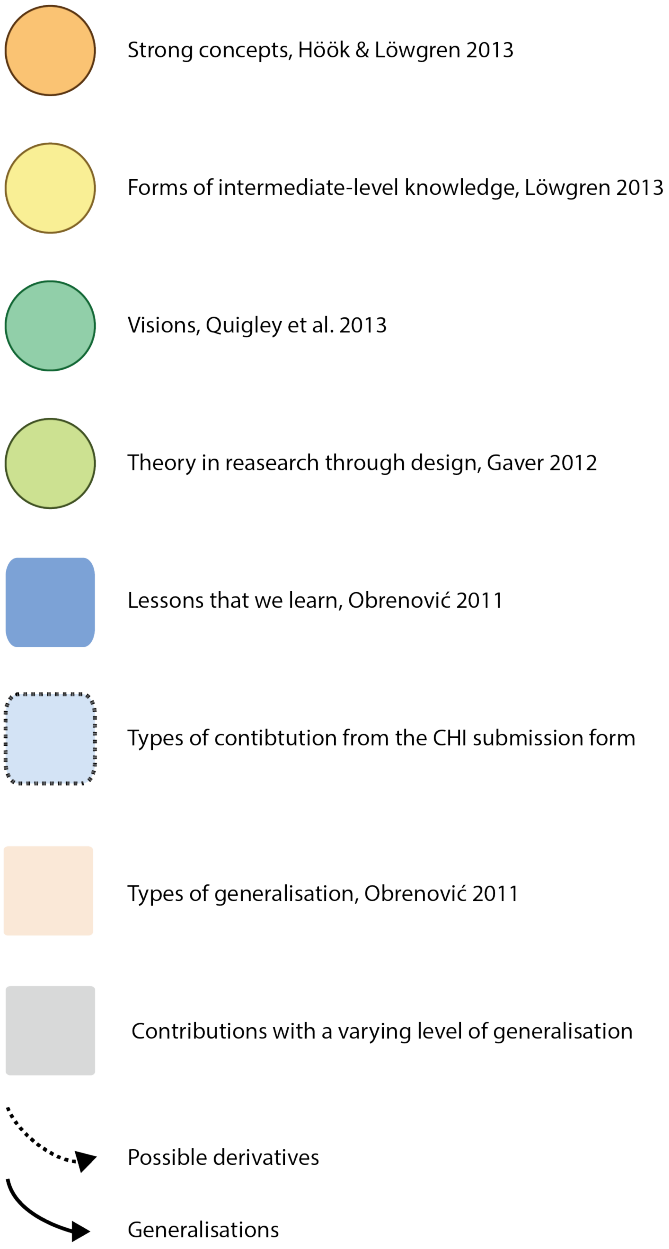

Figure 2.1.: Explanations for the shapes and arrows used in the CTF model representation in Figure 2.2

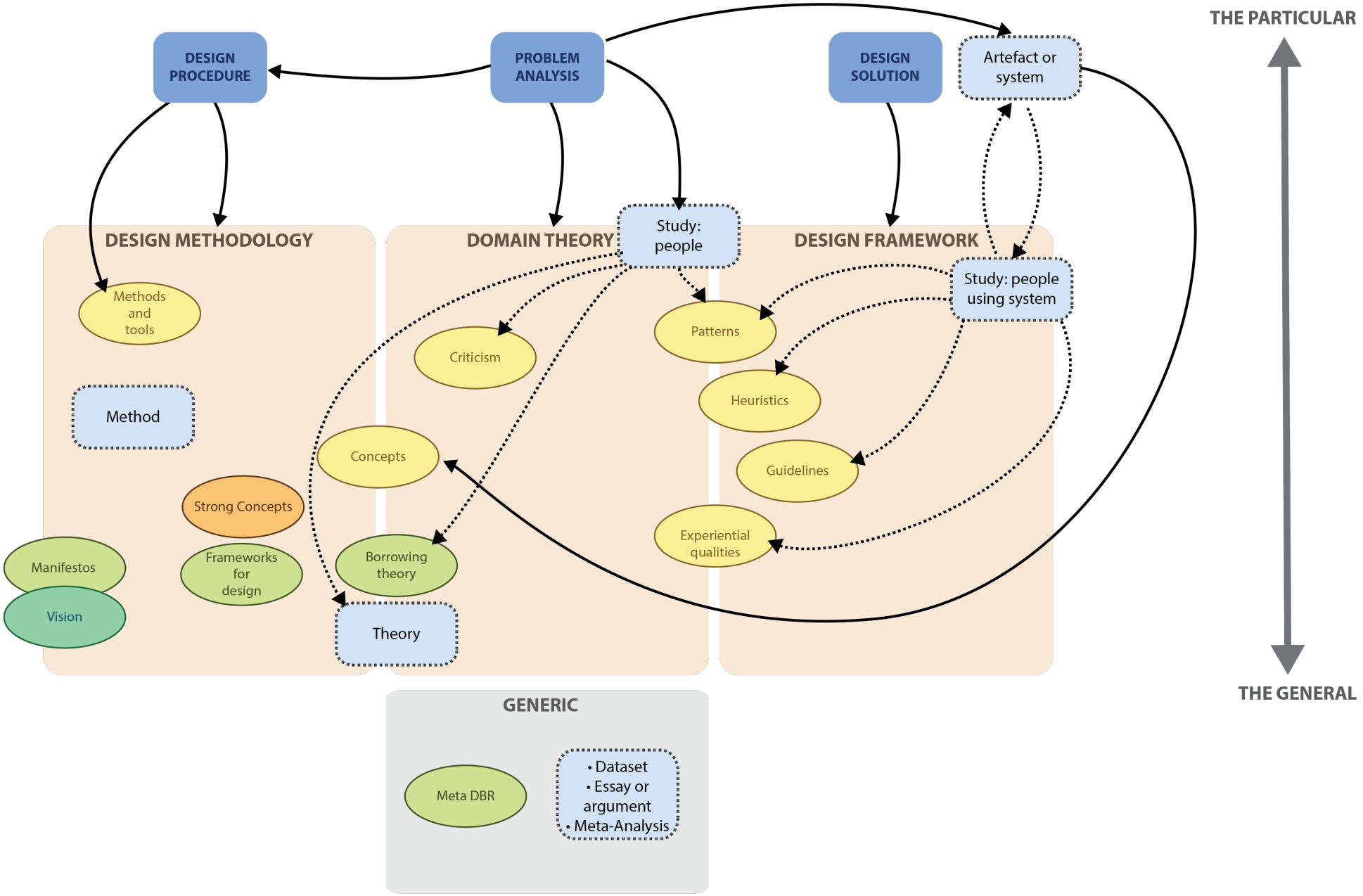

Figure 2.2.: The Contribution Type Family (CTF) model — types of contribution in design-based research in HCI and the proposed relations between them complied into a single diagram. The figure integrates proposed contribution types from (Obrenović, 2011; Löwgren, 2013; Gaver, 2012; Quigley *et al.* , 2013; Höök & Löwgren, 2012) and the CHI contribution types. See Figure 2.1 for explanations of shapes and arrows.

design-based research is an applicable method in a given case or help decide what kind of design-generated knowledge is to be sought. Finally, the CTF model can also be used to reflect on past work and verify how past results fit into the contribution types proposed in the literature. Next, I provide more details about the structure of the model.

The three specific contribution types (procedures, analyses and solutions) proposed by Obrenović are on top of the structure. They characterise the types of activities in which designers** engage and most design-based research activities are composed of these activities in different proportions. Consequently, these categories offer little abstraction. Instead, they can be useful as descriptors for design and help frame activities in an academic context. These categories are inherently related to the'artefact or system' contribution type from the CHI submission form. While it appears that presenting a concrete design artefact (or 'design solution') is a viable contribution, a good design process that includes procedures and problem analysis is usually required to reach one. Furthermore, problem analysis (or the 'understand' phase (Harper, 2008)) can work as a generative tool that drives the creation of design artefacts. Designing an artefact means reaching the final stage of a process, which can be re-framed as a design procedure. Consequently, Obrenović's three aspects of design activities and their three generalisations (methodologies, theories and frameworks) enable building a structure that shows how different contribution types emphasise different aspects of the design activity. In Figure 2.2, I use the generalised categories to relate other contribution types. From the left, methodologies include contribution that mainly address the design process, theories concern the understanding and emphasis needed for design and frameworks address the properties of design artefacts. Furthermore, I adopt Löwgren's (Löwgren, 2013) strategy of placing contribution types in the particular versus general dimension.

The CHI form also proposes two kinds of studies that are to be considered contributions. I suggest to reinterpret the 'study: people using a system' category as the evaluation stage of the design process. Consequently, all the intermediate-level knowledge that spawns primarily from designers engaging with users through artefacts can be considered a part of this category. These contribution types inherently require the presence of an artefact that is novel to the user. I adapted Löwgren's 'cascade' model here to show how the contributions place on the particular vs general scale. However, I reposition heuristics to show how they often aspire to a larger scope of generality than guidelines which are often presented as a set of domain-specific considerations. Heuristics are often centred around the type of artefact being developed. Furthermore, I positioned the 'study: people' category as closely related to problem analysis. These kinds of studies that focus on understanding interaction in a particular context often generate guidelines for possible future designs. Perhaps the best guidelines emerge from a combination of contextualised design activities and a thorough study of the context (or, deep design empathy). Somehow controversially, I also link 'study: people' with criticism. This is an interpretation of the recontextualising and changing of frame of reference required

**In this context, the term 'designer' applies both to academics using design as a tool and design practitioners.

for constructive and generative critique. I further link the theory category in the CHI submission form with Gaver's 'borrowing theory' contribution type. Without considering how much theory can be HCI-specific and how much should be an augmentation of theory from other disciplines, one can see that a thorough understanding of the users is key for generating theory. It also appears that the reinterpretation of theory as suggested by Gaver is intrinsically linked to problem analysis as 'importing' is only meaningful if it yields a better understanding of the design constraints. The method category from the CHI form is the one that is most related to the specifics of the design processes and the particular activities (or their sequence) that designers perform to reach particular goals. My interpretation of this category is close to Löwgren's 'methods and tools' — there are parts of design processes that can be useful to other designers if communicated in a proper way through abstraction. The 'method' category emphasises structured, abstract accounts of parts of design process, thus heavily relating to Obrenvić's design procedure.

Concepts and strong concepts are especially difficult to position within the CTF model as they may span a number of aspects of the design. I interpret them as most relevant for the processes, because of the generative nature of strong concepts, i.e. the potential to inspire design processes and drive them in certain desired directions is what Höök and Löwgren emphasise as the key aspect of concepts (Höök & Löwgren, 2012). Concepts should be manifested by multiple artefacts in order to be impactful, so they are inherently to singular artefacts. It appears that what Gaver calls 'frameworks for design' does not fit in Obrenović's framework category. Frameworks for design help structure the design process and may provide help in determining the sequence of events in iterative design. As they facilitate planning and exploring opportunities, frameworks for design offer a generalised theoretical contribution spawning primarily from multiple design processes. Visions (Quigley *et al.* , 2013) or manifestos (Gaver, 2012) may address future scenarios in many ways, but they are likely to aim at inspiring further designs through discussing possible futures or presenting futuristic designs. Consequently, they are generative in nature, similarly to concepts. Unlike concepts they are generated by risky exploratory design or intellectual engagements. Given the goal of generating more design activity, visions and manifestos seem to address mainly the process apects of design activities.

There are certain relevant types of contribution that simply do not fit within the CTF model proposed in Figure 2.2. Gaver suggest that more research on the nature of design-based research is needed and the CTF is an attempt to contribute in this manner. Conducting more reflective design inquiries is certainly relevant for discovering how knowledge can be generated from design-based research. As a consequence design-based research about design-based research, or, as I named it, meta design-based research, escapes the boundaries of Obrenović's tripartite structuring od the design-based research space, but it has a space on the general side of the my proposed model. The last element in Figure 2.2 are the contribution types from the CHI submission form that can be considered generic. Contributing a dataset, essay or literature study (meta-analysis) does not necessarily require design activities. However, design can be involved in generating these contributions. Datasets can be obtained through artefacts developed

in an interaction design process. Essays may include reflections that explore different levels of design-generated intermediate-level knowledge. A meta-analysis may review literature sources and design artefacts to either explore concepts or reflect on the nature of design-based research.

This section concludes the discussion on the theory of design-based research in this thesis. Next, I will explain the particular structure of this thesis and begin relating the theoretical considerations presented above to the papers included in this work.

2.4. User- and tech-driven inquiry

Having divided the contribution space into three distinct categories, one may wonder how the papers contained in this thesis relate to the proposed model. Indeed, the following chapters of this thesis introduce the reader to the various works I published and attempt to rethink the contributions of these works. The reader will soon notice that the papers in this thesis mainly address the middle (domain theory) and right (design framework) sections of Figure 2.2. This section provides an explanation for the title of this thesis — if one is to identify two discrete strains of work I conducted during my doctoral education, it will be inquiries inspired by technology that explore future technical scenarios and inquiries aimed at understanding users and designing new artefacts based on their needs. On one hand, this division highlights how diverse the work I performed was (I was involved in a number of projects that required answering different research questions and addressing different problem domains, because I was happy to conduct my doctoral studies at a place that offers a large degree of academic freedom and an open-ended supervision style) and may suggest that the range of problems addressed may have been too wide. On the other hand, one must recognise that HCI is still undecided about its boundaries as a collective field of inquiry that spans a multitude of approaches and aspires to solve a range of human problems. Being involved in multiple project enabled me to explore various aspects of HCI research and conceptualise my personal researcher profile.

The two different themes of this thesis show how my research work was primarily inspired by either technology and user needs. Here, I use the names tech- and user-driven inquiry to differentiate between those two themes. Yet, I do not claim to have invented those themes nor will I insists that they are the only reasonable ones to frame the papers included in this thesis. However, they are relevant in a general HCI context. Recently, Schmidt (Schmidt, 2015) considered the relationship between research developments in HCI and the emergence of new technologies. He observes that most technologies that enter the mass market are previously discussed and researched within the HCI community. This way, the research can inspire future commercial developments and explore which technologies are likely to be well received by the users. Schmidt also notices that when most technologies become available, their potential is not fully explored and they are often limited to a single application domain. HCI research often goes

beyond the boundaries set by manufacturers and explores new application fields and interaction patterns. New technologies may also make it possible to implement and evaluate concepts that were previously created only in theory. They give researchers a possibility to reflect on past developments and even conduct additional inquiries to revalidate prior knowledge. Lastly, commercially available technologies simply make some interaction techniques more available — the development of new custom interaction hardware and software is inherently resource-intensive and new technical developments enable creating a larger community. Schmidt's point of view on technology-inspired work in HCI resonates Koskinen et al.'s observation that engineering can often be a fruitful breeding ground for design-based research (Koskinen *et al.* , 2011, p. 173).

These considerations illustrate that new technologies can be inspirational and make researchers push the boundaries of knowledge. This, however, yields another question — acknowledging that HCI is often chasing or driving new technical developments, where does the research place in the temporal dimension? Little work explicitly addresses past, present or future interactions. Instead, a large body of work has focused on preparing interaction for the proximate future (or, *the future around the corner*). This kind of research, also present in this thesis, addresses a seemingly inevitable[††] computational future and aims to develop ways of effectively using future technology. While technology is likely to drive one in the futuristic direction, some have heavily criticised that stance. For example, Bell and Dourish (Bell & Dourish, 2007) warned about focusing on the proximate future being a futile effort. While their considerations were set in the now-outdated context of ubiquitous computing, their main argument is still valid for HCI at large — neglecting problems of the present to focus on the possibilities of the future leads to a utopian view of reality that will never come. An entirely futuristic focus will never lead to conclusions. Instead, research will always focus on predictions and move the 'event horizon' even further. Despite the ironic fact that some say ubiquitous computing did come to an end (as Abowd suggests (Abowd, 2012)), this view shows the largest strength and pitfall of tech-driven research. On one hand, technology is bound to provide inspiration and drive development. On the other, the focus on the future often leaves technologies without a problem to solve (Schmidt, 2015) or human values to which to relate (Sellen *et al.* , 2009).

So how do we make sure we develop technology that is meaningful to users? How do we deal with the future in productive ways? Contrary to Bell and Dourish, Mankoff et al. (Mankoff *et al.* , 2013) propose embracing the investigation of the future and increasing its impact through a more structured approach. They imply that the rapid development of technology makes it impossible for research to cope with the present. Consequently, a critical approach to future scenarios is required. This kind of inquiry enables research to

[††]While many tired to develop means of getting ready for future technology and some past efforts were correct (e.g. the past assumption that mobile projection would become cheap and lightweight, which is now true (Pering *et al.* , 2005)), it also safe to say that we often operate on educated guesses. Aristotelian determinism aside, we know that randomness is an inherent part of the world. Perhaps, it would be beneficial to address assumptions in HCI from an ontological perspective, but the discussion of this question will not fit in this thesis.

explore future needs and increase the relevance of the research activities. Mankoff et al. suggest a number of approaches to investigate what can happen beyond the proximate future and conclude that future scenarios can work as warnings (i.e. showing possible negative consequences of probable developments) or inspiration.

But, there must be a middle ground somewhere, a way to make HCI research impactful and relevant for the present and future. As Schmidt (Schmidt, 2015) rightfully observes, there is no strict division between tech- and user-driven inquiry (in extenso 'technology-driven vs. human-centred research'[‡‡]). Instead, research is involved in an iterative process where needs inspire new technologies and new technologies generate needs. While Schmidt uses that fact to support his argument that looking specifically at technologies in an interaction context per se is a worthwhile effort, this also shows the importance of design-based research. It is design empathy that enables designers to meaningfully choose and augment technologies and put them in contextualised use. Only through understanding how we build new systems that change our world can we assure that technology stays relevant to everyday lives. Finally, through generating intermediate-level knowledge and inspiring more researchers, designers and designer-researchers, we can make sure the cycle is prolonged — new systems will bring positive qualities to our lives and inspire more developments.

I would like this thesis to be a strong argument for embracing design despite the fact that many design activities in this work are hidden behind the veil of academic rigour. I hope the reader will see that the research activities depicted in the appended papers aimed at finding an acceptable balance between curiosity about new technology and understanding designing for real-life contexts. I use the framework of tech- and user-driven inquiry to highlight the differences between the projects in which I was involved. The different papers are discussed in the following parts of the thesis and I then relate them back to the goals set in this chapter in the final part of this work.

The division I make here is primarily a narrative device for this thesis and I do not claim to have mapped the whole spectrum of HCI research. Nor do I attempt to draw clear-cut lines and highlight an internal conflict between research agendas. In fact, I do not agree that there are tensions or conflicts in the CHI field that need to be addressed, contrary to what was suggested by Bartneck (Bartneck, 2008). Instead, I suggest that reinterpreting research results using CTF model may be a useful thinking device and, perhaps, enable reinterpreting some content. Juxtaposing user- and tech-driven inquiries may help us identify new questions that fall within the 'grey zone' of problems[§§] and research questions that HCI research has not yet addressed.

[‡‡]I personally believe that all HCI should be human-centred in a way, so I am hesitant to apply Schmidt's terminology directly.

[§§]And these problems are most likely wicked problems.

Part II.

Tech-driven inquiry

3

Prologue: Exploring multi-device spatially-aware systems

> Space: the final frontier. These are the voyages of the starship Enterprise. Its continuing mission: to explore strange new worlds, to seek out new life and new civilizations, to boldly go where no one has gone before.
>
> From the TV Series *Star Trek: The Next Generation*, narrated by Sir Patrick Stewart

The papers presented in the next four chapters of this thesis describe details of my inquiries in the domain of spatially-aware multi-device systems. Inspired by advancements in sensing technologies and the proliferation of mobile devices in everyday life, this work tries to address a proximate future where multiple devices can offer new and rich user experiences. As a consequence, it can also serve as an example of a tech-driven inquiry. Having acknowledged that new sensing technology was being developed and that mobile devices would soon feature spatial sensing, we decided to investigate possible effective interaction techniques. We also endeavoured to find reasonable application scenarios that would show how the proposed technology could answer to emergent user needs. Fortunately, several other research groups in the world were also interested in the topic and multi-device mobile systems are an often-discussed topic at the time of writing.

This thesis presents the papers in a chronological order in terms of concepts and system evolution, but not in terms of publication. While the first paper included here was published in 2015, it summarises many of our motivations that inspired system development in user studies. The three following papers present three systems with increasing

complexity that show examples of practical uses of multi-device systems accompanied by user studies.

3.1. Paper One — the vision paper

Perhaps it is bold and dangerous to open the papers section of this thesis with a paper that was not published first. In fact, this paper has an unorthodox layout, the publishing venue is a journal that is only vaguely related to HCI and the contributions of the paper are rather indirect. Furthermore, we decided that my supervisor will be the primary author of this piece. However, there is one argument for beginning with this work — it is a visioning paper. In this work, we describe a possible future world that we believe would be better for humans. We envision technology that it still to be built and wonder what researchers can do to make sure it benefits future generations. In our inquiry, we try to anticipate what questions HCI will face will be and how to make sure we can relate future developments in technology to what we already know about humans, the society and designing interactive artefacts.

As discussed in the introductory chapters of this thesis, visions and manifestos can be a way to contribute to the field. Our work here focuses on describing a desirable future practice and the necessary means that we believe are required to make our vision reality. As per Gaver's analysis (Gaver, 2012), our work borrows theories from other disciplines, mainly the social sciences, to gain a better understanding of the needs of the users and opportunities where interactive technology may enhance day-to-day interaction. Furthermore, we also reflect on current practice and our own design experiences to create a more detailed vision. However, as our inquiry here is certainly tech-driven i.e. we propose new development based on our knowledge of upcoming technology, we do not communicate our stance through a designer artefact. This is contrary to the vision-oriented Drift Table (Gaver *et al.* , 2004). Instead, we offer abstract scenarios for future interaction which are not only manifestations of our own vision, but also fit into other envisioned realities such as Ishii's tangible bits (Ishii & Ullmer, 1997).

The three papers that follow this paper show how concrete design activities can help put visions into explorations and system designs. I hope the reader will appreciate this collection of high level ideas and alter explore how they are manifested in the following designs. We illustrate how requirements for HCI emerge from more fundamental issues in social science, particularly the age-old concept of *agora* that was carefully weaved into the paper by Josh Cowls.

3.2. Paper Two — MochaTop

The next paper, MochaTop opens a series of three papers in which we try to ascertain the anticipated benefits of spatial awareness in multi-device mobile systems. Several factors set the framing and context of our inquiry. Firstly, we were determined to build systems that could contribute to exploring our vision presented in the previous paper. While we had not yet explicated our vision in a written form when the studies in MochaTop were conducted, the ideas were already flourishing. We were aware of the fact that high-fidelity around-the-device sensing was possible and would arrive on the consumer market in a foreseeable future. We visited Elliptic Laboratories AS to learn about the possibilities ultrasonic sensing would soon offer in consumer-grade devices. Consequently, a vision of an augmented technological landscape called for developing new interaction techniques. We were also tempted to explore spatial awareness as some work on the topic was conducted in the t2i Interaction Laboratory when I began my work at Chalmers. Piazza et al. (Piazza *et al.* , 2013) conducted preliminary inquiries which investigated limited scenarios using the PixelSense. It was apparent that further research was needed, especially in terms of user studies.

Given a variety of possible tasks that can be accomplished with mobile devices, we aimed to choose a possible application domain that would be relevant and interesting from a research perspective. We chose to investigate interacting with information visualisation. This was caused by a number of reasons. Firstly, I was then employed in the DIVA (Data-Intensive Visualisation and Analysis) project which required that I work with interaction with data sets. Secondly, in line with our vision of future debate systems, we saw two emerging discussion topics in the city of Gothenburg — declaring the city 'Fairtrade City' and the construction of a large underground rail tunnel under the city called Västlänken. Having followed the debate in the newspapers, it was apparent to us that the discussion would benefit from better access to relevant data and citizenship would be strengthened if access to facts was facilitated. As a consequence, we wanted our design to explore future casual settings where multiple devices can fuel a discussion. We also decided that MochaTop would explore data about fairtrade.

One could wonder why we needed to build systems to investigate our vision. Perhaps just formulating and evidencing the vision as illustrated in paper one would suffice? Not only do we see practising interaction design in HCI as the core of our work, but we were also inspired by the long history of ideas communicated through hypothetical designs that enabled researchers to tackle the perceived interactions design challanges of future user environments (e.g. (Press, 1992; Weiser, 1993)). Thus, MochaTop not only contributes to HCI knowledge through an interaction concepts, techniques and design insights (in a variety of ways discussed in parto one of this thesis) but also constitutes the first manifestation of our vision expressed in paper one. MochaTop and the two following papers show how a futuristic tech-driven goal can be approached with multiple design iterations.

Finally, it is worth noting that this paper is the only work-in-progress submission included in this thesis. I think it is important to include it to tell the complete story of our development of multi-device systems so that the reader can see how the concepts evolved and the technical solutions became more refined. It is worth noting that this is the only paper in this thesis also included in my licentiate thesis (Woźniak, 2013) and thus it provides a link to some of the work included in the shorter intermediate work. I also hope this paper can serve as an illustration of my personal development as a researcher as I learnt how to structure and focus the inquiry and conduct better studies. Last but not least, this work constituted Lars Lischke's diploma thesis and I consider having supervised it a great privilege.

3.3. Paper Three — Thaddeus

Thaddeus presents the most conservative inquiry in this thesis. Having built a rather complex system, we conducted a structured quantitative evaluation. Notably, there is little concept validation or discussion on design implications. In retrospect, it appears that simply motivating, describing and designing a multi-device system for exploring information visualisation exhausted the 10-page limit so common in HCI conferences. From a designer perspective, the main message we wanted to communicate in this work is that, after months of theorising and planning, we managed to build the system and invite multiple users to a user study that produced reliable results.

Despite the fact that a number-intensive study is presented here, the Thaddeus paper is the most system-centred paper in this thesis. Looking at the contribution, one can observe that we emphasise the fact the the system was created as the main point of the paper. The main outcome of the study conducted is that the system worked and allowed the users to complete the tasks properly. As it is conventional to compare a newly-build interactive artefact to a baseline system (Hornbæk, 2011), we introduced two conditions in our study. Consequently, Thaddeus can be interpreted as contributing to the field through a single design solution. The work emulates future technologies and enables us to explore potential consequences of anticipated developments. Thus, we contribute our experiences of developing this particular design instance. The description provided in the paper, however, is largely biased by the way we decided to present to warrant acceptance to a conference. It is safe to say that some intricacies of the design process were lost while trying to fit into the 'scientism' trend in HCI described in the thesis introduction.

Thaddeus presents one more milestone in our multi-device research. This was the first time when we managed to effectively use marker-based motion tracking in our work. The possibilities offered by the expensive and robust tracking system also inspired our work. This signifies how a tech-driven inquiry can be inspired by even more technology. While we were aware that less expensive tracking methods were available, we decided to keep our focus on future scenarios and disregard available tracking problems. Consequently, instead of using consumer-grade depth cameras and spending a significant amount of time

developing frameworks that perform image processing on the camera output (which was later accomplished and published by a different research group (Rädle *et al.* , 2014)), we used the most accurate form of tracking possible. While the process still required software development, we were able to focus on creating new interaction techniques instead of developing novel technology. When implementing the interactions, marker-based motion tracking enabled us to consider relative device positions in terms of parallelepipeds in 3D space. This allowed for an analytical approach to implementing the interactions and eliminated the need for developing any artificial intelligence and providing the system with a teaching set. Finally, this work helped us developed the code library and skills needed for working with the motion tracking equipment that we could reuse in further research.

Finally, I would like to note that while Thaddeus serves as an acronym in the paper, it also a little homage to my ancestry, honouring Poland's most admired epic poem *Sir Thaddeus, or the Last Lithuanian Foray: A Nobleman's Tale from the Years of 1811 and 1812 in Twelve Books of Verse* by Adam Mickiewicz.

3.4. Paper Four — RAMPARTS

RAMPARTS constitutes the currently last instance of our work in multi-device environments. The four works in this series describe a larger evolutionary process. From vague concepts and visions of how future technology can benefit the society, through several research prototypes that investigated multiple aspects spatial awareness, we ventured to a system that aids users in performing a well-defined task — soling crime mysteries. On a practical level, RAMPARTS simply constitutes one more iteration of our exploration of spatial awareness for mobile devices. The system is more sophisticated than Thaddeus and it provides support for a more complex task. Consequently, from a pragmatic point of view, it is one more *design solution* (in Obrenović's terms, see section 1.2.7) that contributes to HCI by providing a system example. However, RAMPARTS attempts to go beyond being merely a design instance.

Our experiences of working with multiple devices in MochaTop and Thaddeus provided us with a number of practical considerations and design insights. These experiences enabled us to broaden the scope of our inquiry beyond simple interaction concepts and investigate contexts where the affordances of multiple device could be particularly useful. As we already had significant technical expertise and an overview of related work, we researched related fields for possible solutions. We quickly observed that past research did not investigate how spatial awareness can affect multi-user interfaces, so we observed what tasks users often complete in casual collaborative settings. This was facilitated by the location of our research environment — next to a business centre with large open spaces where users relax, hold meetings and perform collaborative work. The arrival of Przemysław Kucharski was a factor too as he is versed in the field of fuzzy logic. This

discipline excels at interpreting ways humans solve problems and modelling them with computational tools.

This broadened process quickly made us find work on how the spatial arrangement of information can help sensemaking. Clear benefits of using physical space to organise fragmented information were proven to exists and we wondered how to translate these benefits to the digital domain. As we felt we needed more design empathy to better understand the process of sensemaking, we conducted paper-based preliminary studies. While these studies gave us insights into what spatial patterns the users may employ when solving the task, they also required us to choose a well-define mystery. This dilemma illustrates how interaction design in HCI must deal with particulars. We initially thought we could answer the question of how spatial awareness can support sensemaking in digital systems. However, the number of design constraints and the practical considerations involved forced us to focus on a very particular task. We were able to effectively use low-fidelity prototypes to narrow our inquiry to a scope manageable with the resources and time frame given.

RAMPARTS contributes not only one more design solution, but also the concept of using spatial awareness of mobile devices for effective collaborative sensemaking. Consequently, the contribution is somewhat broader than the previous papers and aspires to provide more generalised insights. These contributions resonate with the ideas of strong concepts (Höök & Löwgren, 2012) and domain theories (Obrenović, 2011). It is worth noting that the style of the paper is a bit different from the previous work. This is because Nitesh Goyal and I were the main writers of this piece. As a consequence, the paper is written in a more American style and concentrates on an accurate description of the study and properly interpreting the results. We made this conscious choice as we wanted to focus on the application of spatial awareness for sensemaking and needed to make the paper attractive to an audience interested in HCI for sensemaking. Had the style of the paper been similar to Thaddeus, we would not be able to communicate the insights gained in a way that would contribute to the field of sensemaking systems.

3.5. Summary of findings

Firstly, it has to be noted that when we began our work with multi-device environments, it was not yet confirmed that such environments were attractive to users and that there was a potential for usage in everyday settings. Research on control rooms and environments combining small and large screens has a much longer history, but ethnographic studies have only recently confirmed that users are likely to use more than one device simultaneously in a variety of contexts. Simultaneously, we and other research groups provided examples of how possible scenarios could look like. Consequently, it is now established that spatially-aware mobile interactions can be meaningful, even through the interaction techniques to make the best use of the future spatial sensing capabilities available in mobile devices remain to be fully explored.

Another finding that is apparent in the Thaddeus and RAMPARTS systems is the need for designing for zones for spatial interactions. In all of our systems, users assigned roles to devices based on their positions within certain zones of the table. In designing Thaddeus, we saw that manipulating data on one device with a second device was only only effective if the relative position of the devices was within a certain zone with its size relative to the size of the devices. While past research (Müller-Tomfelde & Fjeld, 2012) and predictions on future sensing techniques advocate large interaction spaces and using the entire surface of the table, our work shows that there is a need for discretising areas on the surface when using mobile devices. This will not only enable more effective interaction (as in the case of accessing data points in Thaddeus), but may also enable widening the repertoire of functionalities provided (e.g. navigating to an upper menu by placing one device in the corner of the table in MochaTop). Finally, RAMPARTS has shown that users will also divide table space in collaborative scenarios and they will do it differently compared to interactive tabletops (e.g. (Scott *et al.* , 2004)). More advanced collaborative multi-device applications are likely to require additional work on defining zones around the devices.

We have demonstrated that spatially-aware multi-device systems can be effective in browsing data, retrieving information from visualisations and supporting sensemaking. As a consequence, it appears that multi-device system can often offer possibilities similar to interactive tabletops without the tabletops' key disadvantages — their bulkiness and high price. In RAMPARTS, we compared our system with an interactive tabletop showing that it was equally effective in supporting sensemaking tasks. These results suggest that further research in spatially-aware system should further explore tasks that are effective on tabletops. Perhaps, multiple devices placed on a surface can benefit from the same affordances as traditional tabletops do, most importantly building on the 'socio-constructivist flavour' (Dillenbourg & Evans, 2011) of horizontal surfaces*.

*Or, perhaps they can even go beyond these affordances as they allow 3D interactions when desired.

4

Paper One: envisioning future deliberation spaces

4.1. Bibliographic data

Title: Ad hoc encounters with big data: Engaging citizens in conversations around tabletops

Authors: Morten Fjeld, Paweł W. Woźniak, Josh Cowls, Bonnie Nardi

Published in: First Monday, Volume 20, Number 2 — 2 February 2015
http://firstmonday.org/ojs/index.php/fm/article/view/5611/4205

DOI: http://dx.doi.org/10.5210/fm.v20i2.5611

5

Paper Two: building data-driven multi-device systems

5.1. Bibliographic data

Title: MochaTop: building ad-hoc data spaces with multiple devices

Authors: Paweł W. Woźniak, Benjamin Schmidt, Lars Lischke, Zlatko Franjcic, Asim Evren Yantaç, and Morten Fjeld

Published in: CHI '14 Extended Abstracts on Human Factors in Computing Systems (CHI EA '14). ACM, New York, NY, USA, Pages 2329–2334

DOI: http://dx.doi.org/10.1145/2559206.2581232

6

Paper Three: exploring information visualisation with multiple devices

6.1. Bibliographic data

Title: Thaddeus: a dual device interaction space for exploring information visualisation

Authors: Paweł W. Woźniak, Lars Lischke, Benjamin Schmidt, Shengdong Zhao, and Morten Fjeld

Published in: Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational (NordiCHI '14). ACM, New York, NY, USA, Pages 41–50.

DOI: http://dx.doi.org/10.1145/2639189.2639237

7 Paper Four: supporting sensemaking with spatial awareness

7.1. Bibliographic data

Title: RAMPARTS: Supporting Sensemaking with Spatially-Aware Mobile Interactions

Authors: Paweł W. Woźniak*, Nitesh Goyal*, Przemysław Kucharski, Lars Lischke, Sven Mayer, and Morten Fjeld

Submitted for review to: Proceedings of the 34th Annual ACM Conference on Human Factors in Computing Systems (CHI '16)

 ISBN 978-1-4503-3362-7/16/05...$15.00

DOI: http://dx.doi.org/10.1145/2858036.285849

*P. Woźniak and N. Goyal are joint first authors and contributed equally to this work.

Part III.

Interlude:
Work in the industry

8

Prologue: working with buzzwords in the industry

Buzz: Don't worry, Woody. In just a few hours, you'll be sittin' around a campfire with Andy, makin' delicious, hot schmoes.
Woody: They're called s'mores, Buzz.

From the film *Toy Story 2*

If the reader is indeed following this book from page one, they may expect another published paper at this point. The next work contained in this thesis comes from a different context and it is very different from all the other papers included. That is why I believe an extended introduction is in order. If one adopts Žižek's metaphor (Žižek, 2014) of a book being essentially a journey on the Cricle Line, this chapter represents the service announcement 'This is Buzzwords. Change here for industrial case studies. This is a thesis line train to the user-driven papers'. The case study presented in the next chapter is a summary of my work at Volvo Group Telematics (VGT) in the area of 'Big Data Analytics'. The purpose of the extended introduction I present here is to show the motivations behind the work and highlight the rather peculiar situation, on which my work in the industry was based. VGT was sure there was a lot of potential in the big data concept and had vast amounts of technical expertise to build big data systems. A user-centred design process was missing. From a metaresearch point of view, perhaps the most interesting fact about that work is that the activities were not motivated by gaps in related work, emergent user needs or researcher curiosity. Rather, the genesis of this work lies in the fascination produced by the term 'Big Data'. One cannot help but wonder how may all of this have happened. In this chapter, I introduce a number of considerations regarding buzzwords and how they inspire inquiry in order to contextualise the work

presented in the next chapter. I look specifically on the meaning of buzzwords in HCI*.

As research professionals, we see buzzwords everywhere. They are in paper titles. They are in grant proposals. They are in press releases. One day, sitting in a paper session at a major HCI conference, I started jotting down the often-repeated phrases. By the end of the day, the list was impressively long and contained all of the usual suspects. An easy conclusion one can draw from our quick impromptu research session is that HCI is boringly predictable and driven by loosely defined ephemeral concepts. We would be rather upset if this were to be true. Believing in the HCI community, we decided to start a more detailed inquiry into how we, as HCI researchers, use buzzwords. Are they just a framework we need to use, because research funding agencies like them? Can we make good use of buzzwords? Rather than blindly putting labels on what we do, can buzzwords inspire us to design better systems? Finally, what are the buzzwords in HCI and how do we define a buzzword for our (i.e. the HCI community) purposes?

Before we start our analysis, it is worth noting that the entire premise of this chapter may be a recursive argument after all. It could be that discussing a particular term in the context of buzzwords contributes to the buzz. While it is unlikely that we will reach a proper definition of 'buzzword', let us at least attempt to define 'buzz'. Looking into a dictionary is not of much help. The Cambridge Dictionary gives us 'informal, a feeling of excitement, energy, and pleasure', which is probably closest to what we mean in a buzzword context. A tempting alternative is to use the definition of 'hype' — 'a situation in which something is advertised and discussed in newspapers, on television, etc. a lot in order to attract everyone's interest', but that feels to negative, as we feel there are some positive aspects to buzzwords. Let us then craft our on definition for the purposes of this chapter. We will define 'buzz' as 'The practice of labelling activities with certain words and phrases in research and business in order to raise their perceived value'. However, we think the these 'words and phrases' are not necessarily buzzwords. But, semantics are of lesser concern in our analysis.

In remainder of this chapter, we present our observations on the role buzzwords play in HCI research. The notes presented here are based on analyzing our own activities, calendars and notes, interviewing fellow researchers and bibliographical analysis.

8.1. Roles of buzzwords

Our first observation is that buzzwords helped us understand some phenomena in the world around us and interpret events in regard to concepts we are already familiar with. Let us take 'big data' as a buzzword example as it is the buzzword that inspired the work presented in the next chapter. The term lacks a widely-accepted definition (Jacobs, 2009) and it appears in a variety of contexts in the computing sciences. It serves as a

*This chapter is heavily based on a currently manuscript for a future publication on which I'm working with my co-authors Lars Lischke and Sven Mayer from the University of Stuttgart.

driving factor in research and business with many projects built around dealing with the ever increasing amounts of data surrounding us everyday (Lehikoinen & Koistinen, 2014). The HCI field is quite responsive to that trend: the flagship Interactions magazine has published 7 articles on big data to date. Along with a larger body of work in journals and conferences, these exemplify possible roles buzzwords may play for the community. We observed how the big data buzzword help us align the discipline with the needs of other disciplines and popular demand. The emergence of big data visual analytics and the consequent need for more refined analytic interfaces opened a number of challenges for HCI and inspired research (Fisher *et al.* , 2012a). Conducting research that may potentially support other disciplines adds legitimacy to our field and opens up new collaboration opportunities.

On the other hand, when faced with a new trend, such as big data, we are eager to show how our methodology and experience can be reapplied in a new setting. Churchill (Churchill, 2012) proposed data-aware design as interaction design's answer to the big data trend. While we are well-aware that design concerns are important in any computer system and even more so when it comes to solutions that may have a societal impact, the article also shows that we, as a community, feel an intrinsic need to respond to trends (which often come in the form of buzzwords) and show how relevant our field is to the new concepts. We believe that our field is capable of using buzzwords effectively to make sure it stays relevant for other research disciplines and general trends in society.

8.2. A subjective analysis of buzzword dynamics

Knowing that buzzwords appear in mainstream HCI literature and play some role in the way we relate to the rest of the world, our next goal is to investigate the dynamic of their use. We used text mining techniques (Meyer *et al.* , 2008) to conduct our investigation. We analysed all the abstracts in the HCI Bibliography[†] database from years 1982–2014 (a total of 499600 abstracts). A python script was designed to retrieve all the abstracts from the database, which were then saved in one file per year. Next, we used a text mining prototype in R. Abstracts were imported from the files and converted to a document corpus. The words in the texts were stemmed and stop-words were removed. We then built document-term matrices for each publication year and looked for association for selected word pairs. Figure 8.1 shows the obtained association values for 'big data', 'cloud computing' and 'internet of things'. We can observe that these phrases occur in HCI literature with increasing frequency. One may wonder what is the meaning of that phenomenon and what are the consequences of this for the field.

A closer look at Figure 8.1 shows three different histories for the buzzwords. We can observe that 'cloud computing' reached its peak and its use decreases. 'Big data' seems to get more and more attention and the usage 'internet of things' has both increased

[†]`http://hcibib.org`

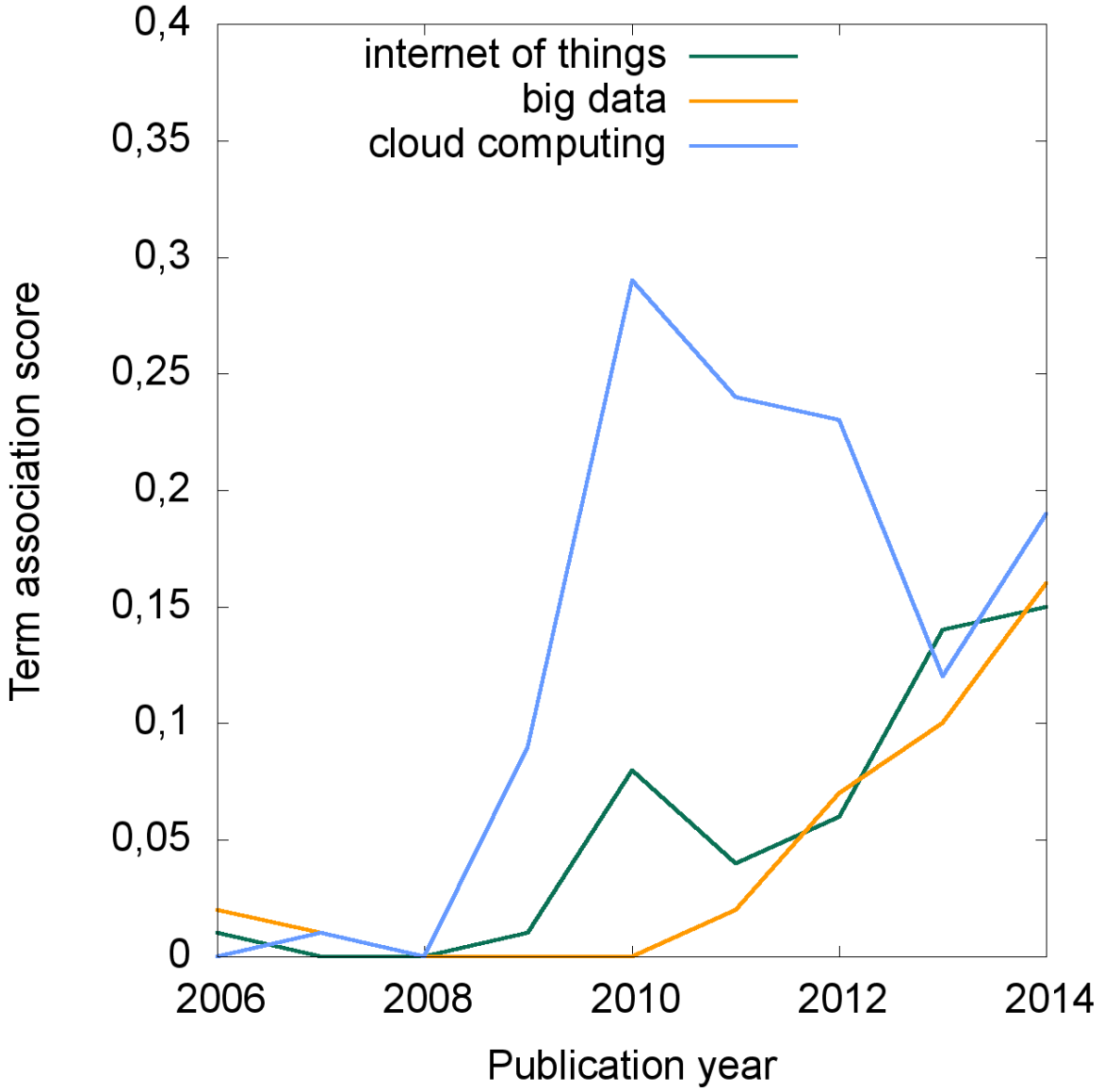

Figure 8.1.: Association values for the word pairs 'big data', 'cloud computing' and 'internet of things' in HCI literature in years 2006-2014. We can observe that the association is varying in time and the total usage is increasing. We need to consider that all three pairs contain a broad, generic word associated with computing ('data', 'computing' and 'internet') and the high association values indicate that whenever one of these words occur, there is a high probability of the second appearing in its proximity.

and decreased in this time period. A simplistic explanation would be that terms in HCI are subject to Gartner's hype cycle[‡] (which was previously proposed in HCI e.g. for tabletops (Müller-Tomfelde & Fjeld, 2012) or to analyse research opportunities (O'Leary, 2008)) and the differences in association values are simply a result of the terms being at different stages of the cycle. However, we believe that while, indeed, some terms may be simply 'fashionable' to use in a given time period, the trends in HCI also reflect how the user experience of everyday devices changes. If we take 'cloud computing' as an example, we can observe that the HCI field was less interested in the work when the technology became domesticated. Once technological constraints are harnessed and interfaces deployed, user feedback for commercial products is available and there is less to do for HCI research. As HCI researchers work at the frontier of technology, they are interested in things which are unfamiliar to the average user. This also explains why 'big data' is still on the rise — it is a still mysterious term for the general public. But, how can we explain the trend for 'internet of things'? We think that this term subscribes to a different buzzword category — words that carry a vision of the future and less technological meaning.

Figure 8.2 illustrated how buzzwords can be a measure of how some terms are integrated in the field. While both virtual reality and augmented reality are subject to new technological developments (such as the Oculus Rift and the Google Glass) we can see that the terms enjoy a considerable amount of attention in HCI. They serve as examples of conceptual buzzwords that are somehow resistant to trends in commercial technology. A look at 'tabletop interface' shows a keyword that, while not very popular, has established a profound presence in the field. This illustrates how a buzzword, and the fact that many are familiar with it, may be used to remind us of design possibilities such as developing a tabletop application. With a buzzword, it is easier to keep the community aware of a concept over a longer period of time.

8.3. Buzzwords and visioning

The somewhat negative meaning of 'buzzword' can be especially misleading in terms of more theoretical phrases. Having asked several colleagues about what buzzwords they can think of, some answers contained terms like 'ubiquitous computing', 'UX' and 'quantified self'. While on one hand these phrases are indeed often repeated, some researchers consider these their area of expertise. It seems that, as with 'internet of things' buzzword can carry visions and thoughts. Ubiquitous computing is now considered a research domain by many, but it used to be a very concrete vision of future from the Xerox PARC (Weiser, 1993). This indicated that some buzzwords may have deeper meaning and describe a broader intellectual act and a way of thinking. They may carry an understanding within the community and an agreement of how some problems should be approached. For example, ubiquitous computing's focus on users in their everyday

[‡]http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

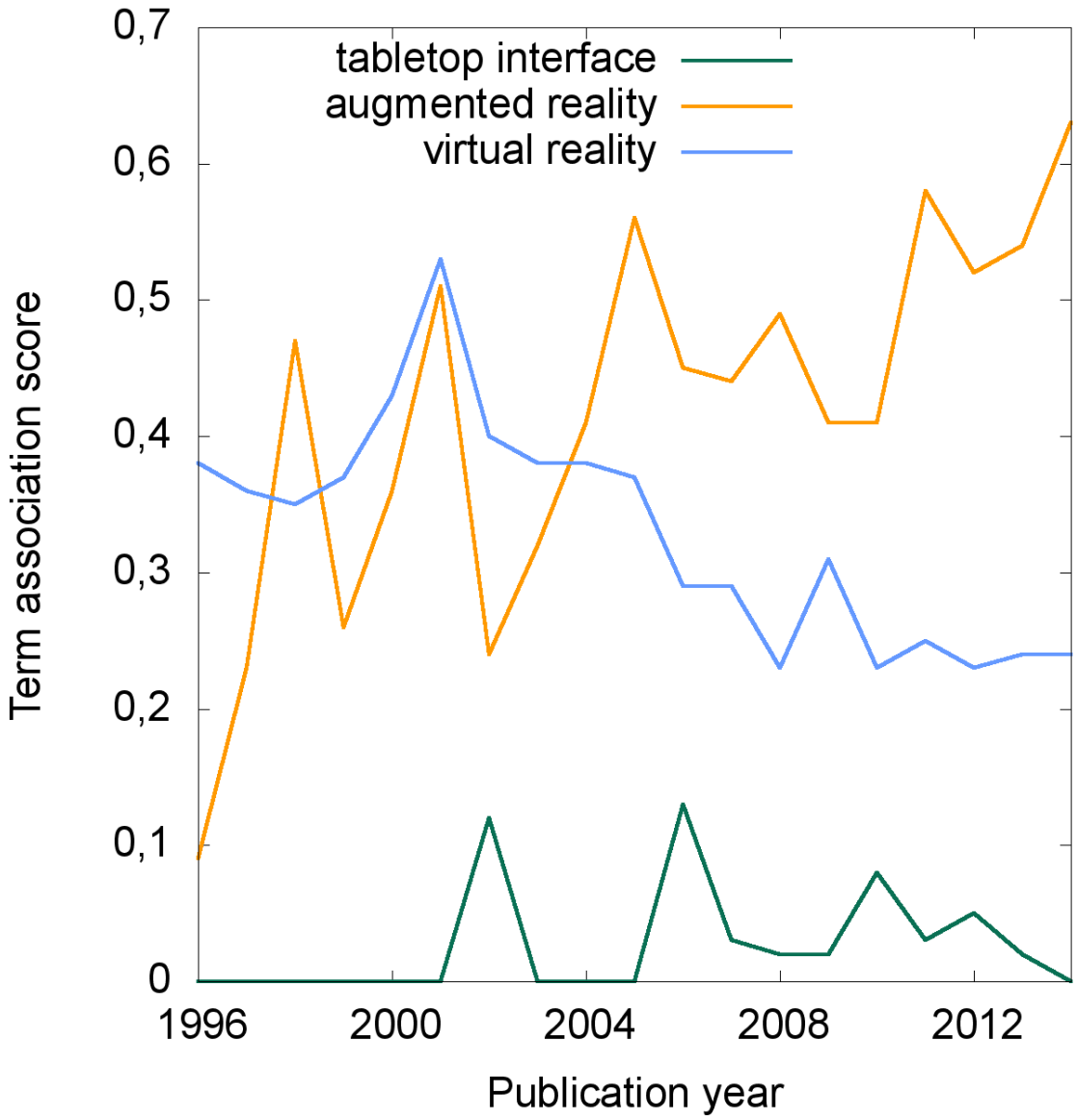

Figure 8.2.: Association values for the word pairs 'virtual reality', 'augmented' and 'tabletop interface' in HCI literature in years 2006-2014. Virtual reality and augmented reality are featured more prominently than the terms show n in Figure 8.1 and may be subject to an increasing or decreasing trend. This is despite the fact that both recently enjoyed significant technological developments. While tabletop interface is oscillating around the 0.10 association mark, we can observe its presence throughout the years.

environments that inspired HCI's turn to the wild (Crabtree *et al.* , 2013). However, as a research community we need words to describe new phenomena or visions without having a widely accepted definition yet. These descriptions are necessary to start a discussion about upcoming issues to develop new techniques or to apply established techniques to new phenomena. These words can later become buzzwords that describe the phenomena or a term for a field of expertise with a precise definition. In retrospect, one may wish to refer back to the first paper of this thesis and reconsider putting a single-word name on our vision of future civic engagement spaces. We can only wonder what effect this semantic trick would have on the impact of the work.

When a researcher or innovator already has a concept they want to communicate to others, buzzwords may play important role. We are often forced to deliver elevator pitches or asked to explain our work in a very limited amount of time. We also need to spread interest in our work. To help other researchers, stakeholders in the industry or the society to find publications of interest, we use keywords. With an ever-growing amount of research publications, we need to provide meta data that will enable search services to properly index our work and make it citable. As citations play a role in assessing an academician's performance, it is quite tempting to put buzzwords in a paper just to increase the chances of getting cited.

In a broader sense, buzzwords are keywords which are less precise, but 'understood' by a large and diverse audience. Referring to terms that are already present in the media and mainstream research not only simplifies the story, but it also enables the listener to relate the new concept to existing semantic structures. Having a great new input interface idea, why not say it can be used to effectively browse big data? This mechanism can also be used to a larger extent. Using buzzwords helps non-technical reviewers to understand and relate to texts such as grant proposals. It also aids in declaring that a given proposal is aligned with general trends in development. For example, querying the European Union's Community Research and Development Information Service (CORDIS) database for 7th Framework Programme projects[§] that mention big data yields 264 results (this data uses project names and short descriptions). This means that there were 264 funded projects that cited big data in the years 2007–2013. While we are still far away from a major big data breakthrough or successful widespread application, we think that 'big data' was used as a way of saying 'there is more data in our field and our project will attempt to deal with that' (as Don M. Norman said in a NordiCHI debate: 'Calling SOMETHING big data does not help much [...] it is the problem that matters not how much'). While we do not know if big data is an approach, a technique, a form of reasoning or a set amount of bits (Lehikoinen & Koistinen, 2014), we can show that we are aware of the trend and dealing with vast amounts of data will be necessary.

[§]`http://cordis.europa.eu/projects/home_en.html`

8.4. Making good use of buzzwords

The fact that we managed to identify a variety of roles for buzzwords through our analysis indicates that they are here to stay. Consequently, instead of trying to fully understand how they work, emerge and disappear (we may leave this to other sciences), HCI researchers should rather think how buzzwords can be used effectively. The challenge is to use buzzwords as innovation drivers as well as effective means of communicating with the general public. On one hand they are needed to communicate research results and the general importance of our field in a widely understandable manner to the public. On the other hand, buzzwords are used to declare interest in specific (research) questions to our community by different stakeholders. As critical researchers we should review the use of buzzwords carefully. There is a thin line between what could be part of the industry's marketing strategy and a word expressing a general trend of what the community is interested in.

Given that scientific work is classified with adequate keywords, we can aim at determining which keywords receive more attention from conferences and grant agencies. We stipulate that this simple mechanism can contribute to the development of buzzwords. If it is indeed true that it is easier to obtain funding given that some fashionable phrases are part of the proposal and, as we discussed before, the trend is unlikely to change, the challenge is to how to harness the power of buzzwords to effectively communicate and gather financial support for research activities that we believe are meaningful. Perhaps an awareness of buzzwords is required to be able to use them as topics, to which one must relate when thinking of a new research project. Researchers in Europe are already used to always considering sustainability as part of their research agendas and buzzwords may play a similar role. As we are aware that using a buzzword may increase our chances of getting funding (or, at least, many believe that is the current trend), we are indirectly obliged to position our research in relation to current trends in technology and society. Hence, there is a way to make meaningful use of buzzwords even in university politics.

8.5. Buzzwords in practice

Having established that buzzwords are certainly not a negligible phenomenon, one may wonder how they impact decisions that concern financial resources. In the next chapter, I describe an inquiry that was funded entirely owing to the assumption that Big Data was perceived as a possible benefit in the business world. In this buzzword-inspired work, the key goal was to investigate how the concepts associated with Big Data can potentially contribute to parts of the business. While one expects business innovation to focus on problem solving and identifying new areas for business development, it appears that the Big Data buzzword generated enough inspiration and merit to warrant directing human and financial resources to investigating the concept. A core problem with buzzword, as highlighted above is that they are often used in many contexts and their interpretation

may vary significantly. Consequently, merely investigating the benefits of Big Data for a given business is a rather abstract endeavour and the search for relevant context becomes the key activity.

In the case of the work presented in this thesis, the data source context was provided by the nature of the organisation conducting the research — we focused on telematics data from commercial vehicles. A technical context was then provided by strategic business decisions — IBM was chosen to be the technical partner and thus their technology was a crucial constraint in our work. However, the most important information was missing — the usage context needed to be identified along with a possible user group and the specification of its needs. The next chapter addresses that question and the methods used to obtain some answers to it.

8.6. Paper Five — work at Volvo

This paper describes a single design case, in which I was involved while working at Volvo Group Telematics (VGT, part of Volvo AB) in 2012–2014. This has certainly been a fruitful time when I was happy to learn how innovation is conducted in a multinational corporation. I got to experience the conventions, workflows and information formats used in everyday work, which enabled me to develop my communication skills. Finally, the work presented here enabled me to use the skills I often teach students in practice one more time and be reassured that they are relevant for inquiries outside the university environment. There are two major takeaways from this work that stimulate my reflection.

Firstly, I was able to explore the challenges and opportunities that collaboration between industry and academia offers. While I was deeply involved in internal innovation processes at VGT, I still remained an external academic consultant. This position and the fact that only part of my time was dedicated to industry work (I was pursuing other research in parallel) enabled me to take a step back from time to time and try to see the larger picture. Furthermore, presenting myself as a Chalmers researcher to engineers and executives provided mostly positive responses, which in turn allowed for asking 'the stupid questions'. I was able to inquire about things that were obvious for Volvo employees without any risk of sounding unprofessional. As a consequence, I gained a good understanding of the organisation quickly and I was able to ascertain from whom information could be obtained. This is a positive outcome as my expectations were rather limited. While HCI research has treated industry requirements with care for a long time (Czerwinski *et al.* , 1996), successful collaborations are usually reported from computing-focused businesses where user experience and design methodologies are widely accepted (Law *et al.* , 2014a). In contrast, I was entering a company built on successful engineering where I have not met a single person who would know what HCI was. This level of uncertainty opens possibilities, but also requires building trust. Oftentimes, I would use my technical background to not seem ignorant and then proceed to design-oriented questions.

Secondly, I have to openly state that the outcome of this work and the entire process used to conduct it was heavily biased by my determination to make it a design-oriented inquiry. Once I knew what the goals of the project were, I made the conscious decision to be the advocate of design in the inquiry and constantly ask for identifying potential target users and considering the user perspective. This was interesting from an HCI research point of view as little design guidelines were available for the given application area or the technology VGT decided to use. Consequently, aiming at reaching a designed artefact with user evaluations at the end of the project (which was not strictly required by the management) seemed to be a way to contribute a design solution. I was fully aware that my technical competence would probably have been enough to deliver an analytical solution to the problem and I believe that was the initial expectation of VGT. A certain amount of luck and trusting in established design tools helped reach a solution that was greeted with enthusiasm by executives and end-users alike.

It is perhaps unorthodox to dedicate a separate part of the thesis to a single paper that is merely a case study i.e. a non-archival publication. While the work seems rather limited in terms of number of pages, it was certainly time consuming. There were several months in my doctoral education that were dominated by work at Volvo. There were many activities in which I was involved that, while they contributed to my development as a researcher and designer, cannot be reported due to a confidentiality agreement. The paper presented below represents a generalised part of the work that shows a tangible example. It also provides the description of the design process in as much detail as possible after negotiations with Volvo public relations. But, most importantly, as this thesis addresses, inter alia, the question of what can be learned from design-based inquiry and tries to identify the benefits such an inquiry may generate, I believe that it is important to show that the design principles under which we operate in HCI are still relevant in applied settings. In other words, this work shows that the interaction design methodology involved in HCI research does can be effectively used to build user-centred systems that also have a valid business goal This paper used the most basic tools in interaction design to explore a new technical field, identify user groups and build user-friendly interfaces. Our work shows that, indeed, design can help us know things about the world that we would not know had we not engaged in a design process. In a way, this is my little manifesto that good interaction design can change the world.

I am also happy to report that the case study below will be soon part of the 6th edition of the book *Designing the User Interface*[¶] as an example of how relevant user interface design principles can be applied in practice.

8.7. Summary of findings

There is only one paper in this part of the thesis, but it is perhaps worthwhile to state the key insights here in the interest of structure and brevity. First and foremost, we

[¶]The book has not been published at the time of printing of this thesis.

found that traditional interaction design methods worked despite a new context which was not previously addressed in the literature. We were in a situation which was quite different from what one may call a typical design settings. We were given assets in terms of data and possible development time to develop services, but the user group was undefined. Therefore, we needed to conduct internal research, find possible users and try to understand their needs. Then, we tried to match those needs with the possibilities offered by a theoretical big data system and start designing features.

One lesson that emerges from my work at Volvo is that hands-on engagement with the big data set was a very productive activity. As none of our potential users were aware of the contents of the entire dataset, it was hard to stimulate them to produce possible ideas. The fact that I was able to use my engineering competence with the help of IBM specialists in order to create data-based conjecture was key in engaging users by showing them examples which were plainly wrong. This suggests that practitioners working with designing big data systems should possess elements of interaction designer and data scientist competence to effectively interact with users.

Finally, the paper offers a pragmatic set of steps that we recommend future designers take when faced with a similar design challenge i.e. the need to determine possible innovative users for a large integrated data set:

1. Identify all the data sources in the data set and the stakeholder responsible.
2. Conduct exploratory data research, keep in mind that correlation does not imply causality.
3. Choose a number of findings to consult with domain experts.
4. Let the domain experts prove you wrong.
5. Engage with the experts to discover what the possible questions may be, now that they know what the wrong queries are.
6. Make sure different experts meet to agree which insights may be beneficial.
7. Use the preliminary insights to build low-fidelity prototypes.
8. The data set, user group and possible use should now be matched.
9. Continue the design process iteratively.
10. Create big data policies in the organisations and include the insights for the development in them.

9

Paper Five: building Big Data systems

9.1. Bibliographic data

Title: Volvo Single View of Vehicle: Building a Big Data Service from Scratch in the Automotive Industry

Authors: Paweł W. Woźniak, Robert Valton, and Morten Fjeld

Published in: Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '15). ACM, New York, NY, USA, Pages 671–678

DOI: http://doi.acm.org/10.1145/2702613.2702972

Part IV.

User-driven inquiry

10

Prologue: Designing engaging interactions in sports

> Advanced marathoning has to be based on more than common sense and running folklore.
>
> Pete Pfitzinger & Scott Douglas, Advanced Marathoning, 2009

The final three papers in this thesis tell the story of my involvement in research on how to design user-oriented technology in the sports domain. Here, the papers serve as an example of a user-driven inquiry. Before beginning our work, we did not have any preconceptions regarding the technology we wanted to use, nor a particular orientation towards designing the interaction techniques of the future. Instead, we believed that there were severe inadequateness in how interactive technology addressed the experiences of those practising sports on a regular basis. Furthermore, even a brief look at the HCI and sports literature available showed that there was much about designing for sports that was unknown. Finally, with the advent of personal trackers and the Quantified Self movement, designing technologies for well-being appears to be a relevant challenge for HCI in the coming years.

The three papers are presented in a chronological publication order in this thesis. The first paper is a detailed account of our preliminary observations that, through long-term engagements with users and literature review, gave us an understanding of the design space we were addressing. The next work, RUFUS, shows a design instance that effectively used all the empathy gained in the initial stages of the process. Finally, in the Boar Board paper, we take an alternative approach and examine a user-designed artefact — a gamified system aimed at supporting group activities — to understand the intricacies of designing for exercise groups with a complex social structure.

10.1. Paper Six – Motivation

This paper presents the most laborious and time-consuming inquiry of all presented in this thesis. In my first truly qualitative inquiry, we conducted hours of interviews, attended numerous races and opened ourselves to the runner culture. While a lot of formal studies and observations are in the paper, what is hard to explicate in an academic context is how we started following runner websites and get had our eyes open for any running-related content around the clock. In Sweden, this yields a lot of information to process. After all, Sweden is the second country in the world in terms of the number of users of the running tracking application Runkeeper. This illustrates not only how a large percentage of Swedes are involved in running, but also that their running is already heavily supported by technology. In a way, we were lucky that interesting technology-related social phenomena that have not been studied before in HCI were right outside of our doorstep — with the runners running along Älvstrandspromenaden or those running the race Göteborgs Jubileumslopp, which had its finish line outside of our building.

This work also marks the beginning of a journey where my colleague Kristina Knaving and I explore how technology can reflect the social day-to-day consequences of the fact that sports has become an important part of the lives of modern western societies. While the body of the paper positions it in relation to past research in the sports domain, I believe the wider context that motivated the research at hand is equally important. From the very beginning of my research work, I was interested in actively using interaction design and conducting work that aims at understanding users. In contrast, the project that provided most of the money for my employment (DIVA) seemed to have been increasingly technical. As a consequence, I was on the lookout for potential research that would feature more hands-on work with users, ethnographic methods and design activities. At the same time, Kristina Knaving was involved in the EVINN project, which was a Nordic endeavour built around the understanding of events. We had several meetings to discuss collaboration where we concluded that investigating Gothenburg's largest and internationally well-known event — the GöteborgsVarvet half marathon was in order. This event is the world's largest of its kind and is mainly an amateur event — it is not a high-ranking event for professionals due to having a difficult course and the general preference for full marathons among professionals. It also seemed that we possessed a unique set of competences that allowed for a promising study. Within a month, I started a preparation training programme for the race and we began collecting data on amateur runners. This collaboration continues to this day and continues to yield new inspiration.

I would also like to mention that the work on interaction in sports is personally important to me. When I moved to Sweden in mid-September 2012, the loneliness and darkness was quite depressing and I believe that running kept me sane. It is a rare occasion to be able to work with what is also therapy and a hobby. We were happy to discover that autoethnography was used in the past to study runner groups and that there were many

questions that were still unexplored from an HCI point of view. I have accumulated many non research-related memories associated with running and evaluated multiple pieces of clothing an equipment. As we study runners and design technology for running, it seems that being actively engaged in running not only offers more design empathy, but also creates a certain sense of legitimacy. After all, I always test all of our designs and check if our study results apply to me and people I know. While this can generate certain biases (as the experimenter/participant boundary becomes somehow blurred), one cannot help but feel stronger when asking people to bet their running experience on a technical artefact having previously done that themselves. This also shows how design-based inquiry is complimentary to other ways of knowing — in a scientific inquiry, our immersion methods would be treated as biases that render the study invalid. However, in our design-oriented perspective, we can conclude that we explored scenarios and learnt things about that users that we would not have observed had I not been actively running and interfacing with running technology throughout the inquiry.

Finally, the work presented here addresses a user group that was previously not addressed in HCI literature. While this was en exciting challenge as we felt that amateur runners had been neglected by the community, we also had to establish that it was relevant to study these particular users. As a consequence, we felt that establishing the relevance of designing for amateur runners and showing how different they were from those users who had been studied previously (mainly users who needed to be convinced to start being physically active) was of particular importance. As our literature studies showed that sources were limited and dispersed, we knew a long-term study was needed to confirm that HCI issues were worth investigating in the context. The paper below sets the scene for all our other research activities by showing it is relevant, interesting and important for HCI to investigate amateur sportsmen. This attitude is in line with a design-based approach (especially the pragmatic account) as we seek to improve the world through understanding the given constraints.

10.2. Paper Seven — RUFUS

This is the thesis's most design-oriented paper, i.e. one that required the largest amount of design empathy and featured the highest number of design iterations. It is a result of a long-running design inquiry with several design interations and in-the-wild studies. The final form of the paper is also the result of many rejections and reviews. After thoroughly studying runners and their experiences of the race day (as shown in the previous paper), we were ready for a design intervention. We decided to dive into delivering a good design as our primary goal and studying its impact on its users. This also meant that we needed to distance ourselves from well-defined research questions and focus on understanding the design constraints and developing usable artefacts, using formative evaluation to generate knowledge. We were fully aware that taking this pragmatic approach would generate problems in describing the work in a way that made it easily acceptable for

publication. However, we were sure that a good design-based exploration and an in the wild study in a true ubiquitous computing spirit (Brush, 2009) would generate insights that could truly influence the design of future technology. After our initial studies, we were sure that current runner support technology lacked social features and we were determined to explore how this gap could be plugged. That is why we decided to use formative evaluation in our work.

Furthermore, this paper shows how limiting the 10-page conference format can be if on is to communicate a design-based inquiry. The in-the-wild study is given a lot of space in the paper as it is the most tangible effect of our research work that not only validates the design, but also shows concrete considerations for future technology. From a pragmatic perspective, one can say that everything went according to plan — there was a problem (the friends and family of runners are not involved in the race as much as they would like to), we examined the means available (the context of usage and the technology at hand), we delivered a solution (the RUFUS device) and confirmed that it worked (there was in-race runner-supporter communication observed). However, if one would aspire to deliver more generalisable knowledge, it seems that a longer description would be in order. Indeed, a full account of our design experinces inspirations and results can only be seen when examining the previous paper and the one discussed here together.

Our multifaceted design process is only described in short below. According to the academic convention, we did not report many failed designs or decisions of which we were unsure. We also explored many alternatives (like displays integrated in clothing) that we did not mention in the paper. As a consequence, the main contribution of this paper is a design solution and its evaluation. While this is certainly desired, this makes one wonder if the design process of RUFUS was not more important than the actual artefact. As we explored a design space which was previously neglected by the HCI field, not only our understanding of the users (described in paper six), but also the little decisions and design iterations seem to constitute an value. Of course, one could simply accept that we are victims to academic convention — we were successful in publishing the paper as presented below. However, it seems that this work shows how we will need to readdress publishing venues and formats to accommodate more design-based research.

Similarly to the Thaddeus paper, this work also contains descriptions of several design iterations. It is widely accepted that the iterative nature of the interaction design process (in whatever form one wishes to apply it) is one of the core reasons for its success (Preece *et al.* , 2002). Given the limited amount of text we can contribute to a single conference, researchers tend to focus on the final prototype. While this is crucial for understanding the evaluation study that follows the prototype description according to convention, the intermediate artefacts are usually lost in the designers' notes, media and memories. This is the case with RUFUS. These intermediate pieces of design knowledge (Löwgren, 2013) may still constitute a contribution, yet they are often omitted. In this paper, we present only fragments of our design journey to add credibility to the process. I hope we will be able to communicate a more detailed account of the work in a later publication.

10.3. Paper Eight — the Boar Board

This final paper of the thesis offers a different perspective on design activities. Instead of designing technology ourselves or investigating what needs to be done to design technology successfully, we observed how others designed an artefact. While we mostly tried to communicate the outcomes of our work and the process in which they were created in the previous papers, here we aim to unveil how non-researchers managed to create a design artefact and affect their social environment. This resulted in requiring an interesting blend of the skills we used in papers six and seven. On one hand, we were still aiming at understanding the users, their reasons for action and needs to which the system catered. However, we also needed to see them as designers as most of the participants of the study were involved in creating the system. Considering our own experience in designing technology for sports*, we knew they were involved in a difficult task that required a repertoire of skills.

Our work here introduces an atypical inverted scenario where the researchers are not part of the design process. There are two major takeaways from our analysis. First, once again, we begin with seeking credibility. We conducted a number of survey studies and interviews to indirectly evaluate whether or not the designed artefacts at hand were indeed successful. This way, we sought to show that our particular case was worth studying in the first place. While there is consensus that a lot can be learned even from failed designs (Gaver *et al.* , 2009), given the unique nature of our case (an artefact designed entirely by non-experts), we were curious whether the product of the design process fulfilled its desired role. It could have been that the users involved in the design simply accepted the design due to their involvement in creating it. That is why we used objective motivation measures to determine that the system offered the desired effect. Consequently, we could see one more design solution that could be a potential contribution to our understanding of designing technology for sports. Yet, to truly learn how this instance may inform the design of future technologies, we needed to understand how the design process of the system was conducted. In contrast to the RUFUS paper, understanding the design process and the qualities of the design solution that made in successful became our focus.

Having ascertained that the system was motivating users and it was well integrated into its social context, we wondered what we could learn about the design process so that similar systems can be build with different target groups. One could easily decide to adopt Fallman's romantic account and assume the users-designers are simply amazingly talented and their genius was represented in creating a gamification system. As researchers, we were drawn to more complex explanations and we endeavoured to uncover as much of the design process as possible. Yet, given that the users had no design education, the descriptions of how they designed the system were rather vague — they did not write notes or preserve snapshots of artefacts at different levels of completion. As a consequence, we could not identify any design patterns or a structure of the process by

*The articles in this part are presented in a chronological order.

interviewing the user-designers. Given that we still believed that the unique setting of the work contained intrinsic value (especially in a field like interaction design for sports, still yearning for exploring new designs), we decided to explain why the system worked and describe its positive qualities. While we do contribute one more design solution (not designed by us this time), we also show a set of signpost for designers and describe how a successful sports gamification system looks like in a domain theory manner.

This work is dangerously close to dropping the 'C' in HCI. We are investigating a system that has a fully analogue printed artefact at its centre. This shows two things. Firstly, as some have already noticed, the age of ubiquitous computing is here (Abowd, 2012). In a Western society, all our activities are supported by technology at different levels and embedded computers are integrated in our culture. The central artefact of the design may be analogue (which is a very effective means of making sure it is not distributed), but it is still surrounded by technology. Users take pictures of it and discuss it on social media. Furthermore, its visual design is based on a video game. This illustrated how difficult it is to draw the line and determine what is outside of the scope of interest of HCI. Additionally, we are certain that this work is interesting to the digital games community, which has an established relationship with HCI. Secondly, as seen in the opening remarks of this thesis, interaction design is a multidisciplinary means of inquiry that spans different methodologies and mediums. This work addresses game design, visual design and interaction design to create a blend of insights that can inspire future gamification systems. Current trends indicate that most such future systems will be digital, but they will need to be designed well and adjusted to their social context before any digital artefacts are created. This is where the work below may be particularly useful.

10.4. Summary of findings

Our long-term inquiry into the role of technology and motivation in the lives of amateur runners showed that an enhanced understanding of individual runners and the running community in HCI was needed to effectively design for this user group. Past research concentrated around the concepts of play and exergaming or attempted to convince users to start a regular training routine. Through own research and importing knowledge from other fields such as sport psychology and sports ethnography, we discovered that the needs of advanced amateur runners were far from the picture then present in HCI. The motivation and RUFUS papers have many detailed insights, but there are several issues that are virtually unexplored to date:

- The need to differentiate between race-day and training technology,
- Providing help in managing the practicalities of running,
- Facilitating family support for regular runners,

- Supporting discussion and race storytelling,
- Maintaining the runner-supporter relationship,
- Handling in-race nutrition.

We have only managed to address a fraction of the issues above. We focused on the runner-supporter relationship and showed that technology can be designed to help manage support and produce engagement in both parties. We have also showcased the importance of working with runners who are preparing for organised races and cooperating with event organisers. In fact, engaging with mass-scale events is what sets our work apart from other research efforts. We commented extensively on the difficulties of in-situ studies during one-off events in our article in the Interactions magazine (Woźniak *et al.* , 2015).

From a theoretical perspective, there is an emerging need to review all of the design approaches used in HCI for sports. We proposed an approach different from past work, but we considered it equally valid. In the future, we will try to integrate the various theoretical influences from fields such as, inter alia, psychology, sport ethnography, game studies and health science to create a more comprehensive inventory of theory that can be used to help designers when designing for sports. While we feel that a strong theoretical grounding is needed in this line of work, our publications show that nothing can substitute more studies that will engage with races[†] and everyday training.

Our work has had a significant focus on the race experience and supporting runners and supporters at this unique time in their lives. With RUFUS, we have demonstrated that the supporters can take a more active role in the race experience and not limit themselves to a single interaction during the race. We have shown that carefully introducing technology may augment the experience of running without providing unnecessary distractions. RUFUS demonstrates that in-race low-fidelity communication is possible and it can have positive effects on the runners and supporters.

We also addressed the social dynamics of practising sports. While past approaches investigated activities in pairs or support groups, we observed a large group of amateur sportsmen driven by passion. In the Boar Board paper, we show how important the understanding of the social dynamics in sports is for designing HCI for sports. In our work, we aim to provide a counterbalance from the 'traditional' approaches such as exergaming (Park *et al.* , 2013), which tend to simplify the sports experience or only analyse its parts.

[†]or events if one wishes to venture beyond the scope of running.

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Paper Six: charting motivation for amateur runners

11.1. Bibliographic data

Title: Flow is Not Enough: Understanding the Needs of Advanced Amateur Runners to Design Motivation Technology

Authors: Kristina Knaving*, Paweł W. Woźniak*, Morten Fjeld, and Staffan Björk

Published in: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, Pages 2013–2022.

DOI: http://dx.doi.org/10.1145/2702123.2702542

*Equally contributing authors.

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Paper Seven: designing support systems for amateur runners

12.1. Bibliographic data

Title: RUFUS: Remote Supporter Feedback for Long-Distance Runners

Authors: Paweł W. Woźniak*, Kristina Knaving*, Staffan Björk and Morten Fjeld

Published in: Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services, ACM, New York, NY, USA, Pages 115–124.

DOI: http://dx.doi.org/10.1145/2785830.2785893

*Equally contributing authors.

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Paper Eight: studying users as designers of gamification

13.1. Bibliographic data

Title: The Boar Board: Understanding Grassroots Sports Gamification in the Wild

Authors: Kristina Knaving*, Paweł W. Woźniak*, Morten Fjeld, and Staffan Björk

Submitted for review to: Proceedings of the 9th Nordic Conference on Human-Computer Interaction — NordiCHI 2016

*Equally contributing authors.

Part V.

Finishing words

14

Reflecting on reflecting

Now that you've seen your true
reflections
What on earth are you gonna do?

Boyd Tinsley

This part of the thesis attempts to answer its key conceptual question. Given the CTF model presented in the beginning of this work and having revisited eight papers, it is time to try to reflect and revisit the contributions of the included papers. The next two chapters present the final reflections on the papers presented in this thesis and attempt to share the experience of looking critically at my almost four years of doctoral education and research work. First, I revisit the contribution types discussed in the introductory chapters and relate them to the papers of the thesis.

14.1. Contribution types in this thesis

The papers in this thesis were ordered around the division between tech- and user-driven research. Re-examining the contribution types provided in each paper using the CTF model presented earlier highlights that division. Figure 14.1 shows that only **paper one** falls outside of the analysis-solution spectrum according to Obrenović. **Paper one** is a visioning paper and one of its key contributions was combining insights from social science and technical developments. Consequently, it explores multiple aspects of what and how to design, straying away from discussing single artefacts or a well-defined usage context. Thus, it escapes the user vs tech division to which all the other papers in this thesis can be related. **Paper two** focuses of an accurate description of the design artefact without aspiring to produce more generic knowledge. It can be interpreted as an intermediate report of the design process that highlights the iterative nature of

interaction design. I positioned it outside of the CTF model as this particular prototype was only a step towards a better understanding of the design to come. **Paper three** mainly contributes a focused study, which aligns it with the CHI contribution types. It is noticeable that the current state of research on spatially-aware devices prevented us from attempting to claim too much generality. Instead, Thaddeus provides a concise description of a single design solution, which, hopefully, can have a generative aspect for other designers and certainly inspired our further inquiries. **Paper four** utilised the design experiences from paper three and incorporated some theory form cognitive science. It also created interaction concepts for sensemaking support based on pre-studies and evaluation. While, again, the paper uses a 'scientistic' study-focused description, it provides more design-centred contibutions as it points designers to theories on spatial organisation of information and shows how they can be operationalised. It also provides interaction concepts relevant in this solution space.

While **paper five** has a dedicated part in this thesis as its origins make it distinct from the rest of the work, its contributions are quite related to the other papers. My work with Big Data analytics required a thorough problem analysis to gain design empathy. The key contribution of the paper can be viewed as suggestions on ways to act in similar settings. We provide a way to work in a highly-specialised automotive context which can be interpreted as a design pattern. I also placed paper five close to the 'study: people' category as it, while not featuring a formal study, offers an understanding of the unique stakeholder situation in the Big Data context.

Paper six explicitly mentions the fact that it contributes guidelines. It is in line with Obrenović's domain theory concept as it addresses a well-defined user group at a specific time and in a specific context. This paper shows how a deep understanding of the design context can yield empathy that in turn generates intermediate-level knowledge. While we do not name experiential qualities in the paper, one can observe that the multiple accounts of desired user experiences provided in paper six can inspire many design processes. In contrast, **paper seven** mainly uses the prototyping phase of the design process (based on the design empathy gained in paper six) to employ formative evaluation that generates a deeper understanding of how the user experience during races can be augmented by technology. This paper is more focused on the particular design instance and provides a type of commentary to the design process. While we do not explicitly provide guidelines or considerations, we provide accurate accounts of user reactions and their interpretations (e.g. cheering strategies employed by users) that can be reused in future designs. Finally, **paper eight** investigates user-designers and their process of building a tailor-made gamification system to build a theoretical contribution. We aim for building a theory of how one particular system emerged and successfully fulfilled its role in order to enable future designs to use similar considerations. This focus on theory spawns from two facts. First, a deeper design reflection is not strictly possible as the researchers are mere witnesses of the design process in this instance. Second, the lack of similar past systems and the studied system's apparent success inspire curiosity. While the eight papers in this thesis could be placed within the CTF model, further work

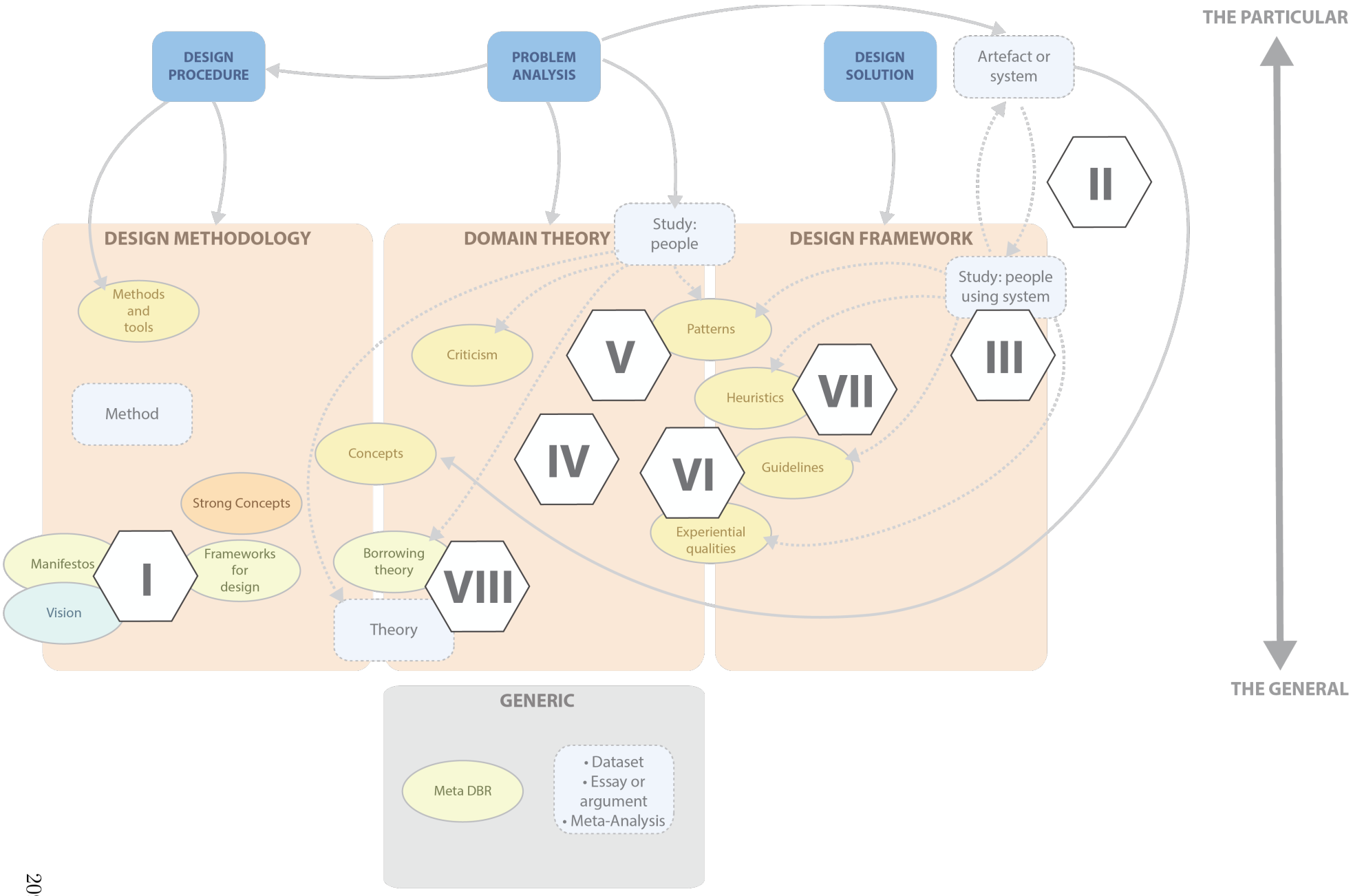

Figure 14.1.: The eight papers of this thesis mapped onto the CTF model (cf. Figure 2.2)

is needed to determine how comprehensive the model really is and how it can be used effectively.

14.2. So is this design after all?

One key observation from the process of understanding the contributions represented in this thesis is that even my own research confirms the flux in HCI (Bødker, 2006). The CTF model is an attempt to add some structure to published work and understand how the contributions differ. I did help me to reflect on my past work and I hope that it may be useful to other researchers. The introductory chapter of this thesis provides examples for all the contribution types in the model, which, together with the theoretical descriptions on which the model is based, enables researchers to position their work in relation to other contributions. This can be helpful for those who have a science background as the multitude of approaches in HCI can be a stark contrast even to the world of computer science research. The intellectual approach taken in this thesis is to look at what HCI has attempted to import from the design domain to understand itself and to interpret HCI's research efforts as design activities. This procedure resulted in an argument and an analysis that created a metaphorical mirror to reflect the papers included in this thesis. But, as mentioned earlier, it is impossible to impose all of design theory and perhaps other domains of inquiry onto the corpus of published HCI work and the scope of sources inspiring the analysis in this thesis is naturally limited. Even more so, there are two important possible fallacies that have to be mentioned for matters of scientific honesty. Firstly, it may be that HCI's past efforts in understanding its contribution through importing bits of design theory may have been wrong, biased or misguided — perhaps the community has not imported enough design theory to understand what it is doing or, simply, not enough design-oriented minds have been involved in understanding the HCI community. Secondly, this entire endeavour may be simply epistemologically wrong. Perhaps interpreting parts of what constitutes research in HCI as design activities is simply wrong — the fact that we do indeed use design methodologies as a tool may not be enough to call some involved in HCI enquiry 'designers'. Personally, coming from a strict engineering background, I was blessed to encounter people educated as designers on my path and start appreciating the designerly way of approaching problems. I have studied design books and engaged in design activities to the best of my abilities. I have felt that many of the research questions I pursued were attributed to design-based research. But, does this mean that I, in some part, have become a designer? More importantly, is design merely a tool that we effectively employ in HCI that serve the purpose of knowing things about the world that escape design per se? While I do not aspire to answer these questions in any way in this thesis, I feel the reader must know that the train of though presented here is heavily based on the aforementioned assumptions.

14.3. The stories gone forever

There is also one more kind of bias involved in the way the work included in this thesis was presented — while I do share some memories and information based on past notes in the respective prologues, the dominant way of reporting on my work is through published papers. Design-based research intoduces new factors that are an intrinsic part of the output of the reserach such as the project history, the team members involved or the methodological preferences of the researchers (Koskinen *et al.* , 2011). While academic communication does have a long and complicated tradition, there is no way to conclude the particular papers involved in this thesis are the optimal way to communicate the work that I and my colleagues performed. As a young researcher, one is not in a position to dispute the current ways work in assessed in a community and what features make a paper more likely to be accepted. The reader will notice that several works question the way we show results in HCI (e.g. (Löwgren, 2013; Gaver, 2012)) and wonder how publication venues can be augmented to accommodate a broader scope of inquiries. Some authors go even further and explicitly state the community is at fault in the way it is organised and what kind of questions it poses (Kostakos, 2015). Recently, Hornbæk concluded that we fail to produce negative results and focus on delivering novel and original work,which is easier to publish at leading conferences (Hornbæk, 2015). I am certain that HCI's apparent dislike of incremental research and the lack of widely accepted facts within the field shaped the choices described in this thesis and the kind of work that I chose to perform. Consequently, in writing the papers included in this thesis, I tended to emphasise some facts over others and retained some of the experiences of designing, implementing and testing the systems involved in my research. Given the time elapsed since I was engaged in many of the activities described in this thesis, I have to conclude that parts of the experiences are gone forever.

Doubting each and every step in one's research history can easily lead to a certain feeling of disconnection and a circular argument. After all, this thesis is also set within an academic convention and certain rigour is required for it to be approved. Part of that rigour is the inclusion of published papers which do follow a convention about which the HCI community is not sure. Certainly, more theoretical work and meta-analysis is required to answer these concerns. I am only voicing these doubts to stress that HCI seems to be constantly redefining itself and looking for new challenges, interpretation lenses and methodologies (Bødker, 2015) and this thesis is inherently subject to some of HCI's self-defining flux. Thus, some of the views presented here are merely the result of a snapshot of my research and the general state of the field at time of writing. While I tried to chart the kinds of contribution spawning from design-based research, some have called for redefining those contribution types from scratch and creating new venues to communicate design-generated knowledge (Höök *et al.* , 2015a). I sincerely hope that HCI's publication model will evolve in a way that less design stories are lost and future theses will not require notes similar to this subsection.

15

Lessons learnt

> Before turning to those moral and mental aspects of the matter which present the greatest difficulties, let the inquirer begin by mastering more elementary problems.
>
> Sir Arthur Conan Doyle
> A Study in Scarlet, 1887

In this chapter, I will juxtapose and contrast the papers to identify key differences in research approach in the hope of informing future inquiries. The findings are presented in the form of several lessons learnt that, I hope, can help in making decisions about future research. The lessons adhere to the theoretical stances presented in to introduction of this thesis, but, as they are related to the thesis papers, they offer a more practical account oriented towards research planning. The lessons helped me to reflect on my work and I hope that they can also help other researchers that come to the HCI field from a science background* and enable making more informed choices about what kind of research to pursue. Together with the CTF model, the lessons are a conceptual tool that can help create research programs. The model enables one to choose what kind of design-generated knowledge to seek and the lessons provide practical considerations that can help steer the inquiry in the desired direction. The two tools combined can build an enhanced awareness of the research activities conducted and their relation to theory.

For each lesson, I first share some general remarks and then show how this is evidenced in the paper included in this thesis. A word of caution: these lessons are not meant to be novel, but rather offer a concise overview that highlights the contrasts between the papers in this thesis.

*They lessons provide less insights for experienced design researchers

15.1. Focusing on the future

Tech-driven inquiry enables research to focus more on futuristic scenarios. If one believes that a core research agenda within HCI is to prepare for an inevitable computational future, a technology-oriented approach facilitates creating futuristic scenarios and approximating possible developments with the means available at a given time. In paper one, we have gathered information on current technical developments as well as reviewed current predictions from technologists to create a plausible vision of the future state of technology. This enabled us to create possible future interaction patterns and set them in possible usage contexts. We also theorised that some thing about users will not change and certain needs will need to be met. Drawing on these predictions, we related our possible interaction scenarios to the needs of a future society postulated by social science and established concepts around discussion. I believe that using technology as a starting point of our inquiry enabled us to set a futuristic frame and the rapid generation of tech-oriented scenarios aided in maintaining that focus.

One should also consider that exploring future worlds is simply exciting both for researchers and users. We have found that introducing users to our systems by stating that the prototypes were approximations of the future produced generally positive reactions. This is not surprising as Future Technology Workshops are a well-established tool in interaction design, even for complex user groups (e.g. older adults (Rogers *et al.* , 2014)). However, the work in this thesis also shows that prototypes approximating future technologies enable users to keep a futuristic focus. Many users were eager to participate in the studies performed in papers two, three and four only to be part of creating future technologies.

Finally, it appears that a tech-oriented future focus allows for more speculative designs, which in turn offers more freedom to the designer. Despite the fact that papers two, three and four were distilled into a structured form to be presented at HCI conferences, the design work required allowed space for extensive design synthesis, much like in Fallman's romantic account. In fact, our work was driven by a design vision of future technology and its future role in the society, which is far from a conservative stance. This would suggest that rational theorising about future technology may produce some unexpected design freedom. It is acceptable to ignore many technical constraints and focus on the context of the design and the user interaction per se. Therefore, it is correlated with the 'leading' stance in terms of Schmidt's paper (Schmidt, 2015).

15.2. Means of evaluation

The widely-accepted evaluation apparatus is wider when one conducts a user-driven inquiry. Given HCI's complicated relationship with computer science, tech-driven inquiries are usually evaluated against more structured metrics, which are more familiar to computer scientists. In the spirit of Weiser's pioneering work (Weiser, 1993), one is often to

tempted to seek what the implications of possible interface designs for technology are. Consequently, all papers in part one of this thesis identify challenges that will need to be met by future technology and indirectly try to drive developers of such technology in a user-oriented direction. This, in turn, leads to a desire to communicate the contributions well to the technology-oriented user. One endeavours to convince them about the credibility of the work and the purposefulness of driving future technology in a direction that could possibly support the HCI researcher's vision. This showcases the importance of what a reviewer of Gaver's work called 'the elephant in the room...: the move towards 'scientism' in HCI (Gaver, 2012, p. 946). The inquiries in papers two, three and four are clearly framed as more 'scientific'[†] in order to be attractive to a technology-oriented audience. This results is some of the design accounts (which are also considered valuable, as possible instances reflective practice (Höök *et al.* , 2015a) or even contirbutions to intermediate-level concepts (Löwgren, 2013)) being permanently lost or, as in the case of this thesis, hidden in design notes, low-fidelity prototypes and disorganised digital media. Given this background, it can be observed that tech-driven inquiry is inevitably tied to highly structured evaluation, mostly in the form of controlled experiments. It is also likely to promote the creation of pseudo-scientific[‡] theory as can be observed in (Woźniak *et al.* , 2014a).

User-driven enquiry provides more room for a varied and less structured evaluation. As established in the first part of this thesis, understanding the user needs and the design context prior to the design intervention can constitute a viable and, sometimes, generalisable contribution. The array of evaluation methodologies is expanded. Furthermore, a successful design somehow intrinsically provides an evaluation of how well the design constraints were understood and processed. For example, in the RUFUS paper, the fact that we successfully designed an artefact that runners willingly used in an organised race shows that our understanding of the design context was at least partially correct. In other words, the goal of our evaluation is to examine user experiences, understand more about the artefacts features and learn how the prototype can be improved. This contrasts strongly with merely seeking credibility as seen in the tech-driven papers. Of course, this is not to say that accounts of user experience or the design of particular features are never present in tech-driven paper. While we collected feature use data in RAMPARTS, we did not seek understanding of the design of the features or its effect on the users, but we rather attempted to confirm that the design was valid and reflects some concepts in sensemaking that were central in creating the prototype. Consequently, the evaluation was, again, centred around concept validity and the qualities of the design[§]. A user-driven inquiry aims, among other things, to convey the qualities of the users that render particular designs suitable and the range of methods to describe these qualities and

[†]This statement is not equivalent to the author claiming that HCI can be considered science. I, personally, disagree with that statement, but there is no consensus in the field of what the suitable should be.

[‡]I am using this strong term on purpose

[§]I am consciously ignoring the issue of the requirements of the target publication venue and its traditions as this is a political matter.

the design in terms of these qualities exceeds the framework of a traditional controlled experiment favoured in a tech-driven inquiry.

15.3. Qualitative and quantitative evaluation

As tech-driven inquiry seems to necessitate validity verification through controlled experiments, it is biased towards quantitative evaluation. As noted in the previous section, one reason for stricter quantitative evaluation when conducting a tech-driven inquiry is the audience at which the work is targeted. There are, however, more reasons why we favoured quantitative evaluation in our tech-driven work. Firstly, when one build prototypes that are to approximate future technology, it is often convenient to support the approximation with tangible proof. The research should show that the assumed extrapolation of the development of technology is reasonable. In papers two, three and four, we have demonstrated how building a working technical solution with existing technology enables one to predict the same features will be soon available in a more compact, more refined and cheaper form. In this proof-of-concept-like endeavour, one seeks to communicate a binary answer — 'Yes, it is doable.'. This allows grounding the research in a technical reality and enables a more detailed investigation of the interaction.

In contrast, user-driven inquiries do not need to seek basic legitimacy. Merely the fact that a particular group of users found themselves in a particular context and the designers had access to the group build the relevance of the design work. In papers five and seven, we encountered design situations where little to no literature provided clues about how to begin design activities. As a consequence, we employed an array of qualitative methods not only to build an understanding of the design constraints, but also to gain design empathy (Wright & McCarthy, 2008). In a tech-driven case, the need for design empathy is largely limited as the focus on the future results in the fact that there are no actual users available. While technical work can still address problems relevant at present, it is harder for a designer to understand the user point of view if they are considering a future scenario. Thus, the more pragmatic character of a user-driven inquiry opens it for a variety of qualitative methods. Papers six and eight show how these methods can be used to chart the design space with a desired level of detail. Paper seven shows the middle ground where we use a mixed-methods approach to first assert the design is fulfilling its basic purpose (runner-supporter communication) and then try to understand why the prototype produced the interactions observed.

15.4. Inter- (or trans-) disciplinary work

Building insights on work from other disciplines and reinterpreting approaches from other fields is more accepted in case of a user-driven inquiry. One can observe that many papers in the thesis are built around a design instance (a design solution). However,

the difference in the character of the reference lists is quite apparent. The user-driven inquries feature many references from the social sciences, psychology or physiology. Of course, this is mainly due to aforementioned differences in methodology, evaluation and focus. But, this difference also shows that user-driven inquires are more likely to explore interdisciplinarity. Understanding the human condition has a long history and HCI borrows, transforms and adapts theories from more established disciplines (Rogers, 2012). While in the formation years of the HCI community, the borrowing and transforming happened mainly in structured experiments, it seems that the process is now more active in design-oriented inquiries that aim to understand users. Given an increased focus on understanding the design constraints (perhaps most famously voiced in (Harper, 2008)) in place, designers often need to study application domains and social sciences to make sure they can proceed with the design process. As research leaders have repeatedly stressed the need for transdisciplinarity in HCI (Rogers, 2011), it appears that user-driven inquiries are more suited for crossing disciplinary boundaries. Considering some expressed concerns about maintaining a user focus (e.g. (Bødker, 2006)), conducting a user-driven inquiry into future technology appears to be the suitable vehicle for HCI to affect other fields and meet the expectations of HCI's third wave.

The work included in the thesis includes a case where we used theories from other fields to build our understanding of the design context. Furthermore, it enabled us to propose an alternative design standpoint that was different from those previously present in the literature. Our studies in advanced amateur runner motivation form the core of the content in papers six and seven. We charted the user needs based on theories from the psychology of running and the emerging field of sports ethnography. We also build on fundamental understandings of motivation in psychology and, specifically, the current models of motivation for athletes. This enabled us to build design guidelines for future technology. Our approach contrasts with an earlier development in HCI — the dominant trend in HCI for sports was exergaming (or exertion games). This approach suggested that the social dimensions of sports can be explored through applying techniques known from game design (Mueller *et al.* , 2010b). This illustrates how a user-driven inquiry may help identify what can be effectively borrowed from other fields and how incorporating knowledge from outside of HCI can fuel a design-oriented discourse within the field. Taking a different disciplinary perspective enabled us to winnow the finer details in designing for amateur runners and offer an alternative perspective on designing for that user group. Had our analysis been limited only to data analysis, the perspective on user needs would have been narrowed thus yielding a shallower understanding and inferior design guidelines. Furthermore, thorough grounding in motivation theory, reflected in the reference list, allowed us to support our stance which was opposed to the well-established exergaming.

15.5. Design interventions

User-driven inquiries create more potential for real-life design interventions and creating user experiences. The tech-driven inquiries in this thesis explored possible future scenarios and put users in hypothetical situations. While we did engage users in new settings and investigate their reaction to new technologies and interaction techniques, the lack of context inherent in a controlled experiment did not permit us to fully investigate how the future technology could change the users' lives. Opportunities for design interventions or even investigating what possible design interventions may involve is largely limited when working with future technology. We tried to illicit possible usage scenarios from the users and they would often share stories of how they could envision using the proposed technologies as parts of their lives. Many of them would express happiness at having participated in our studies, say it was enjoyable or playful. While these findings can surely inform design when technologies similar to those envisioned arrive and allow practitioners to develop customer-ready systems, they can merely serve as starting points and more contextualised inquiries will be required. Consequently, the value of tech-driven inquiries for verifying if design could potentially affect everyday lives is rather limited.

On the other hand, user-driven inquiries open possibilities for interventions. It is up to the researchers whether or not they decide to conduct interventions and concurring views are present in the field. Typically, scholars with a social science background will refrain from affecting users in order not to bias their assessment of the current situation and user needs. A design-oriented researcher will strive to proceed with the design process as their focus will be on reaching a final design artefact (the ultimate particular) and/or understanding the process leading to a design (with the possibility of generalising that knowledge). There is also another possibility where elements of design are used to elicit user reactions and a better understanding of the design constraints. The three aforementioned approaches were employed in the papers that constitute the core of this thesis. Additionally, a significant part of the HCI community is engaged in participatory design (Muller & Kuhn, 1993) which fully blends interventions with studying design. I addressed issues of participatory design in an earlier work (Woźniak *et al.* , 2014c).

In paper six, we conducted an inquiry into the motivation of amateur runners and parts of the data were obtained in the context of a prototype. It is not surprising that some reviewers expressed concern that our analysis may have been biased by using the prototype. However, we decided to use a small design provocation to make sure users were aware of the possibilities offered by current technology and steer our design inquiry towards solutions that were both desirable and possible to implement. This risk seems to have been worth taking in retrospect as it enabled us to discover new user needs (mainly the family's need to be more active on race day) and create a concise set of design guidelines. We then conducted a fully-fledged design inquiry in paper six where applied the guidelines to build a prototype and augment the experiences of runners and their families. We believe out thorough understanding of the design context and the fact that we worked with users willing to explore new technologies assured that all users

were happy to use the device. Furthermore, our results confirmed that most users did communicate using our system thus proving we changed their experience of the race. What we did not expect was that some users were strongly affected and remembered their experience for a longer time. Several months after the study, one of the users visited our research division to inquire about further studies of the prototype, which is perhaps the most rewarding experience possible for a researcher engaged in interaction design. The intervention presented in the RUFUS paper contrasts with the approach we took in the final paper of this thesis. We studied users as designers and we wanted to learn what future designers of technology can learn from how the solution was created and functioning. As a consequence, we refrained from any intervention in order not to bias our evaluation of the success of the system and understand the thinking of the user-designers involved. This shows how a user-driven inquiry creates opportunities for intervention and leaves the researcher with the dilemma of choosing a level of interventionism that will best suit their research goals.

15.6. Understanding implementation

The understanding and meaning of implementation is different in tech- and user-driven work. As discussed before in this chapter, tech-driven inquiries pose a greater need for credibility. Implementation is described in more details in those works. Specific information about the hardware and software used provides extensive proof that the prototypes were actually built and the research was conducted according to the rigour required by the standards of the field. The science-oriented approach of a tech-driven inquiry also necessitates a need for replicability and thus details are usually provided so that the experiment can be conducted again or the system used as a baseline solution in another study. While the technology does not constitute the core contribution of the work (it is merely a means to approximate a future technological landscape) the research questions and the evaluation are still built around the technical qualities of the system. As a consequence, high-fidelity prototyping is a core activity for the researcher and significant amounts of time are spent in efforts that do not directly contribute to the development of ideas, concepts or results. In contrast, in user-driven work, building systems is a means of engaging users and conduct studies and it is necessary for a design intervention if one is to be conducted. Rather than adding credibility, implementation details show how the design process was translated into tangible artefacts. It may also illustrate how the researchers crafted the necessary tools to engage users in a study so that other methodologies can be explored in the future.

This dissonance is apparent in the works presented in this thesis. We provide detailed implementation information for the tech-oriented papers where we aim to convince the reader that the solution was indeed implemented. We identify technical publications that justify our chosen method of prototyping and relate to past work that used similar strategies. The papers also outline which parts of the system include off-the-shelf

solutions and which required custom software. This way, we show how developing the prototype occupied a significant part of the research time and stress the apparatus used in our studies is unique. The RUFUS papers contrasts strongly with the tech-oriented descriptions. Implementing the prototype is described as a part of the HCI design process. We match implementation decisions to user research and show how design constraints are reflected in the choice of technology. Notably, we provide details for both an initial prototype and the solution used in the final study to showcase how the device evolved in the design process. We tried to avoid a 'traditional' implementation section and incorporate technical consideration seamlessly in the flow of our inquiry. As a consequence, we made the lexical choice to name the most technical section of the paper 'system overview'. These differences show that researchers need to be weary of what role they want implementation to play in their and present the technical details accordingly.

15.7. Making efficient use of prototyping

Prototypes play different roles and produce different kinds of insights in tech- and user-driven inquiry. Rational design decisions are necessary in an HCI inquiry that involves developing a system, irrespective of whether it is a tech- or user-driven research instance. Questions about specific features are bound to emerge and, if a finite number of possibilities is considered, they are often best answered by preliminary studies. These activities often happen on an ad-hoc basis and include different levels of prototyping fidelity (Bardram & Friday, 2010). In a tech-driven inquiry, low-fidelity prototypes are often used to eliminate potential practical design flaws or decide on the placement of interface elements. Thus, these prototypes contribute to the legitimacy of the studies — preliminary tests prove that the design is valid and potential flaws were eliminated. For example, in the MochaTop paper, we eliminated interactions that required straining hand postures by asking users to perform a set of gestures using cardboard mock-ups of smartphones. Low fidelity prototypes can also enable researchers to see concepts in action and facilitate translating interactions into the digital domain. RAMPARTS was built based on a study where users solved crime mysteries using only paper. Conducting this preliminary study enabled us to see how the theoretical concepts about organising information from cognitive science work in practice. The study also showed the physical side of organising information on a table and influenced the design of the interaction patterns used in the final prototype. Consequently, the conceptual framework that was manifested in the design of the system and later confirmed in the evaluation was visible early in the design process.

Higher fidelity prototypes may enable researchers to choose which aspects of a system are most interesting to study and may produce most insights. This stance assumes that the researcher is chiefly interested in specific intricacies of the interaction and is thus typical of a tech-driven inquiry. For example, while designing the Thaddeus system, we

decided not to include some types of information visualisations in the final user study despite having implemented them in the prototype. We used a low-fidelity prototype to elicit interaction techniques from users, but only a high-fidelity prototype enabled determining which of those may have provided efficient access to data. This illustrates how prototypes in a tech-driven inquiry can be effectively used to narrow the scope of the research questions thus producing a solution that is easier to quantify.

Finally, in a user-driven inquiry, prototypes serve mainly as vehicles to engage users. The designer can gain more design empathy through users theorising about the usage of a prototype. The RUFUS paper shows how prototyping can be effectively used as part of formative evaluation. Building two functional prototypes of RUFUS enabled us to reflect more on the design process and identify the key qualities and human values involved in creating the system. Initial reactions helped us refine RUFUS, but we do not treat them as a single step of a structured process. Instead, we interpret the two prototypes as part of a continuum that enabled us to explore runner-supporter communication during races. This contrasts strongly with the Thaddeus paper were we could identify clear stages in the design and each of these stages ended with well-defined decisions. These examples indicate how the choice of prototyping methodology not only needs to be tailored to the type of the research inquiry and the questions asked, but also how seemingly pragmatic choices of prototyping fidelities can affect the focus of the inquiry.

15.8. Summary of the lessons

I hope that the pragmatic lessons presented in this chapter will help the reader make better choices in research and, most importantly, showcase the strengths of certain approaches so that researchers can use the appropriate means to generate the kind of knowledge for which they are looking. Here, I provide a summary in the form of Table 15.1 to help find pointers to my experiences about a choice of interest. The respective sections in this chapter provide references to papers included in this thesis that illustrate the differences between tech- and user-driven inquiry.

Question	**Tech-driven inquiry**	**User-driven inquiry**
The future	Facilitates focusing on the future of interactions	Easier to address the challenges of the present
Evaluation	More rigour is expected	A wider array of possibilities
Qualitative and quantitative methods	Quantitative work is almost necessary and usually dominates	A mixed-methods design is to be balanced according to the research question
Interdisciplinary work	Requires more rigour and better justification	Often necessary and widely accepted
Design intervention	Unlikely	Potential
Implementation	Adds credibility and replicability	Is a means to involve users
Prototyping	Motivates decisions and adds credibility	Vehicles for engagement and empathy

Table 15.1.: A summary of the seven lessons learnt through comparing the papers included in this thesis.

I am fully aware that these lessons may seem trivial to some readers as they are congruent with common sense and a basic HCI research intuition. However, I feel that voicing these differences and formulating them in a concise manner can serve an important purpose — when attracted to a possible new research project, why not ask ourselves what kind of inquiry one should choose? Why not try to align our designerly and technical skills with the kinds of questions we can ask and the kinds of knowledge we can generate? Finally, in an utopian belief that all academic research should lead to making the world a better place one way or the other, let us ask how we can affect users, technologies and methodologies given our planned course of action and how to conduct our inquiry so that it affects our social and academic environment in the best possible way.

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