Designing and Evaluating Mobile Interaction: Challenges and Trends

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Abstract

Mobile technology has been rapidly gaining ground and has become intrinsic to our daily lives. As its importance within society continues to grow, features, functionalities and usage opportunities accompany such growth, turning mobile devices into essential tools. Faced with the role that mobile interactive technology has assumed, it is vital that ease of use also reaches new levels, attenuating the growing complexity within the critical status that they represent. Accordingly, mobile usability evaluation needs to re-invent itself to keep pace with this new phenomenon. This article reviews the current approaches and recent advances in the design and evaluation of mobile interaction and mobile user interfaces, addressing the challenges, the most significant results and the upcoming research directions.

Contents

1

Introduction

Our lives and society are rapidly gravitating towards a world in which mobile devices are taken for granted. These are no longer accessory but become natural extensions to our bodies. Their use has become quasi-permanent, following and supporting us in most of our activities and affecting the way we interact, share, and communicate with others. Additionally, they are growing in diversity, and complexity, featuring new interaction paradigms, modalities, shapes, and purposes (e.g., GPS, Portable Media Players, Gaming consoles, Smart Phones, E-book Readers). Together with the evolution of the available hardware, software has also evolved greatly and users are becoming ever more demanding of user interfaces (UIs) that provide both functionality and pleasant user experiences.

The fact that mobile devices are used anywhere and anytime also brought new conditions of use, frequently in austere settings. This pervasiveness of use combined with enthrallment of the devices into our lives and the expectations' growth brings usability and user experience to the front line. As a consequence it is paramount that design methods accompany this evolution, in order to aid designers during this demanding creation process.

Taking into account the strong differentiating factors that characterize mobile devices from traditional personal computing (e.g., desktop PCs), such as their ubiquitous use, usual small size, and mixed interaction modalities, designers are faced with additional challenges. In particular, two design stages show greater difficulties and are most emblematic of the new challenges faced by designers: the prototyping and evaluation of mobile design concepts and mobile interaction.

In face of these new found adversities, research has been gradually responding to these challenges. Several works have been emerging with different approaches. Some depart from traditional evaluation techniques. Others essay rupturing proposals and offer new means to capture and assess mobile usage experience. In general, most rely on prototype design and evaluation and on the acceptance of context as a fundamental cornerstone on the whole process.

This monograph presents an overview of the current state-of-the-art, addressing recent and emerging work that focuses several issues within the two stages of the design process. In particular, it describes research focusing on

(1) the understanding of context and scenarios to drive interaction design and evaluation. With the need to design and test mobile interaction within realistic environments, comes the need to select proper conditions, scenarios, and settings in which to focus on. Some research has been addressing this issue, providing new findings on how to frame concerns and characterize the settings and variables that define and affect mobile interaction;
(2) the updated prototyping techniques that field work requires, which are crucial in order to properly support trials at the very initial steps of conceptualization and design, also offering means to propel user engagement throughout the design process;
(3) the new evaluation techniques that mobile interaction design entails, which can be used in new scenarios and environments, where designers are, many times, required to be as mobile as

their designs and end users, conceiving new strategies and evaluation approaches for ubiquitous use,

Based on these research advances, future directions and trends will be mentioned and suggestions on additional research paths will also be drawn.

References

[1] M. Allen, J. McGrenere, and B. Purves, "The field evaluation of a mobile digital image communication application designed for people with aphasia," *ACM Transactions on Accessible Computing*, vol. 1, no. 1, Article 5, May 2008, ACM.

[2] J. Axup, N. J. Bidwell, and S. Viller, "Representation of self-reported information usage during mobile field studies: Pilots & Orienteers 2," OzCHI, Wollongong, Australia, 2004.

[3] Barnard, et al., "Capturing the effects of context on human performance in mobile computing systems," *Personal and Ubiquitous Computing*, vol. 11, no. 46, pp. 81–96, 2007.

[4] N. Bevan, "What is the difference between the purpose of usability and user experience evaluation methods?," UXEM'09 Workshop, INTERACT 2009, Uppsala, Sweden, 2009.

[5] H. Beyer and K. Holtzblatt, *Contextual Design: Customer Centered Approach to Systems Design*. San Francisco, CA, USA: Academic Press, 1998.

[6] S. Bodker and J. Buur, "The design collaboratorium — A place for usability design," *Transactions on Computer Human-Interaction*, vol. 9, no. 2, pp. 152–169, 2002, ACM.

[7] J. Brandt, N. Weiss, and S. R. Klemmer, "txt 4 l8r: Lowernig the burden for diary studies under mobile conditions," CHI 2007 Extended Abstracts, 2303–2308, San Jose, California, USA, ACM: April 28, May 3, 2007.

[8] C. Burns, E. Dishman, B. Verplank, and B. Lassiter, "Actors hair-dos and videotape: Informance design; using performance techniques in multi-disciplinary, observation based design," in *CHI94 Conference Companion 4/94*, Boston, MA, 1994, ACM.

[9] S. K. Card, T. P. Moran, and A. Newell, *The Psychology of Human-Computer Interaction*. Hillsdale, New Jersey: Erlbaum Associates, 1983.

[10] S. Carter and J. Mankoff, "When participants do the capturing: The role of media in diary studies," in *Proceedings of CHI 2005*, Portland, Oregon, USA: ACM, April 27 2005.

[11] S. Carter and J. Mankoff, "Prototypes in the wild: Lessons learned from evaluating three ubicomp systems," *IEEE Pervasive Computing*, vol. 4, pp. 51–57, 2005, IEEE.

[12] M. Chalmers and A. Galani, "Seamful interweaving: Heterogeneity in the theory and design of interactive systems," in *Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS '04*, pp. 243–252, New York, NY, USA: ACM, 2004.

[13] C. D. Chandler, G. Lo, and A. K. Sinha, "Multimodal theater: Extending low fidelity paper prototyping to multimodal applications," in *CHI2002 Extended Abstracts, CHI 2002*, Minneapolis, Minnesota, USA: ACM, 2002.

[14] C. Cheong, D.-C. Kim, and T.-D. Han, "Usability evaluation of designed image code interface for mobile computing environment," in *Proceedings of the 12th International Conference on Human–computer Interaction: Interaction Platforms and Techniques (HCI'07)*, (J. A. Jacko, ed.), pp. 241–251, Berlin, Heidelberg: Springer-Verlag, 2007.

[15] P. Cohen, C. Swindells, S. Oviatt, and A. Arthur, "A high-performance dual-wizard infrastructure for designing speech, pen, and multimodal interfaces," in *In Proceedings of the 10th International Conference on Multimodal Interfaces (ICMI '08)*, pp. 137–140, New York, NY, USA: ACM, 2008.

[16] B. Collignon, J. Vanderdonckt, and G. Calvary, "An intelligent editor for multi-presentation user interfaces," in *Proceedings of SAC08 — Symposium on Applied Computing*, Fortaleza, Ceara, Brazil: ACM, March 16–20 2008.

[17] K. H. Connelly, Y. Rogers, K. A. Siek, J. Jones, M. A. Kraus, S. M. Perkins, L. L. Trevino, and J. L. Welch, "Designing a PDA interface for dialysis patients to monitor diet in their everyday life," in *Proceedings of the 11th Human–Computer Interaction International Conference, HCII05*, Las Vegas, USA, 2005.

[18] S. Consolvo, I. E. Smith, T. Mathews, A. LaMarca, J. Tabert, and P. Powledge, "Location disclosure to social relations: Why, when and what people want to share," in *Proceedings of CHI 2005*, pp. 81–90, Portland, Oregon, USA: ACM, 2005.

[19] S. Consolvo and M. Walker, "Using the experience sampling method to evaluate ubicomp applications," *IEEE Pervasive Computing*, vol. 2, no. 2, pp. 24–31, 2003.

[20] A. Coyette, S. Kieffer, and J. Vanderdonckt, "Multi-fidelity prototyping of user interfaces," in *Procs. of INTERACT 2007*, pp. 150–164, LNCS 4662, Part I, IFIP, 2007.

[21] A. Coyette and J. Vanderdonckt, "A sketching tool for designing any user, any platform, anywhere user interfaces," in *Proceedings of INTERACT 2005*, pp. 550–564, LNCS 3585, IFIP, 2005.

[22] R. C. Davis, T. S. Saponas, M. Shilman, and J. A. Landay, "SketchWizard: Wizard of Oz prototyping of pen-based user interfaces," in *UIST '07: Proceedings of the 20th Annual ACM Symposium on User Interface Software and Technology*, pp. 119–128, Newport, Rhode Island, USA: ACM, 2007.

[23] M. de Sá and L. Carriço, "Low-fi prototyping for mobile devices," in *Proceedings of CHI'06* (Extended Abstracts), pp. 694–699, Montreal, Canada: ACM, 2006.

[24] M. de Sá and L. Carriço, "An evaluation framework for mobile user interfaces," in *Proceedings of INTERACT 2009, the 12th IFIP TC13 Conference in Human–Computer Interaction*, Uppsala, Sweden: Springer-Verlag, Lecture Notes in Computer Science, 2009.

[25] M. de Sá and L. Carriço, "A mobile tool for in-situ prototyping," in *Proceedings of MobileHCI09, the 11th International Conference on Human–Computer Interaction with Mobile Devices and Services*, Bonn, Germany: ACM Press, 2009.

[26] M. de Sá and L. Carriço, "Defining scenarios for mobile design and evaluation," in *Proceedings of CHI'08, SIGCHI Conference on Human Factors in Computing Systems* (Extended Abstracts), pp. 2847–2852, Florence, Italy: ACM Press, April 5–10 April 2008.

[27] M. de Sá and L. Carriço, "Lessons from early stages design of mobile applications," in *Proceedings of MobileHCI'08*, pp. 127–136, Amsterdam, Netherlands: ACM Press, September 2008.

[28] M. de Sá, L. Carriço, and P. Antunes, "Ubiquitous psychotherapy," *IEEE Pervasive Computing*, vol. 6, no. 1, no. 1, pp. 20–27, IEEE Press, 2007.

[29] M. de Sá, L. Carriço, and C. Duarte, *Mobile Interaction Design: Techniques for Early Stage In-Situ Design. Advances in Human-Computer Interaction,* Chapter 10. Vienna, Austria, EU: I-Tech Education and Publishing, October 2008, ISBN 978-953-7619-14-5.

[30] M. de Sá, L. Carriço, L. Duarte, and T. Reis, "A mixed-fidelity prototyping tool for mobile devices," in *Proceedings of AVI'08, International Working Conference on Advanced Visual Interfaces*, pp. 225–232, Napoli, Italy: ACM Press, 2008.

[31] M. de Sá, L. Carriço, L. Duarte, and T. Reis, "A framework for mobile evaluation," in *Proceedings of CHI'08, SIGCHI Conference on Human Factors in Computing Systems* (Extended Abstracts), pp. 2673–2678, Florence, Italy: ACM Press, April 05–10 April 2008.

[32] M. de Sá, C. Duarte, L. Carriço, and T. Reis, "Designing mobile multimodal applications," in *Multimodality in Mobile Computing and Mobile Devices: Methods for Adaptable Usability*, (S. Kurkovsky, ed.), pp. 106–136, IGI Global, November 2009.

[33] R. Demumieux and P. Losquin, "Gather customer's real usage on mobile phones," in *Proceedings of the 7th international conference on Human computer interaction with mobile devices and services (MobileHCI '05)*, pp. 267–270, New York, NY, USA: ACM, 2005.

[34] A. K. Dey, G. D. Abowd, and D. Salber, "Aconceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications," *Hum.-Comput. Interact*, vol. 16, no. 2, pp. 97–166, December 2001.

[35] A. Dix, J. Finlay, G. Abowd, and R. Beale, *Human–Computer Interaction*. Prentice Hall, 2nd ed., 1998.

[36] P. Dourish, "What we talk about when we talk about context," *Personal Ubiquitous Comput.*, vol. 8, pp. 19–30, February 2004.

[37] H. B.-L. Duh, G. C. B. Tan, and V. H. h. Chen, "Usability evaluation for mobile device: A comparison of laboratory and field tests," in *Mobile HCI'06*, Finland: ACM, 2006.

[38] L. Frishberg, "Presumptive design, or cutting the looking-glass cake," *Interactions*, vol. 8, no. 1, pp. 18–20, ACM, 2006.

[39] N. Frishberg, "Prototyping with junk," *Interactions*, vol. 8, no. 1, no. 1, pp. 21–23, ACM, 2006.

[40] J. Froehlich, M. Chen, I. Smith, and F. Potter, "Voting with your feet: An investigative study of the relationship between place visit behavior and preference," in *UbiComp 2006*, California, USA: Orange County, 2006.

[41] J. Froehlich et al., "Myexperience: A system for in situ tracing and capturing of user feedback on mobile phones," in *MobiSys'07*, pp. 57–70, ACM, 2007.

[42] P. Hagen et al., "Emerging research methods for understanding mobile technology use," in *Proceedings of OZCHI 2005*, Australia: Camberra, 2005.

[43] J. Halloran et al., "Unfolding understandings: Co-designing UbiComp in situ, over time," in *Proceedings of DIS 2006*, pp. 109–118, University Park, Pennsylvania, USA: ACM, June 26-28 2006.

[44] B. Hanington, "Interface in form: Paper and product prototyping for feedback and fun," *Interactions*, vol. 8, no. 1, pp. 28–30, ACM, 2006.

[45] B. Hartmann, S. Doorley, S. Kim, and P. Vora, "Wizard of Oz sketch animation for experience prototyping," in *Proceedings of Ubicomp*, 2006.

[46] R. H. Hegh, J. Kjeldskov, M. B. Skov, and J. Stage, "A field laboratory for evaluating in situ," in *Handbook of Research on User Interface Design and Evaluation for Mobile Technology*, (J. Lumsden, ed.), IGI Global, 2008.

[47] P. Holleis and A. Schmidt, "MakeIt: Integrate user interaction times in the design process of mobile applications," in *Proceedings of the 6th International Conference on Pervasive Computing* (Pervasive '08), (D. J. Patterson, T. Rodden, M. Ott, and J. Indulska, eds.), pp. 56–74, Berlin, Heidelberg: Springer-Verlag, 2009.

[48] L. E. Holmquist, "Generating ideas or cargo cult designs?," *Interactions*, vol. 7, no. 2, pp. 48–54, ACM, 2005.

[49] K. Holtzblatt, J. B. Wendell, and S. Wood, *Rapid Contextual Design: A How-To Guide to Key Techniques for User-Centered Design*. San Francisco, CA, USA: Morgan Kaufmann, 2005.

[50] S. Hulkko et al., "Mobile probes," in *NordiCHI'04*, ACM, 2004.

[51] K. A. Hummel, A. Hess, and T. Grill, "Environmental context sensing for usability evaluation in mobile hci by means of small wireless sensor networks," in *Proceedings of MoMM 2008*, Linz, Austria: ACM, November 24–26 2008.

[52] M. Isomursi, K. Kuutti, and S. Vainamo, "Experience clip: Method for user participation and evaluation of mobile concepts," in *Proceedings of Participatory Design Conference 2004*, Toronto, Canada: ACM, 2004.

[53] M. Jones and G. Marsden, *Mobile Interaction Design*. West Sussex, England: John Wiley & Sons Ltd, 2006.

[54] Y. Jung, P. Persson, and J. Blom, "DeDe: Design and evaluation of a context-enhanced mobile messaging system," in *Proceedings of CHI 2005*, pp. 351–360, Portland, Oregon, USA: ACM, April 27 2005.

[55] E. Kangas and T. Kinnunen, "Applying user-centered design to mobile application development," *Communications of the ACM*, vol. 48, pp. 55–59, 2005.

[56] C.-M. Karat, R. Campbell, and T. Fiegel, "Comparison of empirical testing and walkthrough methods in user interface evaluation," in *Proceedings of CHI'92*, pp. 397–404, Monterey, California, USA: ACM Press, 1992.

[57] A. K. Karlson and B. B. Bederson, "One-handed touchscreen input for legacy applications," in *Proceedings of CHI 2008*, pp. 1399–1408, Florence, Italy: ACM, April 5-10 2008.

[58] J. F. Kelley, "An iterative design methodology for user-friendly natural language office information applications," *Transactions on Office Information Systems*, vol. 2, no. 1, no. 1, pp. 26–41, ACM, 1984.

[59] J. Kjeldskov and C. Graham, "A review of mobile HCI research methods," in *Mobile HCI'03*, vol. 2795/2003, pp. 317–335, Berlin/Heidelberg: Springer, 2003.

[60] J. Kjeldskov, M. B. Skov, B. S. Als, and R. T. Hegh, "Is it worth the hassle? Exploring the added value of evaluating the usability of context-aware mobile systems in the field," in *Proceedings of 6th International Symposium on Mobile Human-Computer Interaction (MobileHCI'04)*, pp. 61–73, Glasgow, Scotland, September 13–16 2004.

[61] J. Kjeldskov and J. Stage, "New techniques for usability evaluation of mobile systems," *International Journal of Human Computer Studies*, Elsevier, 2003.

[62] S. R. Klemmer, A. K. Sinha, J. Chen, J. A. Landay, N. Aboobaker, and A. Wang, "Suede: A Wizard of Oz prototyping tool for speech user interfaces," in *UIST '00: Proceedings of the 13th Annual ACM Symposium on User Interface Software and Technology*, pp. 1–10, San Diego, California, United States: ACM, 2000.

[63] M. Kraub and D. Krannich, "ripcord: Rapid interface prototyping for cordless devices," in *In MobileHCI'06*, pp. 187–190, Helsinki, Finland: ACM Press, 2006.

[64] J. A. Landay, "Interactive sketching for the early stages of user interface design," Phd Thesis, School of Computer Science, Computer Science Division, Carnegie Mellon University, Pittsburgh, PA, 1996.

[65] S. Lemmela, A. Vetek, K. Makela, and D. Trendafilov, "Designing and evaluation multimodal interaction for mobile contexts," in *ICMI08*, pp. 265–272, Chania, Crete, Greece: ACM, October 20-22 2008.

[66] Y. Li, J. I. Hong, and J. A. Landay, "Topiary: A tool for prototyping location-enhanced applications," in *In Proceedings of UIST'04*, Santa Fe, New Mexico, USA, October 24–27 2004.

[67] Y. Li and J. A. Landay, "Activity-based prototyping of ubicomp applications for long-lived, everyday human activities," in *Proceedings of CHI 2008*, Florence, Italy: ACM, April 5-10 2008.

[68] Y.-K. Lim, A. Pangam, S. Periyasami, and S. Aneja, "Comparative analysis of high and low-fidelity prototypes for more valid usability evaluations of mobile

devices," in *Proceedings of NordiCHI'06: Changing Roles*, pp. 291–300, Oslo, Norway: ACM, 2006.

[69] J. Lin, "Damask: A tool for early-stage design and prototyping of cross-device user interfaces," in *Proceedings of Symposium on User Interface Software and Technology, UIST 2003*, Vancouver, Canada: ACM, 2003.

[70] J. Lin and J. A. Landay, "Damask: A tool for early-stage design and prototyping of multi-device user interfaces," in *Proceedings of The 8th International Conference on Distributed Multimedia Systems*, pp. 573–580, 2002 International Workshop on Visual Computing, ACM Press, 2002.

[71] J. Lin, M. W. Newman, J. I. Hong, and J. A. Landay, "DENIM: Finding a tighter fit between tools and practice for Web site design," in *CHI '00: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 510–517, The Hague, The Netherlands: ACM, 2000.

[72] J. Lin, M. Thomsen, and J. A. Landay, "A visual language for sketching large and complex interactive designs," in *Proceedings of CHI 2002*, pp. 307–314, Minneapolis, Minnesota, USA, April 20–25 2002.

[73] A. L. Liu and Y. Li, "BrickRoad: A light-weight tool for spontaneous design of location-enhanced applications," in *Proceedings of CHI 2007*, pp. 295–298, San Jose, California, USA: ACM, April 28-May 3 2007.

[74] L. Liu and P. Khooshabeh, "Paper or interactive?: a study of prototyping techniques for ubiquitous computing environments," in *CHI 03 Extended Abstracts*, pp. 1030–1031, ACM, 2003.

[75] N. Liu, Y. Liu, L. Liu, and X. Wang, "User experience evaluation of post-traumatic mobile service: A case study," in *Proceedings of Mobility 2009*, Nice, France: ACM, September 2–4 2009.

[76] K. Lukander, "Measuring gaze point on handheld mobile devices," in *Extended Abstracts of CHI2004*, Vienna, Austria: ACM, 2004.

[77] J. Lumsden and R. MacLean, "A comparison of pseudo-paper and paper prototyping methods for mobile evaluations," in *Proceedings of the International Workshop on Mobile and Networking Technologies for Social Applications (MONET'2008)*, pp. 538–457, Monterrey, Mexico: part of the LNCS On The Move (OTM) Federated Conferences and Workshops, November 4 2008.

[78] K. Lyons and T. Starner, "Mobile capture for wearable computer usability testing," in *Proceddings of Proceedings of the 5th IEEE International Symposium on Wearable Computers*, Zurich, Switzerland: IEEE Press, 2001.

[79] D. J. Mayhew, *The Usability Engineering Lifecycle*. San Francisco, CA, USA: Morgan Kaufmann, 1999.

[80] M. McCurdy, C. Connors, G. Pyrzak, B. Kanefsky, and A. Vera, "Breaking the fidelity barrier: An examination of our current characterization of prototypes and an example of a mixed-fidelity success," in *Proceedings of CHI 2006*, pp. 1233–1242, Montreal, Quebec, Canada: ACM, 2006.

[81] R. Molich, M. R. Ede, K. Kaasgaard, and B. Karyukin, "Comparative usability evaluation," *Behaviour and Information Technology, Taylor and Francis*, vol. 23, no. 1, pp. 65–74, 2004.

[82] R. Molich, A. D. Thomsen, B. Karyukina, L. Schmidt, M. Ede, W. van Oel, and M. Arcuri, "Comparative evaluation of usability tests," in *CHI'99*, pp. 83–84, Pittsburgh, Pennsylvania, USA: ACM Press, 1999.

[83] Y. Nakhimovsky, D. Eckles, and J. Riegelsberger, "Mobile user experience research: Challenges, methods & tools," in *CHI 2009 Extended Abstracts*, pp. 4795–4798, Boston Massachusetts, USA: ACM, April 4–9 2009.

[84] J. Nielsen, *Usability Engineering*. Los Altos, California: Morgan Kaufmann, 1993.

[85] J. Nielsen and V. L. Phillips, "estimating the relative usability of two interfaces: Heuristic, formal, and empirical methods compared," in *Interchi'93*, pp. 214–221, Amsterdam, The Netherlands: Addison-Wesley, 1993.

[86] C. M. Nielsen et al., "It's worth the hassle! the added value of evaluating the usability of mobile systems in the field," in *NordiCHI'06*, ACM, 2006.

[87] A. Oulasvirta, E. Kurvinen, and T. Kankainen, "Understanding context by being there: Case studies in bodystorming," *Personal and Ubiquitous Computing*, vol. 7, pp. 125–134, 2003, Springer-Verlag.

[88] A. Oulasvirta and T. Nyyssonen, "Flexible hardware configurations for studying mobile usability," *Journal of Usability Studies*, 2009.

[89] A. Oulasvirta, S. Tamminen, and K. Höök, "Comparing two approaches to context: Realism and constructivism," in *Proceedings of the 4th Decennial Conference on Critical Computing: Between Sense and Sensibility*, Aarhus, Denmark: ACM, August 20–24 2005.

[90] L. Palen and M. Salzman, "Voice-mail diary studies for naturalistic data capture under mobile conditions," in *Proceedings of CSCW02*, New Orleans, Louisiana, USA: ACM, November 16-20 2002.

[91] D. Patel, G. Marsden, M. Jones, and S. Jones, "An evaluation of techniques for image searching and browsing on mobile devices," in *Proceedings of SAICSIT09*, pp. 60–69, Riverside, Vanderbijlpark, South Africa: ACM, October 12–14 2009.

[92] T. Pering, "Evaluating the privacy of using mobile devices to interact in public places," in *Permid 2006, Workshop at Pervasive 2006*, Dublin, Ireland, 2006.

[93] H. Petrie and N. Bevan, "The evaluation of accessibility, usability and user experience," in *The Universal Access Handbook*, (C. Stepanidis, ed.), CRC Press, 2009.

[94] J. Preece, *Human Computer Interaction*. Addison Wesley, 1994.

[95] S. Pyykko and M. Hannuksela, "Does context matter in quality evaluation of mobile television?," in *Proceedings of MobileHCI 2008*, pp. 63–72, Amsterdam, The Netherlands: ACM, September 2-5 2008.

[96] P. Reichl, P. Frohlich, L. Baillie, R. Schatz, and A. Dantcheva, "The LiLiPUT prototype: A wearable lab environment for user tests of mobile telecommunication applications," in *CHI 2007 Extended Abstracts*, pp. 1833–1838, San Jose, California, USA: ACM, April 28-May 3 2007.

[97] T. Reis, M. de Sá, and L. Carriço, "Multimodal artefact manipulation: Evaluation in real contexts," in *Proceedings of ICPCA'08, 3rd International Conference on Pervasive Computing and Applications*, pp. 570–575, Alexandria, Egypt: IEEE Press, October 06–08 2008.

[98] Y. Rogers et al., "Why it's worth the hassle: The value of in-situ studies when designing ubicomp," in *Ubicomp 2007*, Innsbruck, Austria: ACM, September 2007.

[99] D. Rosenberg, "Revisiting tangible speculation: 20 years of UI prototyping," *Interactions*, vol. 8, no. 1, pp. 31–32, ACM, 2006.

[100] J. Rubin, *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests*. New York: Wiley, 1994.

[101] E. Rukzio, A. Pleuss, and L. Terrenghi, "The physical user interface profile (PUIP): Modelling mobile interactions with the real world," in *Proceedings of TAMODIA'05 — Tasks Models and Diagrams for UI Design 2005*, pp. 95–102, Gdansk, Poland: ACM, 2005.

[102] S. Carter et al., "Momento: Support for situated ubicomp experimentation," in *CHI'07*, pp. 125–134, ACM, 2007.

[103] A. Salovaara and A. O. G. Jacucci, "The panopticon: A method for observing inter-group interactions," in *CHI2006 Extended Abstracts*, Monteral, Canada: ACM, April 22–27 2006.

[104] N. Savio and J. Braiterman, "Design sketch: The context of mobile interaction," in *Proceedings of MobileHCI 2007*, Singapore: ACM, September 2007.

[105] J. Scholtz and S. Consolvo, "Toward a framework for evaluating ubiquitous computing applications," *IEEE Pervasive Computing*, vol. 2, pp. 82–86, 2004.

[106] B. Shneiderman and C. Plaisant, "Multi-dimensional in-depth long-term case studies," in *Proceedings of BELIV 2006 Venice*, Italy: ACM, 2006.

[107] B. Shneiderman, C. Plaisant, M. Cohen, and S. Jacobs, *Designing the User Interface: Strategies for Effective Human–Computer Interaction*. Addison Wesley, 5th ed., 2009.

[108] T. Sohn, K. A. Li, W. G. Griswold, and J. D. Hollan, "A diary study of mobile information needs," in *CHI '08: Proceeding of the Twenty-sixth Annual SIGCHI Conference on Human Factors in Computing Systems*, pp. 433–442, New York, NY, USA: ACM, 2008.

[109] P. J. Stappers, "Creative connections: User, designer, context, and tools," *Personal and Ubiquitous Computing*, vol. 8, pp. 95–100, 2006, Springer-Verlag.

[110] H. Stromberg, V. Pirttila, and V. Ikonen, "Interactive scenariosbuilding ubiquitous computing concepts in the spirit of participatory design," *Personal and Ubiquitous Computing*, vol. 8, pp. 200–207, 2004, Springer-Verlag.

[111] D. Svanaes and G. Seland, "Putting the users center stage: Role playing and low-fi prototyping enable end users to design mobile systems," in *CHI'04*, Vienna, Austria: ACM, 2004.

[112] S. Tamminen, A. Oulasvirta, K. Toiskallio, and A. Kankainen, "Understanding mobile contexts," *Personal and Ubiquitous Computing*, vol. 8, pp. 135–143, 2004, Springer-Verlag.

[113] H. ter Hofte, K. L. Jensen, P. Nurmi, and J. Froehlich, "Mobile living labs 09: Methods and tools for evaluation in the wild," in *Proceedings of MobileHCI 2009*, Bonn, Germany: ACM, September 15–18 2009.

[114] K. E. Thompson, E. P. Rozanski, and A. R. Haake, "Here, there, anywhere: Remote usability testing that works," in *Proceedings of SIGITE'04*, Salt Lake City, Utah, USA: ACM, 2004.

[115] H. Vaataja, "Factors affecting user experience in mobile systems and services," in *Proceedings of MobileHCI 2008*, Amsterdam, The Netherlands: ACM, September 2-5 2008.

[116] H. Vaataja and V. Roto, "Mobile questionnaires for user experience evaluation," in *CHI 2010 Extended Abstracts*, pp. 3361–3366, Atlanta, Georgia, USA, April 10-15 2010.

[117] R. A. Virzi, J. L. Sokolov, and D. Karis, "Usability problem identification using both low- and high-fidelity prototypes," in *Proceedings of CHI 1996*, Vancouver, Canada: ACM, 1996.

[118] S. Waterson and J. A. Landay, "In the lab and out in the wild: Remote web usability testing for mobile devices," in *Proceedings of CHI 2002*, pp. 796–797, Minneapolis, Minnesota, USA: ACM, April 20–25 2002.

[119] S. Weiss, *Handheld Usability*. England: Wiley & Sons, 2002.

[120] J. Williamson, S. Robinson, C. Stewart, M. Murray, R. Smith, M. Jones, and S. Brewster, "Social gravity: A virtual elastic tether for casual, privacy-preserving pedestrian rendezvous," in *Proceedings of the 28th International Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA, April 10-15, 2010), CHI '10, pp. 1485–1494, New York, NY: ACM, 2010.

[121] A. U.-H. Yasar, "Enhancing experience prototyping by the help of mixed-fidelity prototypes," in *Proceedings of the 4th International Conference on Mobile Technology, Applications, and Systems and the 1st International Symposium on Computer Human Interaction in Mobile Technology (Mobility '07)*, pp. 468–473, New York, NY, USA: ACM, 2007.

[122] K. Yatani and K. N. Truong, "An evaluation of stylus-based text entry methods on hand held devices in stationary and mobile settings," in *Proceedings of Mobile HCI'07*, pp. 487–494, Singapore: ACM, September 9–12 2007.