Evaluating the Usability on Multimodal Interfaces: A Case Study on Tablets Applications

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Abstract. Usability has become the main quality attribute on the development of digital devices. Meanwhile, the new interaction paradigms represent a great challenge for usability. Traditional methods for usability evaluation may not be appropriated to the nature of these new interaction models. This paper introduces a new set of usability heuristics for multimodal paradigm, specially multitouch and speech-based interaction. We analyzed traditional usability heuristics, characteristics of multitouch and speech-based interaction, and guidelines for developers, aiming to reach a satisfactory result. A comparative case study between our proposal and Nielsen's heuristics is then conducted.

Keywords: usability heuristics, new usability, multimodal interaction.

1 Introduction

Usability has become a relevant topic in the literature of human-computer interaction. The ISO/IEC standard defines usability as the capability that an interactive system offers the users, allowing them to perform tasks effectively, efficiently and satisfactorily, in a specified context of use. Currently, evaluating usability can be considered a key point of user-centered technologies [1]. In general, there are two methods of usability evaluation: user tests and inspection. User tests are powerful methods to identify usability problems, but they can be very expensive and time-consuming because it requires collecting users to testing application in specified physical places [2]. Heuristic evaluation is a method of usability inspection often used because it is performed by experts, which makes it cheaper, easy to be executed and able to find many usability problems. By this method, expert evaluators systematically inspect and evaluate a user interface according to usability principles or heuristics [2-4]. Usability inspections are well documented and many publications describe their use and methods. Meanwhile, most of them focus on traditional interaction paradigms, such as WIMP (Windows, Icons, Menus and Pointers). However, there are many others interaction styles, which possess very different characteristics when compared with traditional paradigms. Some new interaction paradigms are already present for many people. Devices such as computer tablets have multitouch and speech-based interaction, i.e. a multimodal interaction. According to IDC (International Data Corporation), the number of tablets sold in

A. Marcus (Ed.): DUXU 2014, Part I, LNCS 8517, pp. 484–495, 2014.

2013 must overcome desktops (growth of 48,7% compared to a decline of 4,3%, respectively). These devices have a relatively new interaction style, and hence, a great challenge to traditional usability methods [5].Therefore, designers and developers will probably adapt the traditional usability literature to create ad hoc methods, many of which are incompatible and incoherent. Thus, it is extremely important to review whether conventional methods of usability evaluation possess a satisfactory and consistent performance for this emerging scenario, and also investigate ways to contribute to a new usability [6]. In this paper, we introduce a new set of heuristics for multimodal interaction focused on tablet applications. In the next section we show concepts of multimodal paradigm. Then, we describe the process that we used to develop the heuristics. We analyse traditional usability heuristics, characteristics of multitouch and speech interaction, and guidelines for developers, aiming to reach a satisfactorily result. Finally, we compare the new set generated with Nielsen's Heuristics in a case study.

2 Multimodal Interaction

Multimodal interactions refer to a combination of inputs and outputs of several sensory modalities (hearing, smell, taste, touch, sight) as part of a more natural computer communication. We can have, for example, inputs and/or outputs via voice, exploring our sensory variety in parallel or sequentially, as part of an interaction that promotes complementary or redundant information to the user [7-10]. Just recently, multimodal interaction systems have gained a maturity level that allows them to be widely applied. However, there is no specific model or interaction style for an appropriate integration among different emerging modalities. Multimodal interfaces still represent a big challenge in technical and human factors terms, which can affect the traditional usability concepts [10-12].

Nevertheless, there are many opportunities to be explored. Multimodal platforms have potential to create powerful user interfaces and channels of interaction. The use of different modalities can demand less cognitive load from the user as well as bring a better recognition performance and interpretation of inputs by the system. In the same way, information provided from the system can be better adapted for people and the context of use whether several outputs are available. The development of multimodal platforms has provided this, mainly by combining the use of multitouch gestures and speech [11-14]. Multitouch technologies allow people to experience more freedom within a simpler and more coherent way of interaction. This interaction provides richer inputs from users into interactive system when compared with single-touch interfaces. However, in spite of its capacity to bring a fuller interaction control, designing gesture-based intuitive interfaces for complex systems is more difficult [15, 16]. According to Norman, gestures are not natural. Cultural factors can hinder the understanding of certain gestures in different places in the world. Thus, gesture-based interfaces require feedbacks and these are only possible with elements of conventional interfaces, such as menus, popups, tutorials and other forms of feedback from Graphical User Interfaces (GUI) [17]. However, this statement only reinforces that this type of interaction is converging to multimodal nature. According to Pfleging, users do not have great difficulties in controlling commands with gestures. Actually, they have a high concordance of movements between them [11]. This, combined with other types of interaction such as speech-based, can enhance the user experience. Speech recognition transforms spoken words from users to readable inputs for machines. These inputs allow systems to identify what people are talking and convert the spoken words from users into commands, and then produce outputs which can also be spoken [14]. Though there are still many challenges with regard to the efficient use of this modality, speech interactions can reduce the amount of interaction time when compared to others mechanisms, allowing people to focus on primary tasks. Other advantages of using speech include reduced learning time (because it is a natural method of communication) and, consequently, increased work productivity [14, 18, 19].

3 Compiling Usability Heuristics for Multimodal Interaction

To reach the new set of multimodal heuristics, we followed a similar method proposed by Rusu [20]. We have gathered some traditional usability heuristics from the usual literature, characteristics of multitouch and speech-based interaction, and some guidelines for developers. The following steps were conducted:

- Step 1: an heuristics review was done from the literature;
- Step 2: characteristics of multitouch and speech interaction were surveyed;
- Step 3: guidelines for developers from iOS, Android and Microsoft Surface documentation were examined;
- Step 4: a crossing between them was performed and the new set of heuristics was compiled.

These steps made it possible to understand this scenario and the current relationship between the new paradigm and conventional usability heuristics. After the last step, a case study with expert evaluators is executed, comparing our proposal with a traditional set of heuristics.

3.1 Step 1 – Heuristic Review

At first, a critical review of the most usual heuristics was performed. For this, we have listed three traditional sets of heuristics from the traditional literature, which are: Nielsen's Heuristics, Norman's Principles of Usability, and the 8 main Ergonomic Criteria by Bastien and Scapin (table 1) [21-23]. With the heuristics at hand, we could note that Nielsen’s heuristics included the others into their criteria. That indicates its generic nature and how it can be considered sufficient when compared with the conventional literature. Because of this, we will take Nielsen’s heuristics as a starting point to generate new heuristics.

Table 1. Some traditional usability heuristics

Nielsen's Heuristics	Norman's Principles	Ergonomic Criteria by Bastien and Scapin
Visibility of system status	Use both knowledge in the world and knowledge in the head.	Guidance
Match between system and the real world	Simplify the structure of tasks	Workload
Consistency and standards	Get the mappings right	Adaptability
Error prevention	Exploit the power of constraints, both natural and artificial	Error management
Recognition rather than recall	Design for error	Consistency
Flexibility and efficiency of use	When all else fails, standardize.	Significance of codes
Aesthetic and minimalist design		Compatibility
Help users recognize, diagnose, and recover from errors		
Help and Documentation		

3.2 Step 2 – Characteristics of Multitouch and Speech Interaction

In general, multi-touch gestures-based devices – such as cell phones, tablets and tabletops – have common shared characteristics that make it possible for them to be included in the same category. However, they can differ in some aspects. Mobile devices can be categorized by their reduced screen size, processing power and limited memory, and because their buttons possess more than one functionality. Others characteristics in relation to user interaction are: used mainly with hands, wireless, support to internet connection and possibility of adding new application [24, 25]. Considering this scenario, Inostroza and collaborators proposed a set of heuristics focused on touchscreen-based mobile devices. The study focus mainly on touch-based phones and it is based on Nielsen's heuristics. The heuristics are: (1) visibility of system status; (2) match between system and the real world; (3) user control and freedom; (4) consistency and standards; (5) error prevention; (6) minimize the user's memory load; (7) customization and shortcuts; (8) aesthetic and minimalist design; (9) help users recognize, diagnose and recover from errors; (10) help and documentation; and (11) physical interaction and ergonomics [26]. Apted and collaborators exposed specific characteristics of tabletops: collaborative interaction, context of use, orientation, tabletop size, human reach, use of table area, clutter and limited inputs. The authors conduct an extension of the guidelines proposed by Stedmon and collaborators, resulting in a set of heuristics for interaction evaluation on tabletops: (1) design independently of table size; (2) support reorientation; (3) use large selection points; (4) minimize human reach; (5) use large selection points; (6) manage interface clutter; (7) use table space efficiently; and (8) support private and group interaction [27]. Multitouch-based devices as tablets are a midway between mobile devices and tabletops. Thus, it is critical to consider these three classes when generating heuristics for a larger class of multitouch-based interfaces. We reached for the general characteristics of multitouch interaction: (1) Gestures-based interaction; (2) Context of use is important; (3) Orientation can change; (4) Human range can be considered; (5) Use of screen area; (6) Content can be organized; (7) Limited inputs; (8) Reduced processing power and memory; (9) Connectivity; (10) Expandability; (11) Possibility of collaborative interaction.

Speech-Based Interaction. Robbe proposed a study of speech and gesture interaction for general public. According to the author, linguistics constraints can be easily assimilated by users in a multimodal environment since they do not generate restrictions on semantic expressions of the users, which may lead to side effects from users [28]. In a later study, Robbe and collaborators noticed that the users understood the linguistic limitations that they should fulfill progressively when they interacted with a multimodal environment. Another result showed that the restrictions did not reduce significantly the efficiency of the interaction, but they could be interfered in multimodal interaction [29].According to Stedmon and collaborators, people use shorter commands and without relative terms when they are confronted with a machine, because they think that it is not capable to understand complex inputs. This can take more time when compared to a human-human interaction, since users ended up repeating commands to complete the task. Another study conducted by the same authors shows that, in spite of people generally using longer and more complex speeches in human-human interaction, the time used to perform tasks and the number of commands are shorter. As a result of this study, we can take the following criteria: (1) more generic and general vocabulary; (2) speech for simpler and direct tasks; and (3) speech should be an alternative input [30]. This way, we note that speech restrictions do not interfere with the efficiency of the interaction. However, a more generic and freer vocabulary can be more appropriate for a multimodal interaction. It also suggests that speech can be offered along with other input methods, allowing more flexibility to users and enhancing a multimodal interaction nature.

3.3 Step 3 – Guidelines from Developer Documentations

Because of the recent nature of multimodal paradigm, collecting data from developer documentations can be considered a good way of analyzing multitouch and speech-based models. This way, we have collected the main guidelines for designing and developing of multitouch devices, such as smartphones, tablets, and tabletops. It is important to remember that these devices also have speech-based interaction. Thus, we gathered guidelines from Android, iOS and Microsoft Surface documentations. We called each guideline as follow (table 2) [31-33]: These criteria will guide us when making a correlation between traditional heuristics and multitouch and speech interactions in the next step.

Table 2. Design and interaction guidelines for developers, divided by initials and colors

Android Guidelines	iOS Guidelines	Microsoft Surface Guidelines
Android Design Principles (ADP)	iOS Design Principles (IDP)	Surface Design Principles (SDP)
	iOS Interaction Guidelines (IIG)	Surface Interaction Design Guidelines (SID)
		Surface Visual & Motion Design Guidelines (SVMD)
		Surface Sound Design Guidelines (SSD)
		Surface Language & Text Design Guidelines (SLTD)
		Surface Input Methods (SIM)

3.4 Step 4 – Compiling Usability Heuristics for Multimodal Interaction

In this step, we crossed the developer guidelines gathered with Nielsen's heuristics and the characteristics surveyed, and then we compared the result in order to generate new heuristics for multimodal interaction. We have the first crossing in table 3.

Table 3. Crossing between Nielsen's Heuristics and Developer Guidelines

Nielsen's Heuristics (NH)	Developer Guidelines
NH1	ADP1, ADP9, ADP15, IDP4, IIG4, IIG12, IIG20, SDP5, SPI4, SPI6, SVMD8
NH2	IDP1, IDP5, IIG6, IIG16, SDP3, SVMD3, SSD2, SSD3
NH3	ADP7, IDP6, IDP4
NH4	ADP11, ADP13, IDP2, IDP6, IIG5, IIG15, IIG21, IIG27, SSD4
NH5	IIG26
NH6	ADP4, ADP10, ADP16, IIG5, IIG7, IIG8, IIG22, IIG24, IIG25, SIM2
NH7	ADP3, ADP15, SID1, SID3, SIM2
NH8	ADP5, ADP6, ADP8, ADP12, ADP17, IIG1, IIG2, IIG3, IIG5, IIG14, IIG17, IIG23, IIG28, IIG29, IIG30, SDP1, SDP2, SVMD4, SVMD5, SVMD6, SVMD7, SSD1, SLTD
NH9	ADP7, IIG26
NH10	

In table 4, we did a combination, crossing the developer guidelines with the characteristics raised in Step 2. When we look at these crossing, we can observe that two of Nielsen's heuristics were not filled by any developer's guideline. At the same time, some guidelines were not put into any these heuristics, which can mean there are specific elements that traditional usability heuristics cannot cover. Some of these developer guidelines were placed in the tablet 4 and others filled both crossings. That suggests a combination and complementation between both analyses. This way, table 5 shows which elements were filled by developer guidelines and tablet 6 shows the correlation between them.

As a result of the analyses above, we compiled a new set of heuristics for multimodal interaction: (1) Visibility and feedback; (2) Compatibility; (3) Control and freedom; (4) Consistency; (5) Error prevention; (6) Minimum actions; (7) Flexibility of use; (8) Organized content; (9) Error management; (10) Direct manipulation; (11) Changes of orientation; and (12) Human range. In order to validate the set of heuristics for multimodal interaction proposed, in the next section we performed a case study comparing it with Nielsen's heuristics.

Table 4. Crossing between Characteristics of Multitouch and Speech Interaction and developer guidelines

Characteristics of Multitouch Interaction	Developer Guidelines
Gestures-based interaction	ADP02, IDP3, IIG21, SID2, SIM1
Context of use is important	
Orientation can change	IIG18, SVMD1
Human range can be considered	IIG19, SIM1
Use of screen area	
Content can be organized	ADP17, IIG1, IIG2, IIG3, IIG10, IIG14, IIG23, IIG28, IIG29, IIG30, IIG31, SDP2, SDP4, SID5, SVMD2
Limited inputs	IIG7, SIM2
Reduced processing power and memory	
Connectivity	ADP10, IIG9, SIM2
Expandability	
Possibility of collaborative interaction	SID1
Characteristics of Speech Interaction	**Developer Guidelines**
More generic and general vocabulary	IIG6
Speech for simpler and direct tasks	SSD1
Speech should be a input alternative	IDP4

Table 5. Heuristics and characteristics filled by guidelines

Nielsen's Heuristics	Multitouch characteristics	Speech Characteristics
NH1	Gestures-based interaction	More generic and general vocabulary
NH2	Orientation can change	
NH3	Human range can be considered	Speech for simpler and direct tasks
NH4	Content can be organized	
NH5	Limited inputs	Speech should be an input alternative
NH6	Connectivity	
NH7	Possibility of collaborative interaction	
NH8		
NH9		

Table 6. Correlation between Nielsen's heuristics and multitouch/speech characteristics

Nielsen's Heuristics	Multitouch characteristics	Speech Characteristics
Visibility of system status		Speech should be an alternative input
Match between system and the real world		More generic and general vocabulary
Recognition rather than recall	Limited inputs, Connectivity	
Flexibility and efficiency of use	Possibility of collaborative interaction	
Aesthetic and minimalist design	Content can be organized	Speech for simpler and direct tasks

4 Case Study

We conducted a case study comparing the new set of usability heuristics focused on multimodal interaction and the Nielsen's heuristics. The goal of that comparison is to verify whether a traditional method of usability inspection is appropriate to this contemporary paradigm and whether specific heuristics are more adequate (table 7).

Table 7. Nielsen's and multimodal heuristics

Nielsen's Heuristics (NH)	Multimodal Heuristics (MH)
NH1-Visibility of system status	MH1-Visibility and feedback
NH2-Match between system and the real world	MH2-Compatibility
NH3-User control and freedom	MH3-Control and freedom
NH4-Consistency and standards	MH4-Consistency
NH5-Error prevention	MH5-Error prevention
NH6-Recognition rather than recall	MH6-Minimum actions
NH7-Flexibility and efficiency of use	MH7-Flexibility of use
NH8-Aesthetic and minimalist design	MH8-Organized content
NH9-Help users recognize, diagnose, and recover from errors	MH9-Error management
NH10-Help and Documentation	MH10-Direct manipulation
	MH11-Changes of orientation
	MH12-Human range

To this end, 12 designers divided into 3 groups performed heuristic evaluations on three tablet applications. The device used was an Acer Iconia B1 tablet, which runs Android OS 4.1, and the following applications were evaluated: Google (4.2.122 version), Facebook (1.2.336 version) and UOL News (2.3.1 version). The groups were divided as follows: MH Group – used multimodal heuristics; NH – used Nielsen's heuristics; and a control group (CG) – that worked freely. Before each evaluation, a set of heuristics to be used was explained as well as the scenario of each application. Each evaluator found usability failures individually. After that, they classified each failure according to the violated heuristic, and then they attributed a degree of severity using a scale from 0 to 4. The set of usability heuristics for multimodal interaction has more criteria than Nielsen's. That probably occurs because there are specific interaction elements in this paradigm. However, most of these (MH1 to MH9) have some equivalence to Nielsen's heuristics and can be considered an extension of these, being better adapted to the use context of multimodal interfaces.

4.1 Results

A total of 123 problems were found in all three applications by the 12 evaluators. The majority of problems were identified by the group that used multimodal heuristics, who also attributed a higher average severity. We can divide them all as follow:

- 13 problems found by both groups (10,57%);
- 25 problems found by MH and NH (20,33%);
- 26 problems found by MH and CG (21,14%);
- 14 problems found by NH and CG (11,38%);
- 55 problems found only by MH (44,72%);
- 19 problems found only by NH (15,45%);
- 12 problems found only by CG (8,94%).

Table 8 shows the numbers of problems divided by heuristics and their average severity.

Table 8. Number of problems divided by heuristics

MG Group			NG Group			CC
Heuristics	Number of problems	Average severity	Heuristics	Number of problems	Average severity	
MH1	12	2,13	NH1	13	1,62	
MH2	11	2,45	NH2	6	1	
MH3	6	3	NH3	10	1,5	
MH4	7	2,14	NH4	3	0,67	
MH5	1	4	NH5	6	2	
MH6	9	2,33	NH6	1	2	
MH7	2	2	NH7	3	1,33	
MH8	29	2,66	NH8	1	1	
MH10	8	2,52	NH10	2	3	
MH11	3	2,75				
MH12	4	3,63				
Total	92		Total	45		38
Average severity		2,55	Average severity		1,53	2,19

Besides finding more problems, the MH group attributed a higher average severity in its evaluation (2,55 compared to 1,53 from NH group, that used Nielsen's and 2,19 from control group – CC). Table 9 shows only the number of problems and average severity in equivalent heuristics between MH and NG groups. Nevertheless, we still have a total of 113 problems found and most of them were still found by MH group.

The severity average from MH group decreases in this case (2,49 compared to 2,55), but it still higher than others groups. This supposed superiority might have occurred because the set of heuristics used by MH group is better adapted for the interaction paradigm in question.

In relation to the problems found only by NG group, they were categorized in the following heuristics: *NH1-Visibility of system status* (7 problems), *NH2-Match between system and the real world* (3 problems), *NH3-User control and freedom* (4 problems), *NH5-Error prevention* (3 problems), *NH7-Flexibility and efficiency of use (*2 problems), and *NH10-Help and Documentation* (2 problems). Only *NH10-Help and Documentation* has no any equivalent heuristic in multimodal set. Nonetheless, in the multimodal heuristic *MH8-Organized content* are mentioned help solutions through tutorial layers on the interface. Thus, it is likely that evaluators from MH group have ignored these problems found only by NH group.

Table 9. Number of problems divided by equivalent heuristics

MG Group			NG Group			CC
Heuristics	Number of problems	Average severity	Heuristics	Number of problems	Average severity	
MH1	12	2,13	NH1	13	1,62	
MH2	11	2,45	NH2	6	1	
MH3	6	3	NH3	10	1,5	
MH4	7	2,14	NH4	3	0,67	
MH5	1	4	NH5	6	2	
MH6	9	2,33	NH6	1	2	
MH7	2	2	NH7	3	1,33	
MH8	29	2,66	NH8	1	1	
			NH10	2	3	
Total	77		Total	45		38
Average severity		2,49	Average severity		1,53	2,19

5 Conclusions

Usability on digital devices has become an essential tool in developing new products and systems in recent decades. It is often cited as a success factor and a useful differential in the market. However, there are many challenges when traditional usability methods are confronted with new interaction paradigms. This paper presents a contribution for a new usability through a new set of usability heuristics for multimodal interaction focused on multitouch and speech. These heuristics have had a better performance when compared to a traditional set of heuristics on tablets applications. As conclusions from the case study we can emphasize:

- The use of more and better-adapted heuristics in the use context of multimodal paradigm has better performance;
- The new set of heuristics are still more adequate when only compared to equivalent heuristics to the Nielsen's;
- The NH group has not had a significant result when compared with the CC group.

It is possible that the lack of significant differences between the use of any usability criteria and Nielsen's heuristics occurs because the latter are widely known by most professionals and academicians in the area. Whereas the better performance of the set of multimodal heuristics probably occurs because there are substantial differences between a traditional interaction style – in which Nielsen's heuristics were founded – and a new interaction paradigm – in which the present work focused on. Thus, we can conclude that the use of more and better-adapted heuristics in a specific context of use had a better performance when compared with a traditional set of heuristics. This reinforces our hypothesis that we need to think in a new usability, which is capable to work with the new challenges that the new interaction paradigms bring. As future work, we intent to conduct a new case study with less experienced participants in order to verify the performance of the new set of heuristics for multimodal heuristics in this scenario. We will also perform similar studies with other emerging interaction paradigms, as well as explore other related disciplines.

Acknowledgments. The authors would like to thank all the experiment participants. And a special thanks to Elis Damasceno for helping in the grammar review.

References

1. International Organisation for Standardisation, Software Ergonomics Requirements for office work with visual display terminal (VDT), ISO 9241, Geneva (1998)
2. Chan, A.J., Islam, M.K., Rosewall, T., Jaffray, D.A., Easty, A.C., Cafazzo, J.A.: Applying usability heuristics to radiotherapy systems. In: Radiotherapy and Oncology, vol. 102, p. 5 (January 2012)
3. Kevin, B., Saul, G., Carl, G.: Heuristic Evaluation of Groupware Based on the Mechanics of Collaboration. Journal (2001)
4. Rusu, C., Roncagliolo, S., Tapia, G., Hayvar, D., Rusu, V., Gorgan, D.: Usability Heuristics for Grid Computing Applications. Journal, 53–58 (2011)
5. IDC Forecasts Worldwide Tablet Shipments to Surpass Portable PC Shipments in 2013, Total PC Shipments in 2015 (May 28, 2013) (press release)
6. Peter, T., Robert, D.M.: Introduction to the new usability. ACM Trans. Comput.-Hum. Interact. 9, 69–73 (2002)
7. Anja, B.N., Ina, W., Jörn, H.: Multimodal interaction: A suitable strategy for including older users? Interact. Comput. 22, 465–474 (2010)
8. Charles, R., Angus, F., Tobias, H.: Enabling Multimodal Mobile Interfaces for Interactive Musical Performance. Journal (2013)
9. Coutaz, J., Nigay, L., Salber, D., Blandford, A., May, J., Young, R.M.: Four easy pieces for assessing the usability of multimodal interaction: the CARE properties. Journal, 115–120 (1995)
10. Wechsung, I., Engelbrecht, K.-P., Kühnel, C., Möller, S., Weiss, B.: Measuring the Quality of Service and Quality of Experience of multimodal human–machine interaction. Journal on Multimodal User Interfaces 6, 73–85 (2012)
11. Bastian, P., Stefan, S., Albrecht, S.: Multimodal interaction in the car: combining speech and gestures on the steering wheel. Journal (2012)
12. Julie, R., Stephen, B.: Gesture and voice prototyping for early evaluations of social acceptability in multimodal interfaces. Journal (2010)

13. Schalkwyk, J., Beeferman, D., Beaufays, F., Byrne, B., Chelba, C., Cohen, M., Kamvar, M., Strope, B.: "Your Word is my Command": Google Search by Voice: A Case Study. Journal, 61–90 (2010)
14. Zhang, H., Wei Lieh, N.: Speech recognition interface design for in-vehicle system. Journal (2010)
15. Gilles, B., Rg, M., Ller,Eric, L.: Design and evaluation of finger-count interaction: Combining multitouch gestures and menus. Int. J. Hum.-Comput. Stud. 70, 673–689 (2012)
16. Oscar Kin-Chung, A., Chiew-Lan, T.: Multitouch finger registration and its applications. Journal (2010)
17. Donald, A.N.: Natural user interfaces are not natural. Interactions 17, 6–10 (2010)
18. Charles, J., Sorin, D.: Speech interfaces based upon surface electromyography. Speech Commun. 52, 354–366 (2010)
19. Dominique, K., Philippe, B., Christine, R., Margot, P., Manuel, G.: Fran, ois, R.,Ludovic Le, B.: Reducing user linguistic variability in speech interaction through lexical and syntactic priming. Journal (2012)
20. Rusu, C., Roncagliolo, S., Rusu, V., Collazos, C.: A Methodology to Establish Usability Heuristics. Journal, 59–62 (2011)
21. Bastien, J.M.C., Scapin, D.L.: Ergonomic criteria for the evaluation of human-computer interfaces. Journal 79
22. Jakob, N.: Usability Engineering. Journal, 358 (1993)
23. Norman, D.A.: Emotional Design: Why We Love (or Hate) Everyday Things. Journal (2005)
24. Jeongyun, H., Dong-Han, H., Sanghyun, P., Chiwon, S., Wan Chul, Y.: A framework for evaluating the usability of mobile phones based on multi-level, hierarchical model of usability factors. Interact. Comput. 21, 263–275 (2009)
25. Young Seok, L., Sang, W.H., Tonya, L.S.-J., Maury, A.N., Kei, T.: Systematic evaluation methodology for cell phone user interfaces. Interact. Comput. 18, 304–325 (2006)
26. Rodolfo, I., Cristian, R., Silvana, R., Cristhy, J., Virginica, R.: Usability Heuristics for Touchscreen-based Mobile Devices. Journal (2012)
27. Apted, T., Collins, A., Kay, J.: Heuristics to Support Design of New Software for Interaction at Tabletops. Journal (2009)
28. Sandrine, R.: An empirical study of speech and gesture interaction: toward the definition of ergonomic design guidelines. Journal (1998)
29. Sandrine, R.-R., NoëLle, C., Pierre, D.: Expression constraints in multimodal human-computer interaction. Journal (2000)
30. Alex, W.S., Harshada, P., Sarah, C.S., John, R.W.: Developing speech input for virtual reality applications: A reality based interaction approach. Int. J. Hum.-Comput. Stud. 69, 3–8 (2011)
31. Android Design Principles, `http://developer.android.com/design/index.html` (retrieved March 27, 2013)
32. iOS Human Interface Guidelines, `http://developer.apple.com/library/ios/-documentation/UserExperience/Conceptual/MobileHIG/Introduction/Introduction.html` (retrieved March 27, 2013)
33. Microsoft Surface User Experience Guidelines, `http://www.microsoft.com/en-us/download/details.aspx?id=19410` (retrieved March 29, 2013)