Behavioural Variables Analysis in Mobile Environments

Denise Marczal[1(✉)] and Plinio Thomaz Aquino Junior[1,2]

[1] IPT - Instituto de Pesquisas Tecnológicas do Estado de SP, São Paulo, Brazil
marczal@gmail.com
[2] Centro Universitário da FEI – Fundação Educacional Inaciana Pe. Sabóia de Medeiros, São Bernardo do Campo, São Paulo, Brazil
plinio.aquino@fei.edu.br

Abstract. Due to the recent proliferation of mobile applications, it has become essential to obtain a better understanding of how people use their devices and applications. However, it is not always possible to reproduce the chaotic environment where the interactions between users and applications take place. Based on this fact, the present study presents a mechanism for the collection and connection of variables of interaction (touches, navigation between screens, etc.) and variables of mobility (sensor data, such as GPS), by the means of an experiment performed in the application made available at application stores and used by real users, performing daily tasks. With the analysis of the data collected it is expected to understand user behavior during interaction and determine usage patterns associating the variables of mobility with the variables of interaction that provide new ideas for interface projects.

Keywords: Mobile usability · Variables of mobility · Large-scale studies

1 Introduction

The mobile applications number grows each day, in February 2014 the two main application stores, Apple Store and Google Play, exceeded the mark of 1,100,000 applications available for download [1]. Along with the applications, number is the massive use of smartphones. According to a study done by Google [18], the number of smartphone users in Brazil rose from 14 % of the population in 2012 to 26 % in 2013. Given this scenario, obtaining a better understanding of how people use their mobile applications is fundamental to provide them a better user experience.

Although the usability is an important factor for the mobile devices, is not unusual to notice problems related to the usability of the applications only when they are already available in the stores. This is because the use of such software is dynamic. There are two approaches to observe the user interaction in mobile applications, lab tests and field tests. In lab tests, model, no or little influence from the external environment interferes in the test. Due to that fact, some authors argue that the usability results of mobile application studies performed in labs may not represent the application real use [22, 30]. On the other hand, the usability tests in the field observe user interaction with the application in real usage environments. However, to capture such

A. Marcus (Ed.): DUXU 2015, Part II, LNCS 9187, pp. 118–130, 2015.
DOI: 10.1007/978-3-319-20898-5_12

interaction in this approach is not an easy task, to follow users in the field is an intrusive method and it may change the user behavior [8].

The mobile applications usage is relatively new when compared with the use of desktops and websites. Preliminary studies have not indicated what is the set of variables that experts can map in mobile applications to be able to acquire knowledge about the audience, context and interaction behavior. The present work had the goal to contribute to mobile devices HCI studies, considering the mobility condition through a variable systematic analysis, which can be considered for usability experience studies. As a result, this work catalogs the group of variables available in a mobile environment that help understands the application usage. The variables are the result of the review of 34 articles, and were collected in an Android application used by real users. Were collected 85,390 occurrences of device variables; 2,391,132 of interaction variables and 9,466,711 of context variables.

2 Usability and Mobility Condition

The traditional HCI evaluation methods are not applicable in an efficient way for the mobile applications, since they were projected for desktop computers which suffer little interference from the external environment [24]. Due to their nature, smartphones can be used in different daily activities, such as during exercising, commuting, during work time, in the traffic, etc. [5].

In literature, it is possible to find two main approaches for the usability studies of mobile applications: lab experiments and field studies. Laboratory experiments performed in controlled environments where the participants perform pre-defined task. Such experiments involve the observation of the participants performance while executing the tasks and the usability is evaluated during such interaction. In these cases, the control of the environment guarantees the only factors related to the experiment affect the interaction of the participant with the application. However, the usage of smartphones and applications takes place in chaotic environments and under the influence of many external factors, such as background noise, conversations, cars, people, etc. To simulate such kind of environment in a lab is a big challenge.

Tsiaousis [44] tried to replicate the main factors from environment distractions in mobile environments, however, it was not possible to predict all the situations in which an application can be used. The study did not consider a varied sample of devices, which also influence the usability of a smartphone. Taking into account a varied sample of devices in lab tests is a big challenge, since there are a great variety of devices available in the market.

Field studies consist in observation and interviews, and the usability is measured based on the execution of tasks in a real environment. While observing the users in their own environments it is possible to capture information, which affect the usage of the product, including interruptions and distractions. That is an investigation of the reality of the users and not of assumptions [4]. Field studies present benefits for the understanding of the interaction of the user with the system and how external factors affect such interaction. However, they present some problems [31]:

- The participants have to deal with devices which they are not familiar, affecting the perception by the participants;
- The recruiting of users is usually made locally, leading to a small number of user, which does not provide the studies with a heterogeneous sample and does not allow for the study of cultural differences;

To solve such problems McMillan [31] recommends studies in a large scale with applications available in the applications stores and participants using the devices, which they already have, and use daily, instead of using devices provided by the researcher. With the appearance of the applications stores in 2008, the researchers visualized a new way of reaching a large number of participants during their experiments. In this approach, applications are developed and published with the objective of measuring the behavior of the users and answering questions related to the study. Henze [16] developed an application to study the interaction of the users with sensitive touch screens. In the study, data of 91,731 players were collected. Analyzing the touches of the users during the game, it was possible to determine the margin of errors for different screen sizes and the position of the touches. Based on this, it was possible to develop a compensation function that reduced such margin of errors.

Through the large-scale studies, using applications stores it is possible to work in real usage environments, with users from different geographic regions and for a long period. Factors related to the usability, such as the screen size, orientation of the screen (vertical/horizontal), touches can be analyzed in different cell phone models and with a real sample of the application users [16, 35].

Such study intends to present a catalog of variables that can be collected in large-scale studies, capturing information in real time from the smartphone users. Such variables can be interconnected and help to answer important questions for the project interface decisions of the product or for the alignment of new strategies.

3 Identifying Process of Mobile Variables

One of the objectives of the present study is to identify, catalog and classify the variables, which are considered in studies about the user behavior in mobile applications. To meet such objective, the systematic review technique was used. The systematic review is a means of evaluation and interpretation of all the research studies available that are relevant for research topic of an area or phenomenon [23].

The systematic review was guided by the following research question: *Which are the variables considered by the researchers to study the interaction between the users and smartphones in natural usage environments?* The bibliographical research identified 1,225 potential articles, of which 34 were selected.

Besides the systematic review, it was necessary to develop three software modules. The client module is a component attached to the mobile device to collect data and send it to the server. Such module is responsible for capturing different usage contexts generating different paths for the study. The server module receives and stores the data collected in the mobile application. The data processing module executes a statistical

analysis and applies the algorithms, which allow the determination of groups based on the level of similarity among the data.

In the review, it was possible to identify some of the variables considered during user behavior studies. Those can be classified into interaction, usage context and device variables. Variables of interaction are those that allow us to determine the user behavior while the user interacts with the application, for example, navigated screens, screen touches, amount of time spent in each screen, etc. The variables of context of use concern to the physical, social, temporal and technical environments [19] where the interaction took place, whereas date and time, geographic location and luminosity are examples of context variables. The device variables are those that represent the device characteristics with which the user interacted, for example, the operational system and the screen size, etc.

As a result from the systematic review, 95 variables presented in the usage behavior studies in mobile applications were identified. Among those variables, 58 (61 %) were classified as context variables, 29 as interaction variables (31 %) and 8 (8 %) as device variables. The device variables are described in Table 1, those of interaction on Table 2 and those of context on Table 3.

The results of the research showed that only 7 studies used the application stores as a large-scale research mechanism.

Table 1. Device variables

Variable	Description	Paper
Device model	Device brand and model	[35]
Platform	Device operational system of the device	[28, 35]
Size of the screen	Real physical size, diagonal measure of the screen	[25]
Resolution of the screen	Resolution of the screen in pixels	[6, 7, 14, 25]
Device name	Name of the device in which the interaction occurs	[14, 28]
Device model	Device model in which the interaction occurs	[6, 7, 14, 28]
Version of the OS	Version of the operational system installed	[6, 7, 14, 34, 37]
Manufacturer	Device manufacturer	[34]

Table 2. Interaction variables

Variable	Description	Paper
Session duration	One session corresponds to the use of the application in first plan	[2, 7, 13, 15, 27, 35]
Action performed	Quantifies the number of actions performed by the user	[25, 37]
Time to perform a task	Amount of time measured in seconds for a user to complete a task	[25, 37]
Number of actions in a task	Number of steps the user took to complete a task	[25]

(*Continued*)

Table 2. (*Continued*)

Variable	Description	Paper
Navigation	Combination of steps and components accessed during the session of use	[14, 27, 28, 35]
Speed of typing	Number of characters typed in a period of time	[26]
Touches in the Backspace Key	Number of times the backspace key was pressed	[26, 37]
Touches on the Enter Key	Number of times the Enter key was pressed	[26]
Size of the text typed	Number of characters typed	[26]
Touches on the symbol keys	Number of times the symbols characters were used	[26]
Size of the erased text	Number of text characters erased	[26]
Number of long touches	Number of long touches made on the screen	[26]
Number of touches	Number of touches made on the screen	[26]
Interactions with the screen	Interaction the user performed (touches, gestures, elements of the screen, etc.)	[2, 14, 27, 33]
Coordinates of the touch	X,Y position of the place where the touch took place	[34]
Coordinates of the target	X,Y position of the component that receives the touch	[34]
Width of the target	Width of the component that receives the touch	[34]
Format of the text	Data format inserted	[28]
Entry elements	Elements that appear in a screen (buttons, texts, etc.)	[28]
Objectives	User goals	[28]
Start of the objective	First element of each goal	[28, 38]
End of the objective	Last element of each goal	[28, 38]
Screens created	Event of the creation of a screen	[9, 27]
Screens discarded	Event when the OS destroys the screen that is not being used anymore	[27]
Permanence in each screen	Amount of time a user has spent on a screen	[27]
Application finalized	Event of the finalization of the application	[27]
Visited screens in each task	All the screens the user accessed to perform the task	[37]
Number of errors made by task	Number of mistakes the user made in a task	[37]
Screen activations	Number of times each screen was activated	[37]

Table 3. Context variables

Variable	Description	Paper
CPU usage	Indicates which is the percentage of use of the CPU during the interaction	[11, 35, 41]
Memory use	Amount of memory used during the interaction	[35]
Latency of the network	Indicates which is the latency of the network during the interaction	[6, 33, 35, 41]
Battery usage, battery level	The battery usage is calculated per session, dividing the change of the charge by the duration of the session	[2, 6, 11, 12, 14, 20, 33, 35, 38, 39, 41, 43]
Brightness	Screen brightness	[35]
Network signal	Indicates the quality of the telephone network signal during the use of the application. Goes from 0-31 to 99 when there is no signal	[35, 38, 41]
Geolocalization	Latitude and longitude of where the interaction took place	[6, 9, 10, 25, 26, 32, 33, 43, 45]
Geolocalization accuracy	Estimated location accuracy (meters)	[10, 25]
Geolocalization provider	Who is providing the location. Ex: Wi-Fi network, GPS or network triangulation	[25]
Date/Hour of use	Date and local time of the moment of the interaction	[6, 14, 35]
Device position	Device position: vertical, horizontal or mixed	[25]
Dislocation speed	Speed of the user during the interaction	[3, 25]
Event of a received call	Number of calls received during the interaction with the device	[3, 7, 15, 21, 33, 41, 43, 46]
Event of text message received	Number of text messages received during the interaction with the device	[6, 7, 14, 34, 37]
Capture of audio	Audio recording during the use of the application	[3, 7, 9, 15, 21, 27, 29, 33, 41, 43, 45, 46]
Capture of video	Video recording during the use of the application	[9, 41]
Processes in execution	List of processes in execution during the interaction	[42, 45]
Data sent by the network	Total of MB of data sent by the application	[6, 41]
WIFI conditions	Wi-Fi on/off	[7, 21, 41, 42]
Bluetooth conditions	Bluetooth on/off	[6, 41, 42, 45]
Vibration of the Device	Determines how much the device is shaken	[26]
Weather	14 weather conditions defined by Google Weather	[26]
Used applications	Consists in the opening event of any application installed in the device	[3, 6, 10, 12, 14, 28, 32, 33, 40, 42]

(*Continued*)

Table 3. (*Continued*)

Variable	Description	Paper
Nearby Bluetooth points	Number of devices nearby with the Bluetooth on	[10, 32, 45, 46]
Plane mode	Indicates when the device is changed to plane mode	[45]
Environment brightness	Intensity of the light in the environment	[14, 25, 26, 33, 38, 46]
Event of email received	Indicates that one email has been received	[41]
Accelerometer	Measures the acceleration force and rotation in three axis	[33, 40, 41, 46]
Applications installed	List of applications installed in the device	[11, 33, 41, 45]
Temperature	Ambient air temperature in Celsius	[26]
Connected antennas	Cellphone antennas connected with the device	[11, 33, 45]
Screen state	State of the screen active/inactive/blocked/unblocked	[6, 7, 12, 13, 20, 27, 42]
Network traffic	Data amount exchange in the network	[11, 12, 20, 33]
Application category	Obtains the category of the applications used, ex (entertainment, education, games and others)	[6, 7, 14, 28]
Data network type	Obtains the type of data network used such as ex 3G, Wi-Fi, etc.	[6, 7, 11, 43, 45]
Application version	Obtains the version of the application installed	[14, 17, 34]
Opening of the application	Captures opening of the application event	[14]
Closing of the application	Captures closing of the application event	[14]
Application in foreground	Indicates if the application retuned to foreground	[6, 7, 12, 15, 27, 40, 41, 43]
Application in background	Captures the event of the application is in background	[6, 7, 12, 15, 27, 40, 41, 43]
Status of the headphones	Indicates if the headphones are being used	[6, 7, 14]
Volume level	Indicates the volume level of the device	[14]
Gyroscope	Provides the orientation of the mobile device in space. Consists of 3 dimensions around the x, y and z axis of the device	[14, 46]
Device orientation	Indicates if the device is being used in the vertical or horizontal	[6, 14, 34, 45]
Event of installation	Indicates that the application has been installed	[6, 7]
Event de desinstallation	Indicates that the application has been uninstalled	[6, 7]

(*Continued*)

Table 3. (*Continued*)

Variable	Description	Paper
Event of update	Indicates that the application has been updated	[6, 7]
Kinds of screen	Possible types of screens	[28]
Notifications received	Indicates if a notification has been received device	[3, 15, 36]
Notifications visualized	Indicates that a notification has been visualized	[36]
Notification visualization interval	Time interval between a notification received viewed by the user	[36]
Event of the call made	Indicates the user has made a call	[21, 45]
Event of sending a SMS	Indicates the user has sent a text message	[21]
Music	Obtains the song the user is listening to	[21]
Alarm	Indicate if the alarm is active and their configuration	[45]
Memory card	Indicates if there is a memory card, capacity and usage	[45]
Carrier	Carrier name used by the device	[45]
Status of battery	Battery status (charging/discharging/charged)	[42]
Noise level	Captures the noise through the device microphone	[38]

4 Data Collection

The experiment was applied in a taxi booking application, which consists in two applications: one for the client that calls the taxi and another for the taxi driver, who is notified of the call. The applications are available in the Google Play and Apple Store applications stores and are used by real users. The application user base is made of 405,000 users, distributed in eight Brazilian cities, including people of different socio-economical profiles, ages and levels of familiarization with mobile devices. Another factor is the diversity of devices in which the application installed, which range from devices with few features and resources and small screens to devices with many features and resources and large screens.

The collection component for the mobile platform was initially developed for the Android platform. In this component, a service was developed that is initialized when the application is opened, which is responsible for collecting the variables coming from the device sensors and the variables that represent the device characteristics. To collect the interaction variables, it was necessary to intercept the touch events in each of the application screens.

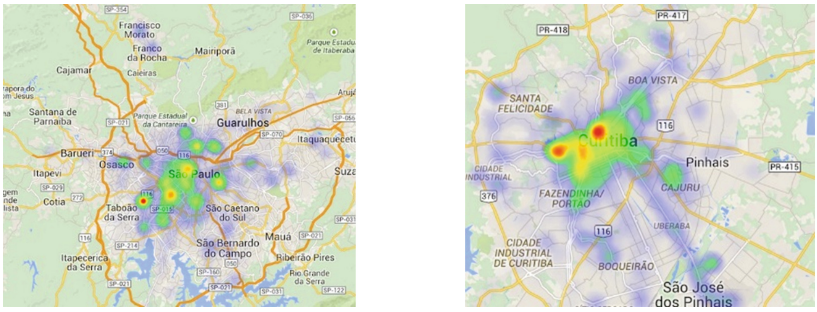
Among the variables presented for this study, 54 variables were collected, of which 41 represent the usage context, six represent the interaction and seven the device. The collection period in the client application was of 30 days, being collected 85,390 occurrences of device variables; 2,391,132 of interaction variables and 9,466,711 of context variables. The application data of the taxi drivers was collected in a period of 25 days, being collected 76,557 occurrences of device variables; 1,891,092 of interaction variables and 75,080,231 of context variables.

5 Data Analysis

In the initial analysis only the passenger's application data were considered, which correspond 20,829 the sessions of use. The application is used in 465 different devices, being the MotoG-XT1033 the most used one. For each session of use considering the user actions from the application opening until its closing. The analysis of the data collected reveals that on average each session lasts 2 min and 10 s, with an average of four screens viewed per session. To determine this information the variables date, session start time, session end time and number of navigated screens were considered. The analysis of the collected data indicate the following behaviors:

Which is the period of the day with more use of the application? Using the variables that mark the beginning and end of the session it was observed that the application is most used during the period of the night. Understanding the usage behavior based on time provides inputs for improvements in the interface design allowing tailor the application for nightly use. It's also possible to determine in which periods of the day, new additional resources should be provided for the application infrastructure and what are the best time frames for application maintenance.

Where the user does uses the application? The geolocation mobility variable was used to indicate the regions with greater intensity of use in Brazil, highlighting the cities of Sao Paulo and Curitiba, as shown the map in the Fig. 1. Understand application usage by regions contributes to build users profile and can help on direct



(a) SãoPaulo (b) Curitiba

Fig. 1. Application usage by geolocation

marketing campaigns. For the analyzed application, this information can be helpful to guide the growth of the taxi network.

Does the user use the application on the go? Which screens are used in motion? To answer these question the variables movement and navigated screen. To determine whether the user is in motion the device accelerometer was used. It has concluded that 48 % sessions were performed in motion. The screen which the user determinates the address for the taxi ride was the most used on the move. Understanding this type of factor helps to do optimizations in application design in order to facilitate use of the tasks that are used while the user is moving.

Can location accuracy cause some impact on the use? Indicate the pickup location when ordering a taxi is one of the most important tasks in the analyzed application. Currently the address is automatically detected by the application, allowing the user to change it if it is incorrect. It was decided to relate the address editing task with location accuracy, to understand if the low location accuracy would lead users to correct the address suggested by the application. The results showed that in 75 % of the time in which the user has corrected the suggested address, the location accuracy was below 60 meters. This information drives the interface improvements to offer mechanism to facilitate the address edition when location accuracy is below 60 m, before the user search for this functionality.

How often the users interrupt the application usage? To answer this question the application in the background variable was considered. It was found that in 85 % of sessions, users left the analyzed application, with an average frequency 6 times per session and keeping the background application on average 9 min and 12 s. All the screens in which this behavior happened were identified and what were the average time each screen remained in the background. This information leads to optimizations in the navigability flow of current screens and helps to identify in which screens the users loses interest or witch screens there is no need of interaction with the user.

6 Conclusions and Future Work

This work presented a study of variables that can be considered to understand the smartphone usage behavior through the collection in large scale in one application used by real users.

As a result it was possible to catalog a set of variables that were considered on user behavior studies in mobile applications and showed the application of some of this variables. To exemplify the use of some variables the data analysis was guided by the following questions: *Which is the period of the day with more use of the application?*; *Where does the user uses the application?; Is the application used on the go by the user?; Which screens are used in motion?, Can location accuracy cause some impact on the use?* and *How often the users interrupt the application usage?*

This research is part of an ongoing study, which aims to understand which are the variables that can be considered in studies of user behavior on mobile applications. The next steps will be: perform the correlation with more variables in order to determine

which ones produces better results; identify personas through the collected variables; improve the data processing component to perform data normalization and analysis incrementally; study and apply pattern discovery techniques.

Acknowledgment. To FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) for financial support.

References

1. 148Apps.biz: app store metrics (2014)
2. Balagtas-Fernandez, F., Hussmann, H.: A methodology and framework to simplify usability analysis of mobile applications. In: 24th IEEE/ACM International Conference on Automated Software Engineering, ASE 2009, November 2009, pp. 520–524 (2009)
3. Banovic, N., Brant, C., Mankoff, J., Dey, A.: Proactivetasks: the short of mobile device use sessions. In: Proceedings of the 16th International Conference on Human-Computer Interaction with Mobile Devices and Services, pp. 243–252. ACM (2014)
4. Barbosa, S.D., da Silva, B.S.: Interacao Humano-Computador. Elsevier, Brasil (2010)
5. Bohmer, M.: Understanding and supporting mobile application usage. Ph.D. thesis, Univesitat des Saarlandes, Postfach 151141, 66041 Saarbracken (2013)
6. Bohmer, M., Hecht, B., Schoning, J., Krüger, A., Bauer, G.: Falling asleep with angry birds, facebook and kindle: a large scale study on mobile application usage. In: Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services, MobileHCI 2011, pp. 47–56. ACM, New York (2011)
7. Bohmer, M., Lander, C., Krüger, A.: What's in the apps for context?: extending a sensor for studying app usage to informing context-awareness. In: Proceedings of the 2013 ACM conference on Pervasive and Ubiquitous Computing Adjunct Publication, pp. 1423–1426 (2013)
8. Brown, B., McGregor, M., Laurier, E.: iphone in vivo: video analysis of mobile device use. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2013, pp. 1031–1040. ACM, New York (2013)
9. Brown, B., McGregor, M., McMillan, D.: 100 days of iphone use: understanding the details of mobile device use. In: Proceedings of the 16th International Conference On Human-Computer Interaction with Mobile Devices and Services, pp. 223–232. ACM (2014)
10. Do, T.M.T., Blom, J., Gatica-Perez, D.: Smartphone usage in the wild: a large-scale analysis of applications and context. In: Proceedings of the 13th International Conference On Multimodal Interfaces, pp. 353–360. ACM (2011)
11. Falaki, H., Mahajan, R., Estrin, D.: Systemsens: a tool for monitoring usage in smartphone research deployments. In: Proceedings of the Sixth International Workshop on MobiArch, pp. 25–30. ACM (2011)
12. Falaki, H., Mahajan, R., Kandula, S., Lymberopoulos, D., Govindan, R., Estrin, D.: Diversity in smartphone usage. In: Proceedings of the 8th International Conference On Mobile Systems, Applications, and Services, pp. 179–194. ACM (2010)
13. Ferreira, D., Goncalves, J., Kostakos, V., Barkhuus, L., Dey, A.K.: Contextual experience sampling of mobile application micro-usage. In: Proceedings of the 16th International Conference on HCI with Mobile Devices and Services, pp. 91–100. ACM (2014)

14. Gencer, M., Bilgin, G., Zan, O., Voyvodaoglu, T.: A new framework for increasing user engagement in mobile applications using machine learning techniques. In: Marcus, A. (ed.) DUXU 2013, Part IV. LNCS, vol. 8015, pp. 651–659. Springer, Heidelberg (2013)
15. Hammer, J.C., Yan, T.: Exploiting usage statistics for energy-efficient logical status inference on mobile phones. In: Proceedings of the 2014 ACM International Symposium on Wearable Computers, pp. 35–42. ACM (2014)
16. Henze, N., Pielot, M.: App stores: external validity for mobile HCI. Interactions **20**(2), 33–38 (2013)
17. Humayoun, S.R., Dubinsky, Y.: Mobigolog: formal task modelling for testing user gestures interaction in mobile applications. In: Proceedings of the 1st International Conference on Mobile Software Engineering and Systems, pp. 46–49. ACM (2014)
18. IpsosGoogle: our mobile planet (2014). http://think.withgoogle.com/mobileplanet/en/
19. Jumisko-Pyykkö, S., Vainio, T.: Framing the context of use for mobile HCI. Int. J. Mob. Hum. Comput. Interact. **2**(4), 1–28 (2010)
20. Kang, J.M., Seo, S.S., Hong, J.K.: Usage pattern analysis of smartphones. In: Network Operations and Management Symposium, 2011 13th Asia-Pacific, pp. 1–8. IEEE (2011)
21. Karkkainen, T., Vaittinen, T., Vaananen-Vainio-Mattila, K.: I don't mind being logged, but want to remain in control: a field study of mobile activity and context logging. In: SIGCHI Conference on Human Factors in Computing Systems, pp. 163–172. ACM (2010)
22. Kawalek, J., Stark, A., Riebeck, M.: A new approach to analyze human-mobile computer interaction. J. Usability Stud. **3**(2), 90–98 (2008)
23. Keele, S.: Guidelines for performing systematic literature reviews in software engineering. Technical report, EBSE Technical Report EBSE-2007-01 (2007)
24. Kronbauer, A.H., Santos, C.A.S.: Um modelo de avaliação da usabilidade baseado na captura automática de dados de interação do usuário em ambientes reais. In: 5th Latin American Conference on Human-Computer Interaction, Brazil, pp. 114–123 (2011)
25. Kronbauer, A.H., Santos, C.A., Vieira, V.: Um estudo experimental de avaliacao da experiencia dos usuarios de aplicativos moveis a partir da captura automatica dos dados contextuais. In: Brazilian Symposium on Human Factors in Computing Systems, pp. 305–314 (2012)
26. Lee, H., Choi, Y.S., Lee, S., Park, I.: Towards unobtrusive emotion recognition for affective social communication. In: Consumer Communications and Networking Conference (CCNC), pp. 260–264. IEEE (2012)
27. Lettner, F., Holzmann, C.: Automated and unsupervised user interaction logging as basis for usability evaluation of mobile applications. In: 10th International Conference on Advances in Mobile Computing and Multimedia, pp. 118–127. ACM (2012)
28. Levy, M., Shoval, P., Shapira, B., Dayan, A., Tubi, M.: Task modeling infrastructure for analyzing smart phone usage. In: Mobile Business and 2010 Ninth Global Mobility Roundtable (ICMB-GMR), pp. 264–271. IEEE (2010)
29. Ma, X., Yan, B., Chen, G., Zhang, C., Huang, K., Drury, J.: A toolkit for usability testing of mobile applications. In: Zhang, J.Y., Wilkiewicz, J., Nahapetian, A. (eds.) MobiCASE 2011. LNICST, vol. 95, pp. 226–245. Springer, Heidelberg (2012)
30. Mayas, C., Hörold, S., Rosenmöller, C., Krömker, H.: Evaluating methods and equipment for usability field tests in public transport. In: Kurosu, M. (ed.) HCI 2014, Part I. LNCS, vol. 8510, pp. 545–553. Springer, Heidelberg (2014)
31. McMillan, D., Morrison, A., Brown, O., Hall, M., Chalmers, M.: Further into the wild: running worldwide trials of mobile systems. In: Floréen, P., Krüger, A., Spasojevic, M. (eds.) Pervasive 2010. LNCS, vol. 6030, pp. 210–227. Springer, Heidelberg (2010)

32. Meng, L., Liu, S., Striegel, A.D.: Analyzing the impact of proximity, location, and personality on smartphone usage. In: 2014 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), pp. 293–298. IEEE (2014)
33. Misra, A., Balan, R.K.: LiveLabs: Initial reflections on building a large-scale mobile behavioral experimentation testbed. ACM SIGMOBILE Mob. Comput. Commun. Rev. **17** (4), 47–59 (2013)
34. Mockler, J.: UX suite: a touch sensor evaluation platform. In: Proceedings of the 16th International Conference on Human-Computer Interaction with Mobile Devices and Services, pp. 631–636. ACM (2014)
35. Patro, A., Rayanchu, S., Griepentrog, M., Ma, Y., Banerjee, S.: Capturing mobile experience in the wild: a tale of two apps. In: 9th ACM Conference on Emerging Networking Experiments and Technologies, CoNEXT 2013, pp. 199–210. ACM, New York (2013)
36. Pielot, M., Church, K., Oliveira, R.: An in-situ study of mobile phone notifications. In: 16th International Conference on HCI with Mobile Devices and Services, pp. 233–242. ACM (2014)
37. Porat, T., Schclar, A., Shapira, B.: Mate: a mobile analysis tool for usability experts. In: CHI 2013 Ext Abstracts on Human Factors in Computing Systems, pp. 265–270. ACM (2013)
38. Pretel, I., Lago, A.B.: Remote assessment of hybrid mobile applications: new approach in real environments. In: 9th Iberian Conference on Information Systems and Technologies (CISTI), pp. 1–6. IEEE (2014)
39. Rahmati, A., Zhong, L.: Studying smartphone usage: lessons from a four-month field study. IEEE Trans. Mob. Comput. **12**(7), 1417–1427 (2013)
40. Sahami Shirazi, A., Henze, N., Dingler, T., Kunze, K., Schmidt, A.: Upright or sideways?: analysis of smartphone postures in the wild. In: 15th International Conference on Human-Computer Interaction with Mobile Devices and Services, pp. 362–371. ACM (2013)
41. Shepard, C., Rahmati, A., Tossell, C., Zhong, L., Kortum, P.: LiveLab: measuring wireless networks and smartphone users in the field. ACM SIGMETRICS Perform. Eval. Rev. **38**(3), 15–20 (2011)
42. Soikkeli, T., Karikoski, J., Hammainen, H.: Diversity and end user context in smartphone usage sessions. In: 2011 5th International Conference on Next Generation Mobile Applications, Services And Technologies (NGMAST), pp. 7–12. IEEE (2011)
43. Srinivasan, V., Moghaddam, S., Mukherji, A., Rachuri, K.K., Xu, C., Tapia, E.M.: Mobileminer: mining your frequent patterns on your phone. In: International Joint Conference on Pervasive and Ubiquitous Computing, pp. 389–400. ACM (2014)
44. Tsiaousis, A., Giaglis, G.: Evaluating the effects of the environmental context-of-use on mobile website usability. In: 7th International Conference on Mobile Business, ICMB 2008, pp. 314–322, July 2008
45. Wagner, D.T., Rice, A., Beresford, A.R.: Device analyzer: largescale mobile data collection. ACM SIGMETRICS Perform. Eval. Rev. **41**(4), 53–56 (2014)
46. Zeni, M., Zaihrayeu, I., Giunchiglia, F.: Multi-device activity logging. In: International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct, pp. 299–302. ACM (2014)