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A Context-Sensitive Tool to Support Mobile Technology Acceptance Research

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Abstract

Context of usage significantly influences acceptance of mobile apps. State of the art methods of technology acceptance research can assess limited aspects of context. In this paper, we outline the development of a context-sensitive support tool for mobile technology acceptance research. The tool consists of four basic components (a tracking service, a survey service, an analytics tool and external sensor hardware) that collect context data from sensors, built-in data sources and cloud services during real-world usage and connect it to acceptance information tracked on the smart phone and collected in the course of context-adaptive mobile surveys. The system was developed in a co-creation process that involved potential users, i.e. members of the mobile Living Lab in which the tool will be used.

1. Introduction

Analysis of usage and evaluation of technology acceptance is a crucial task in the course of mobile app development. Recent discussions addressed the problem that the construct of use itself is understudied [19] in general. Use of mobile technologies is in particular influenced by context factors as usage is performed in highly dynamic and mobile settings [13]. Users move between public and private space during usage which initiates significant changes of context [3]. The differences to stationary computer usage necessitate critical review of renowned and established models and theories of technology acceptance when analyzing mobile technology acceptance [20]. An extensive analysis of the influence of environment features on mobile phone usage resulted in interesting findings regarding these effects [15]. This analysis unveiled that certain environmental factors can have significant effects on the resources of the user and even on the mobile phone. Another recent research on usage and context patterns regarding certain mobile apps indicated that context significantly influences usage even in case of standard applications [18]. These finding in combination suggest that virtually every mobile app is context-sensitive even though it might not be context-aware (e.g. location-based apps).

Currently, we do not exactly know how people use mobile apps. Questioning methods bear the risk of self-reported usage bias. Observations are expensive and limited with regard to the time span that can be covered. Laboratory studies do exclude many factors that occur in real-world usage.

We also do not exactly know why people use mobile apps as most models lack sound theoretical foundations [1].

These facts in combination indicate a need for in-depth knowledge on usage context and on effects of usage context on acceptance of mobile technologies in order to bring forth acceptance research in this field. The practical relevance lies within the opportunity to

a) create better accepted mobile apps based on the novel information,

b) detect potential for novel context-adaptive services,

c) and to unveil unexpected usage patterns that enable improvement of existing apps.

Mobile acceptance research requires supporting tools due to the limitations of traditional methods of technology acceptance research. Such a tool must enable medium/long-term studies in order to capture dynamic changes, be unobtrusive in order to reduce effects on the user and be context-sensitive in order to obtain information on usage contexts.

The main research question is therefore: How can we utilize context information for mobile technology acceptance research in a meaningful way?

The approach presented in this paper includes automated collection of sensory and cloud data in order to obtain context information. Usage is tracked automatically as well to obtain use information. Adaptive mobile surveys are used to collect data that cannot be tracked or obtained by means of non-reactive methods. Data from these sources are combined in order to enable context-sensitive acceptance analysis.

In the remainder of this paper we discuss current research that influenced this project and describe the development of the tool that was conducted as a co-creation project in a mobile Living Lab setting. The paper concludes

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with some general remarks on our findings and an outlook on future research and development.

2. Background

Commonly used methods of technology acceptance research and usage evaluation are interviews and online surveys. These can provide rich data on the user characteristics and factors that influence their usage decisions but at the same time often lack information on usage context and its influence on acceptance. Mallat et al. [14] included some context items in their survey-based research on the usage of mobile ticketing: I use/expect to use mobile tickets if...

- travel card has no value or the period is expired.
- I have no cash for purchasing the ticket.
- I'm in a hurry or need the ticket fast.
- I need the ticket unexpectedly and have not prepared for purchasing it.
- there are queues in points of ticket sale.

In the extension of the Unified Theory of Acceptance and Use of Technology (UTAUT), Venkatesh et al. [21] included social influence and facilitating conditions as context factors. Passing time, task-related, social and work contextual conditions were considered as contextual considerations in a recent examination of users switching behavior between fixed internet ant mobile internet [7]. In most cases the hypothesized effects of context on usage or usage intentions turned out to be significant. In all these cases the number and range of included context factors was narrow due to the limitations of items in questionnaires. Besides that the obtained results are self-reported context perceptions that are subject to self-reporting bias.

Non-standardized interviews not as limited as standardized surveys as it is up to the user to choose the range of context factors. Unfortunately the user might not be aware of the impact of context factors on his or her usage or usage intention, and thus, does not provide meaningful information. In order to obtain meaningful insights on context effects some researchers conduct contextual inquiries. In these cases the designer interviews users directly in the context where usage takes place such as work place during task performance by the user and meanwhile gathers data about usual setting and context of the task performance [8]. Application of this method in mobile technology acceptance research is a non-trivial task as the interviewer would have to follow the user, and thus, might influence his or her usage behavior, e.g. by interruption in crucial moments. Usage behavior in contextual inquiry settings might then be considered to be less realistic. User observation bears similar problems as the observer has to be close to the user and might cause a bias, especially in case of private tasks and also in private locations.

Another methodological stream of user research utilizes applications on mobile devices in order to obtain user feedback without interviewer bias. These applications, e.g. ConTexter [22] or iRequire [17], aim at gathering user requirements and feedback during usage and in the situation of usage [16].

Current smartphones usually come with built-in sensors to recognize, amongst others, the position and orientation of the device in order to allow location-based services and adaptive screen content display without requiring the user to perform actions in the user interface. In addition to sensors for measuring the physical environment, they also contain means of communication with other devices, like data transmission via the mobile phone network, short range communication via the Bluetooth protocol, even Near Field Communication. Thus, they can use additional information from surrounding devices and from remote servers to derive the current context of usage [2].

Smartphones also come with interfaces which enable using external sensing systems [12]. However, external hardware is mostly used for specialized applications, often in the health care area, for example using heart rate monitoring sensors.

Most other applications rely on built-in sensors and connectivity in order to avoid the inconvenience and additional costs of having users carry additional devices with them.

However, when using mobile phones in field trial conditions, using additional devices may be an acceptable option, if it leads to better understanding of the usage context. One might, for example, want to use external GPS (Global Positioning System) sensors or compasses to recognize the user's position with higher precision than with built-in sensors, or use biometric sensors to measure the user's excitement level.

A wide range of sensors is available for the Arduino platform, which is a microcontroller environment connectable to prevalent hardware platforms like smart phones with the Android operating system [5].

3. Methodology

We followed the design science principles provided by Hevner et al. [10] to ensure that the development process and the resulting artifact are scientific in nature. Hevner and Zhang [9] describe three cycles of design research and transfer it to human-computer interaction research:

- The relevance cycle that will provide requirements of practical relevance for the evaluation of the designed artifact. In the present case the evaluation criteria are usefulness of the developed tool for supporting acceptance research by enabling medium/long-term and context-sensitive acceptance research in an unobtrusive manner that is accepted by participants of such studies.

- The rigor cycle ensures contribution to the knowledge base and the innovative character of the research project. In the course of the present research an extensive analysis of technology acceptance models and methods as well as context sensing approaches and tools was conducted.
- The internal design cycle connects the methods used to build and evaluate from the rigor cycle and the requirements from the relevance cycle in a rapid iteration between artifact building activities and feedback mechanisms. We applied a co-creation approach utilizing Living Lab methods to build and evaluate the artifact iteratively. This measure ensured that users of the artifact were involved from the very beginning of the creation process. The single steps of creation and evaluation are provided in the following three sections.

4. Capturing relevant context

The ideation phase was initiated using experience sampling. Twelve participants were recruited from our Living Lab in order to find out which context factors influence acceptance of mobile apps. Members of the Living Lab are in general young adults with high levels of technology affinity. The twelve participants (5 male and seven female, age range 21 to 34) were therefore heavy users of information and communication technology in general and smart phones in particular. All of them owned a smart phone and used more than five mobile apps on a regular basis (more than three times a week). In the course of experience sampling they were asked to go wherever they wanted to for two hours and use their favorite apps in the same way they would use them in daily life. Immediately after app usage they should take a few notes regarding the context in which they used it and how it influenced their usage perceptions. We derived the detailed questions from technology acceptance model (TAM) [6] because it is the most widely used model for testing and explaining technology acceptance:

- Which app did you use?
- What did you use it for?
- Please describe the situational context in which you used the app briefly (e.g. weather conditions, people around you, location, time).
- Which of the context factors made you feel the app is more or less useful?
- Which of the context factor made you feel the app is more or less easy to use?
- Which of the context factors made you want to use the app more or less in future?

Immediately after their return to the TecLab, i.e.the location where laboratory studies and co-creation workshops with Living Lab members usually take place, we started a brainstorming session. The brainstorming addressed context-related influence factors on acceptance in general (not only the apps that were used during experience sampling). Results from both activities, experience sampling and brainstorming, were then merged on a pin board and clustered according to similarities.

We used the context model from [4] for classification of the clustered context factors and completed the list by factors from [11] that were not mentioned during ideation phase.

The next step in the development process required technological expert knowledge. The relevant context factors that were identified during ideation phase needed to be connected to a technical solution to capture them automatically. We therefore invited six experts (two app developers, a software engineer, an acceptance researcher, a system designer and a usability engineer) to transfer the ideas into a technological solution. We applied problem solving tree method in a group setting in order to obtain alternative data sources and data collection mechanisms for all the relevant context factors. The next step was the elaboration of a criteria catalog for ranking the alternatives. The main criteria that were identified are accuracy of measurement respectively data quality and the possibility to utilize the data source in a mobile context. In this step we excluded a huge amount of solutions because they did not meet these criteria, e.g. obtaining data from to do-list apps will not provide task context information on a sufficient level of accuracy or magnetic resonance equipment would provide accurate data of brain activity but cannot be implemented in a mobile context. It turned out that task context, though extremely relevant, cannot be captured automatically at all. It was therefore suggested to include a mobile survey as data source to obtain more accurate information.

This refinement resulted in a set of relevant context information and feasible solutions to capture it automatically. The results were sorted regarding physical, social, temporal, and application context factors and combined to required hardware and data sources to obtain it.

The user context within the application's world describes user-specific information like application settings and physiological measurements. Table 1 depicts relevant user context factors and means to assess them.

Table 1. Factors and data sources for user context assessment.

Information	Hardware	Data Sources
User Settings		Operating System
Time Pressure		Calendar application
Incidental Event	Built-in GPS	Cloud database
Eye movement	Eye tracking sensor	
Emotions (e.g.	Skin response sensor	

excitement)		
Vital status	Heart rate monitor	
Brain activity	Electroencephalograph	

The physical context in table 2 includes surrounding objects and their activities as well as general conditions of the environment.

Table 2. Factors and data sources for physical context assessment.

Information	Hardware	Data Sources
Surrounding objects	Built-in GPS, camera	Cloud maps
Known objects	Built-in GPS	Contacts application
Movement of user	GPS, gyroscope, accelerometer, compass	
Proximity and movement of objects	Built-in camera, sonar, hall sensor	
Weather conditions	GPS, hygrometer, rain sensor	Cloud weather service
Climate	Thermometer, Hygrometer	
Lighting	Photocell	
Noise	Built-in microphone	
Altitude	GPS, barometer	
Odor	Odor sensor	
Air quality	Dust sensor, infrared photometric sensor	

The social context addresses people in the user's environment and their interactions and relationships. Table 3 depicts relevant social context factors and means to assess them.

Table 3. Factors and data sources for social context assessment.

Information	Hardware	Data Sources
Surrounding people	Built-in microphone, hall sensor, infrared sensor, sonar	
Interaction with surrounding people	Built-in microphone and camera	
Interaction with distant people		Telephone application, message application
Familiarity of the environment	Built-in GPS	Social media
Familiarity of surrounding people	Built-in GPS	Social media

The temporal context gives a current situation meaning. It is based on past situations and expected future events, thus capturing context changes and transitions between contexts.

Table 4. Factors and data sources for temporal context assessment.

Information	Hardware	Data Sources
Routine behavior	Built-in GPS, real-time clock	Social media, context history
Causality of context	Real-time clock	Context history
Expected future behavior	Real-time clock	Web browser, context history
Time of day	Real-time clock	
Day of the week	Real-time clock	
Current month	Real-time clock	
Type of day (e.g. birthday)	Real-time clock, built-in GPS	Public calendar in the cloud
Season	Real-time clock, built-in GPS	

An application's context is defined which contains capabilities and limitations of an application and its data sources. Table 5 depicts relevant application context factors and means to assess them.

Table 5. Factors and data sources for application context assessment.

Information	Hardware	Data Sources
Battery level	Built-in voltage sensor	Operating system
Processor speed		Operating system
Memory capacity		Operating system
Screen resolution		Operating system
Application run state		Operating system
Quality of built-in sensors		Device database in the cloud
Quality of cloud services		Web services

Quality of connectivity		Operating system

5. Architecture development and prototyping

The experts where then asked to produce paper prototypes of the components and figure out the communication flows between them.

Their previous findings suggested that the tool needs to include several software and hardware components that communicate with each other. This is necessary as not all relevant context information can be collected automatically. Moreover, interpretations are required when trying to find correlations between context and customer acceptance. However, since it is not immediately clear, which context information is relevant in a particular case, it makes sense to collect raw data for as many context types as possible first and analyze it regarding relevance for user acceptance later. The four main components of the system are therefore:

- the tracking service
- the survey service
- the analytics tool
- the external sensor hardware

Figure 1 depicts components and their connections within the resulting system.

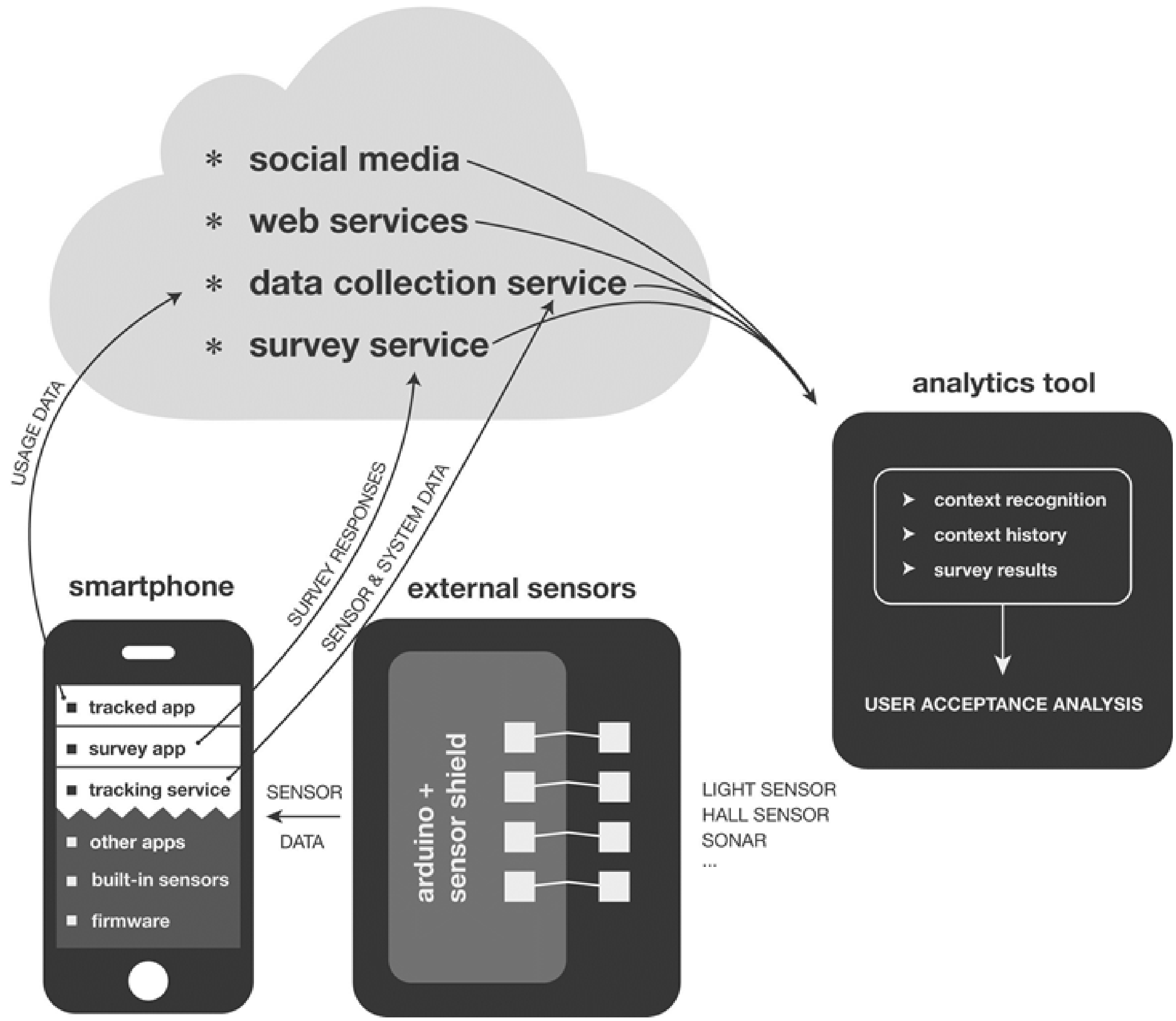

Figure 1: Components and communication between components of the tool architecture.

For mobile application use under real-life conditions only easily portable hardware may be required in addition to the mobile phone. However, the range of external sensors should not be limited to a preselected set of currently available and affordable elements. In order to be able to take advantage of technical progress and experiences gained during field tests, it should be possible to add and remove sensors without redesigning the whole system. Therefore, the smart phone is connected to an Arduino board [5] with a sensor shield for prototype tests, which allows plugging in a large variety of sensors by different vendors. The board can be connected to Android smart phones via the USB (Universal Serial Bus) interface. Different connectivity solutions are available for other devices, like the Apple iPhone.

The Arduino board has to be programmed to read measured sensor values and make them available on demand via the interface. On the mobile phone, software is required which regularly communicates with the Arduino board in order to retrieve these values. It would be impractical to include this software in every smart phone application used for customer acceptance testing. Therefore, an independent tracking service is installed. This is a program which runs in the background without interfering with the smartphone application currently visible to the user. Thus, it is possible to permanently track the user context, even while the smart phone is not actively used. Nevertheless, smartphone applications tested for acceptance have to be modified to track usage information, for example to find out which user interface elements are accessed at which points in time.

For user acceptance testing it is not necessary to interpret measured values immediately on the mobile phone in order to identify context information. Instead, they could just be stored locally and evaluated later. However, regularly retrieved raw sensor data takes up a lot of storage space, which may not always be available on the mobile phone. Also, it should be possible to evaluate context and usage information already during field trials. Therefore, as long as Internet connectivity is available, this information is immediately transferred from the smart phone to a server in the cloud. A tracking data service is installed on this server, which accepts and stores context and usage data from an arbitrary number of devices used in field trials.

Information from the tracking data service can then be retrieved from the server for evaluation at any time. Using the appropriate analytics tools, the user context can be recognized based on the retrieved raw sensor data. This can then be connected to the usage information also available from the tracking service and to additional information from social media and web services available in the cloud. Context-aware applications have to interpret context information in order to be able to immediately react in an appropriate way. This requires both classifying measured context information, like distinguishing between noisy and quiet environments based on measured loudness levels, and recognizing combinations of contexts, typically physical and temporal. Similar interpretations are required when trying to find correlations between context and customer acceptance. However, since it is not immediately clear, which context information is relevant, it makes sense to try to collect raw data for as much context types as possible first and screen it for relevance in customer acceptance later.

The mobile survey is initiated by certain events, i.e. usage of the tracked app and the current user context. Context-awareness is necessary to avoid disturbing the user and to make sure that the user is able to fill in the brief questionnaires or diary entries.

As a result, a comprehensive picture of application usage, embedded in extensive user context information, is available for user acceptance analysis.

6. Findings from user feedback

The twelve Living Lab members who participated in the ideation process were invited to give early feedback on the tool. They were informed regarding the components of the tool and could experience the paper prototypes. In order to achieve a more realistic impression of the hardware components, the technicians produced a prototype using an Arduino board and sensors.

The users and experts jointly designed implementation guidelines for the final solution of the tool in a creativity session:

- The tracking service was considered to be little obtrusive, but users required the possibility to see which data have been tracked, i.e. the tracking history.
- Moreover they demanded an easy to use option to switch off the tracking functionality.
- Users were suspiciously regarding the survey tool as they expected a continuous flow of questionnaires that needed to be answered. They asked to limit the number of surveys to one or two per day during a two week period of observation.
- Users appreciated the advantages of being tracked instead of being questioned everything.
- Regarding the communication and data flow between the components of the system the users asked for transparency. They want to

know in detail which information on their smart phone is accessed by the software components and where the information is sent to.
- The external sensor hardware was unsurprisingly considered to be too heavy in the present version. Moreover the users were reluctant to accept sensors that were attached to their body, especially in case of visible sensors (e.g. EEG).

The design of the hardware component was done in groups of six. The groups collected ideas on how to implement the external hardware. The results were then rated according to their technical feasibility (Is it possible to implement that solution by means of currently available technology?), usability (Is it easy to take the hardware with one for a longer period?), and social acceptance (Will other people be aware of and react to participants using this hardware?). This process resulted in three designs:

1. the pragmatic design
2. the futuristic design
3. the geeky design

The pragmatic design consists of a small package of sensors that can be attached on the backside of a smart phone. As NFC-enabled phones require the backside to be empty it will be better to put the external sensors into an additional cover with elements on top and on the sides of the phone. The backside remains uncovered. This design is most pragmatic as it only requires some miniaturization of the Arduino prototype, and smaller sensor hardware is already available. The advantage of this design is the direct connection to the smart phone that enables utilization of the built-in energy sources as well as avoiding that a participant forgets to take the sensor equipment with him or her.

The futuristic design suggests an additional watch-like bracelet that includes all the sensors and enables additional capturing of vital functions. The design was considered to be very unobtrusive and is expected to be socially accepted. Currently there are not enough sensors miniaturized in a way that enables such a solution as the number of required sensors is rather high and they simply will not fit into a sensor bracelet that is watch-sized. The sensor bracelet would need to communicate with the smart phone. Bluetooth was suggested as an appropriate transfer technology. Huge disadvantages of this solution are the energy-consuming transfer of data and the required Bluetooth connection between smart phone and sensor watch. Most people do not activate Bluetooth all the time and therefore the probability that participants forget to activate Bluetooth and connect the devices is quite high.

The geeky design focused on a drone helicopter that carries all the sensor equipment and follows the participants by communication with his or her smart phone. The main advantage of this solution is that the drone helicopter moves independently and moreover outside pockets or else. This fact enables extended sensing that is impossible when people carry their smart phones in pockets, e.g. using camera information or environment sensing also during non-usage of the smart phone. The social acceptance of such a solution was discussed in detail and participants came to the conclusion that this solution is ambiguous.

7. Conclusions and outlook

The findings from user feedback suggest that the tool will be accepted rather well in case some changes are made. Nevertheless, the tool requires further evaluation in real-world settings. The user feedback needs to be implemented in further prototypes that are fully functional. Currently, the components are available as prototypes or paper prototypes.

In a next step we will implement the pragmatic design of the hardware component and provide a small sample from our Living Lab with devices that are equipped with the hardware. This is done to test and further develop the usability of the component. Subsequently the software components will be installed on the mobile devices of the sample group and functional tests will be conducted. As soon as all components are working sufficiently well for large-scale tests we will provide all our Living Lab members (n=350) with necessary hardware and software. The tool is then utilized for several acceptance tests of applications, i.e. tracked applications within the architecture, within real-world environments of the Living Lab members. As a result from these tests we expect to gain in-depth knowledge concerning usage context patterns that occur in real-world settings. Moreover, it is planned to analyze the obtained data from several tests regarding patterns of contextual influences on mobile app acceptance. The results will provide a foundation for future work on theory-building activities.

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