SocioXensor: Measuring user behaviour and user eXperience in conteXt with mobile devices

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Abstract
Mobile devices tend to travel along with people wherever they are and whatever they are doing, and consequently enter various social contexts of that person. This literally puts these devices in an ideal position to capture several aspects of social phenomena. We are currently designing and implementing SocioXensor, an extensible toolkit that exploits the hardware sensors and software capabilities of contemporary mobile devices like PDAs and smartphones to capture objective data about human behaviour and social context (e.g., proximity and communication), together with objective data about application usage and highly subjective data about user experience (e.g., needs, frustrations, and other feelings). Thus, we provide the social sciences with a research instrument to gain a much deeper, detailed, and dynamic insight into these phenomena and their relations, which in turn can inform the design of successful context-sensitive applications.

Keywords
In-situ measurements, context-sensitive applications; mobile devices; logging; experience sampling

1 Introduction
Man is a social being, continuously and dynamically adapting to his social context, and increasingly supported by advances in mobile technology. Current research into context-sensitive applications stresses the relevance of using context information in applications in order to improve desirable properties such as social translucence (see for example, [3,7]). The massive success of context-mediating applications such as Presence and Instant Messaging applications [8] is a further testimony to the importance of using context information in context-sensitive applications. Mobile applications typically operate in very dynamic contexts of end-users, which makes it even more relevant for mobile applications to be sensitive about context.

Despite occasional design successes such as Presence and Instant Messaging applications, researchers are still lacking a systematic understanding which context information is relevant in what kind of situation and which kind of applications. At the same time, designers of context-sensitive applications (also referred to as context-aware computing and communication, ubiquitous computing and ambient intelligence) face design issues like: selecting which context information should be conveyed or aggregated to other human users (who then interpret that information), and selecting which context information is predictive enough such that it can be interpreted by applications. Although many methods exist to study social phenomena, including interviews, focus groups, surveys, laboratory experiments, ethnography, diary studies, logging and experience sampling, obtaining the right answers to design context-sensitive applications proves to be rather complicated [6].

In this article we describe “SocioXensor”, a research instrument for field trials in experience and application research in the area of context-sensitive applications. In particular, SocioXensor aims to strengthen logging and experience sampling by combining them with contemporary mobile and wearable devices such as smartphones and PDAs. Such devices are personal in nature and stay and travel together with one person most of the time and consequently enter various contexts of that person (e.g., home, work, and mobile context). The hardware sensors and software capabilities of such devices provide ample opportunities to capture objective data about application usage, human behaviour and the context in which this takes place, together with sampling of subjective user experience. In this way, SocioXensor allows scientists to gain a much deeper, quantitative and dynamic insight into the relations between user experiences, human behaviour, context, and application usage. SocioXensor can be applied for formative evaluation, which results in insights that can be used by designers and developers to create successful context-sensitive applications. It can also be applied for summative evaluation, for instance to evaluate a specific application.

In the remainder of this article, we first describe SocioXensor in more detail. Then, we briefly describe how SocioXensor can be applied. We conclude with a brief summary.

2 SocioXensor
The SocioXensor research instrument is an extensible software toolkit for capturing objective data about application usage, human behaviour and the context in which this takes place, together with sampling of subjective user experiences, at any time, in any location. The core idea of SocioXensor is not to bring the people to the lab, but to bring the lab to the people by using wearable, personal mobile devices like smartphones as the primary data capturing device, supported by sensors and beacons in other infrastructures where possible and appropriate (e.g., in mobile testbed networks). Put differently, SocioXensor seeks to maximize the validity of data collected by focusing on in-situ data collection, and therefore, avoiding or minimizing retrospective recall present in other self-report techniques such as surveys and interviews. As illustrated in Figure 2, SocioXensor can be more intrusive than logging, but is typically less intrusive than direct observation methods such as ethnography (which allow for very rich data capturing) or lab experiments.
2.1 Type of data collected
The SocioXensor instrument and method focuses on capturing three types of data:

- **User Experience data**: subjective information such as opinions and feelings, which can be obtained using an experience sampling procedure [2]. For example, by notifying the user of a sample (a survey with several closed questions defined by a researcher), according a pseudo-random schedule defined by a researcher (e.g., an inter-sample time uniformly distributed between 45 minutes and 1 hour and 45 minutes, with the earliest sample of a day not before 8 AM and the latest sample of a day not after 10 PM). It is also possible to notify the user on a schedule based on human behaviour and context data (see below); for example, notify the user of a sample shortly after a telephone conversation is completed.

- **Human behaviour and context data**: raw, objective data about human behaviour and context (e.g., location, proximity, activity and communication) that is captured unobtrusively through device technologies on contemporary mobile devices such as PDAs and smartphones (e.g., GSM Cell-IDs, GPS location data, Bluetooth device detection, audio microphone, call logs, contact data, and calendar data). This raw behaviour and context data can be used in later analysis to find relations and predictiveness with user experiences: for example, which raw context data predicts low tolerance for interruptions? Which raw context data predicts the relevance of other colleagues that might be able to help you given your current context?

- **Application usage data**: raw, objective data about the usage of the application that is being studied. The raw data may range from low-level keystrokes and screens to high-level application events. Note that in formative evaluation usage of SocioXensor, this type of data is typically not collected.

2.2 Architecture
The SocioXensor architecture prescribes what client, network and server elements are involved in SocioXensor, and how they interact (see Figure 1). The SocioXensor architecture also prescribes how (third-party) plug-ins for context sensors, experience samplers, and application usage sensors should interact with the SocioXensor data manager, which takes care of local storage of captured data and uploading data to a central SocioXensor repository via appropriate media at appropriate moments (see Figure 3 for an illustration of this plug-in architecture on a mobile client).
2.3 Approach
SocioXensor fits into an evolutionary prototyping research and design strategy, and can be used to get answers in field trials to formative and summative evaluation questions, such as:

- In which contexts do information and communication needs arise, and how often?
- Which (combination) of context information is relevant for an application?
- In which contexts are application features actually used?
- Which (combination of) context information predicts a user experience of an application?
- Did the user experience of an application improve? In which contexts?

The SocioXensor method guides researchers in their choices which questions to ask, according to which schedule to obtain user experience data, which human behaviour and context data sensors to use and which application usage data to log.

3 An example
In this section we argue how SocioXensor could have been applied, based on an earlier exploratory study we did into context factors that predict availability at home, at work, and on the move, in which we only used experience sampling (for details, see [4]).

It is hard for humans to remember when and under which circumstances one was available for interruption. Therefore, we decided to study availability for interruption with an in-situ research method, which minimizes the problems of retrospective recall. In this study, we used the experience sampling method to get insight in: “Which context factors are most useful in context-aware communication applications that convey availability of people for communication, not only at work and at home, but also on the move?”.

Each sample of our experience sampling instrument consisted of 4-6 questions that could be answered by an experienced participant in less than 15 seconds. The questions for each sample and multiple-choice answers can be found in Table 1. All questions and answers were presented originally Dutch; all respondents understood Dutch; although two subjects were non-native speakers.

### Table 1. Questions and answers of the FRUX ESM interruptability instrument.

<table>
<thead>
<tr>
<th>nr</th>
<th>Question</th>
<th>answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How interruptible are you now?</td>
<td>1 entirely not 2 3 4 5 entirely yes</td>
</tr>
<tr>
<td>2</td>
<td>Are you in conversation?</td>
<td>yes no</td>
</tr>
<tr>
<td>3</td>
<td>How are you in conversation?</td>
<td>face to face via fixed telephone via mobile telephone via Instant Messaging otherwise</td>
</tr>
<tr>
<td>4</td>
<td>Where are you now?</td>
<td>at home at the &lt;company&gt; office in transit somewhere else</td>
</tr>
<tr>
<td>5</td>
<td>Where at the &lt;company&gt; office?</td>
<td>My own office room office room of a colleague hallway/stairs meeting room somewhere else</td>
</tr>
<tr>
<td>6</td>
<td>How are you in transit?</td>
<td>On foot on a bicycle in a car with public transport otherwise</td>
</tr>
<tr>
<td>7</td>
<td>With how many people are you? (incl. yourself)</td>
<td>1 2 3 4-6 7 or more</td>
</tr>
</tbody>
</table>
All questions were presented on a PDA, as illustrated in Figure 4.

Figure 4 Example of a question used in the experience sampling study.

Each subject participated for 7 days. For all subjects and for all days, both weekday and weekend, samples started at the earliest on 8 AM and ended the latest at 10 PM, which corresponds to 14 hours per day. Samples were scheduled to be at least 45 minutes and at most 1 hour 45 minutes (1h45) apart, according to a uniform random distribution.

Examples of results we obtained from this study include the following. Respondents reported 37% of their time to be in conversation, amounting to 36h10 on average of the 97h40 we sampled per respondent per week. Most conversation (34% of all samples) concerned face to face conversation, amounting to 33h12 on average per respondent per week. Moreover, there were some medium correlations [1]: namely between a person’s availability for interruption and respectively being in conversation ($r = - .369$), face-to-face communication ($r = - .343$), and being in a meeting room ($r = - .293$).

Such results can be used to decide which context sensors seem to be the best predictors and hence should be applied in a context-sensitive application. For example, audio sensors might be appropriate to capture “being in a conversation”. In the exploratory study we did, we were especially interested in those variables that are good predictors and at the same time have low costs and are easy to be implemented in a context-sensitive tool.

With SocioXensor, we could have obtained the same data with even less effort of our users, e.g., by asking only the first question about availability for interruption and using context sensors to capture data about the other six questions. Moreover, SocioXensor can provide more reliable answers about the predictiveness of particular sensors (e.g., How predictive is a bluetooth-based proximity sensor for interruptability? How predictive is a audio conversation detector for interruptability?).

### 4 Summary

SocioXensor provides the social sciences with an instrument to gain a much deeper, detailed and dynamic insight into these phenomena and their relations, which in turn informs the design of successful context-sensitive applications. In addition to such formative evaluation for design, SocioXensor can also be extended with modules allowing summative evaluation of application usage in context. SocioXensor not only strengthens this crucial reciprocal link between evaluation and design, but also provides benefits to a broader audience of scientific communities including medical/biological sciences such as epidemiology.

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### References