

# The Value of Location Information

## A European-Wide Study

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**Abstract.** The value attached to privacy has become a common notion in the press, featuring frequent stories of people selling sensitive personal information for a couple of dollars. Syverson argues [1] that we should incorporate the risk of data misuse into our reasoning about privacy valuations. Yet there are doubts as to whether people can, and do, value their privacy correctly and appropriately.

Privacy is a complex notion and as such it is very difficult to value it taking into account its full complexity. In this experiment we consider one aspect of privacy, namely location privacy, that can be compromised through mobile phone network data. We performed a European-wide study to assess the value that people attach to their location privacy using tools from experimental psychology and economics. We present the first results here.

## 1 A Few Words at the Start

Privacy has always been an elusive security property. While it can be partly modelled as confidentiality, or controlled disclosure, of some personal information, individuals seem to be prepared to renounce it even for a modest reward – the popularity of store loyalty cards being a prime example. Similarly, despite declaring some sensitivity to their personal information being leaked, individuals seem to not be prepared to accept the overhead or cost of privacy enabled technologies. The market failures of flagship products like the Freedom network [2,3], an anonymous web browsing solution, illustrate this.

Yet more and more privacy intrusive technologies are deployed and become widely adopted. The GSM mobile network, to choose one that is considered indispensable in everyday life, allows for the tracking of powered-on handsets through the operator BTSs (Base Transceiver Station). This allows real-time tracking of mobile phone devices with a granularity of a few hundred meters within cities, to a few kilometres in less populated areas. The information is recorded by the operators, and often used for network management but also law enforcement operations. A private service is even available in the US that allows anyone to buy the call records associated to any mobile phone for about \$160 [4].

It seems clear that the tools of computer security alone cannot give us the full picture of people's attitudes to privacy, and for this reason we turn to experimental economics to establish the "value" that individuals attach to their privacy. In particular, we shall generalise the study by Anderson *et al.* [5] on the value of location information – and perform it on a wider and more varied population and across multiple E.U. countries. Location is a quite relevant aspect as mobile phones are ubiquitous and can be used to eavesdrop on users' movements. Location privacy study by Anderson *et al.* was done in a relatively small scale at Cambridge University. By measuring the same aspects of privacy, we can compare our results, and establish whether people's attitudes to privacy are uniform across the EU.

Some studies about people's attitudes to privacy have already been published [6,5], and experimentally pinpointing the value people attach to privacy is a difficult problem. We chose, in the tradition of Anderson *et al.*, to use an auction, where people are required in effect to sell their private information. Participants have incentives to communicate to us the true value they attach to their privacy: bidding too high may exclude them from the study, while selling at a lower price than the minimum they are expecting would provide too much discomfort for them to participate.

The key ideas behind the auction methodology used are rather simple: it has been shown that, if they are asked directly in sociological studies, individuals tend to overemphasize how privacy sensitive they are – suggesting behavior that is generally not matched by their actions. For this reason we deceive the subjects of our study and make them believe they participate in an auction where they sell private location information (the consecutive mobile phone cells they used during a month) to use in a fictitious study on mobile phone usage. The lure of real financial returns, and the action structure of the study, gives all participants incentives to state their real privacy valuation on the disclosed location data.

Our study was conducted in the context of, and with the help, of the FIDIS<sup>1</sup> network. Partners in different European countries have been instrumental in allowing us to gather data across Europe.

## 2 Towards the New Study

The original study by Anderson *et al.* [5] that pioneered this approach was limited by several factors. Firstly the population on which it was carried out had very specific characteristics: computer science undergraduates at the University of Cambridge. These were mostly male, highly educated and technically aware. Although some conclusions were drawn about the correlation between privacy sensitivity and general use of the mobile phone, as well as patterns of travel, it was very difficult to assess correlations with gender or nationality. Secondly no

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<sup>1</sup> FIDIS – "Future of Identity in the Information Society" is a 5-year Network of Excellence within the EU 6th Framework Program. Its objective is to research the changes that the concept of identity is undergoing in the developing European information society.

serious analysis was performed on the “self-selection” bias of the participants: those with high privacy sensitivity might have selected themselves out of the experiment, and not participated exactly for this reason. This could have led to a constant bias in the study underestimating the value people attach to their private location data.

Our study attempts to remedy these shortcomings. We performed the same study *in multiple European countries, in which FIDIS institutions are based*. It allowed us to compare the results across different nationalities. Due to relatively large number of respondents, not only the median value attached to the data can be compared, insights into the privacy sensitivity of local populations are also provided by the overall distributions of valuations.

A second considerable improvement over the original experiment was the use of a more gender balanced population. Replies from such a population allow us to draw conclusions about a possible gender bias between men and women when it comes to the sensitivity of location information. Similarly our new study is performed on both Computer Science / Informatics as well as less technically savvy population, to draw better conclusions about the sensitivity of an average individual.

### 3 Implementing the Study

Our study involved a small amount of deception, namely that we informed participants that the study’s object was a research on the mobile networks’ structures. We considered this approach necessary to get less biased data. Despite deception being commonplace in such experiments, it has some ethical implications we are not used to. As a result, all participating institutions had to clear the experiment with their local ethics boards, and the participants had to be informed about the true purpose of the experiment immediately after it was finished.

The study was implemented using web forms containing a questionnaire. We advertised it using emails addressed to university mailing lists to involve as many people as possible. The text of emails also leaked to readers of a large mobile phone web server in the Czech Republic thanks to Czech students contributing to its content. The information text we used was as follows.

Dear reader,

<Institution> participates in a European-wide study organised within the FIDIS (Future of Identity in the Information Society – *www.fidis.net*). This study involves gathering location data for a number of volunteers over a period of 30 days.

We are looking for people who will be monitored for the purpose of a sociological study into mobility of people and also with respect to the appropriateness of mobile phone network structures in regard to the requirements of mobile phone users. Please note that you should not switch off your mobile phone during this experiment.

The location data will be retained, and may be used again for future academic research. The location of mobile phones will be queried every 5 minutes 24x7 in cooperation with your mobile phone operator for the whole period of the study. The resolution of the position is within the phone network's "current cell" – about 800 meters in countryside, 100-200 meters in built-up areas. This querying will not be affecting any functions of mobile phones.

Each participant in the study will receive monetary compensation, and we are running an auction to select those who will take part. We invite you to submit a bid for the amount of money you require to take part in such a study. As our budget is fixed and limited, successful bidders will be those who bid the lowest amounts, and each will be paid the amount of compensation demanded by the lowest unsuccessful bidder.

Please visit the link [www.buslab.org/FIDIS\\_experiment](http://www.buslab.org/FIDIS_experiment) regardless of your intent to take (or not) part in this study.

Best regards,  
<name of sender>

A similar introductory e-mail was sent out to university students in five countries (translated into the local languages and with the institution name of the local partner of the study).

### 3.1 Structuring the Questions

The web questionnaire was structured into four logical parts. The first part contained a longer version of the introductory email (very much similar to part 3.3 in [5]). We put a question about the respondent's interest in the study at the end of the text. There were three options a potential participant would choose from:

- I do not have a mobile phone
- I do have a mobile but I am not interested to participate
- I do have a mobile phone and I am interested to participate

Those answering they both have a mobile phone and are keen on taking part in this study, were presented with a request for their e-mail address. An email was then sent to them with a login name and a password for further communication through the web interface. After a successful enrollment and subsequent authentication, the following questions (with predefined options for answers 1-6 as pull-down menus) would be presented:

- Is your background (area of study)?
  - a) Computer Science, Comp./El./Comm. Engineering, Informatics, b) Law,
  - c) Other areas
- What is your gender?
- What network do you use for your main mobile phone?
  - <list of local operators>

- Do you carry a mobile phone with you most of the time?  
a) yes, b) no
- How often do you make irregular movements (such as shopping, going out with a friend, pub, visiting friends)?  
a) several times a day, b) every day, c) every week, d) every month
- With whom do you communicate using your phone?  
a) friends, b) family, c) partner, d) business
- How much compensation would you require to participate in our study for 30 days (in whole amounts of local currency)?
- Text array for free comments.

The second form (a very short one) was presenting the subject with a possible change in the use of the collected data. The text stated that “there is now some possibility of commercial interest (from partners of your mobile phone operator) in the data collected during our study. We would be grateful if you could let us know whether you would”

- not be willing to participate in the study if the data might be used by a regular business partner of your mobile phone operator.
- allow your data to be used by a regular business partner of your mobile phone operator for the same amount of compensation you originally bid.
- allow your data to be used by a regular business partner of your mobile phone operator only if you were allowed to revise your bid for compensation.

The second form may have benefited from being presented to subjects a few days after the first one. This would allow the subject to “forget” their valuation, rather than facing a sharp contrast between “academic” use, and “commercial” use. This could have been done using the collected email addresses. We conjecture that the results would not have been significantly different, yet confirming this experimentally should be the subject of a further study.

The final form further modified the parameters of the study. It stated that “a business partner of your mobile phone operator inquired about the option to extend the experiment period to 12 months in total. Would you”

- decline your participation in the experiment.
- participate for the following amount of money <enter the sum>.

## 4 Basic Results of the Study

Our web questionnaires were up for about a month. We received majority of responses during the 48 hours after emails were sent out, except for the Slovak Republic where the information was being spread with paper notices. As a result, responses there were uniformly spread throughout the month of the experiment.

We present here the key features of the collected data. In particular, we describe the basic demographics and the distributions of the bids, by questions regarding gender and mobility. A more thorough analysis and modelling of the data is left for future work.

**Table 1.** Numbers of participants in countries

Country	Total	Women
Belgium	37	3
Czech Republic	744	131
Germany	251	33
Greece	30	6
Slovak Republic	152	46

**Table 2.** Who is being called by mobile phones

Calling	friend	family	partner	business
Number	1076	975	598	358

About 1200 participants answered the first set of questions. These were from five countries: Belgium, Czech Republic, Germany, Greece, and Slovak Republic – mainly representing people from the Central Europe, as well as from the Southern and the Western Europe. The partitioning of the participants according to their country of origin is in table 1. The sets of the Czech Republic, Germany, and the Slovak Republic are large enough to allow for very detailed structuring of results. The smaller sets of Belgium and Greece are used more as “control sets” to verify general results.

The set of the participants consists of 800 people with a background related to computers, 32 “lawyers”, and 381 with another (unspecified) background. All but ten participants carry their mobile phone all the time.

The second demographic aspect concerns the frequency of irregular movements: 483 people do such movements several times a day, 520 about once a day, 194 in a week intervals and only 15 monthly – we again obtained three very large sets suitable for an analysis. Mobile phones are mostly used to catch up with friends. The second most often called on average is a family member, followed by a partner and business (table 2).

The first question to be answered was whether the respondents were interested in the study, not interested in the study, or whether they had no mobile phone. We call those who chose the second option “early drop-outs”, and it was chosen by 11 people from Belgium, 85 from the Czech Republic, 65 from Germany, 32 from Greece, and 46 from the Slovak Republic. We recalculate the numbers as ratios of those not interested to those interested by country, and show our results in table 3.

It is obvious that the first irregularity is amongst Greek respondents, where half are not interested in taking part in the study! For the population without

**Table 3.** People not interested in the study to those interested

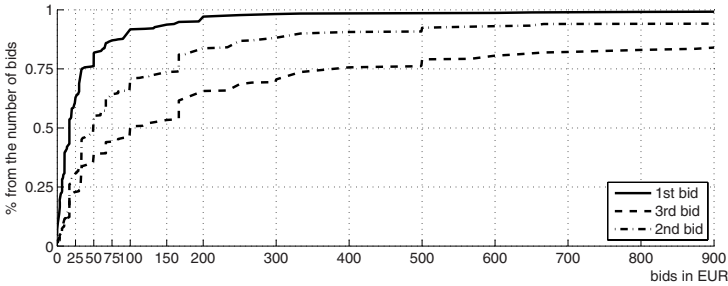
Language	BE	CZ	DE	GR	SK
Not interested	30 %	11 %	26 %	107 %	30 %

**Table 4.** Fraction of the respondents interested and eventually enrolling

Language	BE	CZ	DE	GR	SK
Interested	44 %	56 %	52 %	32 %	42 %

**Table 5.** Distribution of types of answers to the change of data usage

Language	BE		CZ		DE		GR		SK	
Sex	M	M	F	M	F	M	M	F	M	F
Declined	16 %	10 %	13 %	21 %	23 %	25 %	9 %	3 %		
Same bid	39 %	47 %	42 %	51 %	45 %	50 %	49 %	40 %		
Revised bid	45 %	42 %	44 %	28 %	32 %	25 %	42 %	57 %		



**Fig. 1.** Cumulative distribution of bids – people bidding in all three scenarios

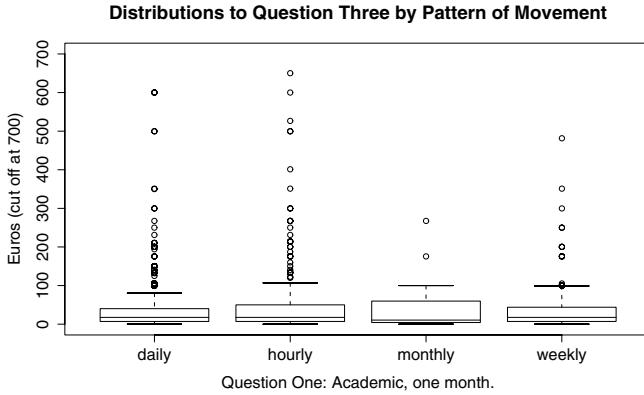
early drop-outs, we get very similar statistics for those who did not fill their e-mail address (table 4). The numbers are fractions of *took\_part* / *were\_interested*.

The differences are not so large in this case but Greek participants are again the most cautious among all the nations.

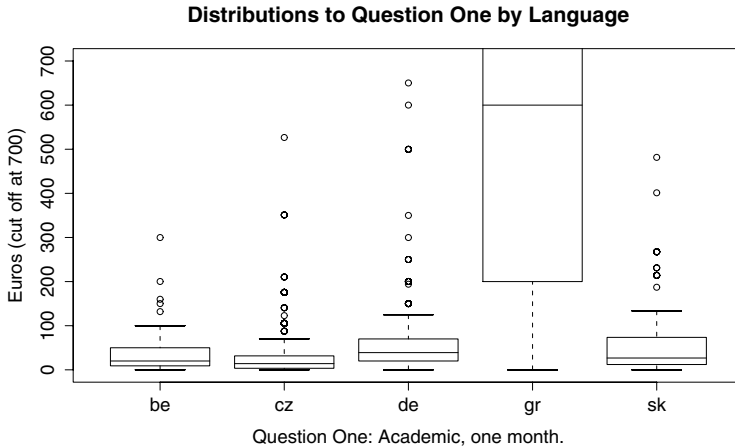
An important part of our experiment was assessing people’s sensitivity to commercial exploitation. Questionnaire 2 was requesting respondents to submit a bid compensating their participation in the experiment involving a commercial partner, and were also given a chance to opt-out. The following table (table 5) shows divisions of participants according to their answer for the 2nd bid.

Table 5 seems to present that participants from the two Central European countries (CZ and SK) were declining participation less often than respondents from other countries. (It might be an interesting fact related to recent history of controlled political environment requiring obedience from citizens.)

The first plot we present (fig. 1) shows bid distributions of people who entered values for all three possible uses of data. The x-axis depicts value of bids in EUR while the y-axis shows the fraction of bidders who entered bids of value lower or



**Fig. 2.** Correlation between distributions of bid values and frequency of movements



**Fig. 3.** Distributions of 1st bid values per country

equal to a given amount. One can see that median of the bids increased about 3 times when comparing the bids when the data were to be used only for academic purposes and for commercial purposes. The extension of the study period from one month to a year yielded only twofold increase in the bids (again measured in medians).

We expected the value of bids to be related to how much people are traveling or, in general, moving irregularly. Figure 2 depicts the distributions of bids according to regularity of movement, and refutes this assumption. The third quartile for hourly movements is higher than that for daily or weekly movements, but monthly movements have an even larger third quartile.

We have already described several results demonstrating the increased sensitivity of Greeks to possible breaches of their privacy. Figure 3 gives an overview



of bids by countries. You can again see that the Greek perception of privacy is much different from all other countries.

## 5 Conclusions

We hope to distill some more information from the experiment described above but we can already list the most interesting facts. There is about ten percents of people bidding below 1 EUR. We believe that this fact comes from curiosity and enthusiasm of participants. We received amount of feedback expressing interest in the results when the deception text (stating the improvement of the network quality as the main goal of the study) was sent out.

Surprisingly, we have not found any correlation between valuations and the way the respondents commute or move in geographic terms. The results do not show any such connection which is slightly contradicting the results of the Cambridge study [5].

The highlight of the experiment is the evidence of Greek sensitivity to possible privacy breaches. This almost certainly follows from an eavesdropping scandal [7]. Top politicians were being wiretapped for a period of eleven months during and after 2004 Olympic Games. This was confirmed at the beginning of February 2006 by the Greek government – just two months before our experiment actually took place.

The revised bids were 2.5 to 3 times higher (in average) than the first bids. We are of the opinion that this was the moment when participants realised that their data might be used for purposes hard to foresee. The third bids increased only twice from the second bids. This contradicts an assumption of proportionality between value of bids and amount of data collected.

Basic results confirm results of the Cambridge study – *e.g.* medians of bids are 20 GBP and 33 EUR for non-commercial use of data.

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