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Does imperfect data privacy stop people from collecting personal health data?

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Abstract

Information problems in healthcare markets arise due to a lack of acquisition and disclosure of personal health data and can result in inefficient outcomes. Privacy regulations can affect the willingness to collect and disclose personal health data to insurers. We contrast three institutional settings in a simple game of persuasion: disclosure duty of collected data, perfect data privacy and imperfect data privacy. In the persuasion game a player's health type influences the insurer's payoff. Given insurers are ex ante willing to contract with unknown health types, under perfect privacy there exists a unique proper equilibrium with complete information acquisition. For disclosure duty no information acquisition is predicted. Imperfect privacy can result in both equilibria. We complement the theoretical analysis with a laboratory experiment. Behavior under imperfect data privacy is similar to perfect privacy. Imperfect privacy does not stop subjects from collecting personal information.

JEL Classification: C90, D80, D82, I10

Keywords: data privacy, endogenous information acquisition, health, experiment, unraveling.

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1 Introduction

Regular visits to the doctor or undertaking specific medical tests such as tests for chronic diseases, sexually transferable diseases (STDs) or genetic tests are important for the prevention and intervention of serious diseases through early interventions. These tests generate data. Since it is in the insurers' interest to discriminate among different health types insurers would benefit from access to the collected data. Anticipating this discrimination, patients may become reluctant to take medical tests and thereby society forgoes potential benefits from early prevention. Several relevant privacy institutions have been theoretically discussed (see e.g. Barigozzi and Henriet, 2011; Doherty and Thistle, 1996; Hoy and Polborn, 2000), among them an environment with perfect privacy where patients are in full control of their collected data and an environment with disclosure duty in which patients have to disclose collected information when contracting with an insurer.[1] If insurers are ex ante willing to match with unknown types, under disclosure duty patients will refrain from collecting information because by collecting this (potentially discriminating) information that will eventually be disclosed to the insurer, patients indirectly reduce future prospects for insurance contracts (e.g. health, life and occupational disability insurance[2]). In this paper we analyze theoretically whether an environment without disclosure duty but without guaranteed privacy (imperfect privacy) is already sufficient to make people stop collecting personal health data and provide empirical evidence on the causal effect of the different privacy institutions on testing and disclosure behavior.

So far the literature has neglected the central aspect that perfect privacy cannot always be guaranteed. However, an environment with imperfect privacy is a reasonable assumption for at

[1] Apart from Perfect Privacy (Consent Law) and Disclosure Duty two more approaches have been considered by Barigozzi and Henriet (2011): a Laissez-Faire approach, under which insurers can access test results and require additional tests and Strict Prohibition of the use of test results.

[2] Of course the same holds for stigmatization and discrimination on other matching markets.

least three reasons. First, it is a representative environment since information about personal health attributes has often to be generated through the help of third parties (e.g. doctors); patients are not in full control of their personal data. Second, technological advances have increased the possibilities of health and genetic testing such that more and more data can be collected, stored and accessed,[3] which has put data privacy issues to public and legal debate.[4] Third, recent developments (such as Wikileaks and the NSA Affair[5] or incidents in the UK, e.g. in 2007 when hundreds of thousands of National Health Service patients' details were lost[6]) have remembered the public that perfect control over personal data may be a naïve conjecture.

To study the question whether imperfect data privacy stops people from collecting personal health data, we investigate behavior in a simplified game of persuasion that captures the main decisions people face in the context of acquisition and disclosure of personal health data. We focus on the decision to take tests which reveal information that is most valuable to the insurer, e.g. information about people's unchangeable health attributes (such as results from tests for chronic diseases or genetic tests). Results from such tests reveal relevant information as soon as they have been taken (irrespective of whether the test is taken several times) such that the decision to test reflects a one shot decision of an inexperienced actor. Therefore we study behavior in a one-shot persuasion game. Patients decide whether to collect information about their own health status - which can be good or bad. Thereafter they decide whether or not to disclose the collected information to persuade the insurer to offer a contract. The information transferred affects the prospects for a contract with the insurer, because the insurer's profits

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[3] See also Kierkegaard (2011) who discuss the merits and weaknesses of a centralized European health record system as planned by the European Commission's Directive 2011/24/EU.

[4] For a discussion with respect to legal aspects see e.g. Peppet (2011).

[5] See e.g. http://www.economist.com/news/briefing/21579473-americas-national-security-agency-collects-more-information-most-people-thought-will (downloaded: September 2013).

[6] See http://news.bbc.co.uk/2/hi/uk_news/7158019.stm (downloaded: September 2013).

depend on the patient's health status. The insurer will contract with an identified good health type but will refuse to contract with an identified bad type.[7] Because the insurer cannot directly identify whether a test has been conducted, it depends on the institutional setting whether or not the insurer will contract with an unknown type.

We contrast three privacy institutions that differ with respect to how information, collected through testing, is transferred to the insurer: First, we study a situation in which patients have to disclose collected information when contracting with an insurer (*Disclosure Duty*). This setup is the regulatory rule for instance in New Zealand, the UK and Germany when it comes to genetic testing (see Barigozzi and Henriet, 2011). Second, we investigate voluntary disclosure of collected information (from now on *Perfect Privacy*). *Perfect Privacy* is equivalent to Consent Law implemented for genetic testing, for instance, in the Netherlands and Switzerland (ibid.).[8] Third, we introduce an institution in which data privacy cannot be guaranteed (from now on *Imperfect Privacy*). This institution reflects Consent Law with the additional possibility of data loss, which enters our theoretical model in a probabilistic way.

We show that given insurers are ex ante willing to contract with unknown health types, the only Proper Equilibrium (Myerson, 1978) for *Disclosure Duty* is a pooling equilibrium in pure strategies, in which patients will not collect information. The only Proper Equilibrium for *Perfect Privacy* is a separating equilibrium in pure strategies with full information acquisition. For *Imperfect Privacy* there exist, both, the separating equilibrium with complete information

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[7] Our framework may also interpreted as a situation in which the insurer offers two tariffs, one for good and one for bad health types.

[8] Consent Law describes the situation in which consumers "are not required to divulge genetic tests results. But, if they do, insurers may use this information" (Viswanathan et al., 2007, 68).

acquisition and the pooling equilibrium without information acquisition as well as a proper mixed strategy equilibrium with incomplete information acquisition.[9]

Due to the existence of multiple equilibria (under *Imperfect Privacy)* our theoretical model does not provide clear guidance with respect to whether imperfect data privacy stops people from collecting personal information. Therefore, it is crucial to investigate which outcomes may result from actual behavior. Although there is data available for differences in medical testing and privacy institutions across countries (for instance data on HIV tests across countries provided by WHO and the Data Privacy Index provided by Privacy International), it is difficult to estimate the causal effect of privacy institutions on testing behavior empirically due to cultural differences across countries, differences in access to medical testing and differences in rules with respect to testing (e.g. opt-in and opt-out rules for HIV testing for pregnant women etc.). Hence, we complement our theoretical analysis with a laboratory experiment which allows identifying the causal relationship between privacy institutions and information acquisition in a simplified but controlled environment.

The participants of the laboratory experiment played a neutrally framed version of our two-player persuasion game. We parameterized the game such that insurers were ex ante willing to contract with unknown health types and implemented three different treatments reflecting the institutions described above. The experimental results show that behavior in *Perfect Privacy* and *Imperfect Privacy* almost coincides. Thus, imperfect data privacy does not stop people from collecting personal information. Only under *Disclosure Duty*, information acquisition is reduced and contracting with unknown types becomes common.

[9] Note that we model both patients and insurers as risk neutral agents and abstain from modelling direct costs or benefits from testing. However, we provide a discussion on the robustness of our results with respect to risk aversion as well as costs and benefits from testing.

The rest of this paper is structured as follows. In Section 2, we review the related literature. In Section 3 we present our theoretical arguments. Section 4 encompasses detailed information about the experimental design, procedures, and results. The theoretical and empirical results are discussed in Section 5. We conclude with Section 6.

2 Related Literature

Our paper relates to two branches of literature. First, we contribute to behavioral and experimental approaches dealing with patients' behavior in the context of health economics. Second, we enrich the discussion on the merits of privacy and testing for quality information.

Most behavioral studies on patients' behavior have focused on prevention through the promotion of healthier lifestyles. In this respect randomized controlled trials have been used to study how dietary and smoking habits, cancer prevention, gym visits, vaccinations and doctoral visits can be affected by small nudges (Altmann and Traxler, 2012; Calzolari and Nardotto, 2011; Cox et al., 2010; Milkman et al., 2013; Rothman et al., 1993), commitment devices and/or monetary incentives (Acland and Levy, 2010; Augurzky et al., 2012; Babcock et al., 2012; Charness and Gneezy, 2009; Giné et al., 2010; John et al., 2011; Volpp et al., 2008).[10] Our study also focuses on patients' decision about preventive actions. We address the question whether or not patients decide to undergo a specific test for their health type, which is important for the prevention and treatment of serious diseases through early interventions. In contrast to nudging and paying for patients' performance studies, we focus on how institutions (in form of different privacy regulations) shape patients' incentive structure and thereby affect their willingness to collect and disclose personal health data.

[10] For an evidence based survey of the literature on incentives for weight loss see also (Paloyo et al., 2013).

Thus, we also contribute to the literature on the merits of privacy for testing and revealing quality information.[11] Testing for quality information has been studied theoretically in the context of insurance markets (see e.g. Doherty (see e.g. Barigozzi and Henriet, 2011; Doherty and Thistle, 1996; Hoy and Polborn, 2000) and matching markets (see e.g. Caplin and Eliaz, 2003; Philipson and Posner, 1995).[12] The theoretical work by Barigozzi and Henriet (2011) relates most closely to our approach. The authors are also interested in the welfare implications of different privacy institutions for costless testing in an insurance market. In contrast to our study, testing in their model allows also for better insurance choices. Although we abstain from modelling such benefits, our approach overlaps.[13] As Barigozzi and Henriet we compare Perfect Privacy and Disclosure Duty. We extend their work by introducing an institution in which patient's face the risk of involuntary disclosure (Imperfect Privacy) and by providing empirical evidence from a laboratory experiment that tests the predictions of our theoretical model for the different privacy institutions. By doing so, we enrich this otherwise theoretical discussion with results on actual behavior of people who faced the incentives shaped by the different privacy institutions.[14]

[11] For early contributions to this discussion see Stigler (1980) and Posner (1981) as well as Hermalin and Katz (2006). Further, see also theoretical contributions based on Grossman (1981)'s and Milgrom (1981)'s idea of unraveling in markets with asymmetric information that model endogenous information acquisition (e.g. Brocas et al., 2012; Gentzkow and Kamenica, 2011; Perez-Richet, 2012). For an experiment on the revelation of quality types in a labor market context see also Benndorf et al. (2013).

[12] Our work relates further to the more general discussion about genetic testing (see Bardey and De Donder, 2013; Hoel and Iversen, 2002; Tabarrok, 1994).

[13] While we abstain from modelling decision making value of testing, we do provide a discussion on the robustness of our results with respect to explicit costs and benefits from testing at the end of our theory section.

[14] The latter also relates our study to experimental studies on the elicitation of privacy preferences (see for instance Acquisti et al., 2013; Benndorf and Normann, 2014; Beresford et al., 2012; Grossklags and Acquisti, 2007; Hall et al., 2006; Huberman et al., 2005; Schudy and Utikal, 2014; Tsai et al., 2011).

3 Theory

3.1 The Model

Our theory builds on a simple game of persuasion which reflects the idea of an insurance market in which a patient (player 1) persuades an insurer (player 2) to contract by providing certified information about her health type. Player 2 can contract (match) with player 1 and both may benefit from the match. A match is always profitable for player 1. However, player 2's payoff depends on player 1's type. Player 1 can be a good (type G) or a bad type (type B). A match with a good type increases player 2's payoff. A match with a bad type decreases his payoff (e.g. costs for medical treatments to be paid by the insurer). A match results in payoff M for each player. However, if player 1 is a bad type, player 2 additionally incurs a loss of I.[15] We assume $M>0$, $I>0$, and $I>M$. The last assumption describes the fact that a match with a bad type decreases player 2's payoff. Let $0<b<1$ be the share of bad types in the population of players 1. We assume both players to be risk neutral.[16]

Player 1 does not know her type ex-ante, but she can test and disclose her type to player 2 before player 2 decides on whether to match. Testing and disclosing is costless.[17] The action of testing (not testing) is denoted by T ($\bar{T}$). The action of voluntarily disclosing (not voluntarily disclosing) the test result to player 2 is denoted by D ($\bar{D}$). Let d_G, d_B be the probabilities that type G and type B voluntarily disclose their type after testing.

Player 2 can learn player 1's type only if player 1 had herself tested. After a test, player 1 might disclose her type voluntarily. However, player 2 might learn the test result although player

[15] We refrain from modeling a partial internalization of the loss of utility (from a match with a bad type) of player 2 by player 1. Nevertheless modelling this internalization as a loss of I' for player 1 does not change the model's predictions as long as $I'<M$.
[16] We discuss the robustness of our results with respect to risk aversion in subsection 3.2.1.
[17] We discuss the impact of explicit testing costs in subsection 3.2.2.

1 decided against disclosing with probability p. Therefore, $p = 1$ reflects *Disclosure Duty*, $p = 0$ reflects *Perfect Privacy* and $0 < p < 1$ reflects *Imperfect Privacy*. Note that the action of testing itself cannot be observed. Hence, if player 2 does not learn player 1's type, he also does not learn whether player 1 had herself tested or not. Let U (unknown) denote the fact that player 2 does not know player 1's type. X ($\bar{X}$) denotes player 2's decision to match (not to match) and s_i denotes the strategy of player i.

We are now ready to describe the existence of equilibria under the different privacy institutions. For all institutions, player 2 will match with an identified type G and will never match with an identified type B. Whether player 2 will match with an unidentified type U, depends on the data privacy institution (i.e. on p). In the following, we present equilibria in pure strategies for each institution separately followed by a short intuitive reasoning.[18]

Proposition 1 (Disclosure Duty)

a) For $p = 1$ and $M \leq bI$
$s_1 = T, s_1(G|T) = D, s_1(B|T) = d_B$ with $0 \leq d_B \leq 1$,
$s_2(G) = X,\ s_2(B) = \bar{X}$ and $s_2(U) = \bar{X}$
is a pure strategy equilibrium (complete information acquisition).

b) *For* $p = 1$ *and* $M \geq bI$
$s_1 = \bar{T}, s_1(G|T) = d_G$ with $0 \leq d_G \leq 1, s_1(B|T) = \bar{D}$,
$s_2(G) = X,\ s_2(B) = \bar{X}$ and $s_2(U) = X$
is a pure strategy equilibrium (no information acquisition).

Because all test results are revealed under *Disclosure Duty*, an unknown type has to be an untested player. The expected payoff of a match with an untested player is non-positive as long as $M \leq bI$. Therefore, for $M \leq bI$ player 2 will not match with untested players and player 1 can

[18] We relegate formal proofs of all propositions as well as the derivation of mixed strategy equilibria to the appendix.

only gain from testing. For $M \geq bI$ the expected payoff of a match with an untested player is non-negative. Therefore, player 2 will match with untested players and player 1 will not test.

Proposition 2 (Perfect Privacy)

a) For $p = 0$

$s_1 = T, s_1(G|T) = D, s_1(B|T) = d_B$ with $0 \leq d_B \leq 1$,

$s_2(G) = X,\ s_2(B) = \bar{X}$ and $s_2(U) = \bar{X}$

is a pure strategy equilibrium (complete information acquisition).

b) For $p = 0$ and $M \geq bI$

$s_1 = \bar{T}, s_1(G|T) = d_G$ with $0 \leq d_G \leq 1, s_1(B|T) = \bar{D}$,

$s_2(G) = X,\ s_2(B) = \ \bar{X}\ and\ \ s_2(U) = X$

is a pure strategy equilibrium (no information acquisition)

If player 2 does not match with unknown types, it is worthwhile to test for player 1. Also, it will be worthwhile for player 1 to disclose her test result if the test reveals that she is of type G. Type B is indifferent whether or not to disclose her type. In turn, as everybody tests and type G discloses her type, player 2 will not match with unknown types (who are all of type B). Given player 2 matches with type G and unknown types U, player 1 is (in expectation) not better of when testing and hence does not deviate from her strategy of not testing.

Proposition 3 (Imperfect Privacy)

a) For $0 < p < 1$

$s_1 = T, s_1(G|T) = D, s_1(B|T) = d_B$ with $0 \leq d_B \leq 1$,

$s_2(G) = X,\ s_2(B) = \bar{X}$ and $s_2(U) = X$

is a pure strategy equilibrium (complete information acquisition).

b) For $0 < p < 1$ and $M \geq bI$

$s_1 = \bar{T}, s_1(G|T) = d_G$ with $0 \leq d_G \leq 1, s_1(B|T) = \bar{D}$,

$s_2(G) = X,\ s_2(B) = \bar{X}$ and $s_2(U) = X$

is a pure strategy equilibrium (no information acquisition).

The intuition for the equilibrium with complete information acquisition (3a) is the same as for (2a). The intuition for the equilibrium with no information acquisition (3b) is that given player 2 matches with type G and unknown types U, it is clearly worthwhile to forgo collecting information as long as data privacy is not guaranteed ($p>0$) because not collecting information prevents involuntary disclosure of being a bad type. If nobody tests, the set of untested players and the set of players of unknown types coincide and thus matching with unknown types will be worthwhile (or at least not harmful) for player 2 with $M \geq bI$.

In addition to the pure strategy equilibria there exist several mixed strategy equilibria in which information acquisition is incomplete. We relegate the derivation of these equilibria to appendix B but report the existence of these equilibria along with the proper pure strategy equilibria in Figure 1.

3.2 Risk aversion, costs and benefits from testing and equilibrium refinements

In this section we discuss the robustness of the different equilibria with respect to our assumption of risk neutral players. Thereafter, we offer a brief discussion of the robustness of the different equilibria with respect to the introduction of explicit costs or benefits from testing. Finally, we show which of the derived equilibria are *Proper Equilibria* (Myerson, 1978).

3.2.1 Risk aversion

For all institutions, equilibria without information acquisition and incomplete information acquisition do not exists if player 2 is sufficiently risk averse because in this case player 2 will only match with identified good types. The equilibrium with full information acquisition holds also for risk averse players, since player 2 chooses the save option (matching with tested good types only) in equilibrium and player 1 has, in equilibrium, nothing to lose by playing the "lottery of testing".[19]

3.2.2 Costs and benefits from testing

We abstained from modeling costs and benefits explicitly.[20] In this section, we briefly extrapolate how the introduction of costs and benefits affects the existence of the different equilibria. We will consider both, costs and benefits from testing that do not depend on the outcome of the test (costs of the test) and costs that depend on the testing outcome (psychological costs).[21]

First, it is clear that pure strategy equilibria in which people decide to test and reveal will still exist, if we introduce benefits from testing (both outcome dependent and outcome independent benefits), because benefits make testing even more attractive. Second and analogously, pure strategy equilibria without information acquisition and matching with unknown types will still exist, if we introduce costs from testing (for both types of costs). Third, it can be shown that the equilibria with full information acquisition also hold with explicit costs from testing as long as the expected gains from testing outweigh the costs. Equilibria with no information acquisition still hold for $p > 0$ as long as the benefits from testing for Player 1 are smaller or equal to the expected loss of a match due to the revelation of a bad test outcome. However, under *Perfect Privacy* ($p = 0$), the equilibrium without information acquisition does not hold as soon as there

[19] Assuming a risk neutral insurer but a risk averse consumer (as Doherty and Thistle, 1996), equilibria with complete information or no information still exist for all institutions. Equilibria with incomplete information acquisition exist only for *Disclosure Duty* and *Imperfect Privacy*.

[20] The assumption reflects the work by Philipson and Posner (1995, p. 446) who also assume that the main beneficiary of the test is the partner who learns about the quality.

[21] By doing so we implicitly deal with benefits from knowing to be the good type (which are in our model mathematically equivalent to costs from knowing to be the bad type) and costs from not knowing to be the good type (which are mathematically equivalent to benefits from knowing to be the bad type).

are benefits from testing. Player 1 will test because collecting benefits from testing is riskless, if privacy is guaranteed.

3.2.3 Equilibrium refinements

We derive several equilibria for each institutional setting. In this section we briefly discuss whether the number of equilibria may be reduced by applying the equilibrium refinement concept of *Proper Equilibrium*. The notion of *Proper Equilibrium* has been introduced by Myerson (1978) and is a further refinement of Selten (1975)'s *Trembling-Hand Perfect Equilibrium*. *Proper Equilibria* consider the possibility that players play also non-equilibrium strategies with positive but very small probability such that decision errors are possible. The main idea of the *Proper Equilibrium* concept is that the likelihood of an error depends on the costs of making the error, i.e. making a more costly error can never be more likely than making a less costly error. Applying this idea to our propositions it can be shown that for *Perfect Privacy* ($p = 0$) the equilibrium without and incomplete information acquisition are no Proper Equilibria. All equilibria we derived for *Imperfect Privacy* and *Disclosure Duty* remain. Figure 1 summarizes these findings. The figure illustrates that privacy institutions do not matter for testing if $M<bI$. Here only equilibria with complete information acquisition are possible. Since $M=bI$ is a very unlikely assumption, we focus on the case $M>bI$. Here, the *Proper Equilibrium* predicts no information acquisition in *Disclosure Duty,* and complete information acquisition in *Perfect Privacy.* However, the theory does not provide clear guidance with respect to the question whether *Imperfect Privacy* stops people from collecting information. Therefore, we implement our model in an experiment that allows us to investigate whether behavior under *Imperfect Privacy* rather coincides with behavior under *Perfect Privacy* or *Disclosure Duty*.

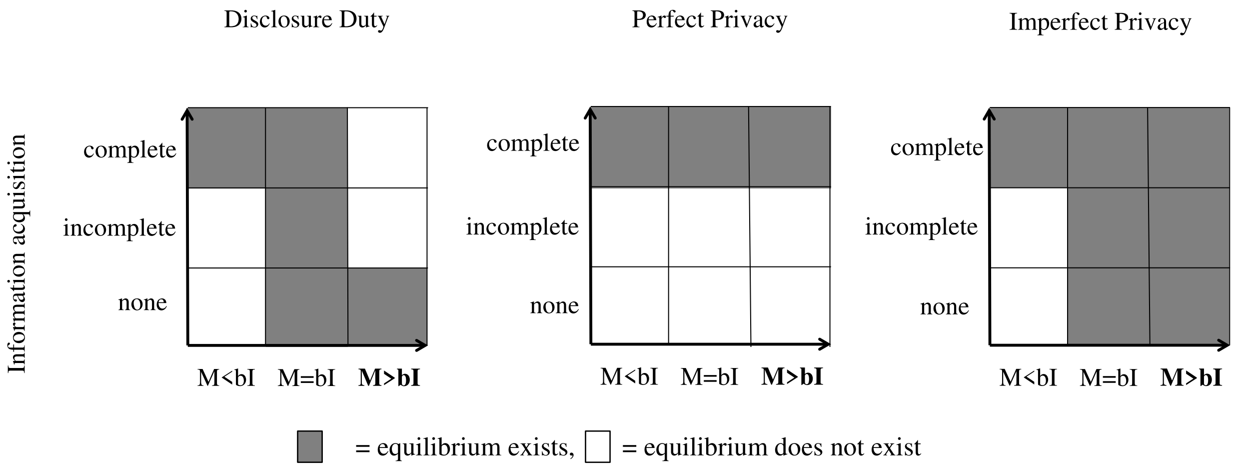

Figure 1: Proper equilibria in the different privacy institutions

4 Experiment

4.1 Experimental design

We chose the following parameter values for the experiment which were all common knowledge: The share of bad types *B* within players 1 was $b = 1/3$. A match yielded 10 points for both players (*M=10*). A match with type *B* additionally decreased player 2's payoff by 15 points (*I=15*). At the beginning of the experiment, each player received an endowment of 10 points to prevent negative payoffs. Two subjects were randomly assigned to each other to form a pair. Player 1 decided whether to test for her type and whether to disclose the test result. Testing was costless. Player 2 potentially learned the test result and decided whether to match.

As in our theoretical framework, the choice of whether or not to undertake a specific test in the experiment is a one shot decision for three reasons. First, specific tests (such as genetic tests) are usually not taken repeatedly. Second, taking a test once is sufficient that the information created by the test can be assessed by others (e.g. insurers). Third, the decision to buy a specific insurance, e.g. disability insurance, is usually non-repeated.

We implemented three values of p as treatment conditions in a between subjects design: $p = 1$ (*Disclosure Duty*), $p = 0$ (*Perfect Privacy*) and $p = 0.5$ (*Imperfect Privacy*). Remember that after a test, the test result was displayed to both players automatically in *Disclosure Duty* whereas in *Perfect Privacy*, player 1 first learned the test result and then decided whether to display the result to player 2. In *Imperfect Privacy,* after a test, player 1 first learned the test result and second decided whether to display the result to player 2. However, if player 1 decided to test she ran the risk of involuntary disclosure of the test result.[22] Note that player 2 only received information about the type of player 1 but not about whether or not this information was voluntarily revealed. Disclosing test results was costless and the test result displayed to both players was true in all treatments.[23]

4.2 Experimental Procedures

We computerized the experiment using z-Tree (Fischbacher, 2007). Each player sat at a randomly assigned and separated computer terminal and was given a copy of instructions.[24] The experiment was neutrally framed.[25] A set of control questions was provided to ensure that participants understood the game. If any participant repeatedly failed to answer correctly, the experimenter provided an oral explanation. No form of communication between the players was allowed during the experiment. We conducted four sessions at the LakeLab (University of Konstanz, Germany) in January 2011 and another two sessions in December 2011. The first four sessions

[22] We implemented two variants of the imperfect privacy institution. In the first variant, subjects first decided whether to transfer information voluntarily and then a random device decided whether the test result was shown on player 2's screen (irrespective of whether player 1 disclosed her type). In the second variant, the random device first chose whether the information about player 1's type was displayed and second player 1 decided about the voluntary disclosure (if disclosure was not forced). We observed no differences in behavior in the two variants. Therefore we pooled the data from both variants in the results section.

[23] For a discussion on imperfect testing devices see e.g. Caplin and Eliaz (2003) or Rosar and Schulte (2010) and more recently Schweizer and Szech (2013).

[24] A copy of translated instructions can be found in appendix C.

[25] We did not use the expressions "good" or "bad" but types A or B.

were run after a completely unrelated experiment with 84 participants in total. The two sessions in December with another 42 participants were run independently. We recruited participants from the local subject pool using ORSEE (Greiner, 2004). In all treatments each participant decided in both roles, first as player 1 and then as player 2. For every role players were matched with a different player (perfect stranger matching). Players received no feedback on their payoff as player 1 until the end of the experiment. To avoid testing out of general curiosity, players were informed about their type as player 1 at the end of the experiment and knew this ex ante. Players were paid for both roles. Procedures and parameters were common knowledge. Our experiment lasted 30 minutes. 1 point translated into 20 cents. Participants in our experiment received a 2 euro show-up fee and earned 6.62 euros on average ($9.94 at that point in time).

4.3 Experimental Results

Figure 2 presents testing frequencies for all treatments. Testing in *Perfect Privacy* is significantly more likely than in *Disclosure Duty* (χ^2-test, p-value < 0.001). Also, testing in *Imperfect Privacy* is significantly more likely than in *Disclosure Duty* (χ^2-test, p-value < 0.001). Testing frequencies in *Perfect Privacy* and *Imperfect Privacy* do not significantly differ (χ^2-test, p-value = 0.645). Thus our data indicates that testing behavior under perfect and imperfect privacy is very similar. Only if data loss is certain, a significant share of players stops collecting information. We summarize this finding in Result 1.

Result 1 Compared to *Perfect Privacy*, *Imperfect Privacy* does not stop people from collecting information.

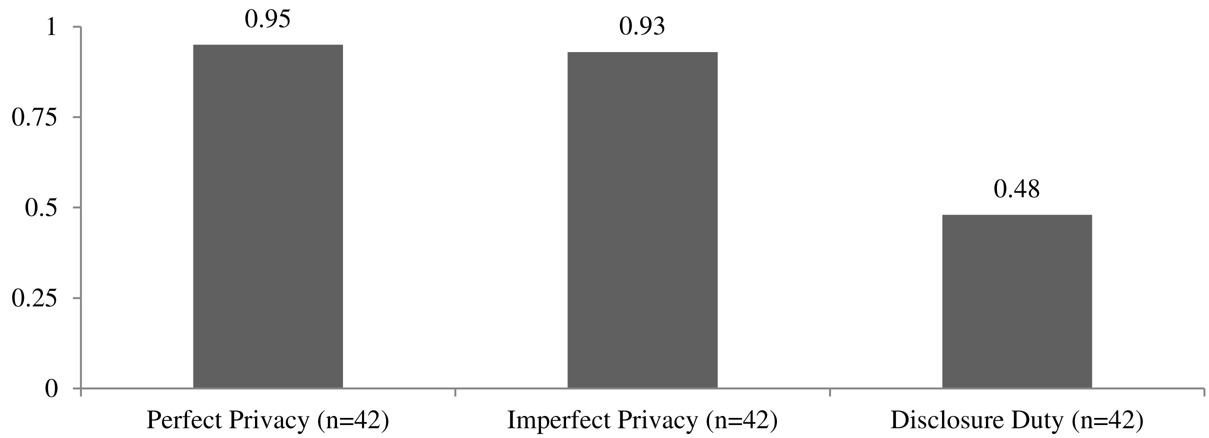

Figure 2: Test frequencies across treatments

Figure 3 shows that all tested good types disclose their type in *Perfect Privacy* and 13 out of 14 tested good types do so in *Imperfect Privacy,*[26] whereas voluntary disclosure of bad types is rare. Following, all players in *Perfect Privacy* and (almost all players in) *Imperfect Privacy* who did not disclose their type, are tested type *B* or untested players.

Result 2 Disclosure behavior in *Perfect Privacy* and *Imperfect Privacy* does not differ. Good types disclose their type, bad types do not.

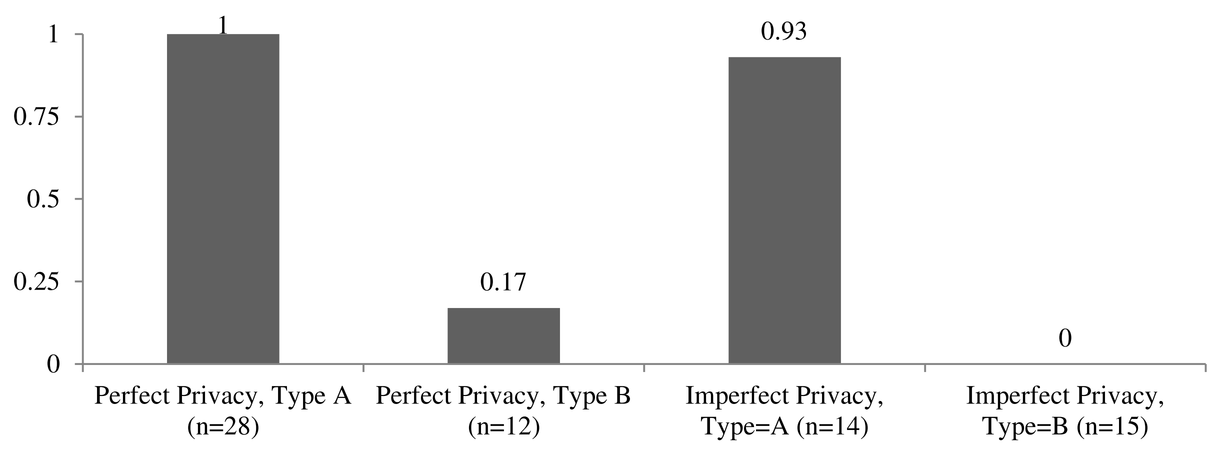

Figure 3: Disclosure frequencies when tested (in Perfect Privacy and Imperfect Privacy)

[26] We cannot reject the hypothesis that disclosure behavior of tested good types is identical in *Privacy* and *Imperfect Privacy* (Fisher's exact test, p-value = 0.333).

Because people test and good types disclose their type in *Imperfect Privacy* and *Perfect Privacy,* but few do so in *Disclosure Duty,* we should observe fewer matches with unknown types in *Imperfect Privacy* and *Perfect Privacy* than in *Disclosure Duty*. Indeed, as Figure 4 shows, this is exactly what we find: Compared to *Disclosure Duty* fewer players match with unknown types in *Perfect Privacy* (Fisher's exact test, p-value = 0.001) and in *Imperfect Privacy* (Fisher's exact test, p-value = 0.014). Although the figure suggest matching with unknown types to be more likely in *Imperfect Privacy* than in *Perfect Privacy*, the difference is not statistically significant. (Fisher's exact test, p-value = 0.453). Finally, subjects rarely make errors when matching with disclosed types.[27] We summarize this finding in Result 3.

Result 3 Matching with unknown types is not more likely in *Imperfect Privacy* than in *Perfect Privacy* but significantly more likely in *Disclosure Duty.*

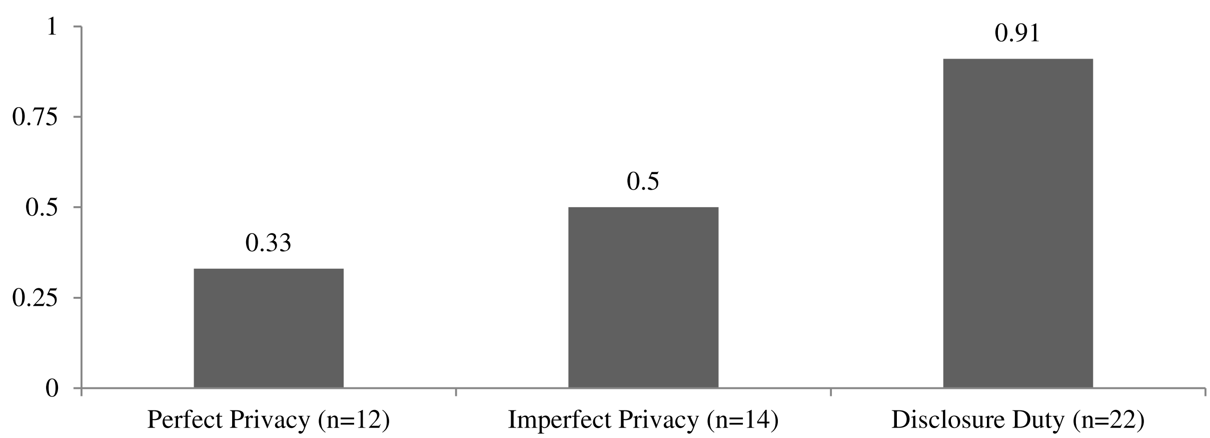

Figure 4: Matching with unknown type
(# subjects matching with an unknown type / # subjects facing an unknown type)

[27] Out of 55 disclosed good types all received a match. Out of 8 disclosed bad types 1 received a match.

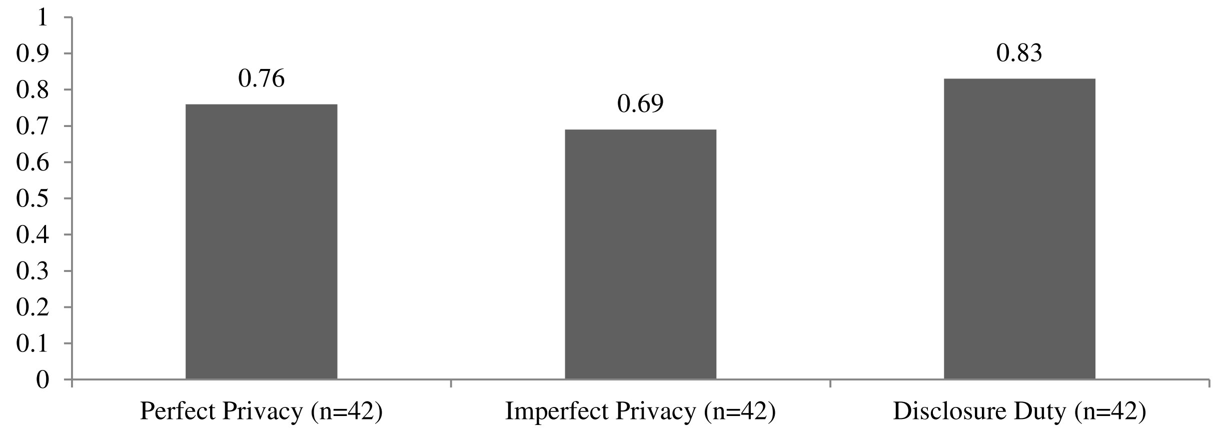

Figure 5: Total frequencies of matches

Finally, we analyze whether efficiency varies across the different privacy institutions, and in particular shed light on whether efficiency in *Imperfect Privacy* differs from efficiency in *Perfect Privacy*. We measure efficiency as the surplus generated by player 1 and 2.[28] Since information acquisition and transmission does not significantly differ in the two privacy institutions and people rarely make errors when matching with disclosed types, differences in efficiency between *Imperfect Privacy* and *Perfect Privacy* are expected to be small. If at all we should expect slightly fewer matches (and thus lower efficiency) in *Imperfect Privacy*, because insurers can identify some tested but undisclosed bad health types in *Imperfect Privacy,* given data is disclosed involuntarily. Indeed, we find that earnings tend to be smaller in *Imperfect Privacy* compared to *Perfect Privacy*, but differences are small. Earnings amount to 13.81 in Perfect Privacy and to 11.31 points in *Imperfect Privacy* and fail to differ significantly (Wilcoxon rank sum test, p-value = 0.102). *Disclosure Duty* yields the highest level of efficiency, since it yields the most matches (see also Figure 5). People received on average 14.17 points, which is significantly different from

[28] Note that with M=10 and I=15, a match with a good type yields a surplus of 20 points, a match with a bad type yields a surplus of 5 points. Not matching yields no surplus.

the earnings in *Imperfect Privacy* (p-value = 0.054) but fails to be significantly different from earnings *Perfect Privacy* (p-value = =0.729).

Result 4 Efficiency levels between *Imperfect privacy* and *Perfect Privacy* do not significantly differ.

5 Discussion

We study whether imperfect data privacy stops people from collecting personal information about their health type. Our theory does not provide a clear answer to this question. However, the behavioral results from the laboratory experiment suggest that imperfect privacy does not stop people from collecting information. Information acquisition, disclosure behavior and efficiency in *Imperfect* and *Perfect Privacy* almost coincide. Two possible reasons may explain why behavior does not differ in the two privacy institutions: First, at the testing stage in *Imperfect Privacy* people may not take into account the consequences of involuntary disclosure. Second, people may expect that, irrespective of potential involuntary disclosure, insurers are likely to only match with identified good health types. However, the latter is not the case. Half of the insurers who faced an unidentified type did match in *Imperfect Privacy* indicating some insurers expected that not everyone tests under *Imperfect Privacy*.

The results provide insights relevant to policy makers. From a perspective of equal opportunities for good and bad health types, a social planner might be interested in maximizing the number of insured persons. For this goal, *Disclosure Duty* performs best. However, if we interpret the simple game of persuasion as a reduced form of a matching market in which (un)infected persons look for sexual partners, a policy maker may be interested in maximizing the number of tests. Instead of modeling two potential partners in a symmetric way, our game simplifies the decision framework such that one partner always wants to match but might be infected (player 1) whereas the other is not infected and only wants to match with healthy partners (player 2). A policy maker interested in maximizing the number of tests and thereby eventually minimizing the frequency of infections (mismatches) will prefer *Perfect Privacy*.[29] Under *Perfect Privacy* almost all players test and the good types disclose their test result. Under *Imperfect Privacy*, players also test and good types disclose their test results, however, (insignificantly) more matches with unknown (bad) types occur. Under *Disclosure Duty* the most matches with unknown types occur. [30]

Behavior in the experiment corresponds to qualitative differences of our theoretical predictions (more information acquisition and fewer matches with unknown types in *Perfect Privacy* than *Disclosure Duty*). Also, given the actual frequencies, equilibrium predictions for testing, disclosure and matching behavior are optimal in the experiment. However, actual behavior does not coincide with the point predictions of the model. While testing frequencies in *Perfect Privacy* and *Imperfect Privacy* almost perfectly correspond to the theoretical prediction, testing is observed too frequently in *Disclosure Duty.* Further, we observe more matches with unknown types in *Perfect Privacy* and *Imperfect Privacy* than predicted in the proper equilibrium with complete information acquisition. Such behavior may be driven by social preferences, assumptions about other players' risk aversion, curiosity or simple decision errors. Our design does not allow distinguishing between social preference concerns and beliefs about other players' risk aversion. Curiosity is, however, unlikely to explain frequent testing because all subjects knew that they would learn their own type at the end of the experiment (irrespective of their

[29] More testing eventually reduces the number of mismatches. Engelhardt et al. (2013) for instance argue that on internet platforms for semi-anonymous encounters, provision of information about the own HIV status might result in a directed search and reduce the transmission rate by separating the uninfected and infected, e.g. through the use of condoms.
[30] We carefully note that in the context of HIV testing, social preferences may matter strongly and many people may test and report their result, irrespective of the institutional setup.

testing decision). Frequent matching with unknown types may also be a result of efficiency concerns, since a match always increased the total surplus. Future research may try to disentangle which of the reasons discussed above explain off equilibrium behavior. Further, we focused on a one shot decision because taking a test once is sufficient that the information created by the test can be assessed by others and the decision to buy a specific insurance is usually non-repeated. It will be interesting to see in future work how theoretical predictions and behavior change in a repeated persuasion game that focuses on repeated tests which yield additional information.

6 Conclusion

The behavioral literature on preferences for privacy has so far focused on information transmission (see e.g. (Acquisti et al., 2013; Benndorf and Normann, 2014; Beresford et al., 2012; Schudy and Utikal, 2014). In this paper, we argue that it is also important to investigate how different privacy regulations affect the willingness to collect personal health data. Studying the impact of privacy regulations in the context of health markets is crucial, because information about personal health characteristics has to be generated through the help of third parties (e.g. doctors). If privacy about personal health data is guaranteed (Perfect Privacy), testing without the risk of involuntary disclosure is possible and results in complete information revelation. In contrast, if patients have to disclose collected information when contracting with an insurer (Disclosure Duty) no information acquisition will result. If data privacy is the rule but cannot be guaranteed (Imperfect Privacy), people face the risk that their test results are disclosed involuntarily. In turn, people may refrain from testing. The behavioral results from our laboratory experiment suggest, however, that people collect information irrespective of whether data privacy is perfect or imperfect. Consequently, people do not seem to take into account that testing for diseases may affect their future prospects for insurance contracts.

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Appendix A – Proofs of propositions 1 to 3

We provide proofs of propositions 1 to 3 for risk-neutral players. However, note that the propositions also hold as long as expected utility of matches with unknown types are sufficiently high or the utility function is not too concave.

Note that π_i denotes player i's expected payoff.

Proof of proposition 1

a) Assume player 2 will not match with unknown types $s_2(G) = X,\ s_2(B) = \bar{X},$ and $s_2(U) = \bar{X}$. If $p = 1$, player 1 will test, i.e. $s_1 = T$, because $\pi_1(T) = (1-b)M > \pi_1(\bar{T}) = 0$. Player 2's best response is $s_2(G) = X,\ s_2(B) = \bar{X},$ and $s_2(U) = \bar{X}$ if $M \leq bI$, because $\pi_2(X|G) = M > 0$, $\pi_2(X|B) = M - I < 0$, and $\pi_2(X|U) = M - bI \leq 0 \Leftrightarrow M \leq bI$.

b) Assume player 2 will match with unknown types $s_2(G) = X,\ s_2(B) = \bar{X},$ and $s_2(U) = X$. If $p = 1$, player 1 will not have herself tested, i.e. $s_1 = \bar{T}$, since a tested player 1 will automatically be disclosed and in case of a bad test result, player 1 would not receive a match. Player 2's best response is $s_2(G) = X,\ s_2(B) = \bar{X},$ and $s_2(U) = X$ if $M \geq bI$ because $\pi_2(X|G) = M > 0$, $\pi_2(X|B) = M - I < 0$, and $\pi_2(X|U) = M - bI \geq 0 \Leftrightarrow M \geq bI$.

Proof of proposition 2

a) Assume player 2 will not match with unknown types $s_2(G) = X,\ s_2(B) = \bar{X},$ and $s_2(U) = \bar{X}$. If $p < 1$, player 1 will disclose her type after a good test result $s_1(G|T) = D$ because $\pi_1^G(\bar{D}|T) = 0 < \pi_1^G(D|T) = M$. After a bad test result player 1 is indifferent whether to disclose her type $s_1(B|T) = D$ with $0 \leq d_B \leq 1$ because $\pi_1^B(\bar{D}|T) = 0 =$

$\pi_1^B(D|T)$. Player 2's best response is $s_2(G) = X,\ s_2(B) = \bar{X},\ \ s_2(U) = \bar{X}$ because $\pi_2(X|G) = M > 0\ , \pi_2(X|B) = M - I < 0$, and $\pi_2(X|U) = M — I \leq 0$ for all M.

b) Assume p=0. Assume further that player 1 will never test and player 2 will match with unknown types. Clearly, player 1 cannot gain from testing if player 2 matches with unknown types. The same holds for player 2's matching strategy $s_2(G) = X,\ s_2(B) = \bar{X}$, and $s_2(U) = X$ because $\pi_2(X|G) = M > 0\ , \pi_2(X|B) = M - I < 0$, and $\pi_2(X|U) = M — bI \geq 0 \Leftrightarrow M \geq bI$.

Proof of proposition 3

a) Analogous to proposition 2a.

b) Assume player 2 will match with unknown type, i.e. $s_2(G) = X,\ s_2(B) = \bar{X}$, and $s_2(U) = X$. If $0 < p < 1$, a tested player 1's best response will be $s_1(G) = d_G\ with\ 0 \leq d_G \leq 1$ because $\pi_1^G(\bar{D}|T) = M = \pi_1^G(D|T)$ and $s_1(B|T) = \bar{D}$ because $\pi_1^B(\bar{D}|T) = (1-p)M > \pi_1^B(D|T) = 0$. It follows that $s_1 = \bar{T}$. Player 2's best response is $s_2(G) = X,\ s_2(B) = \bar{X}$, and $s_2(U) = X$ if $M \geq bI$ because $\pi_2(X|G) = M > 0\ , \pi_2(X|B) = M - I < 0$, and $\pi_2(X|U) = M — bI \geq 0 \Leftrightarrow M \geq bI$.

Appendix B – Incomplete information acquisition (Mixed strategy equilibria)

Let m denote the probability that player 2 matches with an unknown type and t the probability that player 1 tests.

Incomplete information acquisition under Disclosure Duty

For $p = 1$ and $M = bI$.

$s_1 = t \in (0,1),\ s_1(G|T) = D, s_1(B|T) = \overline{D}$

$s_2(G) = X,\ s_2(B) = \overline{X},\ \ s_2(U) = m = 1 - b$

is a mixed strategy equilibrium.

Proof

Assume $s_2(U) = m = 1 - b$. Player 1 is indifferent between testing and not testing because $\pi_1(T) = (1 - b)M = \pi_1(\overline{T}) = mM$. Player 2 is indifferent between matching and not matching with unknown types because $\pi_2(X|U) = M - bI = 0 \Leftrightarrow M = bI$.

Incomplete information acquisition under Perfect Privacy

For $p = 0$ and $M > bI$

$$s_1 = t \in \left(0, \frac{M - bI}{d_G M(1 - b)}\right),\ s_1(G|T) = d_G\ with\ 0 \le d_G \le 1, s_1(B|T) = \overline{D}$$

$s_2(G) = X,\ s_2(B) = \overline{X},\ \ s_2(U) = X$

is a mixed strategy equilibrium.

Proof

If player 2 matches with unknown types, a tested good type is indifferent whether to disclose her type, i.e. $s_1(G|T) = d_G\ with\ 0 \le d_G \le 1$ and indifferent whether to test as long as player 2 matches with unknown types. Player 2 matches with unknown types if

$$\pi_2(X|U) = M - \frac{b}{b+(1-t)(1-b)+t(1-d_G)(1-b)} I \geq 0 \Leftrightarrow t \leq \frac{M-bI}{d_G M(1-b)} \text{ and } M > bI.$$

The left side of the equation derives from the fact that the fraction of undisclosed players consists of all players with Type B, untested players with Type A, and tested but undisclosed players with type A.

Incomplete information acquisition under Imperfect Privacy

For $0 < p < 1$ and $M \geq bI$

$$s_1 \colon t = \frac{M - bI}{pbM + M - bM - pbI}, \; s_1(G|T) = D, s_1(B|T) = \bar{D}$$

$$s_2(G) = X, \; s_2(B) = \bar{X}, \;\; s_2(U) = m = \frac{1-b}{1-b(1-p)}$$

is a mixed strategy equilibrium.

Proof

Assume $s_2(U) = m$ with $0 \leq m \leq 1$. If 0< p <1, player 1 is indifferent whether to test as long as $s_2(U) = m = \frac{1-b}{1-b(1-p)}$. For player 2 a match with an unknown player yields:

$$\pi_2(X|U) = M - \frac{(1-t)+t(1-p)}{(1-t)+t(1-p)b} bI = 0 \Leftrightarrow t = \frac{M-bI}{pbM+M-bM-pbI} \text{ and } M \geq bI.$$

The left side of the equation derives from the fact that the fraction of undisclosed players consists of *1-t* untested players and *t(1-p)b* tested but undisclosed players with type B.

Appendix C - Instructions (Translated from German)

We cordially welcome you to this economic experiment. Your decisions and possibly other participants' decisions in this experiment influence your payoff. It is therefore very important that you read these instructions very carefully. For the entire experiment communication with other participants is not allowed. If you have questions, please read again the instructions. If you still have questions, please raise your hand. We will then come to you and answer your question in private.

During the experiment we will not speak of euros, but of points. Your entire income will at first be calculated in points. The total number of points earned in the experiment will then at the end be exchanged into euros with the exchange rate **of 10 points = 2 euros.** On the following pages we will explain the exact procedure of the experiment.

The Experiment

Summary

In this experiment two participants (participant 1 and participant 2) will be randomly assigned to each other. Each of the two participants receives 10 points. Participant 1 is either a type A or type B. Whether participant 1 is a type A or type B depends on chance. For each participant 1 the probability of being a type A is exactly 2/3 (or 66.66%). The probability of being a type B for participant 1 is exactly 1/3 (or 33.33%). Participant 2 has no special type.

Participant 2 decides whether he would like to enter into an interaction with participant 1. If no interaction takes place, points do not change. An interaction changes both participants' number of points.

- An interaction gives an extra 10 points for participant 1.

- How participant 2's points change depends on participant 1's type is. If participant 1 is a type A, participant 2 receives an extra 10 points. If participant 1 is a type B, participant 2's points are reduced by 5 points.

Procedure in detail

- One participant 1 and one participant 2 will be randomly assigned to each other. Each participant 1 as well as participant 2 receives 10 points. Participant 1 does not know whether he is of type A or of type B. Participant 2 also does not know participant 1' type..
- Participant 1 decides whether he wants to learn his type.
- **The following section was only included in the *Perfect Privacy* treatment:** [If participant 1 has decided to learn his type, he decides whether to tell his type to participant 2. Please take note: If participant 1 decides to reveal his type, participant 2 learns participant 1's actual type. Otherwise participant 2 receives no information before his decision on participant 1's type, and also no information on whether participant 1 knows his type himself.]
- **The following section was only included in the *Imperfect Privacy* treatment:** [If participant 1 decided to learn his type, he decides whether to tell his type to participant 2. If participant 1 decided to learn his type, but does not tell his type to participant 2, a random mechanism determines whether player 2 nevertheless learns player 1's type. In this case player 2 learns player 1's type with a probability of 50%.]
- **The following section was only included in the *Disclosure Duty* treatment** [If participant 1 decides to learn his type, participant 2 will learn participant 1's type too**.** Please take note: If participant 1 knows that his type is type B, participant 2 will know as well that participant 1 is of type B. If participant 1 knows that his type is type A, participant 2 will know as well that participant 1 is of type A. If participant 1 does not know his type, participant 2 will also

not know participant 1's type. However, participant 2 knows that participant 1 is of type A with a probability of 2/3 (66.66%) and of type B with probability 1/3 (33.33%).]

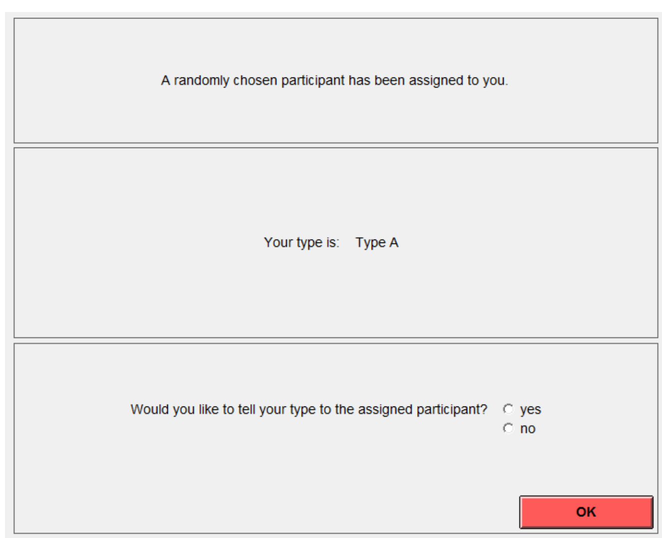
- Participant 2 decides whether he wants to enter into an interaction with participant 1.
- If participant 2 enters into the interaction, participant 1 receives an extra 10 points. Participant 2's points depend on participant 1' type. If participant 1 is of type A, participant 2 receives an extra 10 points. If participant 1 is of type B, participant 2's points are reduced by 5 points. If participant 2 does NOT enter into the interaction, both participants receive no extra points, so each of the participants has the 10 points received at the beginning.

All participants received the same instructions and will be in the role of participant 1 once and in the role of participant 2 once. All participants receive payment for the decisions in each of the two roles. For each role another (new) participant will be randomly assigned to you. After all participants have made a decision in each role you will receive information about your earned points in both roles. At the same time both the type of participant 1 and whether an interaction took place will be shown.

Procedure on-screen

Each participant in the experiment decides once in the role of participant 1 and once in the role of participant 2. First, all participants make a decision in the role of participant 1. You will see the following screen.

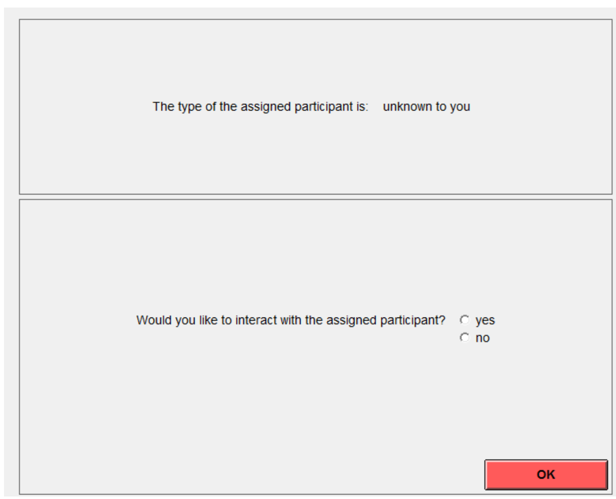
The following section was only included in treatments Perfect Privacy and Imperfect Privacy: [Let's assume that participant 1 learned his type. Then he decides whether he wants to tell participant 2 his type. You will see the following screen (we assume in the example that participant 1 is a type A):]



[The following **section was only included in the Imperfect Privacy treatment:** [If participant 1 knows his type but did not tell participant 2, a random (50% probability) mechanism determines whether participant 2 learns participant 1's type. For the random mechanism. the participant with ID number 1 will roll a die. You will learn the detailed procedure on screen.]

Then all participants make a decision in the role of participant 2.

You will see the following screen. (On the example screen we assume that participant 2 does not know participant 1's type.)



At the end all participants learn their types as participant 1 and participant 1's type when they were participant 2. In addition the screen shows whether an interaction took place and how many points each of the two participants received. You will see the following screen

Comprehension questions: (correct answers in parentheses, DD=*Disclosure Duty*, PP=*Perfect Privacy*, IP=*Imperfect Privacy*)

True or false?

□T □F Participant 1 always learns his type at the beginning of the experiment. (F)

□T □F If participant 1 learned his type participant 2 learns it as well. (DD: T, PP &IP: F)

□T □F At the end of the experiment you will always learn your type as participant 1. (T)

□T □F At the end of the experiment you will always learn participant 1's type when you are participant 2. (T)

Further questions:

How many points do you receive before each decision? (10)

What is the probability that participant 1 is of type A? (2/3)

What is the probability that participant 1 is of type B? (1/3)

What is the probability that a participant 1 who didn't want to learn his type is of type A? (2/3)

What is the probability that a participant 1 who didn't want to learn his type is of type B? (1/3)

The following two questions were added in IP:

If participant 1 learned his type but did not tell the type to participant 2, what is the probability that participant 2 learns the type nevertheless? (1/2)

If participant 1 DID NOT learn his type, what is the probability that participant 2 learns the type nevertheless? (0)

Please fill in the blanks:

This section was added in DD:

If participant 1's type is unknown and participant 2 decided to interact, he receives___ (10) points in___ (2) out of____(3) cases and loses____(5) points in___(1) out of___(3) cases.

If participant 2 decided to interact and participant 1 is of type A, participant 2 receives____(10) points.

If participant 2 decided to interact and participant 1 is of type B, participant 2 loses ___ (5) points .

If participant 2 decided to interact, participant 1 receives an extra ____(10) points.

If participant 2 refused to interact, participant 1 receives an extra___ (0) points and participant 2 an extra ___ (0) points.

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