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# *Design and Evaluation of an Economic Experiment via the Internet*

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# Design and Evaluation of an Economic Experiment via the Internet *

Vital Anderhub[†] Rudolf Müller[‡] Carsten Schmidt[§]

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The paper investigates whether Internet experiments are an appropriate alternative to traditional laboratory experiments. For an economic experiment of individual decision making results obtained over the Internet are compared to results obtained in the laboratory using exactly the same software. Of particular interest are differences in individual behavior. Our main findings are: (1) Running our own experiment on the Internet and in the laboratory generated similar data when economic decision behavior is concerned. (2) Variance in economic decision behavior is generally higher on the Internet experiment. (3) Decision times are shorter on the Internet. (4) Internet software provides a helpful platform for implementing economic experiments. The paper also reports on design challenges and how we have solved them.

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# 1 Introduction

Recently social psychologists have been using the Internet as a medium for experimental research on behavior. Reips (1997) summarizes some of the approaches. Indeed, there are several limitations with laboratory experiments that might be overcome in an Internet setting. The Internet provides the potential to reach a large subject pool which is heterogeneous in terms of education, profession, age *et cetera*, whereas laboratory experiments recruit their subjects predominantly among students of the same university. The Internet enables "double blindness" between experimenter and subject. In a laboratory all participants have to be present at the same time, while an Internet experiment can be done asynchronously. These potential advantages suggest to adapt Internet communication and emerging Internet technologies for experimental economics. However, there are requirements of economic experiments that distinguish them from their psychological counterparts, for example the generally accepted concept of monetary motivation, i.e. paying participants. Meeting these requirements raises implementational and organizational challenges. Further, the environment of subjects in a laboratory is quite different from the environment of subjects using a Web browser at any place in the world. To make Internet experiments comparable with laboratory experiments we have to investigate whether these differences influence the results of the experiment. The first results of psychological studies by Krantz et al. (1997) and Reips (1997) are encouraging, since they do not find significant differences in the evaluated psychological variables.

This paper presents our experiences with designing and performing an experiment on individual decision making using the Internet. We focus on two topics. The first is organizational and software design decisions to meet the requirements specific to experimental economics. We present a generally applicable design for Internet experiments and show how current Internet technology can be employed for its implementation. The second topic is a comparison of data that we obtained from running the experiment on the Internet with results from the laboratory, using exactly the same software.

Our results may be summarized in four points:

1. Running our own experiment on the Internet and in the laboratory generated similar data when economic decision behavior is concerned. For example, no significant difference in participants payoff can be measured.

2. Variance in economic decision behavior is generally higher on the Internet.

3. Decision times are shorter on the Internet.

4. The software that is emerging with the Internet is a useful platform for implementing economic experiments. The same software can be used in a laboratory (or *Intranet*) and on the Internet.

The paper is organized as follows. The next section describes briefly the experiment setting. The design of our implementation is illustrated in Section 3. Section 4 presents an evaluation of results. Section 5 summarizes our findings. The appendix contains a translation of the instructions and screen shots of the user-interface of our implementation.

## 2 An experiment on individual decision making

For the Internet experiment we have chosen an individual decision problem with uncertainty as described by Anderhub et al. (1997). The problem is inspired by theoretical life-cycle models of saving and consumption behavior. Although the setting in the experiment is very abstract compared to real life, the aim is to observe some fundamental aspects of inter-temporal decision behavior. In particular, the experiment allows studying of such inter-temporal decision behavior on the individual level. For a survey on saving experiments see Anderhub and Güth (1999).

In our experiment "life" consists of an unknown number of periods. In the beginning, participants are given some amount of money. Before each period they have to decide how much of the remaining amount of money they are willing to consume. Their payoff at the end is the product of the single consumption levels over lifetime. The difficulty in decision making is that participants do not know in the beginning how many periods they are going to live. As a further complication, after the first and after the second period participants are given an indication on whether their survival probability in future periods will be relatively low or high.

The precise setting is as follows: Subjects play 12 rounds of the same "game" (i.e. every player has 12 lives). In the beginning of each round they get the same amount of money (in our setting $S = 11.92$ units). At the beginning of each period players have to choose how much of the remaining amount they are spending in this period. The savings are accordingly decreased and the payoff is multiplied by this amount. The number $T$ of periods they are going to live is between 3 and 6. Thus, the payoff $P$ for one round is the product over consumptions $x_i$ in the periods $i = 1 \dots T$:

$$P = \prod_{i=1}^{T} x_i$$

Whether a player lives 3, 4, 5 or 6 periods is determined by throwing a die. In the beginning each player has three dice, a green, a yellow and a red one, representing three different survival probabilities. After the first consumption choice one die is excluded, the second die after the consumption choice in period 2. After a player has chosen the amount to spend in period 3, the remaining die, say the red one (representing survival probability 1/2), is cast. If it gives him another period, he is asked for the consumption in period 4, if not, the round is over. This continues up to a maximum of 6 periods. The survival probability of the green die is 5/6, that of the yellow die 2/3. After having played 12 rounds, the final payoff is the average of the payoffs in the rounds.

A feature of this model is that it is practically impossible for subjects to derive analytically an optimal strategy[1] (Optimal with respect to, e.g., risk neutrality and rationality). Instead subjects must act on information about their personal survival probability. It can thus be analyzed whether participants reveal bounded rational behavior of various types. The complexity of the underlying decision problem makes the experiment also particularly suited for the Internet since it can be excluded that the outcome is influenced by using decision support tools. Figure 1 shows the consumption behavior which maximizes the expected value for a risk neutral decision maker. Anderhub et al. (1997) have calculated the strategy by a backward induction that compared all possible strategies.

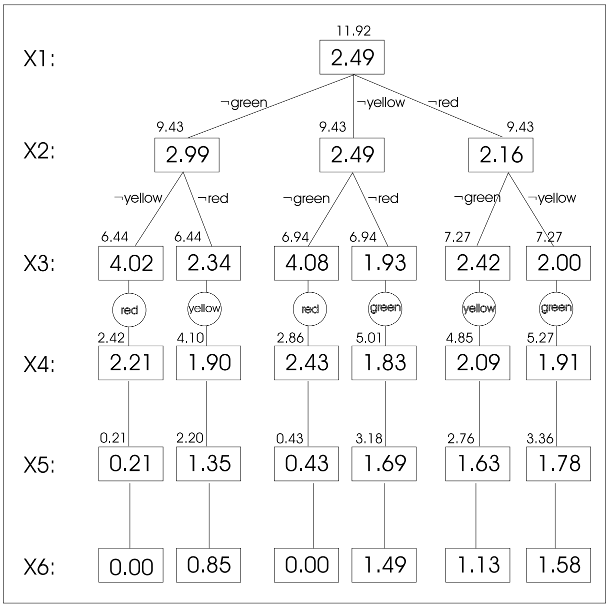


Figure 1: Optimal consumption decisions assuming risk neutrality

A simple comparison with the results from the laboratory experiment by Anderhub et al. could provide an indication of the admissibility of our Internet experiment. However, for several reasons a new laboratory experiment was a more appropriate approach. First, it should be

[1]The backward induction procedure involves solving non-linear equations.

excluded that differences in user-interfaces or the instructions caused differences in observations. This required a laboratory experiment that used exactly the same software.

Second, several details in the design were changed which might as well have changed results. These changes were partly proposed by readers of the previous paper, partly motivated by simplifying the experiment for the Internet setting. The old experiment did not allow for mistakes in period 6 by automatically spending all savings. Actually, it turned out that requiring a decision from players in period 6 gave different results on the Internet and the laboratory (see Section 4.3). In the old experiment a calculator had been integrated in the program. In the new implementation participants were free to use any available help. Yet, the instructions did not give any hint to the subjects concerning the use of calculators or other help tools. The random moves for the exclusion of the die were in the previous layout organized in two cycles such that, although in a random order, every participant had to react on every sequence of exclusions twice. The new layout excludes one die in every round completely independently. The previous experiment used as a second payoff function the sum of savings over all rounds. Also subjects could choose between the average payoff and the payoff from a randomly selected round. The latter was decided by throwing a real die in the presence of the participants. Another difference to the old experiment was in planning decisions. The old laboratory asked participants to plan in every period already for the next period and report their plan to the software. An evaluation showed however that the plans rarely coincided with actual decision, so we left the planning out. Finally, the list of questions in the beginning and at the end of the game has been reduced to a small subset of the previous pre- and post-experimental questionnaires.

A third reason to do a new laboratory experiment using Internet software was to evaluate how well an Internet based implementation is suited for usage in a laboratory. If it is well suited it might become easier to run experiments, as all PC labs have Web browsers installed. In particular, an Internet implementation would allow to use a third-party experimentation side. Schmidt and Jacobsen (1999) describe in a recent paper how such a side may provide researchers the service to design their own experiments without running an own Web server and database.

# 3 The software design of the Internet experiment

The primary goal of the experiment was to compare the quality of results obtained on the Internet with the quality obtained in a laboratory. To achieve this goal, an experimental setting for participants on the Internet was created which emulated as much as possible the laboratory setting. For example, it tried to exclude that Internet participants exchange information before and during the experiment. This section describes the organizational and software design decisions that were done to achieve a maximum of similarity between the settings.

What remained were differences of the experimental environment for participants, as well as differences in the recruited subject pool. The impact of these differences is shown using a statistical comparison of results. This is the topic of section 4.

## 3.1 An overview

Figure 2 shows an overview of the game. Horizontal arrows describe the main interactions between the user-interfaces, those of a subject and the administrator, and the server, which is actually a combination of a World Wide Web server and a database [2]. Note that the implementation follows a client-server principle. As client one may use of the two commonly available Web browsers Netscape Navigator 3 and later, and Microsoft Internet Explorer 3 and later. They are both able to handle HTML fill-out-forms and to run Java applets. Both technologies are used to realize user-interfaces.

Fill-out-forms are a feature of the Hypertext Markup Language that allows to create forms by which users submit input data to Web servers. The Web server connects to the database with the Common Gateway Interface (CGI). The Java language enables to download programs, so-called *applets* into a Web browser. Applets may embed a direct communication with a remote server via Internet. In particular they can use database connectivity software to exchange data with a remote database [3]. The reason for using Java in addition to HTML form is its superiority when session state has to be maintained in the client. For example, with HTML forms session state may be lost because the user activates the back button of his browser.

The play is partitioned into an application phase and a play phase. In the application phase subjects submit an application by an HTML form. They are required to provide their e-mail address, the town and state from where they register, and information about the type and costs of Internet connection they are using[4].

Administration is done by a Web interface to the database as well. The administrator checks daily the applications. Subjects are notified of acceptance via an e-mail message which contains the Web address of the playing phase and a password. The latter is necessary to log into the Web address. Generation of e-mail messages is done automatically but must be initiated by the administrator.

[2] An NCSA Web server on a Sun workstation under Solaris, mSQL 1.0.16 as database management system, and w3-mSQL as script language to connect Web server with database was used.

[3] We used Java version 1.0.2 and mSQL-Java classes, today one would use Java's database connectivity classes (JDBC).

[4] Internet connectivity in Germany is often charged on the basis of connection time instead of flat monthly fees. See Section 3.3.

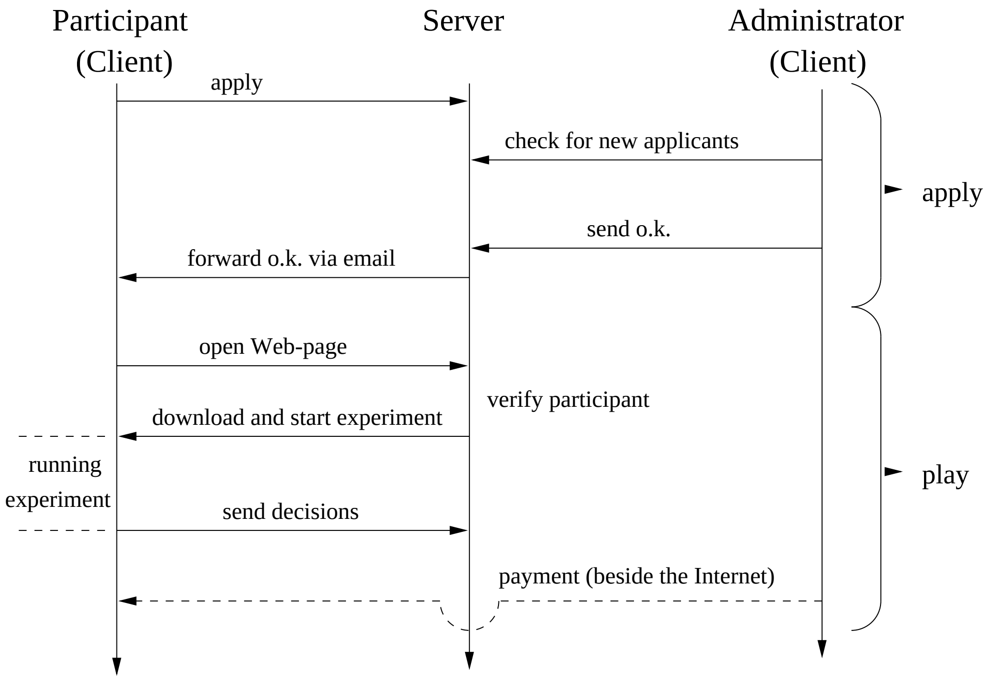


Figure 2: Interactions between clients and server in the application phase and during the game

After being accepted, participants have one week to start the game. After accessing the Web-page a description of the experiment is shown. At the bottom of the description a button starts the game and opens a separate window by which the participants submit their decisions. Before playing the first round participants must fill out a short questionnaire. We ask for age, gender, education and profession. We also ask for information about the bank account that is necessary to process the payment[5]. The description of the experiment that is shown in the beginning of the game remains present during the game (see Figure 6). After each of the 12 rounds of the game the decisions are transmitted to the server. At the end there is another short questionnaire. The first part checks whether some plausible rules in decision making were understood by the participant, such as how to react to the exclusion of the red die in the first period. The second part is reserved for comments concerning the experiment.

Important in the design is that the subjects must run the experiment without interruption. Every password is locked after it has been used. Another login with the same password is only possible by special request. This is to prevent the participants from playing the first rounds, thinking for some days about the decision problem and then playing the game again. An upper limit for playing time was not imposed. However, only one subject used this freedom and played longer than the recommended one hour (see Section 4.2).

[5]We used bank transfers since in Germany they are free of charge for the recipient, see Section 3.3

The next paragraphs discuss in more detail how this design emulates the laboratory setting on the Internet.

### 3.2 Subject selection

The experiment was announced by various Internet services, such as mailing-lists, newsgroups, WWW-sites, and search-engines[6]. Everyone who fulfilled the following requirements, could sign-up for participation:

- Internet connection with personal e-mail,
- browser with Java ability,
- bank account in Germany for money transfer,
- good German language skills.

Because we had more applications than the target of 50 participants a selection process was needed. Subjects were selected by the administrator based on the submitted attributes (e-mail, place, Internet connectivity, and the HTTP headers, including for example the Web browser that is used). Applications were not accepted in cases where double participation could not be excluded. For example, we did not accept applications that used mail aliases that hide a person's name (e.g. webmaster). And we rejected free of charge e-mail accounts (e.g. hotmail), since it is rather simple and also usual to open a second account in addition to an account at work. Furthermore, we did not accept more than 3 applications from the same Internet domain, and rejected a second application from the same sub-domain [7]. Only one participant per city/town was accepted.

Since we could not be sure that all accepted visitors would actually play, we used an iterative process. In the beginning we accepted every 3 days all applicants eligible to the above criteria. As we got closer to the goal of 50 participants we accepted always a few more than we had open slots. In total we received 126 applications, from which we accepted 86 and rejected 40. Out of the accepted 30 did not log in. Datasets from 6 participants were not usable because of technical problems during the game. In the end usable data from 50 subjects were obtained. Overall the experiment was active for 6 weeks.

[6] Unfortunately we did not ask our participants how they have heard about the experiment. This would have given an impression of the value of different ways of advertising—a question that is of general interest on the Internet.

[7] For example, only one of `jane@wiwi.hu-berlin.de` and `jack@wiwi.hu-berlin.de` would have been accepted, and at most three participants from the domain `hu-berlin.de`.

### 3.3 Payment of participants

According to Friedman and Sunder (1994) economic experiments must pay participants relative to their success. Due to the explicit application phase we could limit the number of players, to meet a limited budget for payments. Contrary to this, previous Internet experiments allowed everyone to participate (e.g., the experiment by Budimir, 1997), with a randomly selected subset of participants receiving a payment. We believe that our design, which guarantees all players a payoff, creates more trust in the experimenter since it does not insert an additional uncertainty between performance and payoff. This should lead to a more serious type of behavior.

As a method of payment transfers to bank-accounts were chosen. To keep costs low only participants with a bank-account in Germany were admitted. Due to this constraint the game was only offered in German. It is important to note that in Germany transfers to private bank accounts are free for the recipient.

Other costs for participation should be considered, in particular as they vary between subjects. This is due to different costs for Internet access depending on the type of connection. Some participants have free Internet access. Other participants have to pay Internet providers depending on the connection time. Private users connecting via a modem have to pay at least a local phone call[8]. The different cost structure might influence behavior. For instance, a participant with very high costs per minute may want to play fast. Our method of dealing with this problem is to ask players in the application phase for their connection costs in order to be able to measure this influence (see Section 4.2).

### 3.4 Controlling subjects and the experimental environment

In order to put all observed effects down to its cause one tries to exert as much control as possible in an experimental environment. Our laboratory environment thus tried

- to exclude decisions made by a group instead of by individuals,
- to control decision making aids,
- to exclude that the same person plays twice,
- to generate trust in the reputation of the experimenter,
- to ensure that subjects participate seriously.

[8]Although telecommunication costs are decreasing in Germany, local area calls are still not free of charge. When we did our experiment the costs were about $ 1 (DM 1.80) per hour between 9 p.m. and 5 a.m.

Certainly we have to do without some of these features on the Internet. So, it could not be guaranteed at all that subjects are individuals. Further, there is no control on the help that has been available to the participants. However, as mentioned already, the decision problem underlying our game is very hard to analyze and to solve. Thus it is reasonable to assume that none of the subjects has been able to implement within one hour a dynamic program deriving a strategy that maximizes the expected payoff. And one hour was about the maximum time used by participants to play all 12 rounds.

Concerning observable learning and repeating the game we utilized the strict registration process. The process allows every "virtual" player to play the game only once. If the same person wants to register as two virtual players, he needs two different e-mail addresses, two different bank-accounts (running on different names), and must have Internet access through two different domains. Furthermore participants were selected from different regions and domains to minimize contact between players.

Concerning trust in the experimenter the presentation and organization of the game are crucial. Two issues are of particular relevance: Obtaining correct data in the questionnaire and encouraging serious participation based on trust in payment. To achieve these issues it is important to give the user-interface an academic look and feel. For example, the banner of Humboldt-University was present on most pages. All personal data except data required for subject selection was asked only from accepted participants. A participant who is already accepted might be less inclined to cheat. Finally we ask for the bank-account immediate before the game starts, thus generating trust in a payment after the game.

Subjects were told to use about one hour for playing the game. This was about the average that we observed in an earlier laboratory experiment. We also believe that this much time is required to understand the problem and develop a reasonable strategy.

### 3.5 Confidentiality

An important issue in the whole design is data confidentiality. We tried to guarantee this by splitting any personal data (like name, address, bank-account) from the data we need for the scientific evaluation. In addition, we deleted all personal data as soon as the payment process was finished. Finally all personal data was strictly password protected on the server such that only the administrator could read and change it. All this had to be done to comply with German law concerning data privacy, which states that personal data may only be used for the task it was raised for.

Another issue is data security during transport via the Internet, which was not satisfactorily addressed. The Internet technology used for communication (the Web protocol and client-server communication in Java) will soon have encryption as a built-in feature. Thus switching of versions of code underlying our implementation adds secure communication. Secure data transmission is certainly a concern for payment data. In addition, we expect an overall increase in trust if Internet experiments present themselves as a secure application.

### 3.6 Technical problems

The main challenge in implementing an economic experiment on the Internet is providing a robust user-interface and communication with the server. A participant could not be allowed to interrupt his game and restart it again, in particular if it is induced by bad performance of the participant. However, interruptions could have as well their origin in a broken network connection or an error in the user-interface.

The part of the user-interface that was implemented in Java (the questionnaires and the game itself) was tested extensively on many different platforms. It turned out that platform independence as it is claimed for Java is only granted to a certain degree as implementations of Java virtual machines proved faulty on some platforms. In particular, problems often arise when a Java applet connects to the window manager which is responsible for the layout on the screen. Therefore opening Java windows outside the Web browser had to be tested and adjusted for different window managers.

A second point of failure is the network. Security policies in organizations may exclude to use Java database connectivity from a computer in-house to a computer outside. So-called *firewalls* or proxy servers restrict in these cases Internet access to specific services (Web, E-Mail) and corresponding protocols. In these cases our software could not be used. To let a participant be aware of this a very small applet was included in the application page. This applet tested the communication with the database. If it worked the communication between the game applet and the server would work as well. It should be noted that a pure HTML interface would be less problematic at this point.

### 3.7 Using the Internet software in the laboratory

After running the experiment on the Internet we conducted the experiment in the laboratory by using the same software. The intention was to provide an environment similar to the Internet experiment, including the features of a laboratory experiment. Therefore the experiment was announced as a regular laboratory experiment: Handouts on campus and slides in class were used to attract participants. It was verified that applicants did neither participate in other laboratory versions of this kind of experiments, described by Anderhub et al. (1997), nor on the Internet experiment.

Participants were required to bring their bank account information, since the Internet experiment used bank transfers as well. The experiment was announced to take no longer than two hours in total, similar to the announcement of the Internet experiment.[9] The identity of the participants was checked by the experimenter and subjects received a login/password combination. Subjects were seated at a computer with an open Web browser.

There were no general spoken instructions except for a welcome and the announcement of the URL of the game. So participants had to rely on the very same online instructions as participants on the Internet. During the experiment the experimenter did answer questions concerning the unfamiliar computing environment. For example, one subject asked the experimenter how a calculator could be used. In this case the experimenter helped to open a calculator software on the screen. Questions on instructions were not replied to, instead subjects were advised to read the instructions again.

# 4 Experimental results

In this section the data obtained on the Internet are compared to the data obtained in the laboratory using the same software. In cases where the data from the Internet is different from the laboratory explanations are provided. Some illustrative results from our Internet experiment are also reported. Of particular interest are the characteristics of the subject pool that could be attracted to participate.

## 4.1 Characteristics of the participants

The Internet game had 50 participants as described in Section 3.2. The laboratory experiment was announced by posters and leaflets on campus. Five dates for the laboratory experiment were offered for which the participants could sign up. From 60 applicants 47 actually participated.

Participants on the Internet were located throughout Germany. In Figure 3 participants are counted by states in Germany. With regard to time of the day Internet subjects preferred the afternoon between 2 p.m. and 6 p.m. Based on the application information and the questionnaire age, education, gender, and profession are known, as well as attributes about their Internet connection such as the browser, the provider, and fixed and variable costs.

[9] The Internet experiment was announced to take one hour. In the laboratory additional time was needed to check the participants identity and to assign to them a workstation. Participants were as well less familiar with the computer environment, such that time to answer questions had to be taken into account.

| | Internet | | laboratory | | Internet |
|---|---|---|---|---|---|
| | cases | % | cases | % | laboratory |
| Total N | 50 | 100.0 | 47 | 100.0 | |
| Gender | | | | | |
| Female | 5 | 10.0 | 17 | 36.2 | |
| Male | 45 | 90.0 | 30 | 63.8 | |
| Age | | | | | |
| 0–19 | 4 | 8.0 | – | – | |
| 20–23 | 5 | 10.0 | 29 | 61.7 | |
| 24–27 | 19 | 38.0 | 16 | 34.0 | |
| 28–31 | 9 | 18.0 | 2 | 4.3 | |
| 32–35 | 8 | 16.0 | – | – | |
| 36– ... | 5 | 10.0 | – | – | |
| Education | | | | | |
| school dropout | 1 | 2.0 | – | – | |
| 9 years of schooling | 1 | 2.0 | – | – | |
| 10 years of schooling | 5 | 10.0 | 1 | 2.1 | |
| 12–13 years of schooling | 20 | 40.0 | 45 | 95.7 | |
| Master degree | 19 | 38.0 | 1 | 2.1 | |
| Ph.D. | 4 | 8.0 | – | – | |
| Profession | | | | | |
| Business administration | 10 | 20.0 | 19 | 40.4 | |
| Economics | 4 | 8.0 | 16 | 34.0 | |
| Other academic field | 27 | 54.0 | 12 | 25.5 | |
| other non–academic | 9 | 18.0 | – | – | |

Table 1: Self-reported subject characteristics

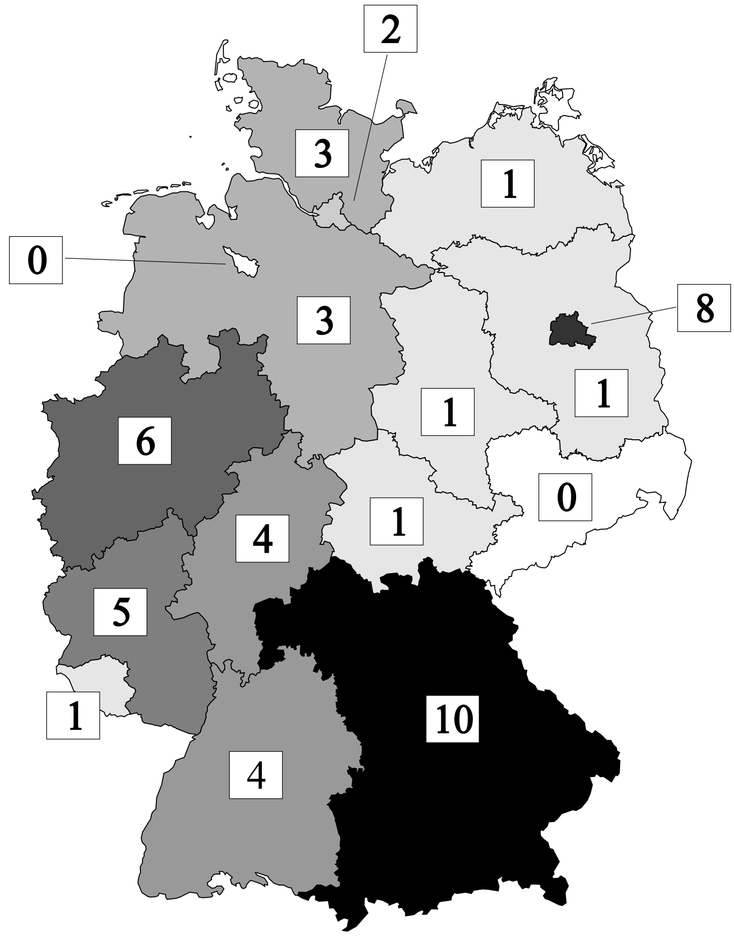


Figure 3: Number of participants from states in Germany

In the lab, participants were almost exclusively students of age 20 to 27. Accordingly, the education is very homogeneous. The players on the Internet were on average older and we have larger variety of participating age groups (Table 1).

Similarly, the Internet provided more variety in terms of education although 86% of the subjects had at least 12 years of schooling. A large difference shows up in the attribute "profession". While the laboratory subjects are drawn from the department of business administration and economics at Humboldt-University, the Web provided predominately subjects from other academic fields (Table 1).

The variety on the Internet is smaller when it comes to gender. 45 from 50 participants on the Internet were male, in the laboratory there were 30 males among the 47 subjects. Nevertheless, our results indicate that the subject pool is more heterogeneous on the Internet than in the laboratory. We believe that this characteristic can be further improved if experiments are better advertised, for example by a central brokerage site[10].

## 4.2 Decision times

After subjects had read the instructions and clicked the start button of the game we measured for each decision the time they needed. A drawback of this approach was that obviously several participants read the instructions *after* they had started the game[11]. Therefore we consider in the following analysis only the time subjects needed for rounds 2 to 12.

The instructions recommended participants a one hour playing time. This was a reference point from the experiment reported by Anderhub et al. (1997). The maximum time used in the Internet was 52 minutes and 48 seconds, in the laboratory the maximum was only 34 minutes and 59 seconds. However the average time on the Internet was 15 minutes and 39 seconds which is lower than the 18 minutes and 39 seconds in the lab. The effect of the average time used to play the experiment ($T = 2.237, p < 0.028$)[12], and the effect of the greater variance in the Internet environment ($F = 4.640, p < 0.034$) is significant. The effect of reduced decision times in later rounds reported by Anderhub et al. (1997) can be observed in both environments (see Figure 4). Finally, we were concerned about the effect of variable costs for local telephone calls in Germany on decision times in the Internet setting. Yet, the effect did not prove to be significant. Subjects with dial-in connection to the Internet tended even to play a bit longer than their counterparts with all-time Internet access.

Certainly, we cannot observe whether Internet subjects were concentrating all the time. As well, unexpected interrupts such as the doorbell cannot be excluded. This may explain some outliers in the Internet data. Taking these into account, our data does not indicate that subjects are playing less serious on the Internet. Indeed, as described in the next subsection, the Internet subjects also improved their payoff in the second part of the game.

## 4.3 Average payoffs and efficiency

The total payoffs on the Internet were lower, even though the effect did not prove to be valid ($T = 1.375, p < 0.086$). The variance of the total payoffs is higher on the Internet ($F = 4.059, p < 0.047$). In both environments a slight improvement of performance from the first 6 rounds to the second 6 rounds is observed (Table 2).

[10] At this point we would like to thank the commercial site spiele.de which pointed to our experiment for a couple of days.

[11] In the Internet experiment we had a player who used 5580 seconds to make the first decision.

[12] Because of the stochastic lifetime, we used only the first three periods of every round for the test.

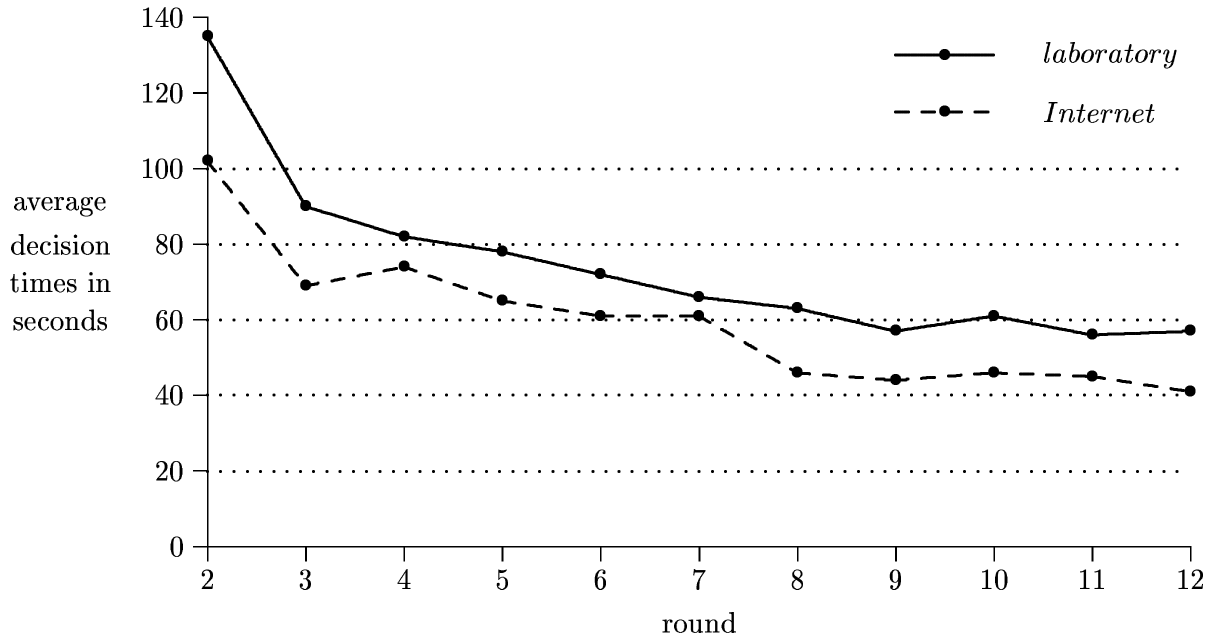


Figure 4: Reduced decision times in later rounds

An indication that participants on the Internet played less attentively than in the lab is given by examining decisions in period 6. At this point of a round it is obvious to spend all the remaining amount. In 22.16% of the cases on the Internet where participants reached $T = 6$ they decided not to spent all of the remaining money, whereas in the laboratory this was only 3.13% (Table 3). This difference is statistical valid ($\chi^2 = 26.08, p < 0.001$) and reduced the payoff of the Internet participants.

A reason for this behavior could be a missed warning that players are in the last period. As in each other period, "Period 6" was only written in the headline of the decision window (see Figure 6 in the appendix).

## 4.4 Consumption decisions

We have analyzed consumption decisions for every possible path of the game.[13] A path is defined by the sequence of die exclusions in the first two periods. Figure 5 displays these paths and for each node the number of cases and observed behavior in terms of mean, minimum and maximum consumption, as well as variance of consumption.

Again, in most of the cells the variance is higher among Internet subjects. However, the mean of $x_1$ is on the Internet closer to the optimal value (assuming risk neutrality) than in the

[13]Throughout this subsection we exclude the decisions of the first round.

| | Internet | | laboratory | |
|---|---|---|---|---|
| rounds | payoff | efficiency | payoff | efficiency |
| 2 − 6 | 24.47 | .70 | 26.86 | .76 |
| | (16.72) | | (14.52) | |
| 7 − 12 | 25.85 | .74 | 27.31 | .78 |
| | (15.23) | | (14.74) | |
| all 2 − 12 | 25.22 | .72 | 27.10 | .77 |
| | (15.92) | | (14.63) | |

Table 2: Improved payoff in later rounds

| | Internet | laboratory |
|---|---|---|
| cases | 41/185 | 5/160 |
| % | 22.16 | 3.13 |

Table 3: Participants that did not spent all money at $T = 6$

| sequence $k$ | $1^{st}$ chance move | $2^{nd}$ chance move | Internet $y_k$ | laboratory $y_k$ | optimal consumption |
|---|---|---|---|---|---|
| 1 | ¬green | ¬yellow | .73 | .74 | .80 |
| | | | (.133) | (.088) | |
| 2 | ¬yellow | ¬green | .73 | .74 | .76 |
| | | | (.135) | (.093) | |
| 3 | ¬green | ¬red | .67 | .71 | .66 |
| | | | (.103) | (.091) | |
| 4 | ¬red | ¬green | .66 | .68 | .59 |
| | | | (.110) | (.100) | |
| 5 | ¬yellow | ¬red | .66 | .65 | .58 |
| | | | (.117) | (.107) | |
| 6 | ¬red | ¬yellow | .63 | .65 | .56 |
| | | | (.127) | (.112) | |

Table 4: Ranked sequences of initial consumption in periods 1 to 3

laboratory. We analyzed the effect of the initial consumption $x_1$ on individual level, yet, a t-test proved not to be significant ($T = -0.243, p < 0.808$). Remarkable in these figures is the average reaction on information for decision $x_2$, *i.e.*, when subjects know the first die that is excluded. In the laboratory, higher survival probability is correctly recognized by lower consumption, in particular, the different signal of the green die compared to the yellow die is recognized with higher consumption ($T = 3.375, p < 0.001$). On the Internet however, the participants did not recognize this signal ($T = -0.393, p < 0.695$).

Next we compare average consumption in the first three periods (Table 4). For each of the six different paths $k$ the ratio between the consumption in period 1 to 3 and the overall amount was evaluated, *i.e.*, $y_k = (x_1^k + x_2^k + x_3^k)/11.92$. The last column gives the value of this ratio that maximizes expected payoff, as computed by Anderhub et al. (1997). Again, no substantial difference between the Internet and the laboratory was observed.

When choosing consumption $x_t$ for periods $t \geq 3$ participants face a stochastic lifetime. Due to this uncertainty of the time horizon optimal behavior requires to strictly reduce consumption in later rounds $x_3 > x_4 > x_5 > x_6$. For both datasets the predictive success of the weak criteria $x_3 \geq x_4 \geq x_5 \geq x_6$, where participants should at least not raise consumption, is higher. In table 5 the percentage of consumption decisions of participants in periods 3,4,5, and 6 that correspond

| | Internet | laboratory |
|---|---|---|
| $x_3 > x_4$ | 62.8% | 70.6% |
| $x_3 \geq x_4$ | 89.2% | 86.3% |
| $x_4 > x_5$ | 64.5% | 69.2% |
| $x_4 \geq x_5$ | 89.3% | 89.9% |
| $x_5 > x_6$ | 75.1% | 78.1% |
| $x_5 \geq x_6$ | 89.1% | 95.0% |

| | Internet | laboratory |
|---|---|---|
| $x_3 > x_4 > x_5$ | 44.3% | 50.2% |
| $x_3 \geq x_4 \geq x_5$ | 81.3% | 78.0% |
| $x_4 > x_5 > x_6$ | 49.7% | 47.5% |
| $x_4 \geq x_5 \geq x_6$ | 79.5% | 84.4% |

| | Internet | laboratory |
|---|---|---|
| $x_3 > x_4 > x_5 > x_6$ | 32.4% | 33.8% |
| $x_3 \geq x_4 \geq x_5 \geq x_6$ | 70.3% | 72.5% |

Table 5: Percentage of rounds where consumption $x_t$ was reduced (not raised) in periods with uncertain future (4 to 6)

| | Internet | | laboratory | |
|---|---|---|---|---|
| | cases | payoff | cases | payoff |
| periods $= 4$ | 15 | 25.43 | 15 | 27.71 |
| | | (7.231) | | (4.892) |
| periods $\neq 4$ | 35 | 25.00 | 32 | 26.48 |
| | | (7.043) | | (5.616) |
| total | 50 | 25.13 | 47 | 26.87 |
| | | (7.028) | | (5.373) |

Table 6: Total payoffs separated by question about periods

to the above criteria is shown. The samples consist of all rounds, where subjects had to make the specific decisions. Independent of the setting Internet or laboratory, we see that only a small percentage behaved in the sense of the strict criteria and lowered consumtion, while a large part of the subjects at least not raised consumtion.

After the game the following question was asked: “Suppose you could determine in advance how many periods you are going to live. What would be your choice in order to maximize your payoff (3, 4, 5 or 6 periods)?”. The correct answer is 4. Again, similar results were obtained on the Internet and in the laboratory when we relate the answer to total payoff per participant (see Table 6).

# 5 Conclusions

The results of Internet studies will most likely be challenged because of their less controllable environment. At the beginning of experimental economics on the Internet experiments should therefore try to measure the influence of this change of experimental settings. We have presented an experiment where the same software was used on the Internet and in the laboratory. This is the first comparison of this type.

The Internet experiment did not provide an identical environment for participants in the laboratory and on the Internet. The subject pool on the Internet was, by design, quite heterogeneous. We observed statistically significant differences in some collected data, such as decision times. These differences could result from the different subject pool, the different experimental environment, or neither of the two. We observed on the other hand strong similarities in general economic behavior.

Our findings motivate two directions of future research. The first is further cross-comparison of results obtained in different environments. For example, Internet experiments should be conducted with a subject pool similar to the typical subject pool in laboratories. Or, restrictive designs of Internet experiments, like no second login and careful subject selection, should be compared with non-restrictive designs. This paper has shown that differences of the results are not as large as might be expected. Further research would make us more confident in using the Internet as an alternative to the laboratory. This is of particular interest as our experiment has proven that Internet technology is a valuable resource for the implementation, as Web browsers are today state of the art in every PC laboratory.

The second direction of research should use the Internet to perform experiments that are explicitly different from those in the laboratory. Features of a traditional laboratory experiment, like decisions being made by individuals and strict control on helper tools, might be given up in order to measure the natural decision behavior of subjects. One might encourage individuals to make decisions as they are used to make them, like discussing saving decisions with their spouses. As well, one might think of longtime experiments in which participants interrupt the game and continue some time later. The Internet might encourage to do experiments with rather different subject pools, where it remains the main problem to create the right incentives for subjects to reveal correct personal attributes.

Overall, we believe that the Internet is a sound environment for experimental economics, especially in cases where the laboratory approach has limitations. It does not require a laboratory and it allows to attract a large number of participants, with payment being a major limitation. It simplifies to get diverse participants from outside the universities. Finally, it gives participants full flexibility when to play. In cases where no immediate reaction is required, the Internet provides a valid platform also for multi-player experiments. Examples are e-mail games (Baier et al., 1997) or electronic markets (e.g. Berg et al., 1997).

A demo version of our game is available on the Web, unfortunately without payments. The URL is http://grimnir.wiwi.hu-berlin.de/spiel.

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# 6 Appendix

## 6.1 Translation of the instructions

### Instructions

Please read the instructions carefully before you start the game.

Your task is to distribute a given amount of money to several periods the best way. The better you do this, the higher is your round payoff. You will play 12 rounds. The average payoff of all 12 rounds will be calculated at the end of the experiment and then transferred to your bank account.

During a round you have to spend money in every period. Your payoff will be calculated by the product of the spent amounts of each period. The main problem is that you do not know for sure how many periods each round consists of. Three, four, five, or six periods of play may take place in each round period. Whether periods four, five, and six are reached is determined by throwing a die. There are three possible dice, a red one, a yellow one, and a green one. In the following table you see in which cases you reach the next round.

| Color of the die | No further period if the die shows these numbers of points: | Next period is reached if the die shows: |
|---|---|---|
| red | 1,2,3 | 4,5,6 |
| yellow | 1,2 | 3,4,5,6 |
| green | 1 | 2,3,4,5,6 |

Note that it is impossible to play more than six periods.

In beginning of each round, you do not know which of the three dice will be thrown in this round. This information will be provided only after you have already taken several decisions.

The proceeding of each of the rounds is as follows:

**1st period** You receive a free disposable amount of S which you can spend during the periods of the round. You can not spend more than this. You choose x1, the amount you want to spend during the first period. Please be sure to consider carefully the amount you want to spend and the amount you want to keep for the following periods. After your decision one of the three dice is excluded randomly by the computer. Every die will have the same exclusion probability. You will then know which of the dice will not be thrown to determine whether you reach the periods four, five, and six.

**2nd period** You choose x2, the amount you want to spend during the second period. Of course, you can not choose more than what is left over from period one. After your decision one further die is excluded randomly by the computer. Every die will have the same exclusion probability. You then know exactly which of the three dice determines whether you reach periods four, five, and six.

**3rd period** You choose x3, the amount you want to spend during the third period. After your decision, the computer will throw the remaining die, revealing whether you reach period four or not. Every die will have the same exclusion probability. If you do not reach the fourth period, the round is finished. The amount you did not spend up to this point of time becomes invalid.

**4th period** If you have reached the fourth period, you choose the amount x4. After that, the same die will be thrown again.

**5th period** If you have reached the fifth period, you choose the amount x5. The die is then thrown once again.

**6th period** If you have reached the sixth period, you choose the amount x6.

Your payoff is determined by the product of all amounts you spent in the periods you actually reached. For example, if you reached exactly four periods, your payoff is determined by: $P = x1 * x2 * x3 * x4$. If you reached all six periods, your payoff is: $P = x1 * x2 * x3 * x4 * x5 * x6$, with x6 being the amount you left over after period five. Please note: If you spend the amount of 0 in one of the periods, your payoff will be 0 as well since one of the factors is 0. This can happen if, for example, you spend all remaining units in period four and survive, i.e. reach period five. Then you would be forced to spend x5 = 0 (and, possibly, x6 = 0), resulting in a payoff of P = 0. Therefore, you have a trade off between the risk of spending everything you have too early and the possibility that the remaining amount becomes invalid in case of an early end of the round.

When you press the start button, the game will be loaded. The download time depends on your Internet-connection. Please do not press the reload button or change the size of your browser window at this point. The experiment can be started only once using the supplied e-mail address.

The game window offers a button info (have a look at the menu bar) where you can find a documentation of your former results.

When you thoroughly understand the instructions you can start the game now!

## 6.2 Screenshots of the program

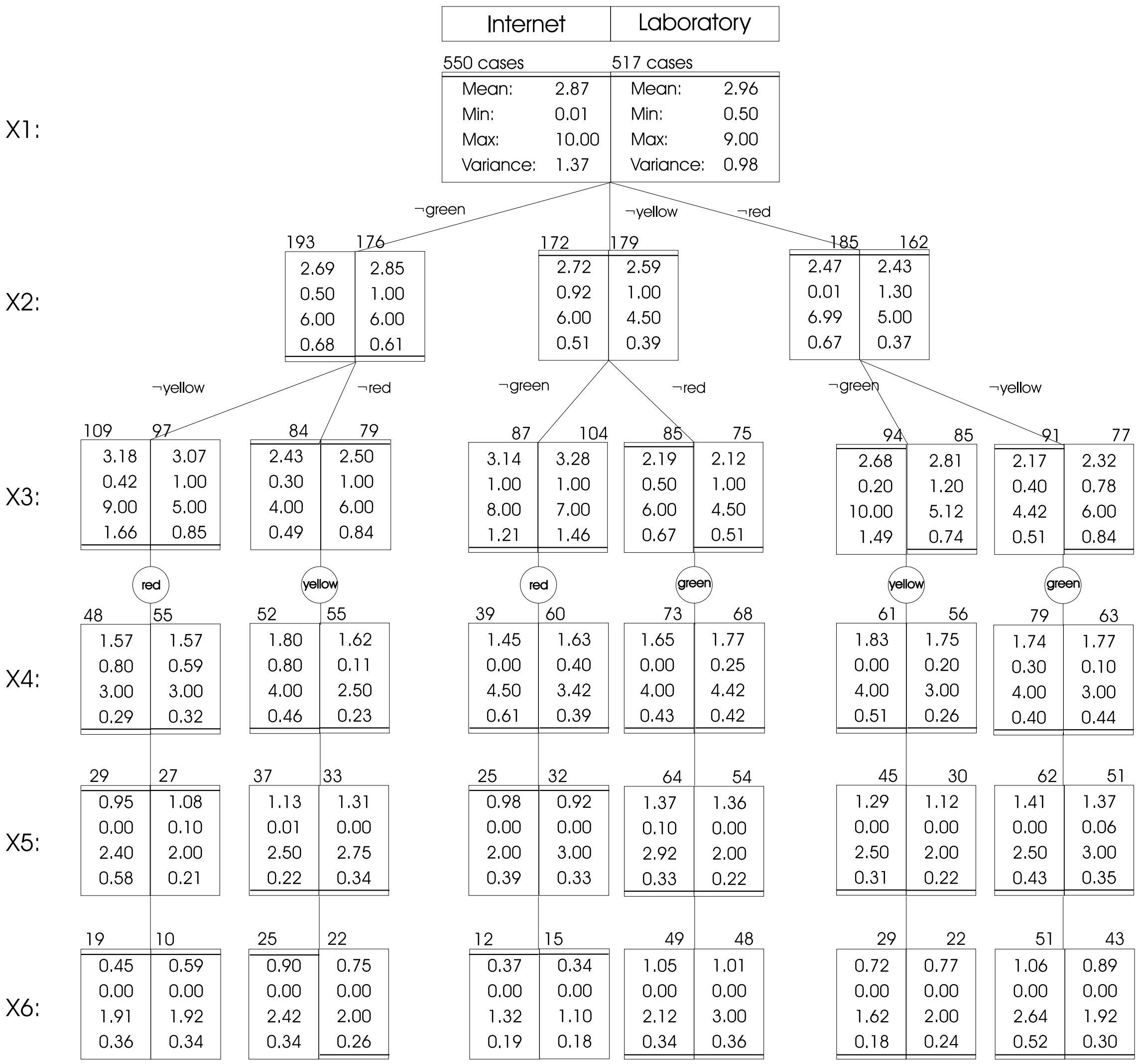


Figure 5: Average behavior: left side Internet, right side laboratory

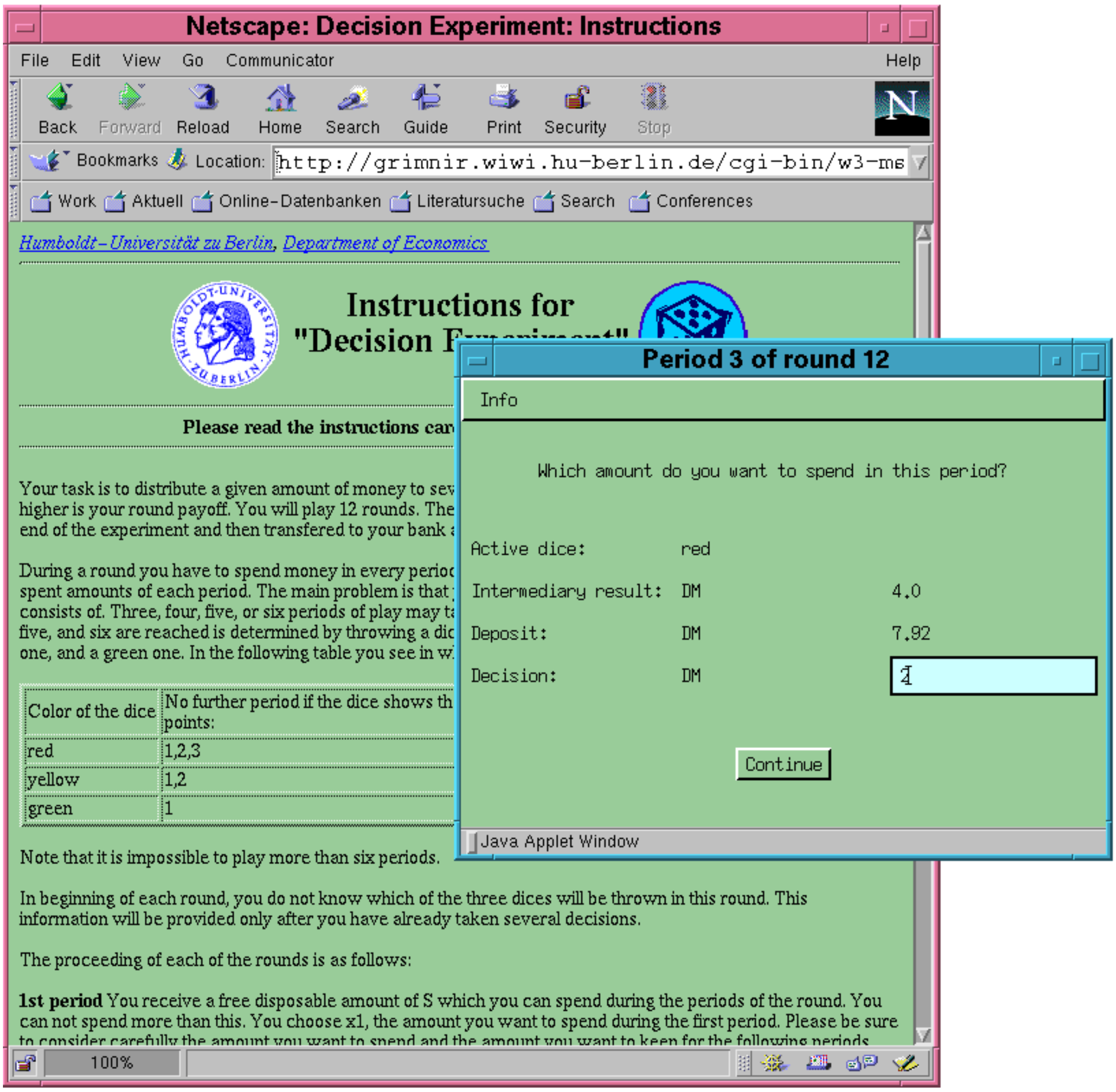


Figure 6: The interface to decide on the savings in a round

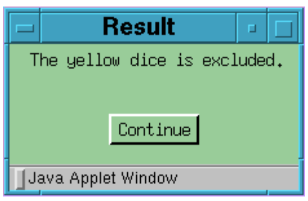


Figure 7: Notification of the exclusion of a die

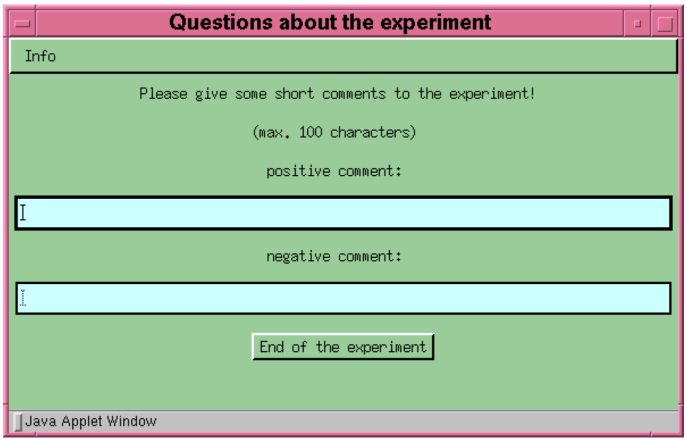


Figure 8: The interface to submit comments at the end of the game

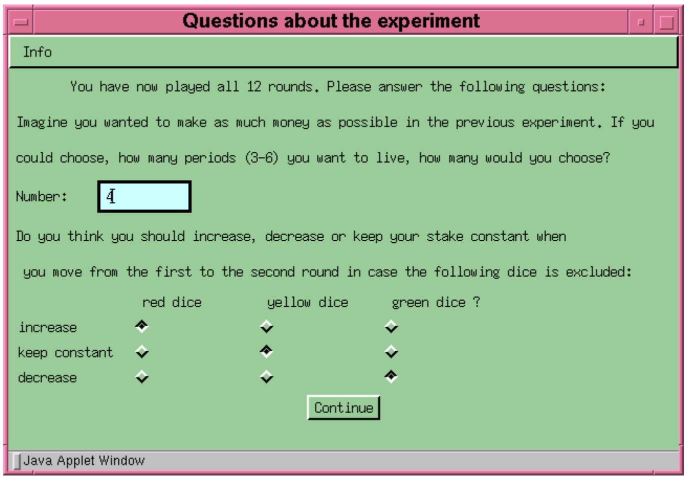


Figure 9: Questions to test plausible decision rules

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