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How performance based payoffs influence estimates of complex information? An experimental study on quality and precision in estimation tasks

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Abstract

This paper investigates the processing of repeated complex information. The focus of this study is, whether additional information and the introduction of performance-based payoffs have an influence on judgement. Therefore, an experiment is designed to investigate the degree of precision and quality of interval estimates. The data shows that providing additional information decreases the precision of stated estimates, while it improves its quality. The same result is obtained, when performance-based payoffs are introduced to an otherwise hypothetical decision environment. That means, while the variation in the treatment variables increase the quality of the estimate, the precision as a reflection of the decision makers confidence is reduced.

Keywords: interval estimates; uncertainty; judgmental estimation; repeated information; hypothetical versus payoffs; experiment
JEL classification: C90, C91, C92, D81

Introduction

Whenever judgments are made on the basis of complex or incomplete information, estimates are specified. In private as well as in professional life the processing of complex information is an important part of judging one's surroundings. Each time complex information is the basis of people's judgment, they have to use estimates for received information in order to simplify the task at hand (San Minguel 1976, Siegler and Opfer 2003). The use of estimates instead of the complete information is necessary because the human brain has only a limited capacity for processing information (Miller 1982). For instance the human short-term memory can only hold between four and six chunks of information for processing (Estes 1975). This limitation of the human brain in turn is the reason why additional information does not necessarily lead to an improvement of the judgment. This means that additional information may lead to an increase of complexity, which provides no additional benefit for the decision maker since the limitations of the human brain do not allow processing it. However, increasing the complexity of the task at hand does not automatically cause people not to process additional information. But this may cause them to use heuristics to simplify the judgment task (San Minguel 1976). Overall, it can be stated that the information processing by the human brain is very complex and no model exists that covers all components of processing information by human beings (Miller 1988). Although there is no general model for these situations, for economic estimation tasks the commonly adopted methods are simple heuristics for describing the information processing by the human brain (Einhorn and Hogarth 1975, Einhorn, Hogarth and Klempner 1977, Dawes 1979, Penningtonn and Hastie 1986, Sniezek and Henry 1989, Cosmides and Toobi 1995). In this paper the influence of complex information on the estimations performed by individuals is investigated. Therefore data of interval estimates based on complex information is used which is collected in a controlled experiment.

The processing of complex information leads to simplification, which has a direct impact on the judgment of the received signal. This influence is reflected by the imprecision of the judgment. As mentioned above, the human brain has a limited capacity for processing complex information, which consequently leads to imprecise judgments (Miller 1956).

Furthermore different degrees of imprecision of estimates reflect different degrees of uncertainty which subjects associate with their estimation. This means that the higher the imprecision of an estimate is the higher is the uncertainty associated with the performed judgment (Halberg and Teigen 2009). Also a high degree of accumulation of information can not completely reduce the complexity of the task. This causes a remaining degree of uncertainty (Hayes 1993). As a result the processing of complex information and its transformation into estimates is associated with a bias (Huttenlocher, Hedges and Bradburn 1990). The degree of this bias can be determined by applying two measures, the interval width as an indicator of the degree of uncertainty of the estimate and the quality of the estimate, which can be reflected by either the distance between the judgment and the true value of the task (Yanvi and Foster 1997) or the average hit rate indicating how often the true value is within the stated interval. Even if people made repeatedly judgments based on complex information a certain bias remains (San Miguel 1976). This can be seen in contrast to economic models which assume that additional information always leads to better judgments. This theoretical adoption about a linear correlation between additional information and the improvement of the judgment cannot be observed in experiments (Fiedler & Kareev 2006). In general information processing depends on the degree of expertise of the processing person thus incomplete information causes a bias of judgment. Situations of incomplete information are part of the economic life, caused by the fact that the gathering of information is costly (Edwards 1965). Therefore judgments are often made by using incomplete information because the costs for gathering the information are higher than the expected benefit (Booth and Siegler 2006). Imprecision can be caused by complex information as discussed before or by having incomplete information.

Besides interval estimates there are point estimates. Point estimates refer to the exact value which is considered to occur with the highest probability. In contrast, interval estimates imply a range of values which take place with different probabilities that are modeled using density functions reflecting a distribution of observing any given value (Murphy and Winkler 1974). Studies show, that people feel more comfortable with the specification of a number of possible outcomes, by specifying a direct point (Murphy and Winkler 1974). This can be interpreted as people state point estimates, although they actually have an interval in mind. This causes that interval estimates can be observed more frequently, if people have the choice between point and interval estimates. A possible explanation for this observation is that using an interval indicates a range of probable conditions (Kosslyn and Osherson 1995). Therefore, in this paper judgments are analyzed which are made on the basis of complex information and presented as interval estimates.

Whenever people perform estimates, they are assumed to use simple statistical methods, as for example the simple mean which constitutes a heuristic that reduces the complexity of the task at hand (Evans and Pollard 1985). Following the assumption that people use the mean for estimating, it is assumed that additional information reduces the error in stated estimates.

In addition to the complexity and completeness of information the judgments of others can influence the judgment of an individual (Surowiecki 2004). Various experiments show that the performance of a group is better than the judgment of an individual (Surowiecki 2004, González, Modernell and Paris 2005, Bloomfield and Hales 2009). Thus, the average performance of a group is better than the results of most individuals within that group (Klugmann 1947). This means, that people adjust their judgments to the observed judgments of the other group members. Even if the group is wrong in its judgment, this behavior can be observed (Anderson and Holt 1997, Prechter 2001). Experiments have revealed that analysts adjust their own forecasts if information about the forecasts of others is available neglecting their own private information (Bloomfield and Hales 2009, Quiamzade and L´Huillier 2008). This reaction can also be observed in simple games with two agents where subjects copy the decision of the first mover when it is observable significantly more often than when it is not observable (González, Modernell, and E. París 2005). This paper examines to which extent the information about the judgment of other group members influences the judgment of the individuals within the group. It will be analyzed how the precision and the quality of an individual's estimate changes if information about the estimates of other group members is available.

By analyzing judgments, two major forms of judgments can be observed. First there are judgments which have an immediate and direct impact on the financial situation of the individual performing the task and second there are judgments which have no immediate or direct impact. An example for a judgment which has direct and immediate consequences on the financial situation of the individual is the purchase of shares. In this case the decision to buy shares on the basis of different sources of information available to the individual. A price increase or decrease of the shares has a direct impact on the financial situation, either positive of negative, of that decision maker. In contrast, there are situations requiring an individual to perform judgments, which do not have a direct and immediate impact on the financial situation of the individual. An example is the question about what one would do with a possible lottery prize. In this respect, economic and psychological experiments have distinct differences. While experimental economists only provide real choice situations which have a direct and immediate impact on the financial situation of the subjects, while psychologists mainly use hypothetical settings. The question whether a performance dependent payoff or hypothetical decision tasks lead to better results is unclear in the scientific literature. On the one hand there are some opinions which assume that performance based payments lead to better experimental results, because the subjects immediately feel the consequences of their judgments. This is not the case by experiments with a hypothetical based payment, because in this situation subjects usually only imagine the consequences of their actions (Wallis and Friedmann 1942). On the other hand some experiments show that under certain conditions the results decline if a performances based payment is adopted (Connolly, Arkes and Hammond 1999). In this paper it is analyzed which effect the two conditions have on the quality and precision of estimates.

The results of the experiments reported in this paper show, how judgments based on complex information are influenced by the information available and whether a performance related payoff is offered or not. The experimental results show that providing information about estimates of other participants does not lead to higher precision of estimates, but increases the quality. Furthermore, it is shown that the estimates which are performed in settings including performance related payoff are more precise compared to settings without performance related payoff, but do not have a higher quality.

Experiment

The experiment is conducted at the laboratory of the Otto-von-Guericke University Magdeburg. A total of 189 subjects participate in the experiment who are students from different academic backgrounds at the Otto-von-Guericke University Magdeburg. These are randomly selected using the ORSEE system (Greiner 2004) and assigned to 4 experimental treatments. The experimental tasks are implemented using a computerized decision environment implemented in ztree (Fischbacher 2007).

The experiment consists of the following steps. First, each participant sees a randomly generated scatter plot for 10 seconds. During this time period the participants are not able to count all the points of the scatter plot (Höfelmeier 1996). The number of points in this case varied between sessions in a range of 130 and 250. After the scatter plot is shown to the participants they are asked to estimate the number of points shown to them. The participants are asked to specify an interval framing the true number of points in the scatter plot. The upper interval bound should specify the maximal number of points and the lower bound of the interval should specify the minimal number of points the participants saw on the screen. This task performed 10 times. The number of points remains the same, but the distribution of points in the scatter plot varies, while this fact is included in the experimental instructions handed out at the beginning of the experiment.

The experiment consists of 4 treatments in a 2x2 factorial design. The first treatment variable is the information provided to the participants. The experimental task described above represents the case where subjects do not receive any information about the estimates of other subjects (Treatment: I-). In an extension of this treatment the participants receive information about the sated intervals of the other participants in their session after each round (Treatment I+).

<table>
<tr><th>Step</th><th colspan="2">Treatment</th><th>Screen</th><th>Time Frame</th></tr>
<tr><td>1</td><td rowspan="2">I-</td><td rowspan="3">I+</td><td>Scatter plot</td><td>10 sec.</td></tr>
<tr><td>2</td><td>Provide upper and lower bound of interval</td><td>Press OK</td></tr>
<tr><td>3</td><td></td><td>Table with answers of all the other participants</td><td>Press OK</td></tr>
</table>

Table 1: Experimental setting

The second treatment variable concerns the remuneration of the subjects. The first experimental conditions provides a hypothetical choice scenario, where subjects receive a fixed show up fee of 7 euros regardless to the quality of their estimates during the experiment (Treatment: HY). The second experimental condition provides performance based payoffs the amount of this payment dependent on the quality of the decisions of the participants (Treatment PY). The payment was calculated by the following rule: After the expiry of the ten rounds, one round was randomly selected for payoff. In this case the payoff is determined to be incentive compatible and is calculated as described below. The subject only receives a payoff, if the true number of points is within the interval stated by the participant. The monetary amount rewarded in this case depends on the width of the interval and is in this case 200 Euro divided by the width of the stated interval.

	hypothetical payment	Performance based payment
without information	I- / HY 48 subjects	I- / PY 36 Subjects
with information	I+ / HY 48 subjects	I+ / PY 57 subjects

Table 2: 2x2 factorial experimental design

Results

In the experiment, interval estimates for complex information are elicited. For the analysis, the interval width can be interpreted as a reflection of the individual's degree of confidence about the estimate. That means, the smaller the stated interval, the more confident the subject is with her estimate. Furthermore, a smaller interval is considered to provide a higher precision of the estimate.

In addition to the precision of an estimate the quality of an estimate is evaluated. The degree of the quality of an estimate is investigated in the following analysis by using two measures. First, the hit rate which indicates, how often the real number of points of the scatter plot lies within the estimated interval (Yanvi and Foster 1997). This means the higher the hit rate the higher the quality of the given estimate. In addition to the hit rate the absolute value of differences between the real number of points and the estimated number of points are calculated as the distance between the midpoint of the stated interval and the true number of points in the scatter plot. The two measures for the quality of the estimate differ in a different way of measurement. The hit rate indicates as binary measurement, whether the true value of points on the scatter plot is within the estimated interval or not. The differences however take into account the distance between the true value and the estimate. This means how far the estimate is away from the true value.

The following analysis deals with the question whether the precision of an estimate differs between I+ and I- Therefore the data of the estimates of HY and PY are pooled. It turns out, that the precision of the estimates for both I+ and I- decreases over the rounds. Furthermore, there are no significant differences between the two treatments, although subjects who have information about others' estimates have more independent observations for estimate of the received signal (see figure 1). However, subjects of I- in round ten have the same number of independent observations as subjects of I+ in round two. Comparing the interval width in round two for the estimates of I+ and the interval width for I- for round ten, the interval width have to be nearly the same value. This is caused by the fact, that the number of independent observations for both situations is the same. For I+ participants in round two can take ten observations into account for their judgment. They know their own estimate and the estimations of nine other participants. This is the same as participants of I- in round ten, who have the information about their own estimates performed in the previous nine rounds.

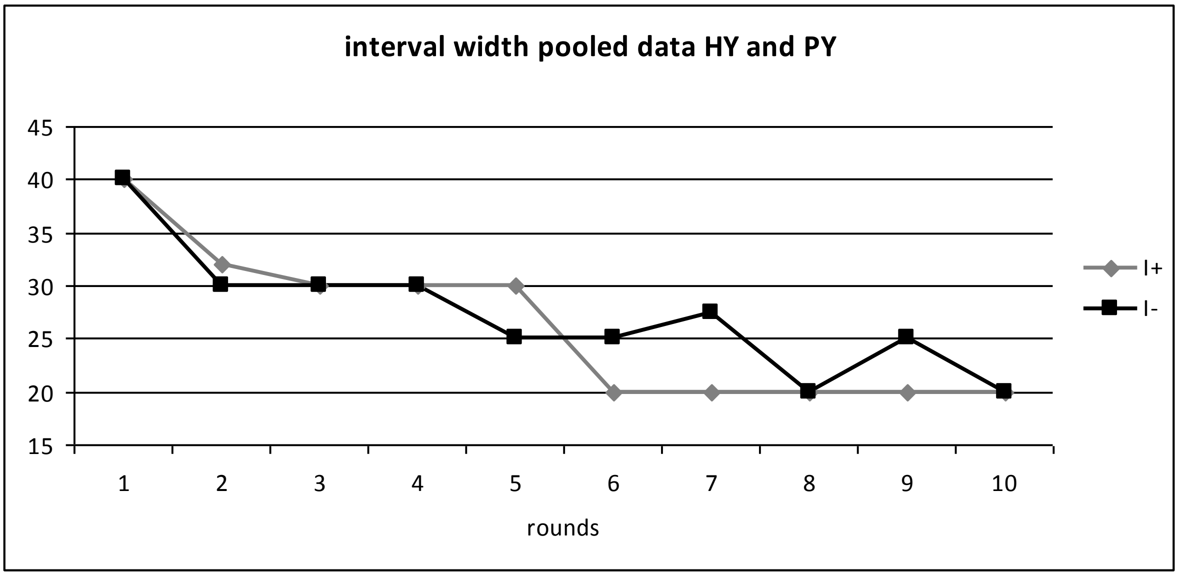

Figure 1: interval width hypothetical and payoff over the rounds

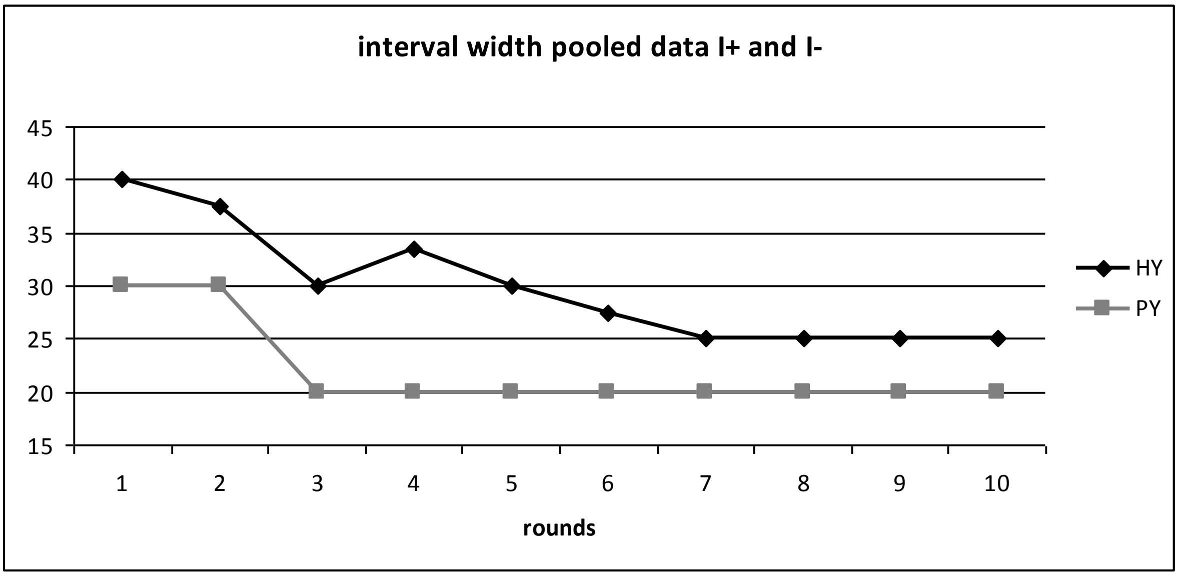

Figure 2: interval with and without information over the rounds

The second treatment variable allows an analysis, whether having a hypothetical setting or performance based payoffs has an effect on the precision of an estimate. Therefore the pooled data of I+ and I- over the rounds is used (see figure 2). The average interval width for HY is 29.85 which is significant higher than the average interval width of PY with a value of 22.00. Furthermore, the interval width of the estimates of HY are significantly larger than the width of PY in all rounds (Wilcoxon-Test, 1%-level). In summary it can be concluded, that the precision of the estimates in the hypothetical condition is higher than the precision of the estimates when performance based payoff are offered.

In the next step the influence of the treatment variables on the quality of the stated estimates is analyzed. To assess the quality of the estimates the average hit rate of all rounds of the experiment is considered first.

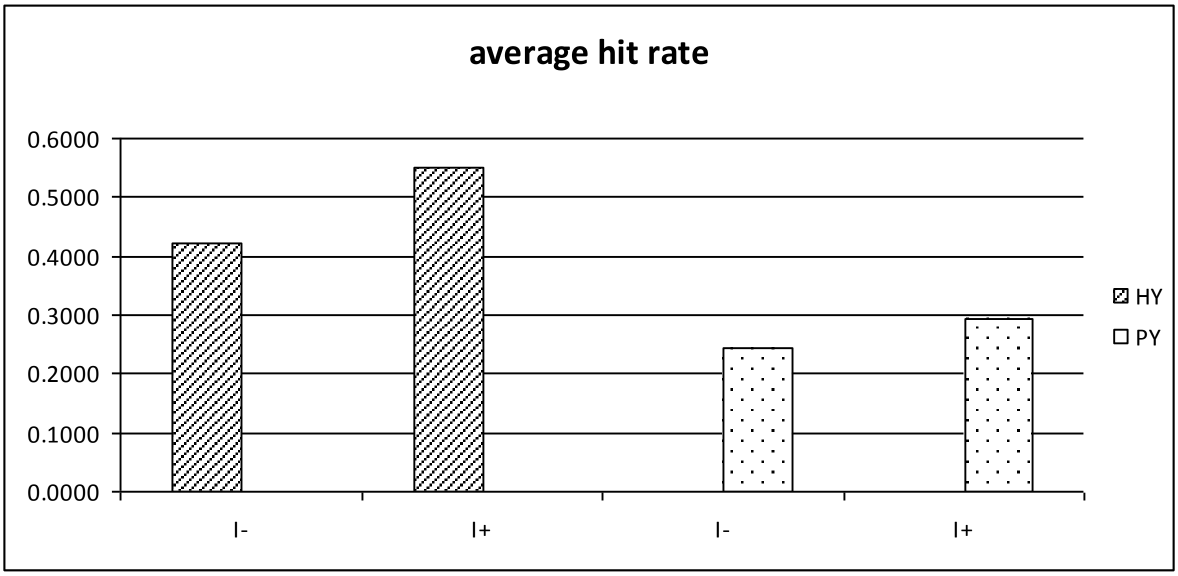

Figure 3: average hit rate over all rounds

Examining the data it can be determined, that the average hit rate of I- is significantly less than for I+ (chi-square Test, 1%-level). This difference occurs for the hypothetical as well as the performance-based payoff condition. Thus, that the quality of the estimates of I+ is higher than for the estimates of I-. Further it can be stated, that the average hit rate for HY is significantly higher than for PY (chi-square Test, 1%-level). Again, this result exists under both conditions, I+ and I-. This means, on the one hand the quality of an estimate is higher if information about the estimates of other participants is available. On the other hand causes a performance related payoff compared to a hypothetical a decrease of the quality.

The next object of investigation is how the quality of the estimates changes over the rounds. In particular it is interesting what differences occur with respect to the quality of an estimate, if on the one hand there is no information about the estimates of the other participants or on the other hand if this information is observable. To answer these topics, the average hit rates for the pooled data of HY and PY are used (see figure 4).

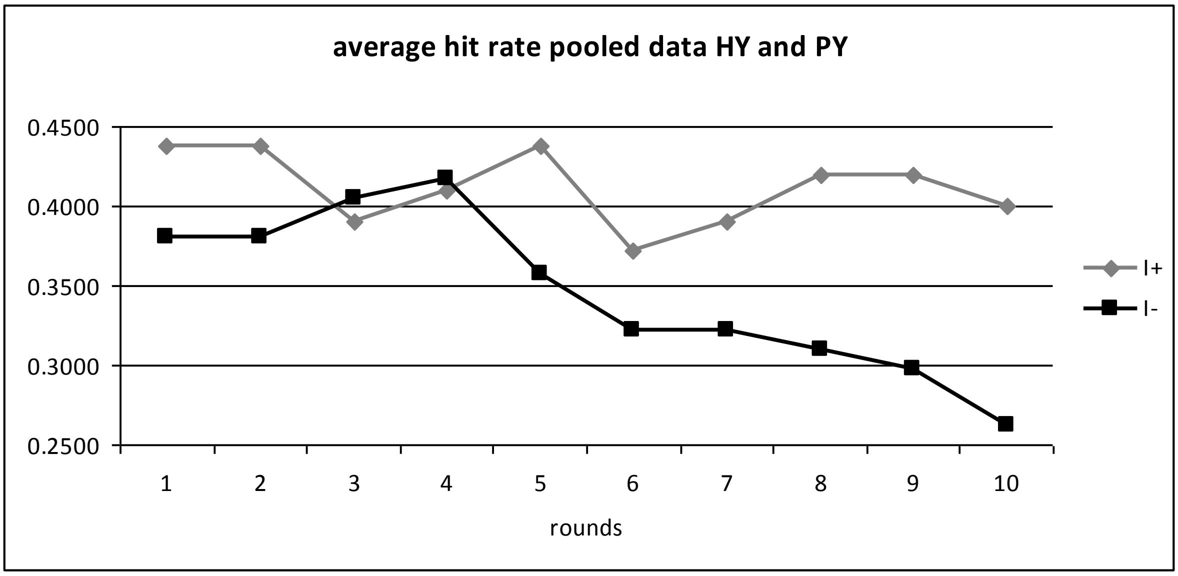

Figure 4: average hit rate hypothetical and payoff over the rounds

The data shows that the hit rates for I- decreases over the rounds (see figure 4). This means, that the quality of the estimates for I- is decreasing significantly over the rounds (Wilcoxon-Test, 1%-level). In contrast to this, the quality of the estimates for I+ is nearly constant over the rounds of the experiment.

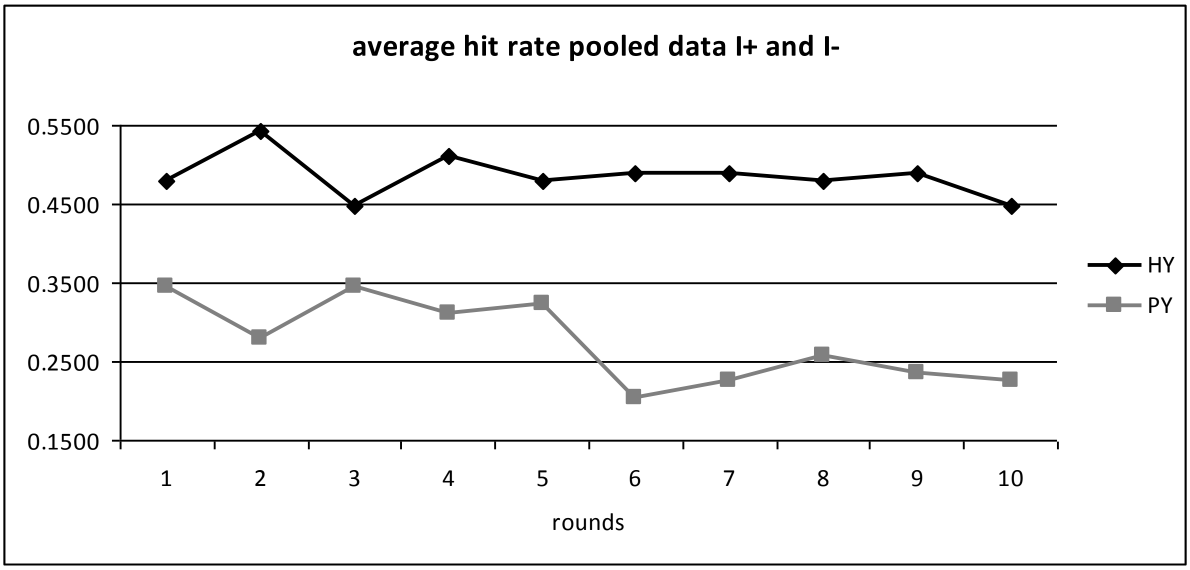

Figure 5: average hit rate with and without information over the rounds

For the pooled data of the hit rates for both conditions, I+ and I-, it can be observed, that the hit rates for HY are almost constant over all rounds. In context of the average hit rates of PY, a small decrease over the rounds is observed. Basically it is striking, that the average hit rates of the HY are significantly higher than the hit rates of PY over all rounds (Wilcoxon-

Test, 1%-level). That means, the quality of the estimates of HY is higher than the quality of the estimates of PY. This result is also determined by the evaluation of the data differentiated according to treatments.

To extend the analysis of the quality of the estimates the absolute values of the differences between the midpoint of each stated interval estimate and the true number of points of the scatter plot is calculated. For interpretation this means, the smaller the absolute value of the difference the smaller the distance between the actual number of points and the interval midpoint of the estimated interval.

Again the differences of the pooled data of HY and PY (figure 6) are used to analyze the quality of the estimations which are performed repeatedly. In this case it is interesting to compare the qualities of the estimates of I+ and I-.

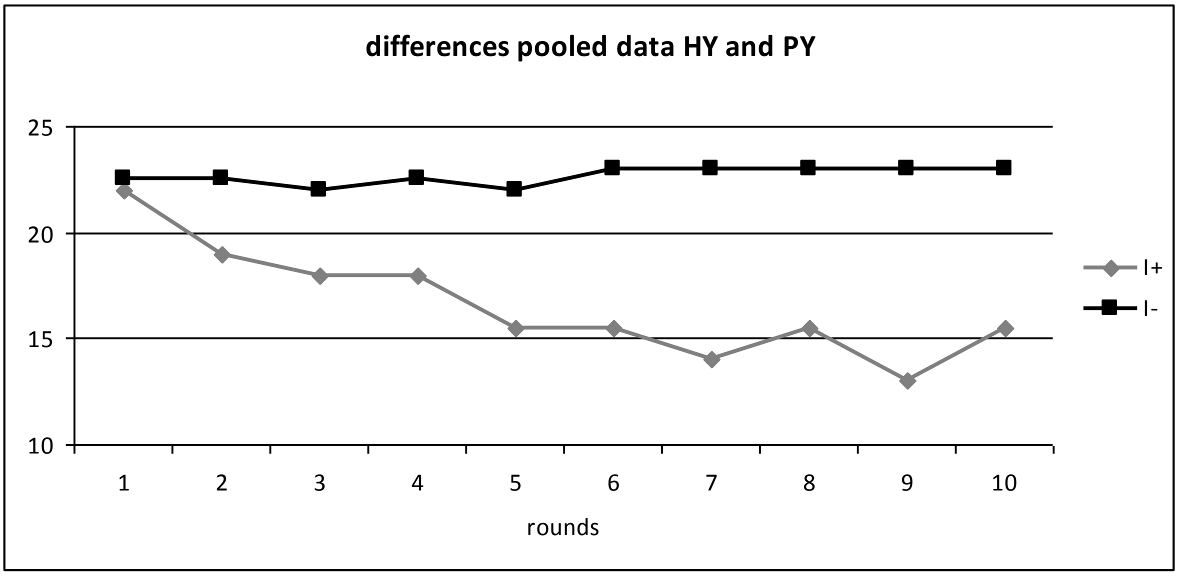

Figure 6: differences hypothetical and payoff over the rounds

The calculations show, that the differences over the rounds are almost constant. For the data of I+ a decrease of the differences can be seen. In other words, the quality of the estimates increases over the rounds. Furthermore the data shows a significantly lower quality of the estimates of I- compared to the estimates of I+ (Wilcoxon-Test, 1%-level).

To answer the question whether the estimates which are performed by the participants of HY compared to those of PY, the differences of the pooled data for the treatments I+ and I- are calculated (figure 7).

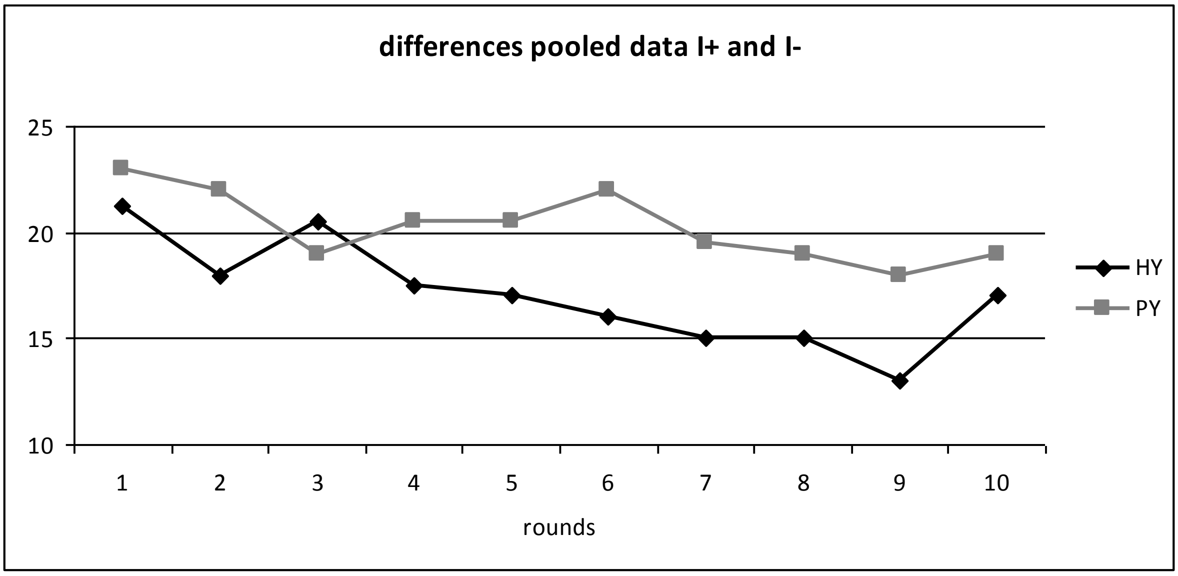

Figure 7: differences with and without information over the rounds

The differences of the pooled data indicate that the quality of the estimates of HY is higher in most of the rounds than the quality of PY. Also, a decrease over the rounds of the differences of the estimates of both experiments can be noticed. This means that, the quality of the estimates is increasing from round one to ten.

Conclusion

This paper analyses the processing of repeated complex information and individual judgments of the perceived signals. Two factors are the focus of our experimental setting. One experimental setup analyses the influence of additional information on judgement and a second experimental setup addresses the question, whether the introduction of performance related payoff affects individual judgments. For purposes of this paper, two characteristics of the performed judgement are subject to the investigation, which are precision and quality of estimates.

Contrary to assumptions of economic models and models about the statistical man, providing additional information does not improve the precision of an estimate. That means

it does not increase confidence of the individuals about their stated estimates. However, the quality of an estimate is significantly increased by providing additional information.
The second experimental treatment variable shows that estimates performed under conditions including performance based payoffs have a higher precision than those which are made under hypothetical conditions. Although subjects state a higher degree of confidence with their estimate, the analysis show that the quality of their estimates is significantly reduced by the introduction of performance related payoffs.

It is striking, that additional information decreases the precision of an estimate while its quality actually increases. That means, although the quality of the estimate increases, the individual decision maker feels less confident about the statement. Furthermore it is emphasized, that the introduction of performance based payoffs leads to higher precision, which is a statement of higher confidence, while the quality of estimates under these conditions is reduced. That means, for both experimental treatment variables the confidence is reduced for situations actually leading to higher quality.

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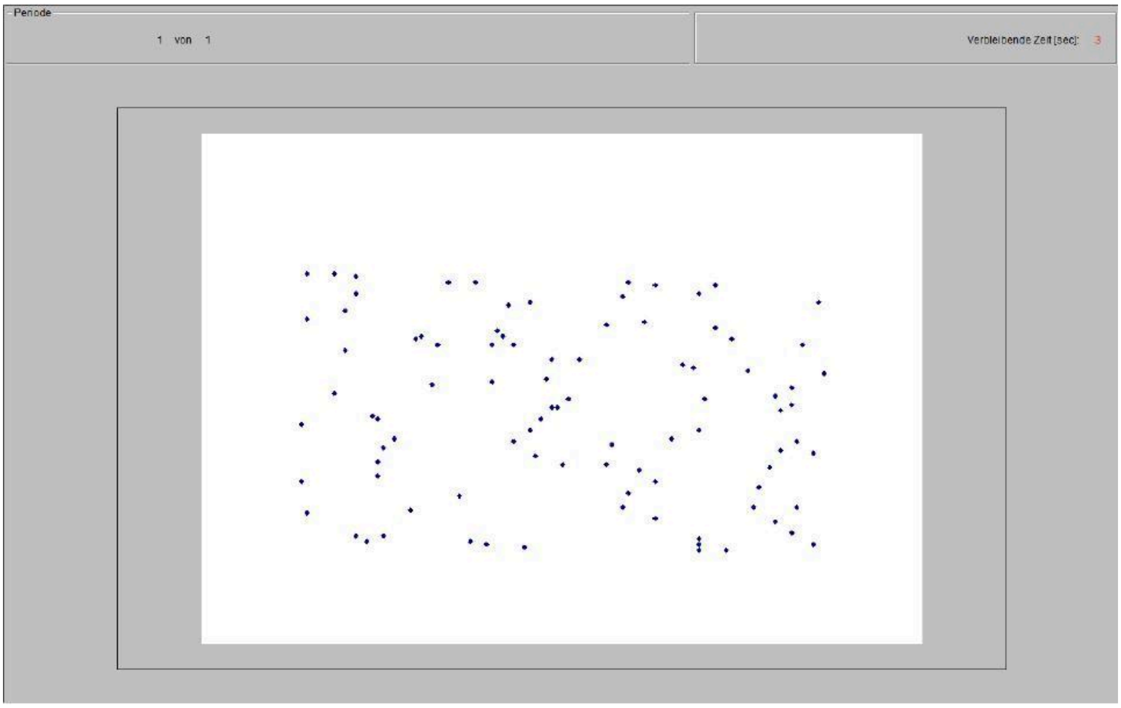
Appendix

A. Experimental Instruction for the hypothetical related Experiment without information)

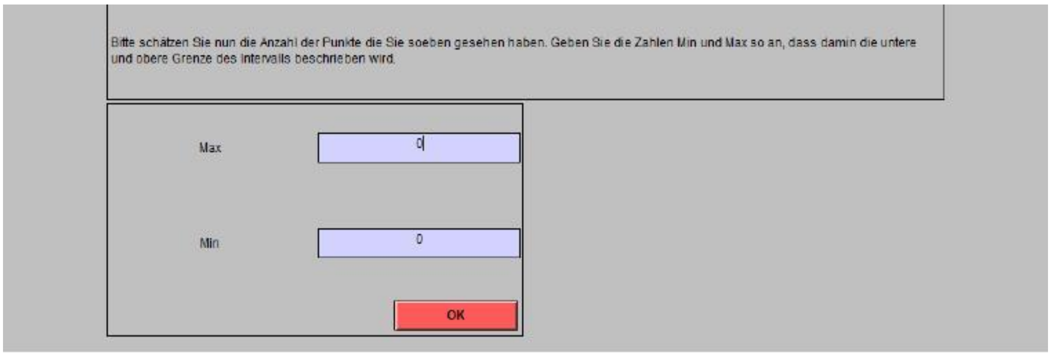
You are taking part in an experiment to investigate behavior under uncertainty. The Experiment consists of 10 rounds. Each round consists of the following parts:

We will show you a series of images with points. The number of points lies between 100 and 300. Each of these scatter plots is visible for 10 seconds. The number of points in all rounds is the same, the distribution on the screen may change. The following screenshot shows an example of such a scatter plot:



Once you have seen the scatter plot, we ask you the estimate the number of points seen in the picture. Please enter your estimate for an interval.

The following screen shows the input window of the interval to be estimated:



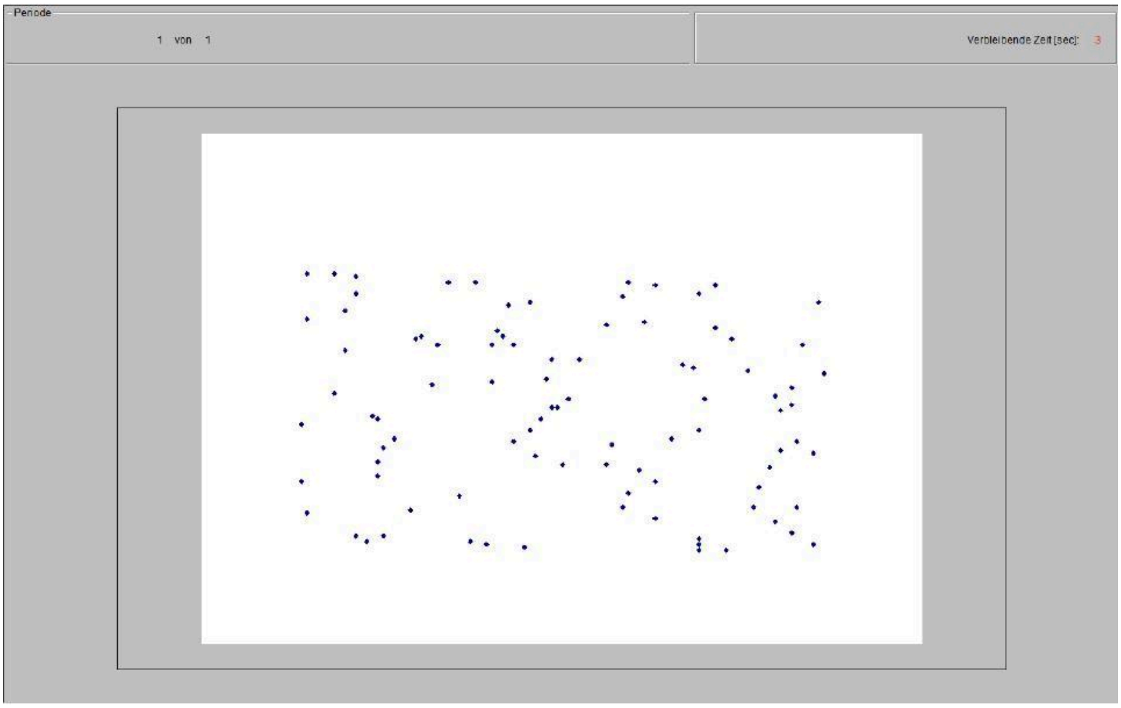
Enter for "Max" that number that the number of points seen in your opinion, does not exceed. Enter for “Min” that number that the number of points seen in your opinion does not fall below. Confirm your entry with "OK".

After pressing “OK”, the next round starts.

B. Experimental Instruction for the hypothetical related Experiment with information

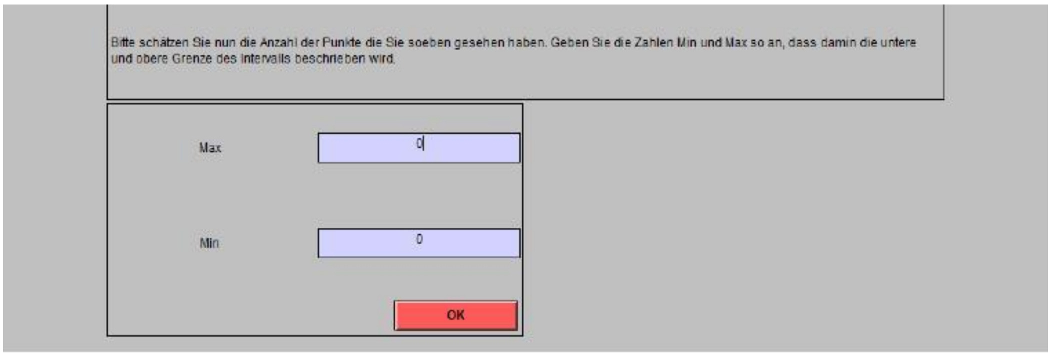
You are taking part in an experiment to investigate behavior under uncertainty. The Experiment consists of 10 rounds. Each round consists of the following parts:

We will show you a series of images with points. The number of points lies between 100 and 300. Each of these scatter plots is visible for 10 seconds. The number of points in all rounds is the same, the distribution on the screen may change. The following screenshot shows an example of such a scatter plot:



Once you have seen the scatter plot, we ask you the estimate the number of points seen in the picture. Please enter your estimate for an interval.

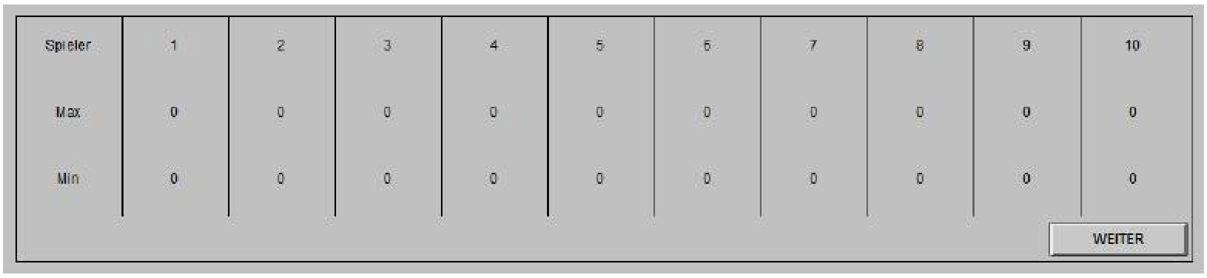
The following screen shows the input window of the interval to be estimated:



Enter for "Max" that number that the number of points seen in your opinion, does not exceed. Enter for “Min” that number that the number of points seen in your opinion does not fall below. Confirm your entry with "OK".

After that you will see a screen which shows the estimated intervals of the other participants of the experiment. All subjects have previously seen the same picture.

The following screen shows an example of the interval data of all participants (including yourself):



Spieler	1	2	3	4	5	6	7	8	9	10
Max	0	0	0	0	0	0	0	0	0	0
Min	0	0	0	0	0	0	0	0	0	0

WEITER

After pressing “Done”, the next round starts.

C. Experimental Instruction for the performance related Experiment without information)

You are taking part in an experiment to investigate behavior under uncertainty.

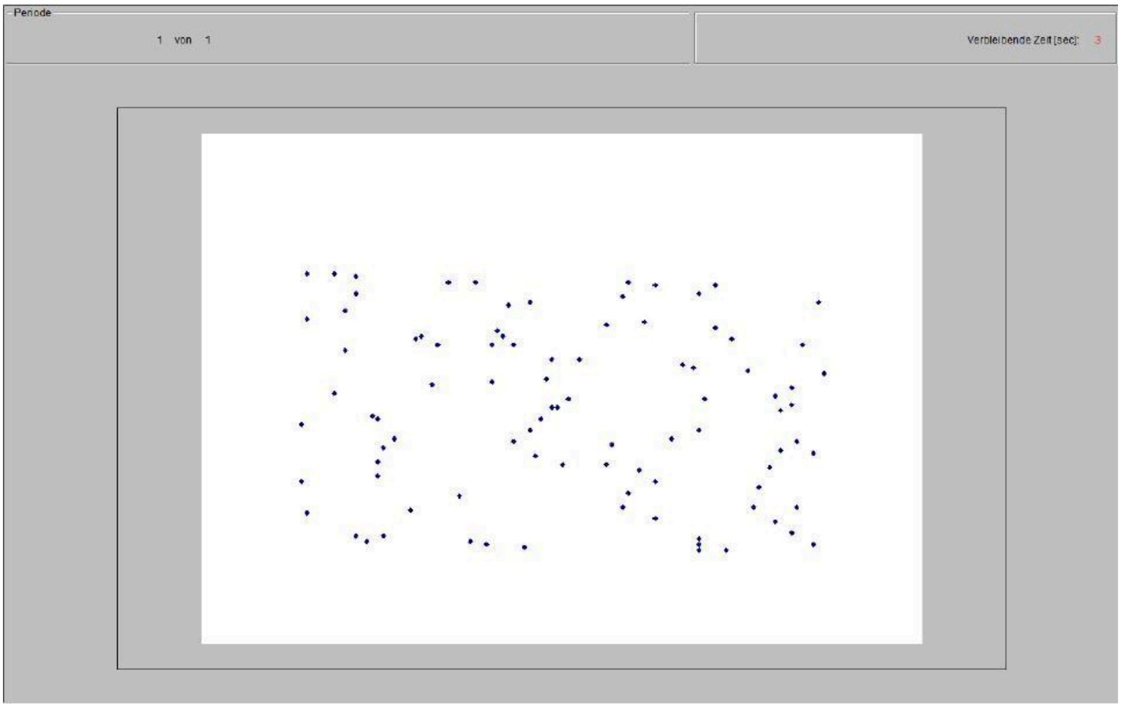
The Experiment consists of 10 rounds. At the end of the experiment exactly one round will be randomly selected which is relevant for the payment. How your payment is calculated is described at the last section of this instruction.

Each round consists of the following parts:

1.) A scatter plot is shown

We will show you series of images with points. The number of points is part of the interval 100 to 300. Each of these scatter plots is visible for 10 seconds. The number of points in all rounds is the same; the distribution on the screen may change.

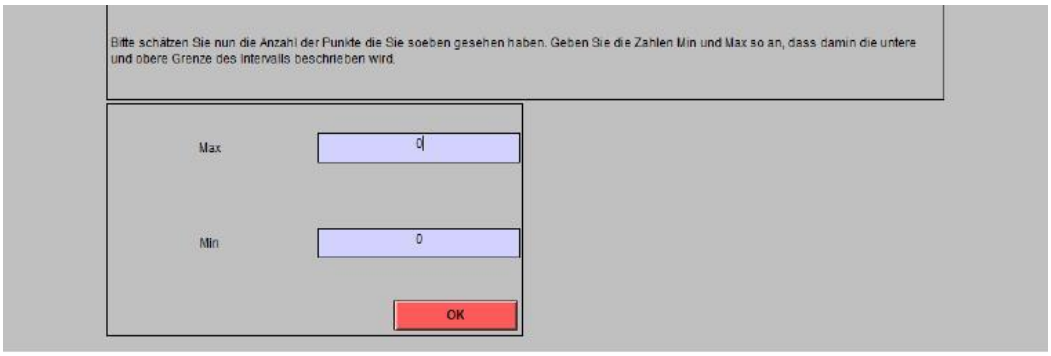
The following screenshot shows an example of such a scatter plot:



2.) Specify the interval

Once you have seen the scatter plot, we ask you to estimate the number of points seen in the picture. Please enter your estimate for an interval.

The following screen shows the input window of the interval to be estimated:



Enter for "Max" that number that the number of points seen in your opinion, does not exceed. Enter for “Min” that number that the number of points seen in your opinion does not fall below. Confirm your entry with "OK".

Calculation of the payment

After the expiry of the 10 rounds for each participant one of the rounds is randomly drawn, this round is relevant for the payment. For this, the experimenter draws one ball from an urn with balls numbered 1 to 10. The number on the drawn ball is the round that is relevant for your payment. For this round your payment is calculated as follows:
For the payment the experimenter compares the true number of points of the scatter plot with your estimation of the drawn round. This gives two possibilities:

True value is NOT in your interval
You get no payment

True value is in your interval

You will receive a payment that depends on the width of the interval you estimate.
The narrower the interval you estimated is, the higher your payment. This is calculated as follows. 200 Euro / interval width. The table below shows an example of the payments which are possible at any interval width.

	payment in Euro	
interval width	true value not in the interval	true value in the interval
1 point	0	200,00
5 points	0	40,00
10 points	0	20,00
20 points	0	10,00
50 points	0	4,00

D. Experimental Instruction for the performance related Experiment with information

You are taking part in an experiment to investigate behavior under uncertainty.

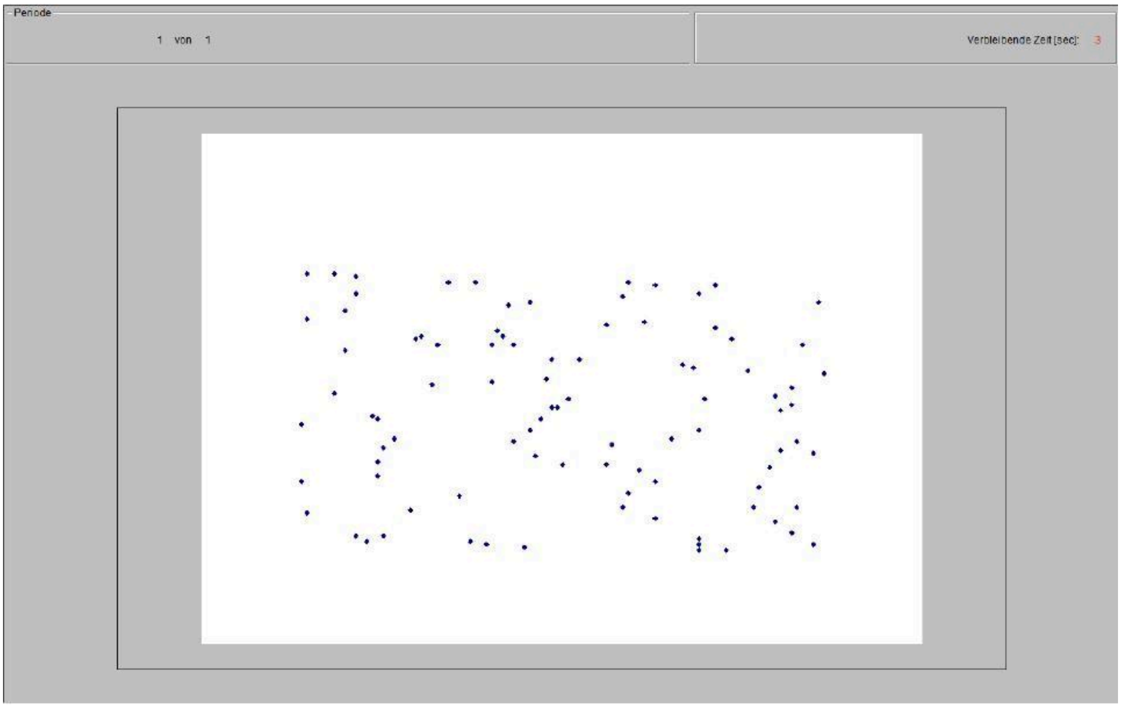
The Experiment consists of 10 rounds. At the end of the experiment exactly one round will be randomly selected which is relevant for the payment. How your payment is calculated is described at the last section of this instruction.

Each round consists of the following parts:

1.) A scatter plot is shown

We will show you series of images with points. The number of points is part of the interval 100 to 300. Each of these scatter plots is visible for 10 seconds. The number of points in all rounds is the same; the distribution on the screen may change.

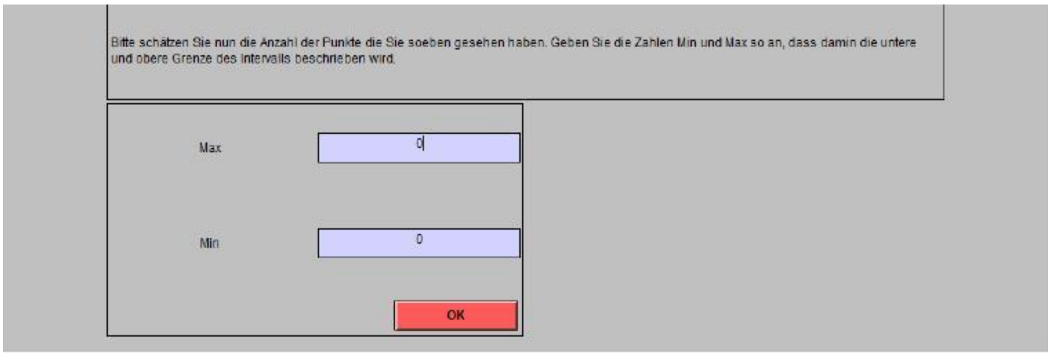
The following screenshot shows an example of such a scatter plot:



2.) Specify the interval

Once you have seen the scatter plot, we ask you to estimate the number of points seen in the picture. Please enter your estimate for an interval.

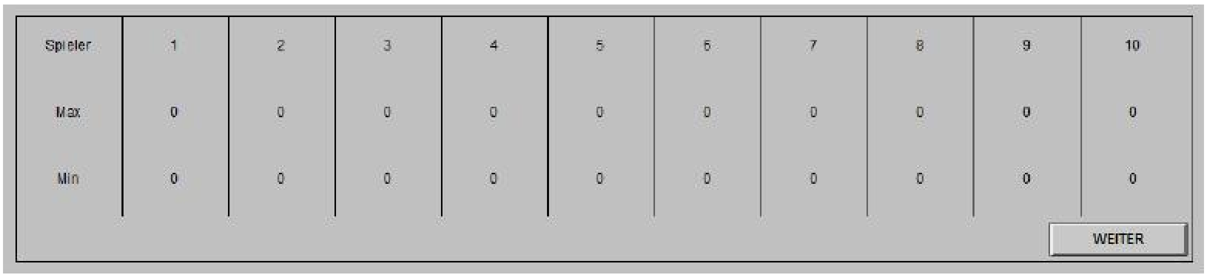
The following screen shows the input window of the interval to be estimated:



Enter for "Max" that number that the number of points seen in your opinion, does not exceed. Enter for “Min” that number that the number of points seen in your opinion does not fall below. Confirm your entry with "OK".

After that you will see a screen which shows the estimated intervals of the other participants of the experiment. All subjects have previously seen the same picture.

The following screen shows an example of the interval data of all participants (including yourself):



Spieler	1	2	3	4	5	6	7	8	9	10
Max	0	0	0	0	0	0	0	0	0	0
Min	0	0	0	0	0	0	0	0	0	0

WEITER

Calculation of the payment

After the expiry of the 10 rounds for each participant one of the rounds is randomly drawn, this round is relevant for the payment. For this, the experimenter draws one ball from an urn with balls numbered 1 to 10. The number on the drawn ball is the round that is relevant for your payment. For this round your payment is calculated as follows:
For the payment the experimenter compares the true number of points of the scatter plot with your estimation of the drawn round. This gives two possibilities:

True value is NOT in your interval
You get no payment

True value is in your interval

You will receive a payment that depends on the width of the interval you estimate.
The narrower the interval you estimated is, the higher your payment. This is calculated as follows. 200 Euro / interval width. The table below shows an example of the payments which are possible at any interval width.

	payment in Euro	
interval width	true value not in the interval	true value in the interval
1 point	0	200,00
5 points	0	40,00
10 points	0	20,00
20 points	0	10,00
50 points	0	4,00

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