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# Proof Beyond a Reasonable Doubt: Laboratory Evidence

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Tim Friehe

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# *Proof Beyond a Reasonable Doubt*: Laboratory Evidence

Florian Baumann[1] Tim Friehe[2]

March 2015

**Abstract**

We investigate how third-party punishers and potential violators decide under evidentiary uncertainty in a take game. In line with the legal requirement and in contrast to economic models, neither the sanction nor the harm level affects the punishment probability, but the quality of evidence does have an impact. Potential violators' decisions are strongly influenced by the expected punishment probability but not by the level of the sanction.

*JEL-Codes*: K42, D81, C91

*Keywords*: experiment; standard of proof; third-party punishment

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## 1. Introduction

When deciding whether to convict a criminal suspect, legal decision-makers ask for *proof beyond a reasonable doubt*. This standard of proof does not vary with the aspects of the case; however, from an economic point of view, the evidence required for conviction should be tailored to the case at hand. Andreoni (1991) provides a theory in which decision-makers choose between convicting a suspect or not for a given sanction and harm level under evidentiary uncertainty, establishing that the standard of proof is increasing in the sanction and decreasing in the harm level. This results because a higher sanction increases the costs of erroneously imposing the sanction (i.e., a legal error of type I), while higher harm makes not punishing a guilty suspect more costly (i.e., a legal error of type II). Miceli (2009) notes the lack of evidence on how legal decision-makers interpret *reasonable doubt*.

This paper presents results on how third-party punishers deal with evidentiary uncertainty in a take game when the aspects of the case vary, considering sanction and harm levels in a 2x2 design. We are interested in the implications of the aspects of the case for the likelihood of legal errors, the individual punishment decision and the taking probability.

The effect of evidentiary uncertainty has been studied in VCM experiments (Ambrus and Greiner 2012, Grechenig et al. 2010); however, third-party punishment is more relevant to our interests. Rizzolli and Stanca (2012) consider how exogenously imposed legal errors influence deterrence. Most closely related to our research question is Feess et al. (2014), a study designed and implemented independently from ours. In fact, Feess et al. and the present work are the only contributions in which the risk of legal errors depends endogenously on the behavior of potential violators – practically speaking, the most relevant scenario. Our paper is complementary to Feess et al. due to important differences in experimental design (to be explained at the end of Section 2).

## 2. Experimental design

Subjects were endowed with 20 points each (1 point = 40 Euro cents), and three subjects assigned different roles formed a group.[3] In stage 1, player A could take $h$ points from player B to receive 5 points, $h \epsilon \{10; 20\}$.[4] In stage 2, player C could punish player A at no cost by subtracting $s$ points, $s \epsilon \{10; 20\}$. Player C had to decide whether to punish or not, having received only a noisy signal about player A's choice. Specifically, player C learned the color of a ball drawn randomly out of either urn BLACK when player A took points from player B or out of urn WHITE otherwise (see Table 1). Player A determined whether or not to take points for urn compositions (1)-(6), and player C chose between no punishment and punishment contingent on the color of the ball for all compositions.[5]

Table 1: BLACK and WHITE urn compositions

| Composition | Urn BLACK | Urn WHITE |
|---|---|---|
| (1) | 10 black & 0 white balls | 0 black & 10 white balls |
| (2) | 9 black & 1 white balls | 1 black & 9 white balls |
| (3) | 8 black & 2 white balls | 2 black & 8 white balls |
| (4) | 7 black & 3 white balls | 3 black & 7 white balls |
| (5) | 6 black& 4 white balls | 4 black & 6 white balls |
| (6) | 5 black & 5 white balls | 5 black & 5 white balls |

In stage 3, subjects stated their (incentivized) beliefs regarding how many players A outside of their group took points and how many players C assigned punishment for all contingencies.

We analyzed data from 51 groups for treatment 20/10 (i.e., when *s=20* and *h=10* applied), 55 for 10/10, 32 for 10/20, and 30 for 20/20.

The experiment was concluded by a questionnaire. Payoffs were assessed for one randomly drawn urn composition in accordance with the players' choices and a ball drawn based on the probabilities for the relevant urn. In addition, subjects received payments for correct beliefs and a risk elicitation procedure (Holt and Laury 2002). On average, participants

[3] Instructions may be found in the Supplementary Material.

[4] We rely on the take game to bring norm violations into the lab (as in, e.g., Schildberg-Hörisch and Strassmair 2012).

[5] Because we are interested in decision-making when there is an informative signal, we did not include urn (6) in our data analysis; however, it was included in the instructions to make them easier to understand.

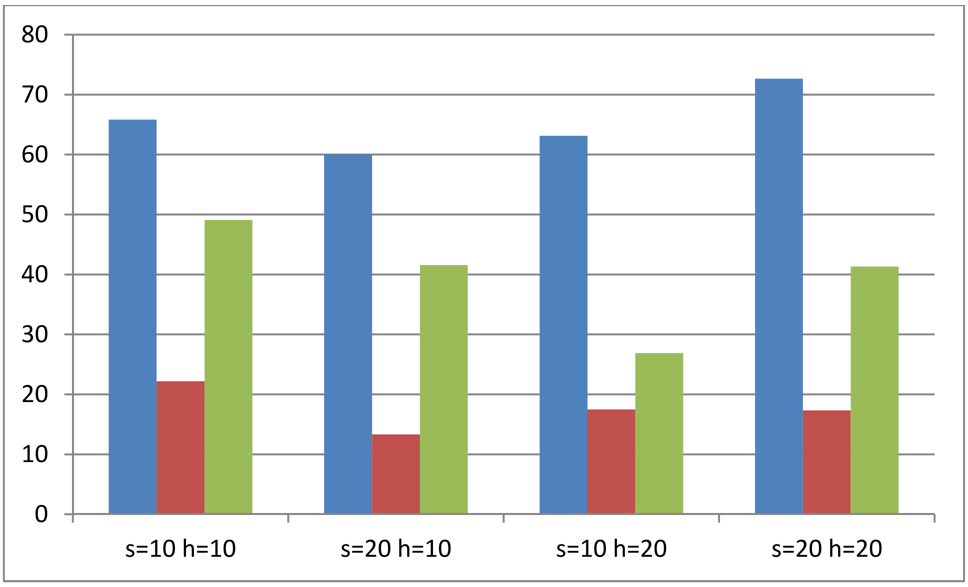
earned €18.05 in the experiment, which lasted an average of 80 minutes. 504 subjects (mean age 24, 56 % female) participated in our experiment at the University of Bonn, which was computerized using zTree (Fischbacher 2007). ORSEE (Greiner 2003) was used for recruitment. Data was collected from June to October 2014.

We now briefly relate our design to that of Feess et al. (2014). A key difference is that Feess et al. consider within-subject variation with regard to the level of the sanction, which may draw subjects' attention to this key variable. Importantly, we elicit beliefs about the *a priori* violation probability and about the expected punishment probability, allowing us to include these variables in our empirical analysis.[6] Finally, we also investigate the effects of different harm levels. We will relate our findings to their results below.

## 3. Results

The share of players C who punished is shown in Figure 1. The share of taking was the highest in treatment 10/10, very similar in 20/10 and 20/20, and the lowest in 10/20.

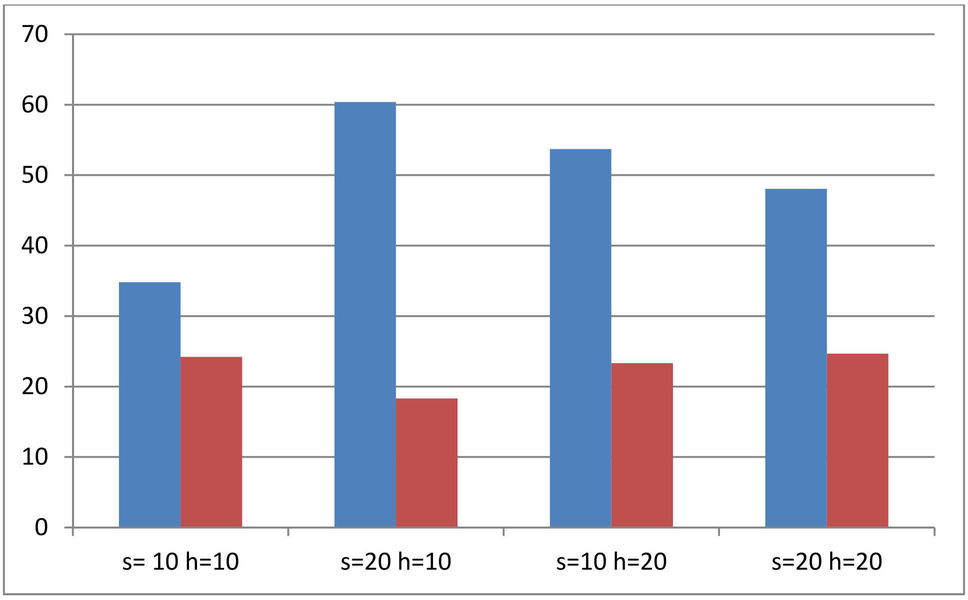
Figure 1: Average share of punishers when the ball was black (blue bar) or white (red bar); average share of takers (green bar)




Punishment and taking decisions together imply a likelihood of legal error, which depends on the treatment (Figure 2).

[6] In addition, the violation considered by Feess et al. consisted of reducing a donation to a charity, and they allowed all subjects to participate as both potential violators and judges.

Figure 2: Probability of legal errors of type II (blue bar) and type I (red bar)




To understand what influences the probability of error, we turn to a regression analysis (Table 2). The probability of an error of type II is higher when the sanction is high for the low-harm baseline. This impact of a higher sanction is no longer found when the level of harm is high. The probability of an error of type I is not significantly affected by the aspects of the case. Intuitively, the probability of error is decreasing in the precision of the signal.

Table 2: Tobit regressions for error probabilities of types I and II

| | Probability Type II Error | Probability Type I Error |
|---|---|---|
| Fine high | 0.564**<br>(2.43) | -0.054<br>(-0.44) |
| Damage high | 0.419<br>(1.40) | 0.005<br>(0.03) |
| Fine high * Damage high | -0.685*<br>(-1.67) | 0.132<br>(0.72) |
| High precision | -0.763***<br>(-6.93) | -0.409***<br>(-6.92) |
| Constant | 0.491***<br>(3.53) | 0.222**<br>(2.23) |
| N | 346 | 494 |
| F-stat. | 16.67 | 12.63 |

Notes: The dependent variable is defined as the probability that taking points will not be punished (error type II) or as the probability that a player A who did not take points will be punished (error type I). Fine high and Damage high are dummy variables. High precision is also a dummy variable that is equal to one when the urn composition is either (1) or (2). t-values in parentheses; standard errors clustered at the group-level; *** 0.01, ** 0.05, * 0.10 significance level.

Next, we explore the standard of proof used by third parties. Table 3 shows that the aspects of the case do not significantly influence player C's probability of punishment. This is aligned with the legal concept of *proof beyond a reasonable doubt*. Importantly, individual punishment decisions clearly exhibit the *in dubio pro reo* principle. A high-precision signal significantly increases (decreases) the likelihood of punishment for a black (white) ball. Intuitively, players C who believe that many players A take points are more likely to punish when they observe a white ball. A measure of player C's moral expectations of others cannot explain punishment decisions. In comparison, Feess et al. consider three sanction levels in their within-subject analysis and find that the punishment probability varies with the sanction level only when the sanction gets very high.

Table 3: Probit estimates of punishment

| | Punish when ball is black | | | Punish when ball is white | | |
|---|---|---|---|---|---|---|
| | All | Only Damage Low | Only Damage High | All | Only Damage Low | Only Damage High |
| Fine high | 0.009<br>(0.16) | -0.058<br>(-0.80) | 0.134<br>(1.60) | -0.039<br>(-0.96) | -0.077<br>(-1.53) | 0.024<br>(0.38) |
| Damage high | 0.054<br>(0.95) | | | -0.003<br>(-0.07) | | |
| High precision | 0.220***<br>(8.24) | 0.206***<br>(6.41) | 0.245***<br>(5.27) | -0.125***<br>(-4.66) | -0.073**<br>(-2.24) | -0.224***<br>(-4.75) |
| Belief steal | 0.005<br>(0.06) | -0.005<br>(-0.05) | 0.053<br>(0.46) | 0.139**<br>(2.35) | 0.173**<br>(2.41) | 0.134<br>(1.50) |
| Risk aversion | -0.013<br>(-0.78) | -0.002<br>(-0.10) | -0.035<br>(-1.34) | -0.004<br>(0.36) | -0.015<br>(-1.22) | 0.049*<br>(1.91) |
| Male | -0.030<br>(-0.52) | 0.008<br>(0.10) | -0.054<br>(-0.67) | -0.052<br>(-1.19) | -0.119**<br>(-2.26) | -0.07<br>(-0.11) |
| Morality | -0.090<br>(-1.34) | -0.110<br>(-1.24) | -0.107<br>(-1.10) | -0.054<br>(-0.99) | -0.120*<br>(-1.74) | 0.030<br>(0.36) |
| N | 840 | 530 | 310 | 840 | 530 | 310 |

Notes: The dependent variable is equal to one when player C chose punishment for the given color of the ball. Fine high, Damage high, and High precision are explained above. Belief steal is the share of players A who take according to the beliefs of player C. Risk aversion is the number of risk-averse choices in the Holt and Laury procedure. The dummy variable Morality reflects the response to the question "I believe that most people would lie if it were beneficial for them." Marginal effects; z-values in parentheses; standard errors clustered at the individual-level; *** 0.01, ** 0.05, * 0.10 significance level.

Another key question is how potential violators behave under evidentiary uncertainty. Table 4 shows that higher evidentiary quality deters taking. Conversely, there is more taking when players A expect to receive punishment even when a white ball is drawn. Interestingly, a higher level of the sanction does not produce additional deterrence. This stands in sharp contrast to experimental findings by Friesen (2012), who used fixed detection probabilities. In Feess et al., taking rates decrease only when the sanction is raised to its highest level. In our setting, when the level of harm is high, increasing the sanction even seems to legitimize taking (i.e., lower deterrence). One interpretation is that in such cases, law enforcement is sufficiently strict to crowd out moral (as in Schildberg-Hörisch and Strassmair 2012). The first column shows that there is less taking when the level of harm is high, and the second column establishes the importance of moral concerns.[7]

Table 4: Probit estimates of taking

| | All | All | Only Damage Low | Only Damage High |
|---|---|---|---|---|
| Fine high | 0.027<br>(0.49) | 0.043<br>(0.78) | -0.042<br>(-0.62) | 0.176**<br>(2.02) |
| Damage high | -0.098*<br>(-1.68) | -0.076<br>(-1.33) | | |
| High precision | -0.109***<br>(-3.16) | -0.105***<br>(-3.14) | -0.086**<br>(-2.07) | -0.118**<br>(-2.02) |
| Belief punish black | -0.197*<br>(-1.92) | -0.202**<br>(-2.05) | -0.319***<br>(-2.77) | -0.052<br>(-0.28) |
| Belief punish white | 0.328***<br>(3.49) | 0.341***<br>(3.73) | 0.378***<br>(3.38) | 0.296**<br>(2.12) |
| Risk aversion | -0.029<br>(-1.51) | -0.031*<br>(-1.68) | -0.023<br>(-0.99) | -0.036<br>(-1.30) |
| Male | 0.006<br>(0.11) | 0.014<br>(0.25) | 0.016<br>(0.23) | 0.025<br>(0.26) |
| Morality | | -0.269***<br>(-3.37) | -0.319***<br>(-3.17) | -0.195*<br>(-1.71) |
| N | 840 | 840 | 530 | 310 |

Notes: The dependent variable is equal to one when player A chose to take points. Fine high, Damage high, High precision, Risk aversion, and Morality are explained above. Belief punish black/white is the share of players C who punish when the ball color is black/white according to the beliefs of player A. Marginal effects; z-values in parentheses; standard errors clustered at the individual-level; *** 0.01, ** 0.05, * 0.10 significance level.

## 4. Discussion

In our experiment, third-party punishers respond strongly to the quality of evidence, confirming *in dubio pro reo*. The standard of proof used by third parties is not significantly related to either the level of the sanction or that of harm, as required by the legal understanding of *proof beyond a reasonable doubt*. Potential violators also strongly respond to the quality of evidence. Moreover, we find that the probability of taking decreases with the expected punishment probability but not with the level of the fine.

[7] Using logit instead of probit does not significantly affect any of the results in Tables 3 and 4.

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# Supplementary Material

**Translated version of the instructions for the treatment harm low and sanction low (h=10 and s=10)**

## *General explanations*

Welcome to this economic experiment.

In the following pages, we explain how you can earn money from your decisions in this experiment. Please read the instructions carefully. If you have any questions, please raise your hand and we will come to your seat.

During the experiment, you are not allowed to talk to the other participants, use cell phones, or start any programs on the computer. Disregarding any of these rules will lead to your exclusion from the experiment and from all payments.

During the experiment, your gains and losses are counted in points instead of in Euros. Your total income will be calculated in points first. At the end of the experiment, your total points will be converted into Euros:

1 point=40 cents.

At the end of the experiment, you will receive the income that results from your decisions in cash.

In the following section, we will describe the exact experimental procedure.

## *The experiment*

**Summary:**

There are three roles in this experiment: A, B, and C. All participants receive the same endowment of points. Participant A decides whether to take points from participant B. Participant B is passive. Participant C can deduct points from player A (points that A would receive for answering a post-experiment questionnaire) without thereby gaining any points and without being able to observe A’s choice. Participants A, B, and C then state their beliefs about the behavior of other groups.

After the experiment, you will be asked to complete a questionnaire. In addition to some questions pertaining to the experiment, you will fill out a scientific questionnaire, for which you will receive an additional 20 points.

**Procedure in detail:**

There are three roles in this experiment: A, B, and C. Your role will be communicated to you via the screen before the experiment starts. You will not learn the identities of the other participants in your group. Likewise, the participants in your group will not learn your identity. Each group has real participants A, B, and C.

The experiment unfolds in four stages. In stage 1, only participant A makes a decision. In stage 2, only participant C makes a decision. In stage 3, all participants (A, B, and C) make decisions. Payoffs are assessed in stage 4.

*Stage 1:*

All participants receive an endowment of 20 points.

Participant A can decide whether or not to deduct 10 points from player B in order to gain 5 points.

Participant A's decision also specifies from which urn a ball will be drawn in stage 4. There are two urns containing 10 balls each. Urn BLACK is relevant if participant A deducts points from participant B. Urn WHITE is relevant if participant A does not deduct points from participant B. The number of black balls is weakly higher in urn BLACK than in urn WHITE. The remaining balls are white. The possible compositions for urns BLACK and WHITE are laid out in Table 1.

| Composition | Urn **BLACK** | Urn **WHITE** |
|---|---|---|
| (1) | 10 black & 0 white balls | 0 black & 10 white balls |
| (2) | 9 black & 1 white balls | 1 black & 9 white balls |
| (3) | 8 black & 2 white balls | 2 black & 8 white balls |
| (4) | 7 black & 3 white balls | 3 black & 7 white balls |
| (5) | 6 black & 4 white balls | 4 black & 6 white balls |
| (6) | 5 black & 5 white balls | 5 black & 5 white balls |

Participant A makes the decision in stage 1 for all possible urn compositions. The payoff-relevant composition will be determined in stage 4 by a random mechanism.

*Stage 2:*

In stage 2, participant C can deduct 10 points from player A's compensation for filling out the questionnaire. Participant C does not gain points thereby, but neither does the deduction cost participant C any points. Participant C can decide on this potential punishment contingent on the color of the ball drawn and the applicable composition of the urns BLACK and WHITE. Participant C does not observe participant A's decision in stage 1.

The color of the ball can inform participant C about whether or not participant A has deducted points from player B:

- When composition (1) applies, there are only black balls in urn BLACK and only white balls in urn WHITE. Knowing that a black ball was drawn means knowing that urn BLACK was relevant. (Urn BLACK is only relevant when participant A deducted points from participant B.) As a result, participant C knows participant A's choice when composition (1) applies.
- When composition (6) applies, urns BLACK and WHITE both contain 5 black balls and 5 white balls. As a result, knowing the color of the ball allows participant C no

inference about whether or not participant A deducted points from participant B in stage 1.

- For compositions (2)-(5), the probability of observing a black ball is higher when participant A deducted points from participant B than when no points were taken. When composition (2) applies, observing a black ball indicates participant A's taking with relatively little uncertainty; however, this uncertainty steadily increases for compositions (3)-(5).

In addition to the color of the ball, the general expectation about participants A deducting points from participants B influences the assessment of whether or not participant A did in fact deduct points from participant B. The following examples are intended to convey the relative importance of these two factors to you.

Table 2: Conditional probabilities when player C has the prior that 20% of all players A deduct points

| | Probability that player A took points from player B if … | | Probability that player A did not take points from player B if … | |
|---|---|---|---|---|
| | a black ball is drawn | a white ball is drawn | a black ball is drawn | a white ball is drawn |
| Urn B: 10 black and 0 white balls<br>Urn W: 0 black and 10 white balls | 100% | 0% | 0% | 100% |
| Urn B: 9 black and 1 white balls<br>Urn W: 1 black and 9 white balls | 69% | 3% | 31% | 97% |
| Urn B: 8 black and 2 white balls<br>Urn W: 2 black and 8 white balls | 50% | 6% | 50% | 94% |
| Urn B: 7 black and 3 white balls<br>Urn W: 3 black and 7 white balls | 37% | 10% | 63% | 90% |
| Urn B: 6 black and 4 white balls<br>Urn W: 4 black and 6 white balls | 27% | 14% | 73% | 86% |
| Urn B: 5 black and 5 white balls<br>Urn W: 5 black and 5 white balls | 20% | 20% | 80% | 80% |

Table 3: Conditional probabilities when player C has the prior that 80% of all players A deduct points

| | Probability that player A took points from player B if … | | Probability that player A did not take points from player B if … | |
|---|---|---|---|---|
| | a black ball is drawn | a white ball is drawn | a black ball is drawn | a white ball is drawn |
| Urn B: 10 black and 0 white balls<br>Urn W: 0 black and 10 white balls | 100% | 0% | 0% | 100% |
| Urn B: 9 black and 1 white balls<br>Urn W: 1 black and 9 white balls | 97% | 31% | 3% | 69% |
| Urn B: 8 black and 2 white balls<br>Urn W: 2 black and 8 white balls | 94% | 50% | 6% | 50% |
| Urn B: 7 black and 3 white balls<br>Urn W: 3 black and 7 white balls | 90% | 63% | 10% | 37% |
| Urn B: 6 black and 4 white balls<br>Urn W: 4 black and 6 white balls | 86% | 73% | 14% | 27% |
| Urn B: 5 black and 5 white balls<br>Urn W: 5 black and 5 white balls | 80% | 80% | 20% | 20% |

Participant C decides for all urn compositions. The composition of the payoff-relevant urn will be determined in stage 4 by a random mechanism.

*Stage 3:*

In stage 3, all participants specify their beliefs about the behavior of other participants. Specifically, participants are asked to specify how many participants A have decided to deduct points from their respective participant B for a given urn composition, and how many participants C punish for a given urn composition and color of the ball. As a result, there are three expectations for each urn composition. One composition will be selected by a random mechanism. You will receive 4 points for each correct expectation.

*Stage 4:*

A random mechanism chooses the urn composition. Participant A's choice for this urn composition becomes payoff-relevant and assigns whether urn BLACK or WHITE applies. Another random mechanism draws a black or a white ball according to the number of balls in the urn. Participant C's choice is implemented accordingly.

After the conclusion of the first experiment, a second experiment starts. This experiment is not related to the first one and will be explained to you on the screen. In this second experiment, your decision will be relevant to your payoff only. At the end of today's session, you will fill out a questionnaire for which you will receive 20 additional points. You will receive your payoffs after you have completed the questionnaire.

At the end of the experiment, all participants will receive their income **in cash**. Please raise your hand if you have any questions. One of the experimenters will come to you to answer them.

Below, you will find some test questions. Please raise your hand when you have answered all the questions. The experiment will start when all participants have answered all the questions.

**Test questions**

How many additional points does participant A obtain by deducting 10 points from participant B?

____________

How many additional points does participant C obtain by deducting 10 points from participant A?

____________

Is the color of the ball more informative for participant C with regard to the behavior of participant A when composition (2) applies (where urn BLACK has 9 black balls and 1 white one, and urn WHITE has 1 black ball and 9 white ones) than when composition (3) applies (where urn BLACK has 8 black balls and 2 white ones, and urn WHITE has 2 black balls and 8 white ones)?

Yes: _____________ No: ____________

When urn BLACK contains 5 black and 5 white balls and urn WHITE contains 5 black and 5 white balls, is the color of the ball informative for participant C?

Yes: _____________ No: ____________

When urn BLACK contains 10 black and 0 white balls and urn WHITE contains 0 black and 10 white balls, is the color of the ball informative for participant C?

Yes: _____________ No: ____________

What is the conditional probability that participant A has deducted points from participant B when the ball is black and composition (2) applies (i.e., urn BLACK contains 9 black balls and 1 white ball, and urn WHITE contains 1 black ball and 9 white balls), when participant C's prior is that …

20% of all participants A deduct points from participant B: _________________

80% of all participants A deduct points from participant B: _________________

What is the conditional probability that participant A has *not* deducted points from participant B when the ball is black and composition (4) applies (i.e., urn BLACK contains 7 black balls and 3 white balls, and urn WHITE contains 3 black balls and 7 white balls), when participant C's prior is that …

20% of all participants A deduct points from participant B: _________________

80% of all participants A deduct points from participant B: _________________

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