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Abstract

We investigate whether violations of canonical axioms of choice under risk are mistakes or a manifestation of true preferences. First, we elicit axiom and gamble preferences and then allow subjects to revise their potentially conflicting preferences. Among the behavioral patterns that allow for a clear-cut interpretation on the decision level, we find that roughly 70% of axiom violations are intentional whereas only 30% are mistakes. On the subject level we can clearly categorize almost half of our subjects. Among those, roughly 24%are rational expected utility maximizers, 24% make occasional mistakes, and 52% refute the normative value of these axioms.

JEL-Codes: C910, D010, D810, D910.

Keywords: axiomatic rationality, choice under risk, context-dependent preferences, mistakes, regret theory.

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1. Introduction

> *"[...] people are generally quite rational; that is to say, they usually have reasons for what they do."*
>
> —Herbert A. Simon (1985)

Economic analysis is based on the idea of axiomatic rationality, i.e., a decision is considered rational if it obeys certain axioms. For decisions under risk most economists arguably believe that a rational decision should satisfy canonical axioms such as transitivity or first-order stochastic dominance. Not surprisingly, most theories of choice under risk that lay claim to a normative appeal satisfy these axioms, e.g., expected utility theory (von Neumann and Morgenstern, 1947) or cumulative prospect theory (Tversky and Kahneman, 1992). From this axiomatic point of view, ample empirical evidence that documents actually observed behavior to often violate these "rationality" axioms seems to call for and justify paternalistic interventions that steer choices towards "more rational" decisions. This, however, raises the question whether decision makers who violate canonical axioms agree with economists regarding the normative value of these axioms or not. In other words, do these decision makers prefer to delegate choices to someone who makes rational decisions on their behalf?

Building on and expanding the experimental design recently proposed by Nielsen and Rehbeck (2022) (henceforth NR), we address this research question in an environment where systematic violations of the aforementioned axioms have been documented. Specifically, the axioms in question are not building blocks of context-dependent theories for choices under risk, such as regret theory (Loomes and Sugden, 1982, 1987a) or salience theory (Bordalo et al., 2012), which capture axiom violations as juxtaposition effects. That is, these theories allow for systematic violations of the axioms by positing that decision makers react to within-state comparisons of outcomes across lotteries which makes choice behavior correlation sensitive. Existing empirical evidence shows that juxtaposition-driven context effects are particularly powerful in explaining choice behavior when the correlation structure is transparent as well as salient (Starmer and Sugden, 1998). Therefore we opted for display formats under which context effects (such as regret) should have a high chance of playing a decisive role not only in shaping lottery choices but also with regard to axiom preferences.

Notably, in the spirit of the above quote by Herbert A. Simon (1985), regret theory regards such axiom violations not as a mistake, but as a genuine and rational manifestation of the decision maker's preferences.[1] For our analysis to capture this aspect in an adequate

[1] The view that the preference for avoiding post-decisional regret is rational was already advocated by Loomes and Sugden (1982). While supported by the neurodata reported in Bourgeois-Gironde (2010),

way, we follow an empirical strategy that puts equal focus on the question when choices that violate canonical axioms *are* mistakes as well as on the question when choices that violate canonical axioms *are no* mistakes but intentional. We build on the three-stage experimental design in NR, which comprises elicitation of axiom preferences (Stage 1), lottery choices (Stage 2) and revision of axiom preferences and lottery choices (Stage 3). Within this framework, we classify those lottery choices in Stage 2 that violate a given axiom as *mistake* if, in Stage 3, the respective subject changed her lottery choice to be consistent with that axiom and she additionally stated a preference in favor of the axiom. On the other hand, we classify those lottery choices in Stage 2 that violate a given axiom as *intentional* if, in Stage 3, the respective subject continues to violate that axiom and additionally did not express a preference for that axiom. In other words, these subjects repeatedly and knowingly violated the axiom in question. Notably, the elicitation of axiom preferences in Stage 1 in our experiment is to be understood primarily as an opportunity to familiarize subjects with the axioms on neutral grounds upfront. The classification of behavioral patterns in NR restricts attention to only those subjects that endorsed a given axiom in Stage 1 and then violated the axiom in Stage 2. Thus, NR investigate whether the axiom choice in Stage 1 or the lottery choice in Stage 2 constitutes a mistake, whereas our complementary approach aims at capturing to a fuller extent whether axiom-violating lottery choices are intentional or not.

Thus, guided by a distinct research question, we complement and expand on the study in NR by implementing a variation in the display format as well as a different empirical approach, thereby providing further and more nuanced insight into the question where and when violations of canonical axioms are mistakes or intentional. We used two different display formats with transparent correlation structures for the pairwise lottery choices in question, a matrix display and a purely verbal display. In contrast to what is suggested by earlier experimental studies (Battalio et al., 1990; Harless, 1992), we do not observe significant differences in behavior under these two display formats, neither regarding axiom violation rates in Stage 2 nor regarding axiom endorsement rates in Stage 3. Pooling the data from these two treatments, we find that, on the decision level (i.e., with regard to one of the considered axioms in isolation), on average 60% of our subjects do not violate the axiom in Stage 2 and thus ultimately display behavior compatible with standard expected utility theory. A sizeable 25% of our subjects, however, exhibit behavior that allows for a clear-cut interpretation as either an intentional axiom violation or an axiom violation by mistake, with almost 70% of the behavioral patterns reflecting intentional violations and only 30% representing mistakes. While this data on the decision level is already

this view is not uncontroversial. For opposing arguments, see the discussion in Bleichrodt and Wakker (2015).

indicative for the normative appeal of canonical choice axioms being questionable, this impression is only strengthened by our findings on the subject level. When aggregating each subject's decision across axioms, we can rather unambiguously categorize roughly 50% of our subjects. Of these, only 24% never violate any of the axioms in Stage 2 and thus can be regarded as behaving in accordance with expected utility theory. The axiom violations of another 24% of these subjects, who ultimately endorse the axioms in question as universally valid guiding principles, turn out to be unintentional mistakes. A sizeable 52% of these subjects, however, ultimately violate at least one of the axioms intentionally, thereby clearly refuting the axiom's normative appeal. Notably, as a detailed comparison to the study by NR shows, our findings are not merely driven by a different empirical approach, but also prevail if the empirical strategy from NR is applied to our data.

The rest of the paper is structured as follows: After the related literature is reviewed at the end of Section 1, Section 2 introduces the theoretical framework, followed by the experimental design in Section 3. After outlining our empirical strategy to differentiate mistakes from intentional axiom violations in Section 4, we present the results of our experiment in Section 5. Section 6 provides an in-depth comparison of our experimental design and our findings with the design and the results obtained by NR. Section 7 concludes.

Related Literature. Our paper adds to the literature that investigates the normative content of (subjective) expected utility theory and its underlying axioms. Specifically, it contributes to the literature that assesses to which extent the explicit presentation of axioms and subsequent deliberation of earlier choices makes respondents revise their choices to be aligned with these axioms.[2] This approach was pioneered by MacCrimmon (1968), who held a free-form discussion of several decision-theoretic postulates with his participants. Subsequent contributions (Slovic and Tversky, 1974; MacCrimmon and Larsson, 1979; Moskowitz, 1974; Eli, 2017), which focused on the independence axiom and the sure-thing principle, provided more structured arguments both in favor and against the axioms' normative appeal. By and large, these contributions often observe that respondents rate situation-specific arguments favoring an intuitively appealing axiom violation

[2] There is a different complementary experimental approach under which deliberation of earlier choices is analyzed without axioms being presented explicitly to respondents. In the spirit of this alternative approach, several studies allow respondents to revisit earlier lottery choices by either presenting the same choice problems over several rounds (van de Kuilen, 2009; van de Kuilen and Wacker, 2006; Nicholls et al., 2015; Birnbaum and Schmidt, 2015) or by allowing respondents to revise their initial lottery choices (Breig and Feldman, 2021; Yu et al., 2021; Crosetto and Gaudeul, 2023). By and large, these contributions find that revisiting earlier choices leads to higher alignment with expected utility. Other studies present one and the same choice problem in different frames (Miller and Fagley, 1991; Sieck and Yates, 1997; McNeil et al., 1988; Druckman, 2001). Recently, without any mentioning of the independence axiom itself, Benjamin et al. (2021) analyze the normative appeal of the independence axiom's implications for choices between either simple lotteries or compound lotteries. They find that respondents, when being confronted with both frames simultaneously after having made choices under separate frames before, on average revise choices to align with the axiom's implications.

as more persuasive. Specifically, in a properly incentivized replication with significantly larger sample size, Humphrey and Kruse (2023) show robustness of the finding in Slovic and Tversky (1974) that there is a systematic violation of the sure-thing principle in post-argument choices that was not present in pre-argument choices. Also in the spirit of this second approach, NR introduced a novel experimental design which, instead of presenting situation-specific arguments in favor or against a given axiom, elicited preferences over axioms as universally valid guiding principles directly in an incentive-compatible manner. Under this design, when confronted with inconsistencies between their initial endorsement of an axiom and their subsequent lottery choices, almost three times as many of the respondents revise their lottery choices to align with the axiom in question rather than unselecting the axiom and sticking to their lottery choices – a finding that NR regard as suggestive confirmation of the axioms' normative content. Benjamin et al. (2021), however, believe the findings in NR to possibly overstate the axioms' normativity, because the plausibility of an axiom, when presented as a decision rule, may have served as an implicit argument in favor of the axiom, whereas there was no argument (neither implicit nor explicit) against the axiom.

Our paper builds on and expands the experimental paradigm introduced by NR. With numerous deliberate differences in comparison to the experimental design in NR, which we lay out in more detail in Section 6, our study is not a mere replication, but rather answers to the call in NR (p.2239) "to show where and when these [axiom] violations are mistakes". Specifically, in contrast to NR, our experiment involves both placebo revisions and badge revisions, i.e., respondents revise all their decisions (rather than only those in which axiom preferences and lottery choices are inconsistent) and all lottery choices concerning the same axiom are revised simultaneously (rather then independently of each other in subsequent revisions). Thus, our experiment can be seen to address the concern voiced by Benjamin et al. (2021) at least to some extent as now also an individual's own behavior across choices may serve as an implicit argument against the axiom in question.

2. Theoretical Framework

In our experiment, we consider four canonical axioms:

First-order Stochastic Dominance (FOSD): If under one lottery the probability to obtain at least a particular monetary amount is weakly higher for all amounts and strictly higher for at least one amount than under the alternative lottery, then the decision maker must prefer the former lottery over the latter.

Transitivity (TRANS): If a first lottery is preferred over a second and the second lottery is preferred over a third, then the first lottery must also be preferred over the third.

Consistency (CONS): If a first and a second lottery both represent one and the same probability distribution over the set of feasible payoffs (i.e., if the two lotteries are stochastically equivalent) and the first lottery is preferred over a third lottery, then the second lottery must also be preferred over the third lottery.

Branch Independence (BRANCH): If a first and a second lottery yield a given payoff x with equal probability and the first lottery is preferred over the second lottery, then the preference must not change if the payoff x is interchanged with some other payoff y.

We focus on these axioms for three reasons. First, these axioms have a strong normative appeal, i.e., they should be satisfied by "rational" decisions.[3] Second, context-dependent preferences like regret theory (Loomes and Sugden, 1982) predict systematic violations of these four axioms.[4] Third, provoking violations of these axioms allows us to focus on simple binary decisions.

As an example for how context-dependent preferences like regret theory can lead to a violation of these axioms, consider the choice between the two lotteries L_1 and L_2 depicted in Table 1, which is based on Loomes et al. (1992).[5] With the probability of obtaining at least a given payoff being at least as high under L_1 as under L_2 for all payoffs, L_1 dominates L_2 in the sense of FOSD. From the perspective of regret theory, however, also the within-state comparison of payoffs across choice options matters. The choice of L_1 exposes the decision maker to the risk of experiencing severe post-decisional regret if state 4 turns out to be the true state of the world – in which case the decision maker obtains €0 but would have gotten €30 if she had chosen the dominated lottery L_2. Thus, a regret-averse decision maker, who factors the anticipation of ex post regret into her ex ante decision, may well end up choosing the dominated lottery L_2.[6]

	$s = 1$	$s = 2$	$s = 3$	$s = 4$
L_1	€0	€30	€9	€0
L_2	€9	€9	€0	€30
Prob.	18%	20%	42%	20%

Table 1: Lotteries L_1 and L_2 depicted in the action-state matrix.

[3] Arguably, most economists agree that any rational theory of decisions under risk should satisfy FOSD, TRANS and CONS. The normative value of BRANCH might be slightly more controversial.

[4] While our leading example will be regret theory (Loomes and Sugden, 1982, 1987a), all explanations could be phrased equally plausible in terms of salience theory (Bordalo et al., 2012). For details see Herweg and Müller (2021) and Lanzani (2022).

[5] The choice problem depicted in Table 1 is an example from our actual study. The difference to Loomes et al. (1992) is that we triple all payoffs and choose the currency to be €. For a complete overview of the choice problems in our study see Appendix B.3.

[6] In fact, Loomes et al. (1992) find that 42% of their 90 subjects choose the dominated lottery L_2 in the choice problem in Table 1 (with one-third of the payoffs in £).

Precise formal definitions of all four relevant axioms as well as specific examples for how regret theory can accommodate also violations of TRANS, CONS and BRANCH are provided in Appendix A.

3. Experimental Design

To identify whether axiom violations are intentional or not, we build upon the three-stage experimental design proposed by NR: first, elicitation of preferences over canonical axioms; second, lottery choices; third, providing the opportunity to revise axiom preferences and lottery choices.[7] Next, we describe the specifics of the experiment's three stages in more detail and also outline the general procedures (including the incentivization of the decisions in each of the three stages).[8]

3.1. Stage 1: Axiom Preferences

To elicit whether a subject considered a given axiom as a desirable guiding principle, the subject was asked whether she wants the axiom – which was labeled as *choice assistant* – to make choices on her behalf or to make the respective choices herself. Overall, subjects had to make this decision for each of the four axioms that were introduced in Section 2: FOSD, TRANS, CONS and BRANCH. If a subject opted for an axiom to make choices on her behalf and if this decision later became payoff relevant, then the axiom would be applied to a choice situation (the specifics of which were not known to the subject at the point of this decision) and the subject would receive the outcome of that choice 'made by' the axiom.

With axioms being a highly abstract concept, we tried to make them as tangible as possible. Specifically, we used a pictorial logic statement to explain each axiom, with colored circles representing otherwise unspecified lotteries. Whenever specific additional assumptions on the properties of the involved lotteries were imposed, these were clearly spelled out to our subjects. Furthermore, we complemented each such pictorial logic statement with a verbal explanation of the workings of the respective axiom as well as an easy-to-understand example that related directly to the pictorial presentation.

For example, consider the TRANS axiom as depicted in Figure 1. Here, it was explained to subjects that if they 1) prefer a lottery represented by a blue circle over a lottery represented by an orange circle and 2) prefer a lottery represented by an orange circle over a lottery represented by a green circle, then if they should select the axiom to make

[7] In our analysis, we take as given the insight of NR that axiom selection is not driven by experimenter demand effects, avoidance of responsibility or algorithm aversion but reflects a manifestation of genuine preferences over axioms.

[8] To avoid any order effects, decisions in each stage were randomized on the subject level.

choices on her behalf, the axiom would choose the lottery represented by the blue circle instead of the lottery represented by the green circle.

The working of the remaining three axioms was explained in an analogous fashion. The full description of all axioms can be found in Appendix B.2.

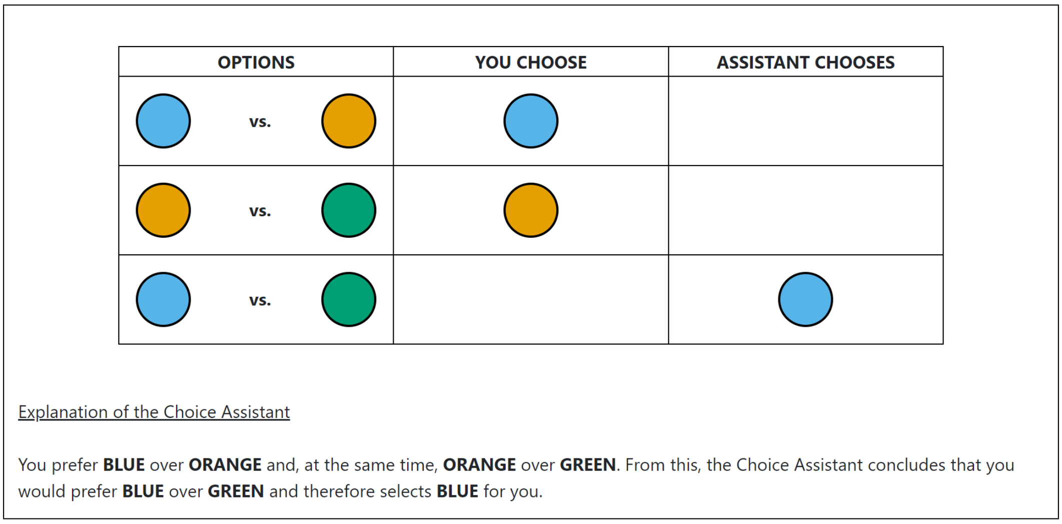

Figure 1: Depiction of transitivity (TRANS).

3.2. Stage 2: Lottery Choices

Each subject made 20 subsequent pairwise lottery choices. Specifically, subjects were informed that they would have to make all these choices on their own even if they had selected one or more of the axioms in Stage 1. In our experiment, a lottery assigned a monetary amount between €0 and €60 to each integer number from 1 to 100. At the end of the experiment, if a given lottery was selected as payoff relevant, the computer would randomly generate an integer number between 1 and 100 and the lottery's actual payoff corresponded to the monetary amount that the lottery assigned to this randomly generated number.

The 20 pairwise lottery choices that subjects had to make in Stage 2 are depicted in Appendix B.3, from which it can be seen that Problems 1 to 16 allowed for each axiom to be violated in exactly two instances and that each of these sixteen pairwise choice problems was associated with exactly one axiom. To construct these sixteen choice problems, we relied on guidance obtained from previous experimental studies as far as possible.[9] Problems 17 to 20 did not allow for any axiom to be violated. These choices

[9]Problems 1 and 2, which allow for a violation of FOSD, are based on Questions 3 and 5 in Loomes et al. (1992). The pair of Problems 3 and 4 as well as the pair of Problems 5 and 6 allow for a violation of CONS and are inspired by Questions 8 and 8D and Questions 2 and 2D in Starmer and Sugden (1993), respectively. The triple of Problems 7, 8 and 9 as well as the triple of Problems 10, 11 and 12, which both allow for a violation of TRANS, are based on Triples 8 and 3 in Loomes et al. (1991),

were used as preference input for axiom application in case that a subject's axiom choice from Stage 1 turned out to be payoff relevant.[10]

As was already explained in Section 1, we wanted to allow for context effects such as regret to shape decisions. With such effects (at least according to theory) being driven by state-wise comparison of outcomes across lotteries, we opted for two widely used display formats under which the correlation of outcomes is fully specified and transparently displayed.

Treatment M (Matrix Display): In Treatment M we presented the 20 pairwise choice problems in a matrix display, as depicted in Figure 2.[11] Here, the two feasible lotteries correspond to the two rows labeled with A and B, respectively, and the numbers within these rows' cells denote amounts of money in Euro. For each of a lottery's potential monetary outcome, the numbers along the top of the matrix indicate the range of numbers for which the respective monetary amount would be paid out. The numbers along the bottom of the matrix show the probability with which the randomly generated number falls into the corresponding range indicated at the top of the matrix. The width of each column is proportional to the respective probability.

	1 18	19 38	39 80	81 100
A	**€9**	**€9**	**€0**	**€30**
B	**€0**	**€30**	**€9**	**€0**
	18%	20%	42%	20%

Figure 2: Matrix display (Treatment M).

Treatment V (Verbal Display): In Treatment V we employed a verbal display format, as depicted in Figure 3.[12] For a given lottery, here denoted as either "Option A" or "Option B", the left entries specify the monetary amounts that are potentially paid out, the entries in the middle denote the ranges of numbers for which the respective monetary amount is paid out, and the right entries list the probabilities of the corresponding events.

Notably, for each pairwise choice problem, both the matrix display and the verbal display fully specify the correlation of the monetary outcomes of the two feasible lotteries.

respectively. The pair of Problems 13 and 14 as well as the pair of Problems 15 and 16 allow for a violation of BRANCH and are partly based on Starmer (1992).

[10] While Problems 17 and 18 were used as input for TRANS, Problem 19 and Problem 20 were fed into CONS and BRANCH, respectively.

[11] This display format was used, for example, by Loomes (1988a,b, 1989), Loomes and Sugden (1987b), Loomes et al. (1989, 1991, 1992), Starmer (1992), Starmer and Sugden (1989, 1993, 1998), and Castillo (2020).

[12] This display format was used, for example, by Battalio et al. (1990) and Harless (1992).

OPTION A

€9	if	1-18	(18%)
€9	if	19-38	(20%)
€0	if	39-80	(42%)
€30	if	81-100	(20%)

OPTION B

€0	if	1-18	(18%)
€30	if	19-38	(20%)
€9	if	39-80	(42%)
€0	if	81-100	(20%)

Figure 3: Verbal display (Treatment V).

Under the display format used by NR, in contrast, there is no mentioning of how the payoffs of the two lotteries are correlated; each lottery's payoffs are listed from top to bottom in increasing order together with the associated occurrence probabilities. With the display formats in our Treatments M and V being strictly different from the display format used by NR with regard to informational content concerning the correlation structure, any comparison of our and their results would be ambiguous at best. Therefore, we also conducted a third "quasi-replication" treatment with the exact same display format as in NR.[13]

Treatment R (Replication): As depicted in Figure 4, in Treatment R, for each lottery the left entries list the monetary amounts (in increasing order) that are potentially paid out and the right entries correspond to the occurrence probabilities associated with these outcomes.[14]

OPTION A

€0	with	42%
€9	with	38%
€30	with	20%

OPTION B

€0	with	38%
€9	with	42%
€30	with	20%

Figure 4: Verbal display without correlation structure (Treatment R).

3.3. Stage 3: Revision Behavior

After stating their axiom preferences in Stage 1 and making their lottery choices in Stage 2, subjects had the opportunity to revise any of their previously made decisions. These

[13]Treatment R is not a replication in a strict sense because we implemented further design changes in comparison to NR. An in-depth discussion of these design details as well as a comparison of results is provided in Section 6.

[14]The display format in Treatment R does not make the assignment of monetary outcomes to the integer numbers from 1 to 100 transparent for the subjects at the moment of the decision in Stage 2. If, however, a lottery choice became payoff relevant at the end of the experiment, any uncertainty involved was resolved in the exact same way as in Treatment M and Treatment V.

revision opportunities were grouped according to the four axioms. First, for a given axiom, a subject was shown whether she had endorsed this axiom to make choices on her behalf. Thereafter, the subject was shown all her lottery choices from Stage 2 that had the potential to violate the axiom in question.[15] Finally, the subject could freely decide whether to change her axiom preference, to change any number of the lottery choices that related to the axiom in question, to change both axiom preference and lottery choices, or leave each of these decisions unchanged. Importantly, with each of the 16 core lottery choice problems from Stage 2 having been associated with exactly one axiom from Stage 1, every axiom choice from Stage 1 and each of these core lottery choices from Stage 2 could be revised exactly once.

Each axiom from Stage 1 could be violated in exactly two instances in Stage 2. In consequence, in Stage 3, subjects had to make their revision decisions with regard to a given axiom after having been informed that either they had adhered to the axiom on all occasions or that they had violated the axiom on all occasions or that they had adhered to the axiom on one occasion and violated the axiom on the other occasion. The associated revision process comprised a series of information screens followed by a decision screen. On the first information screen, an example of which is shown in Figure 5, a subject was informed about her axiom decision in Stage 1, where the pictorial logic statement of the axiom in question was presented once again, and she was shown her decisions for the first constellation of lotteries from Stage 2 that potentially allowed for a violation of that axiom. Notably, lottery decisions were presented in the exact same display format as in Stage 2. On the next information screen the subject was shown the second constellation of lotteries from Stage 2 that potentially allowed for a violation of the axiom. The last information screen contained the subject's axiom decision as well as her decisions in both constellations of lotteries. While the subject's previous decisions from Stages 1 and 2 were "locked-in" throughout all these information screens, they could be freely changed in the final decision screen, which the subject could only access by actively clicking on the "Make Changes" button positioned in the lower part of the last information screen.

As can be seen from Figure 5, two further features were implemented to make the revision process as transparent as possible. First, to highlight how a subject's lottery choices in Stage 2 relate to her axiom preferences in Stage 1, the pairwise choice problems in each constellation of lotteries that allowed for a violation of a given axiom were matched to the colored circles of the pictorial logic statement used to describe that axiom. Furthermore, for each such constellation of lotteries, a short written explanation in neutral language

[15]In reference to Appendix B.3, a subject was shown her decisions in Problems 1 and 2 with regard to FOSD, in the pair of Problems 3 and 4 as well as in the pair of Problems 5 and 6 with regard to CONS, in the triple of Problems 7, 8 and 9 as well as in the triple of Problems 10, 11 and 12 with regard to TRANS, and in the pair of Problems 13 and 14 as well as in the pair of Problems 15 and 16 with regard to BRANCH.

reminded the subject of what option she had chosen and which option the axiom would have prescribed to be chosen.

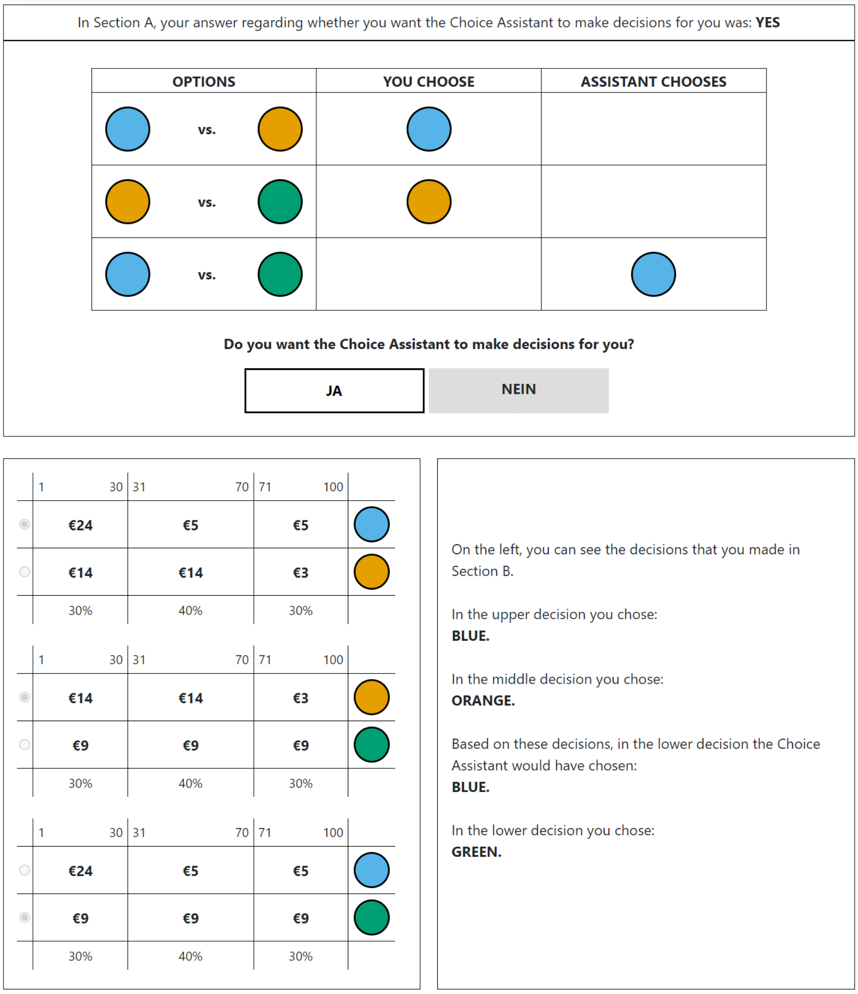

Figure 5: Information page about decisions made in Stage 1 and 2.

3.4. Procedures

At the beginning of the experiment the subjects were informed that the main part of the experiment consisted of three stages and that they had to make a series of decisions in each of these stages. The instructions proceeded with an illustration of what a lottery is. In the two main treatments, Treatment M and Treatment V, the concept of a lottery was explained as a dice roll with each number between 1 and 100 being equally likely to come up and with a monetary amount between €0 and €60 being assigned to each number. In the replication treatment, Treatment R, the concept of a lottery was explained as a random draw from an urn that contains 100 balls with each ball being equally likely to be drawn and a monetary amount between €0 and €60 being printed on each ball. The complete instructions can be found in Appendix B.1.

Furthermore, subjects were informed about the incentivization procedure which strictly followed NR and is described in detail in Appendix B.4. Exactly one decision from any of the stages described above became payoff-relevant, i.e. a subject could be paid for one of her original axiom choices from Stage 1, one of her original lottery choices from Stage 2, or one of her (potentially revised) decisions from Stage 3. Which decision became payoff-relevant was determined by a random draw of the computer at the end of the experiment. The probability of being payoff-relevant was identical for each and every decision made.

The experiment was conducted at the BonnEconLab of the University of Bonn, Germany, in November 2022. It was computerized using the software o-Tree (Chen et al., 2016). Subjects sat in visually isolated cubicles. Before each stage in the main experiment, subjects had to answer check questions to ensure their understanding. From a database of more than 5,000 people, we recruited 349 subjects using hroot (Bock et al., 2014). Each subject participated only in one treatment (between-subject design), 122 in Treatment M, 115 in Treatment V and 112 in Treatment R. Subjects were mainly undergraduate students from a variety of disciplines. On average a session took 90 minutes and subjects were paid €25.95, including a show-up fee of €5. After the main experiment, we elicited subject's risk attitudes, regret aversion and cognitive reflection ability.[16] Additionally, we had a questionnaire asking for each subject's sociodemographics (gender, age, field of study, aspired university degree and final math grade in high school) as well as the strategy pursued when making their decisions in each of the three stages of the main experiment.

4. Empirical Strategy

Our empirical analysis aims to capture the full extent not only of axiom violations by mistake, but also of intentional axiom violations. We divide the observed behavioral patterns from Stages 2 and 3 into different categories, which we then use to classify our subjects. As explained earlier, observing that a decision maker's lottery choices violate canonical axioms and that she does not revise the lottery choices to be consistent with the axiom is indicative of an intentional violation not only in the case where the axiom was selected beforehand, but also if the axiom was not selected beforehand. Thus, we do not base our categorization of intentional or non-intentional axiom violations on whether subjects did or did not endorse an axiom in Stage 1. This is not to say that we consider the first stage of the design in NR as irrelevant per se. To the contrary, we believe that having subjects assess an axiom's appeal as a desirable guiding principle before contrasting it with their own specific lottery choices should allow for a more neutral evaluation of the

[16] See Appendix B.5 for more details on the post-experimental tests.

Category	*S2: Violation*	*S3: Axiom Preference*	*S3: Violation*	*Label*
[**1**]	No	Yes/No	No	**EUT**
[**2**]	Yes	Yes	No	**Mistake**
[**3**]	Yes	No	Yes	**Intention**
[**4**]	Yes	No	No	
[**5**]	No	No	Yes	**Other**
[**6**]	Yes/No	Yes	Yes	

Table 2: Categorization of behavioral patterns on the decision level.

axiom.

Next, we first outline the categorization of behavioral patterns. Thereafter, we explain how we use the variation in the display format embodied in our two main treatments to assess the robustness of our results.

4.1. Disentangling Mistakes from Intention

We begin by defining categories of behavioral patterns on the decision level, i.e., with regard to each axiom in isolation, upon which we then base our categorization of behavioral patterns on the subject level, i.e., across axioms.

Categorization on the Decision Level. To categorize a subject's behavior with regard to a particular axiom, we ask three questions: First, did at least one of the subject's lottery choices in Stage 2 violate the axiom? Second, did the subject express a preference for the axiom in Stage 3? Third, did at least one of the subject's (potentially revised) lottery choices in Stage 3 violate the axiom? Based on the answers to these questions, a subject's behavior in Stages 2 and 3 with regard to a particular axiom can take one of eight possible behavioral patterns, which we group into the six categories displayed in Table 2.

In category [1], a subject's lottery choices never violate the axiom in question, neither in Stage 2 nor in Stage 3. With this behavioral pattern being compatible with expected utility theory (von Neumann and Morgenstern, 1947), we take a conservative stand here and label category [1] as "EUT". Moreover, we stack the deck in favor of this "EUT" category as we do not require the axiom in question to be explicitly endorsed in Stage 3.

In category [2], a subject violates the axiom in question in Stage 2 but then, in Stage 3, endorses this axiom as a desirable guiding principle and revises her lottery choices to be consistent with the axiom. This behavioral pattern, where a subject corrects her initially conflicting lottery choices to be consistent with an axiom that she ultimately deems worthwhile following, reflects an unintentional violation of the axiom and is labeled as “Mistake”.

In category [3], a subject violates the axiom in question in Stage 2 and then, in Stage 3, renounces this axiom as a desirable guiding principle and keeps violating the axiom with her lottery choices. We classify this behavioral pattern, where a subject ultimately rejects and knowingly violates the axiom in question, as an intentional violation and label it as “Intention”.[17]

The remaining behavioral patterns do not allow for such a straightforward interpretation. In category [4], a subject revises her initially conflicting lottery choices to align with the axiom in the end, which could be interpreted as the initial axiom violation having been a mistake. In contrast to category [2], however, in category [4] there is no ultimate endorsement of the axiom as desirable guiding principle, which makes category [4] less indicative of a mistake than category [2]. In category [5] a subject's behavior in Stage 3 coincides with the behavior in category [3]: ultimately the axiom in question is violated and not endorsed. This behavior in Stage 3 suggests that the final violation of the axiom is intentional. This intentional violation is less clear though than for category [3], where, in contrast to category [5], a subject violated the axiom already at Stage 2. Finally, in category [6], a subject's behavior is inherently inconsistent because ultimately, in Stage 3, the subject states a strict preference for adhering to the axiom in question but locks in (possibly revised) lottery choices that violate the axiom.

To provide an as clear-cut interpretation as possible of whether lottery choices that violate a given axiom are intentional or not, in the following, we pool categories [4], [5] and [6] under the label “Other”.

Categorization on the Subject Level. To categorize behavior on the subject level, we individually “aggregate” each subject's behavior on the decision level. The resulting subject-level categories are summarized in Table 3, the left column of which shows the decision-level categories into which a subject's behavioral patterns with regard to the four axioms fall.

Following our conservative approach from the decision-level categorization, we categorize subjects who never violate any axiom – i.e., whose behavior on the decision level falls into category [1] for all axioms – under the label “S-EUT”, where S refers to the subject level.

To reduce the scope for any ambiguity in the interpretation of our results as far as possible, we extend the decision-level categories labeled “Mistake” and “Intention” to the subject level in the strictest possible sense. Requiring that a subject's decision-level

[17] Notably, those subjects in category [3] who reject the axiom in Stage 1 and then stick to this decision in Stage 3 are excluded from the analysis in NR.

Decision-level behavioral patterns	*Label*
Category [1] only	**S-EUT**
Category [2] (at least once) or category [1]	**S-Mistake**
Category [3] (at least once) or category [1]	**S-Intention**
Any other combination	**S-Other**

Table 3: Categorization of behavioral patterns on the subject level.

behavior for each axiom falls exclusively into either category [2] or category [3], however, seems too hard a requirement, because even context-dependent theories such as regret theory do not predict axioms to be violated in each and every circumstance (but rather allow for axioms to be violated occasionally). Therefore, to establish the subject-level category "S-Mistake", we require a subject to violate *at least one* of the four axioms in Stage 2 and then, in Stage 3, to address *any* axiom violation in the spirit of decision-level category [2] while any non-violated axiom remains non-violated. Likewise, to fall into the subject-level category "S-Intention", a subject has to violate at least one axiom in Stage 2 and then, in Stage 3, has to address any axiom violation according to decision-level category [3] while leaving any non-violated axiom non-violated.[18]

Any other combination of decision-level behavioral patterns bears a less clear-cut interpretation and therefore is subsumed under the category "S-Other". In particular, this includes profiles where the decision-level behavioral pattern for at least one axiom falls into the categories [4], [5] or [6] as well as profiles under which one axiom violation is addressed according to category [2] and another axiom violation is addressed according to category [3].

4.2. Variation of the Display Format

According to most axiomatic theories of choice the framing of a choice problem has no impact on behavior. Thus, common economic theories of choice under risk predict no systematic difference in behavior between Treatments M and V. It could be argued, however, that the correlation structure between the two lotteries' monetary outcomes is more transparent under the matrix display than under the verbal display as the former facilitates within-state payoff comparisons across lotteries. Thus, it might be the case that the difference in transparency with regard to the correlation structure induces a systematic difference in the behavior in our two main treatments that is not even captured by

[18]Thus, while behavioral patterns in the subject-level categories "S-Mistake" and "S-Intention" may contain up to three decision-level behavioral patterns from category [1], they otherwise comprise only decision-level behavioral patterns from category [2] and category [3], respectively.

context-dependent theories such as regret theory.[19]

Empirically, the occurrence of juxtaposition-driven regret effects has indeed been found to be highly susceptible to the format of problem representation. Specifically, Battalio et al. (1990) and Harless (1992) provide evidence that the prevalence of such effects is greatly diminished if the choice problem is not represented in the matrix display but in the verbal display.[20] Extending this reasoning to our experimental setting suggests the following testable hypothesis regarding the lottery choices in Stage 2:

Hypothesis 1. *The share of subjects that violate a given axiom in Stage 2 is higher in Treatment M than in Treatment V.*

While the earlier empirical literature does not address the impact of the display format on how subjects revise their initial decisions, the aforementioned findings nevertheless are suggestive also in this regard. Specifically, if the violation of a given axiom indeed represents the deliberate choice to avoid the experience of post-decisional regret and if such regret effects are more prevalent under the matrix display than under the verbal display, more subjects should shy away from ultimately endorsing the axiom under the matrix display than under the verbal display. In consequence, one might expect the following hypothesis regarding axiom selection rates at Stage 3 to hold:

Hypothesis 2. *Axiom selection rates in Stage 3 are lower in Treatment M than in Treatment V.*

5. Results

In this section, we address our primary research question whether lottery choices that violate canonical axioms are by mistake or intentionally. We categorize experimentally observed behavioral patterns both on the decision level and on the subject level according to the empirical strategy outlined in Section 4. Before doing so, we analyze potential effects of a variation in the display format of problem presentation.[21] *En passant*, we present some descriptive statistics on the decision behavior of our subjects.

[19] Note two small deviations that we had to make from the pre-registered data analysis. First, we realized that context-dependent preferences like regret theory do not make sensible predictions for our replication treatment of NR, where the correlation structure is completely opaque. Therefore, we now abstain from a direct comparison with our other treatments. Second, our original Hypothesis 2 suffered from an endogeneity problem. Therefore, we had to rephrase it, while retaining its analytical purpose to compare Stage 3 behavior between treatments.

[20] That is, to put it in the words of Starmer and Sugden (1998), "it seems that [regret effects come] into play only when decision problems are framed in ways that make within-event, cross-act comparisons particularly salient."

[21] Unless stated otherwise, in the following all p-values are from probit regressions with robust standard errors clustered at the subject level. Controls include risk attitudes, regret aversion and cognitive reflection ability, as well as sociodemographics (gender, age, field of study, aspired university degree and final math grade in high school). Qualitative results are the same for Fisher exact tests.

5.1. Results on the Variation of the Display Format

To account for potential effects of the display format of problem presentation, our experiment comprised two main treatments: matrix display in Treatment M and verbal display in Treatment V.

Notably, this treatment variation was administered in Stage 2, i.e, after subjects had already stated their axiom preferences in Stage 1. Thus, we should not expect any differences between Treatment M and Treatment V with regard to subjects' axiom preferences elicited in Stage 1 of the experiment. As suggested by Figure 6, this conjecture is confirmed by the data. Overall, subjects chose an axiom in 61.29% of cases, with no significant difference between Treatments M and V ($p = 0.69$). This also holds true for each of the four axioms separately ($p > 0.38$ for any of the four axioms).

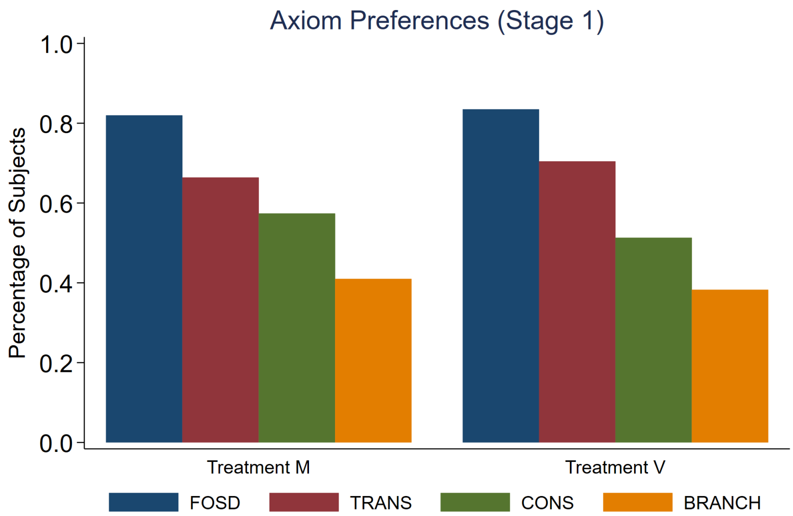

Figure 6: Percentage of subjects that endorse a given axiom in Stage 1.

Based on the findings of earlier experimental studies (Battalio et al., 1990; Harless, 1992), we hypothesized that the share of subjects that violate a given axiom in Stage 2 is higher in Treatment M than in Treatment V – cf. Hypothesis 1. When comparing violation rates for subjects that had at least one axiom violation, however, there is no significant difference between Treatments M and V (p=0.9).[22] Violation rates split up by axioms are depicted in Figure 7, from which it becomes apparent that also with regard to the violation of a particular axiom there is no difference across treatments for CONS (p=0.56), TRANS (p=0.89) and BRANCH (p=0.39). The share of subjects that violate FOSD is slightly, but not significantly, higher under Treatment V than under Treatment M (p=0.13), which goes against the effect suggested by earlier findings. Thus, we come to reject Hypothesis 1.

[22]This result does not change when we additionally control for Stage 1 axiom choices in the probit regression.

Result 1. *Regarding violation rates in original lottery choices, there is no systematic difference depending on whether a matrix display or a verbal format is used to present pairwise lottery choices.*

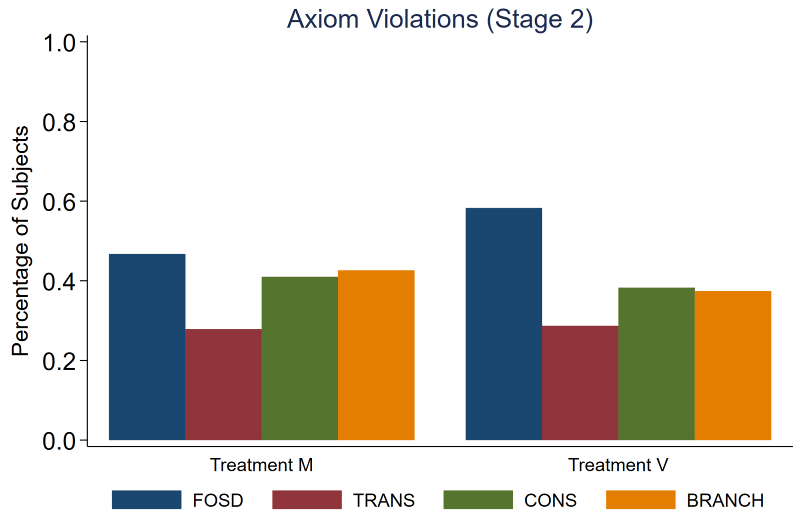

Figure 7: Percentage of subjects that violate a given axiom at least once in Stage 2.

In the spirit of the reasoning that underlies Hypothesis 1, we hypothesized that axiom selection rates in Stage 3 are lower in Treatment M than in Treatment V – cf. Hypothesis 2. When comparing axiom choices in Stage 3 across subjects, however, there is no robust significant treatment effect (p=0.11).[23] Axiom selection rates in Stage 3 split up by axiom are presented in Figure 8. Here, there is no significant treatment effect for TRANS (p=0.89), CONS (p=0.41) and BRANCH (p=0.53). Only FOSD (p=0.01) shows a significant treatment effect which, however, does not go into the hypothesized direction. Thus, not overly surprising in the light of Result 1, we reject Hypothesis 2.

Result 2. *Regarding revised axiom selection rates, there is no systematic difference depending on whether a matrix display or a verbal format is used to present pairwise lottery choices.*

Overall, contrary to previous literature that suggests the matrix display to be more suited to trigger context effects (such as regret) than the verbal display format, we do not find a systematic effect on decision behavior in either Stage 2 or Stage 3. Therefore, in the following classification of behavioral patterns we pool the observations from Treatments M and V.

[23]This result does not change when instead comparing axiom violation rates in Stage 3 (p=0.25)

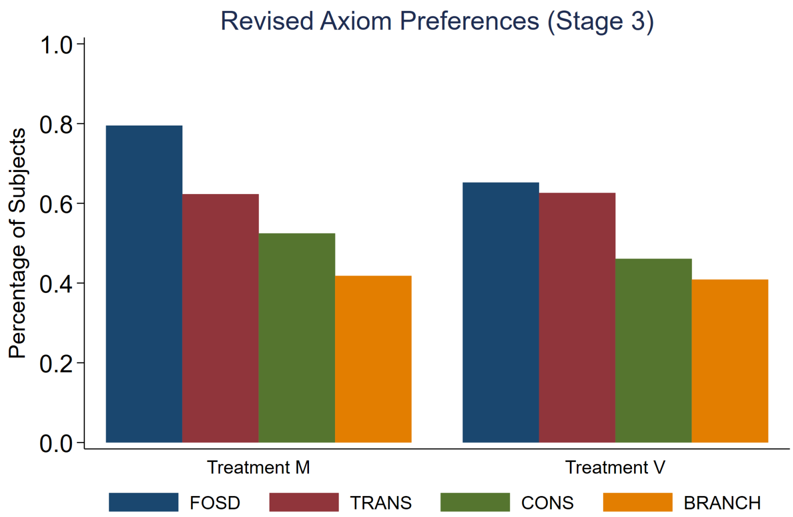

Figure 8: Percentage of subjects that endorse a given axiom in Stage 3.

5.2. Results on Disentangling Mistakes from Intention

Pooling the data from Treatments M and V, our analysis of whether axiom violations are by mistake or intentional is based on a total of 948 behavioral patterns that result from 237 subjects making choices with regard to four axioms. As outlined in Section 4, a behavioral pattern here refers to a subject's revised preference statement regarding a given axiom together with her original and revised lottery choices in the two constellations that allow for a violation of the axiom in question.

On the decision level, we categorize the 948 behavioral patterns according to Table 2. Viewed across all four axioms, a majority (59.18%) of behavioral patterns involves no violation of the axiom in question and therefore falls into category [1], and only a minority (15.51%) of behavioral patterns does not allow for an unambiguous interpretation and thus falls into categories [4] to [6]. The remaining quarter (25.32%) of behavioral patterns falls into the categories [2] and [3], such that a sizeable share of behavioral patterns represent an axiom violation that is either intentional or by mistake. Of these behavioral patterns, a clear majority of 69.58% can be categorized as an intentional violation of the axiom in question (category [2]), whereas only 30.42% represent mistakes (category [3]). Thus, viewed across all axioms, more than twice as many axiom violations are by intention rather than by mistake.

Figure 9 shows the decision-level categorization split up by axiom. Overall, the picture looks quite similar for each axiom, with the majority of behavioral patterns (ranging from 47.68% to 70.46%) falling into category [1] and only a minority (ranging from 12.24% to 20.68%) falling into categories [4] to [6]. The share of behavioral patterns representing an intentional violation of the axiom in question (category [2]) ranges between 12.66% and

24.47%, whereas the share of behavioral patterns that embody a mistake (category [3]) is only between 2.53% and 17.30%. Notably, except for FOSD, where categories [2] and [3] are of about equal size (Binomial test, p=0.82), for TRANS, CONS and BRANCH there are significantly more behavioral patterns categorized as having violated the respective axiom intentionally rather than by mistake (Binomial test, $p < 0.01$ for TRANS, CONS and BRANCH).

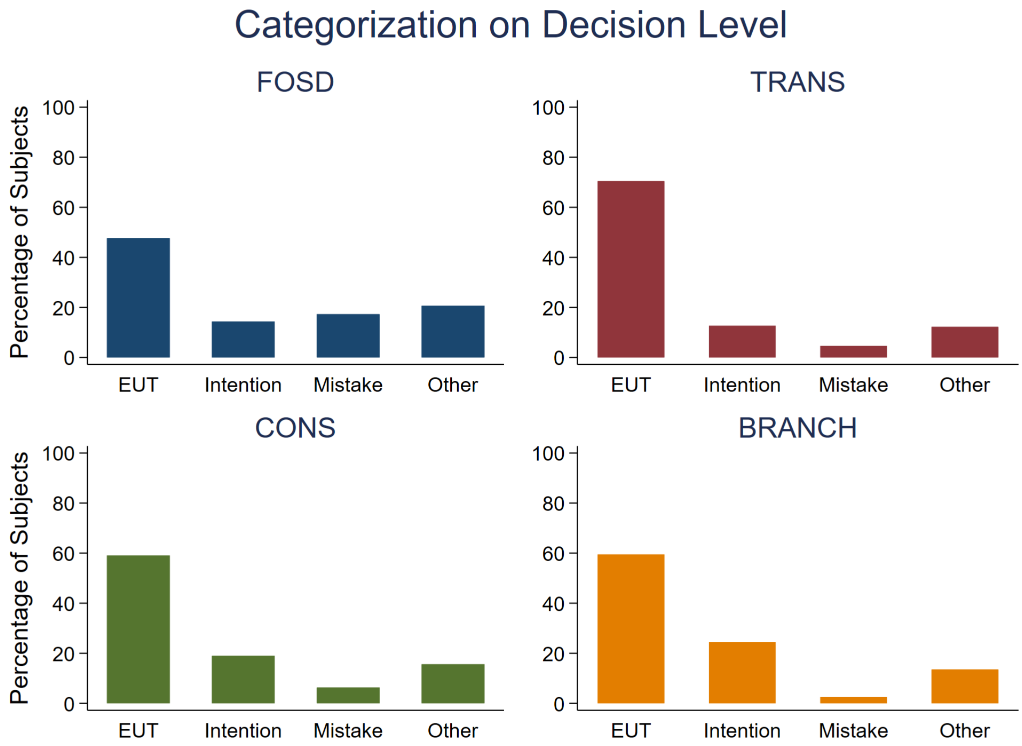

Figure 9: Categorization of behavioral patterns on the decision level.

As depicted in Figure 10, on the subject level, we aggregate the four behavioral patterns that a subject exhibited for the four different axioms into a subject-level categorization according to Table 3. Of the 237 subjects that participated in Treatments M and V, only 10.97% never violated any of the four axioms and therefore are classified as "S-EUT", and 54.58% at least once exhibited behavior that is not to be interpreted unambiguously and therefore are classified as "S-Other".[24] The remaining 34.18% of subjects fall in the two categories of primary interest, "S-Intention" and "S-Mistake". Of these subjects, sizable 67.90% addressed any axiom violation according to decision-level category [3] and therefore are categorized as "S-Intention", whereas only 32.10% addressed any axiom violation according to decision-level category [2] and therefore fall into the category "S-Mistake". Thus, the ratio of these two subject-level categories is very similar to the ratio of the

[24]Hardly surprising, by construction, the share of subjects in category "S-EUT" is lower and the share of subjects in "S-Other" is higher than in the corresponding decision-level category "EUT" (category [1]) and "Other" (categories [4], [5] and [6]), respectively.

corresponding decision-level categories, with more than twice as many subjects violating axioms intentionally rather than by mistake – a difference that is highly significant (Binomial test, $p < 0.01$).

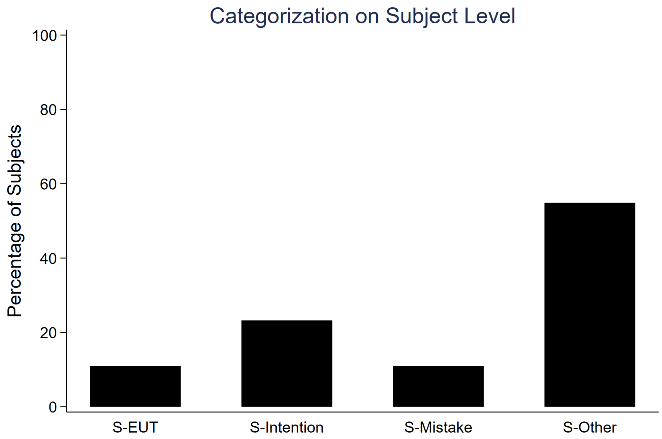

Figure 10: Categorization of behavioral patterns on the subject level.

The following observation summarizes the results from our categorization of behavioral patterns on both the decision level and the subject level.

Result 3. *Overall, significantly more subjects violate axioms intentionally rather than by mistake. This also holds true for all axioms separately, except first-order stochastic dominance.*

To complete the picture, we now carve out to what extent the behavior of subjects in our two subject-level categories of main interest, ”S-Intention” and “S-Mistake”, differs. First of all, the average number of violations is higher in category “S-Intention” (1.61) than in category “S-Mistake” (1.31). Notably, the share of subjects violating exactly (a) two, (b) three and (c) four axioms is – for all three cases – higher in “S-Intention” than in “S-Mistake”: (a) 34.55% vs. 23.08%, (b) 10.91% vs. 3.85%, (c) 1.81% vs. 0.00%.

Subjects in the two categories also tend to violate different axioms. While the share of intentional violations of FOSD is significantly lower than the share of violations by mistake (43.64% vs. 69.23%, Fisher exact test, $p = 0.036$), the contrary is true for BRANCH (49.09% vs. 15.38%, Fisher exact test, $p = 0.004$) and CONS (40.00% vs. 19.23%, Fisher exact test, $p = 0.08$). The difference for TRANS is not significant (29.09% vs. 26.92%, Fisher exact test, $p = 1.00$).

Finally, initial axiom selection in Stage 1 is highly predictive for the decision-level category that subjects fall into. Overall, in 89.66% of all cases, subjects do not change their axiom preference between Stage 1 and Stage 3. However, when restricting attention to behavioral patterns from categories [2] and [3], we observe much more changes in axiom preferences for intentional violations (29.34%) than for violations by mistake (2.74%).

6. Comparison to Nielsen and Rehbeck (2022)

Our analysis builds on the experimental design developed by NR, who focus on those behavioral patterns where an axiom is endorsed at Stage 1 and then violated at Stage 2. For this subset of their observations, NR ask the question whether the initial axiom choice in Stage 1 or the conflicting lottery decision in Stage 2 is a mistake. They find that "it is far more common for individuals to change their lottery choices to be consistent with the axiom than to unselect the axiom" (p.2251). More specifically, among the behavioral profiles that allow for a clear-cut interpretation as a mistake according to NR, roughly 78% are mistaken lottery choices and only 22% are mistaken axiom choices.

Unlike NR, we are not interested in whether the axiom choice or the lottery choices constitutes the mistake, but rather to identify the full extent to which lottery choices that violate a given axiom are intentional violations or mistakes. As explained in detail in Section 4, the violation of a given axiom might be considered intentional in particular in the case where the axiom in question was not endorsed before. Thus, we apply an empirical strategy under which the classification of whether an axiom violation is a mistake or intentional is not conditioned on whether the axiom in question was endorsed in Stage 1 or not. Following this approach, we find that more than twice as many of our subjects violated axioms intentionally rather than doing so by mistake.

The research questions as well as the empirical approaches in our experimental study and the one conducted by NR are different. Nevertheless, the experimental procedures employed in both studies are highly similar, which warrants the question whether our subjects "overall" behaved similar to the subjects of NR or not. To address this question, we conducted a "quasi" replication, namely Treatment R, which presented all lottery choices from our experiment in the exact same display format that NR used. That is, as described in Section 3, we ran our experiment with each lottery's payoffs being listed from top to bottom in increasing order together with the associated occurrence probabilities – without any mention of how the two lotteries' payoffs are correlated. We assess the impact of the different approaches by applying the empirical analysis by NR to our data as well as our empirical strategy to their data. The implementation of this rather straightforward idea as well as the interpretation of the associated results is hampered, however, by several other differences in the respective experimental designs and the different structures of the resulting data sets. Therefore, to make this approach as transparent as possible, we first provide an overview of the aspects in which the experimental design in NR differs from ours.[25] Thereafter, we compare and interpret the resulting findings.

[25] A detailed discussion of the differences and our reasons to depart from the design of NR is provided in Appendix C.

6.1. Differences in the Experimental Design

Different Axioms. While our study is concerned with four axioms, NR overall investigate 18 axioms. Specifically, with regard to canonical choice axioms, next to FOSD, TRANS, CONS and BRANCH, NR also include *mixture independence* and *independence of irrelevant alternatives*. Moreover, to rule out experimenter demand effects, their study includes the 'reverse' axiom to each included canonical axiom as control axiom. Additionally, NR include six rather meaningless distractor axioms. To streamline our experiment and to avoid choice fatigue, we refrained from including control and distractor axioms.

Different Depictions of Axioms. We followed NR and used pictorial logic statements to illustrate each axiom. Our depiction of FOSD, CONS and BRANCH, however, differs from NR.[26] Only the pictorial logic statement to depict TRANS is identical in both studies.

Different Lottery Choices. Both studies used lottery choices where existing evidence reported relatively high rates of axiom violations. Our study involves choice situations for which it was conjectured that a particular juxtaposition of outcomes is important for triggering axiom violations. NR, on the other hand, mainly used lottery choices where existing evidence reported high violation rates of the respectively targeted axiom in situations where lotteries were uncorrelated or information regarding the correlation was not provided.

Different Structures for the Revision Opportunity. We modified the design of the third stage of the experiment in two aspects compared to NR. First, we do not restrict the opportunity to revise one's choices to the case where a subject's stated axiom preferences and her subsequent lottery choices turned out to be inconsistent. Instead, we allow subjects to revise *all* their axiom preferences and lottery choices. Second, we implement "badge revisions" for each axiom rather than independent revisions to underline the axiomatic character of our choice assistants. In particular, in our study, a subject had to decide *once* whether to revise her preference for a given axiom in the light of *all* the lottery choices that were related to the axiom in question. In NR, in contrast, if a subject violated an axiom on multiple occasions, this subject had as many revision opportunities with regard to the same axiom preference.

Different Wordings. First and foremost, while the study by NR was conducted in the English language, we conducted our experiment in the German language. Furthermore,

[26] For example, with the correlation between the lotteries' payoffs being transparent in our Treatments M and V, our pictorial logic statement regarding CONS takes into account that two lotteries with identical probability distributions may appear different due to a different juxtaposition of outcomes in comparison to a given alternative.

NR labeled axioms as "rules", whereas we referred to axioms as "Auswahlassistenten (choice assistants)". We also opted for a different wording for the revision opportunity in Stage 3. Specifically, we did not directly tell subjects that their "choices were inconsistent with [the] rule" (NR, p.45 in the Online Appendix). Instead, we only reminded subjects of the lottery choices they had made in Stage 2 and told them what option the corresponding choice assistant would have chosen.

6.2. Comparison of Results

6.2.1. Comparing Axiom Preferences (Stage 1)

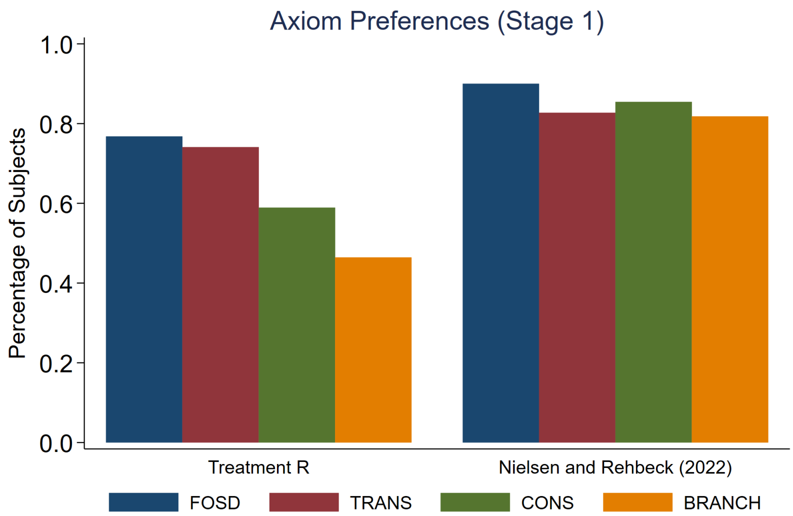

Figure 11: Comparison of axiom preferences between treatment R and NR.

Figure 11 depicts the selection rates for the four canonical axioms analyzed in both, our experiment and in the study by NR. In our experiment, these four axioms are selected at an average rate of 64%, with relatively high selection rates of 77% for FOSD and 74% for TRANS and lower selection rates of 59% for CONS and 46% for BRANCH. In NR, the four axioms in question are selected at an average rate of 85%, with the highest selection rate of 90% for FOSD, a selection rate of 83% for TRANS and CONS, and the lowest selection rate of 82% for BRANCH.[27] Thus, axiom selection rates were overall lower in our experiment than in the study by NR, which may have been caused by labeling axioms merely as "choice assistants" instead of calling them "rules".

Notably, axiom selection rates are also way more dispersed in our sample than in the sample of NR. The reason for this might be that subjects in both studies thought that they were expected to differentiate between desirable axioms, which it made sense to endorse,

[27]In NR, 67% of the subjects chose all of the four canonical choice axioms in question. In our study, despite generally lower selection rates, still more than half of the subjects (53%) found at least three of the four axioms convincing, whereas only a minority of 17% chose one or none axiom.

and non-desirable axioms, which it made sense not to endorse. If this was the case, in the design of NR it may have been comparatively easy to identify all of the four canonical choice axioms as sensible as they were contrasted with counter-intuitive control axioms or nonsensical distractor axioms. In our design, on the other hand, no such referents were present, such that subjects may have grouped the four canonical choice axioms themselves into desirable and non-desirable axioms – with FOSD and TRANS possibly being regarded as intuitively more appealing axioms and CONS and BRANCH possibly being regarded as intuitively less appealing axioms.[28]

6.2.2. Comparing Lottery Choices (Stage 2)

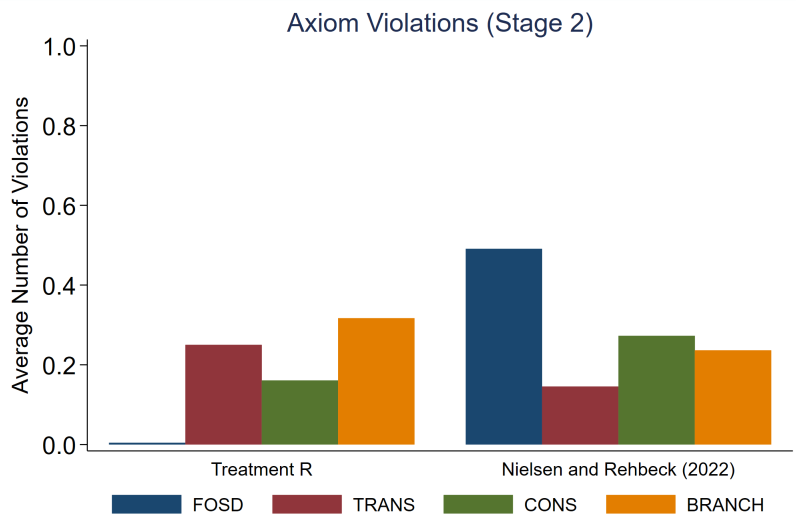

Figure 12: Comparison of lottery choices between treatment R and NR.

When averaged across all four axioms, we find about 10 percentage points less violations than NR (18% vs. 29%). Split up by axioms, as depicted in Figure 12, on average, there have been more violations of TRANS (25% vs. 15%) and BRANCH (32% vs. 24%) in our experiment, whereas NR found more violations of FOSD (0% vs. 49%) and CONS (16% vs. 27%).[29]

Quite remarkable is the difference regarding FOSD, of which we have no violations at all in our Treatment R, whereas NR found almost half of their subjects (49%) to violate this axiom. Comparing Figures 4 and 13 suggests that this difference might be rooted in

[28] Regarding BRANCH, NR find that the share of subjects that chose the axiom as well as the corresponding control axiom is relatively high compared to the other canonical choice axioms. NR conjecture that BRANCH might be harder to understand such that a higher number of their subjects was confused and therefore chose both.

[29] We focus on average numbers of violations to account for the different numbers of incidents where a subject could violate an axiom. Specifically, while each of the four relevant axioms could be violated in two instances in our experiment, FOSD could be violated four times, TRANS thrice, CONS twice and BRANCH once in NR.

10%	chance of	\$2		5%	chance of	\$2
5%	chance of	\$16		5%	chance of	\$3
85%	chance of	\$19		90%	chance of	\$19
	Lottery A				**Lottery B**	

Figure 13: Example for lotteries targeting FOSD in NR .

the use of different lottery choices that allowed for a violation of FOSD. Specifically, as explained in Section 2, our choice of lotteries is motivated by our Treatments M and V and depends on a particular juxtaposition of outcomes to elicit violations by emphasizing the possibility of regret after the decision if one chooses the dominant lottery. With payoffs being listed in increasing order in Treatment R, the dominance relation was very easy to detect for the two lottery choices that we used to target FOSD (see Figure 4 and also Appendix B.3). Moreover, with no correlation being spelled out, juxtaposition driven regret effects should not significantly affect choices. Thus, it it not surprising that we did not observe any violations of FOSD in our Treatment R. The corresponding lottery choices in NR, on the other hand, all follow the construction in Birnbaum and Martin (2003), which deliberately shrouds the dominance relation for independent lotteries in order to trick subjects into committing an axiom violation. Specifically, in the example Lottery A vs. Lottery B in Figure 13, it stands to reason that subjects make line-wise comparisons. While the two lotteries are relatively similar in line one and line three, the dominated lottery A is significantly better in line two than lottery B: paying \$16 instead of \$3 with equal probability of 5%.

6.2.3. Comparing Revision Behavior (Stage 3)

Applying the empirical approach in NR to our data. Following NR, we restrict attention only to those subjects that endorsed a given axiom in Stage 1 and subsequently violated that axiom in Stage 2. Furthermore, we have to account for subjects in the study by NR having multiple revisions of their initial endorsement of a given axiom if they violated the axiom on multiple occasions, whereas in our experiment's badge revisions the endorsement of a given axiom is revised only once in the light of both lottery choices that relate to the axiom. We address this issue as follows: First, for those of our subjects who violated a given axiom in only one of the two possible instances in Stage 2, we only include the revision of the axiom-violating lottery choice in Stage 3. Second, for subjects who violated an axiom on both occasions in Stage 2, we "split" our badge revision into two revisions of lottery choices to which we then assign one and the same revision of the

Axiom total	*Keep inconsistent*	*Unselect axiom*	*Change lotteries*	*Change and still inconsistent*
Treatment R total ($n = 95$)	52%	36%	11%	2%
FOSD ($n = 0$)	-	-	-	-
TRANS ($n = 42$)	64%	31%	0%	5%
CONS ($n = 19$)	21%	53%	26%	0%
BRANCH ($n = 34$)	53%	32%	15%	0%
NR (2022) total ($n = 309$)	38%	14%	44%	4%
FOSD ($n = 194$)	49%	21%	29%	1%
TRANS ($n = 41$)	17%	5%	66%	12%
CONS ($n = 52$)	13%	0%	79%	8%
BRANCH ($n = 22$)	41%	0%	55%	5%

Table 4: Comparison of percentages of revision behavior between Treatment R and Nielsen and Rehbeck (2022).

initial axiom endorsement.[30]

Based on this restricted data set, we group our subjects' behavioral patterns in Stage 3 into the four categories upon which the analysis in NR relies: "Keep inconsistent", "Unselect axiom", "Change lotteries" and "Change and still inconsistent". As can be seen from Table 4, 36% of our subjects in Treatment R unselect the axiom, whereas only 11% change their lottery choices. This pattern holds true for all axioms separately.[31] Notably, this is the opposite from the observation in NR that for "[...] those who do change their choices, it is far more common [...] to change their lottery choices to be consistent with the axiom than to unselect the axiom" (p. 2251). Furthermore, we find a higher number of subjects that keep their choices inconsistent and do not change any of their previous decisions (52% vs. 38%).

Applying our empirical approach to the data in NR. In contrast to our experiment's badge revisions, in NR, if a subject violated a given axiom on multiple occasions, she had an independent revision opportunity for each of these conflicting decisions. In consequence, in NR, such a subject could stick to endorsing the axiom on one occasion and renounce the very same axiom on another occasion. With regard to our decision-level categorization (cf. Table 2), we treat each of these independent revisions as an independent

[30]To check for robustness, instead of splitting up our badge revision into two revisions, we alternatively randomly dropped one of the two revisions concerning axiom-violating lottery choices and assigned the revision of the initial axiom endorsement to the remaining revision of lottery choices. Overall, the following results qualitatively remain unchanged.

[31]Note that due to zero violations of FOSD in Stage 2, we do not have any revision behavior to display from our Treatment R.

observation.[32]

More problematically, with NR providing a revision opportunity only to those subjects who endorsed the axiom in Stage 1 and then violated that axiom in Stage 2, their data set misses information that our categorization relies on, i.e., data on the revision decisions of subjects who either endorsed the axiom in Stage 1 and then did not violate it in Stage 2 or who did not endorse the axiom in Stage 1 in the first place. Specifically, the 110 subjects in NR faced ten different lottery constellations that targeted the four relevant axioms FOSD, TRANS, CONS, and BRANCH (cf. footnote 29). Thus, if subjects would have been allowed to revise all their decisions as in our experiment, this would have resulted in 1100 behavioral patterns upon which to base our decision-level categorization. Of these 1100 potential observations, however, only 28% involved actual revision decisions because a given axiom was endorsed in Stage 1 and then violated in Stage 2. For the remaining 72% combinations of initial axiom preference and lottery choices, on the other hand, there was no revision behavior observed.

Of the "complete" behavioral patterns that involve a revision decision, 44% change their lottery choice to be consistent with the axiom while keeping the axiom selected, thereby falling into our category [2], and 14% unselect the axiom while keeping to violate the axiom, thereby falling into our category [3]. The remaining 42% of the "complete" behavioral patterns can be classified into one of our categories [4], [5] and [6]. Of the "incomplete" behavioral patterns that do not involve a revision decision, 95% do not involve an axiom violation in Stage 2. In principle, the subjects who made these decisions might have ultimately violated the axiom in Stage 3 if they had been given the chance to revise their earlier decisions. With this happening in our whole experiment in less than 0.8% of observations, we take a conservative stand here and assume that these subjects would have stuck to not violating the axiom in Stage 3 – which results in these behavioral patterns to fall into our category [1].[33] The remaining 5% of the "incomplete" behavioral patterns thus involve the axiom not being endorsed in Stage 1 and then being violated in Stage 2. While being a prime candidate for resulting in an intentional violation of the axiom in question, with no revision opportunity being offered for these decisions, we do not dare to make a claim in which of our categories ([2], [3], [4], or [6]) the corresponding behavioral patterns most likely would fall. As a thought experiment, however, consider the extreme case in which all these behavioral patterns would fall into category [3]. In this hypothetical scenario, the data collected by NR would show that about two-thirds of interpretable axiom violations are mistakes (category [2]) and only one-third are intentional violations

[32] Notably, this implies that a subject here may end up in more than one of our decision-level categories even with regard to one and the same axiom.

[33] Overall, this translates into 68% of the relevant observations in the data of NR to fall into our category [1], compared to quite similar 70% in our own Treatment R.

(category [3]). This is again the opposite from what we observe in our data. Our results for Treatment R (18% in category [2] vs. 82% in category [3]) mirror our main results from Section 5, showing a significantly higher rate of behavioral patterns that violate the axiom intentionally rather than by mistake.

At first glance, our primary results from Section 5 seem to drastically challenge the conjecture by NR that canonical choice axioms have a high normative appeal. As our in-depth comparison in this section shows, however, this point of view would be short-sighted. Specifically, as our comparison reveals, there is a subtle robustness of the two studies' respective results in the sense that each study's key finding regarding revision behavior prevails if the other study's empirical strategy is applied to the former study's data set. In our opinion, this should rather be taken as an indication that (some of) the differences in our experimental design have a considerable impact on the results. Clearly, the data used in Stage 3 heavily depends on the decisions made in Stages 1 and 2. Therefore, changes in the experimental design that already led to our lower axiom selection rates in Stage 1 as well as our lower violation rates in Stage 2 might also have influenced the results found in Stage 3. Importantly, we use a different set of choice problems to trigger axiom violations than NR. NR use choice problems that induce subjects to make mistakes, whereas we use choice problems that induce subjects to respond to context effects. This difference is most apparent in the choice problems used to target FOSD. Furthermore, our different structure of the revision opportunity in Stage 3 might also have impacted how subjects perceived their revision decisions. Specifically, in comparison to the independent revisions in NR, the badge revisions in our study not only may have emphasized the axiomatic character of our choice assistants, but also gave our subjects more information on how their lottery choices related to the axioms (as all instances where a given axiom could have been violated were displayed next to each other). Thus, all in all, we see our results as complementary rather than contradictory to the findings in NR, echoing the insight in NR (p.2239) that "it will take much more work to show where and when [...] violations are mistakes."

7. Conclusion

When facing choices under risk, human beings often make decisions that violate standard rules of economic rationality. This raises the question whether these violations are a manifestation of true preferences, in which case the respective decision maker rejects the normative value that economists typically ascribe to these canonical choice axioms, or mistakes made by boundedly rational individuals. Addressing this research question in a laboratory experiment, we categorize subjects whose behavior allows for a clear-cut interpretation into three groups: first, rational expected utility maximizers (24%); second, boundedly rational expected utility maximizers who would like to adhere to the canonical axioms but occasionally make decisions in violation of these axioms (24%); third, subjects that rationally violate the tested canonical axioms and thus reject their normative value (52%). Thus, less than 50% of our unambiguously classifiable subjects consider the rationality axioms in question as desirable general guiding principles – an observation that can be interpreted as casting severe doubt on the often ascribed normative appeal of standard economic models for choice under risk.

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A. Supplementary Material to the Theoretical Framework

In the following, we formally define each of the axioms relevant for our study and explain, by means of the example of a regret-averse decision maker, how context-sensitive theories can lead to a violation of the respective axiom.[34]

We denote the set of feasible monetary payoffs by $\mathcal{X}$, the set of potential states of the world by $\mathcal{S}$, and the occurrence probability of state $s \in \mathcal{S}$ by $p(s)$. A lottery L_i assigns a monetary payoff to each state of the world. Let $x_i(s)$ denote the monetary payoff assigned to state s, i.e., $x_i : \mathcal{S} \to \mathcal{X}$.[35] The set of all lotteries is denoted by $\mathcal{L}(\mathcal{X}, \mathcal{S})$. As usual, $\succ$ denotes the strict preference relation. Furthermore, for $L_i \in \mathcal{L}(\mathcal{X}, \mathcal{S})$ and $z \in \mathbb{R}$, define $F_i(z)$ as the probability of obtaining a payoff not larger than the amount z under lottery L_i; i.e., $F_i(z) = \sum_{\{s \in \mathcal{S} | x_i(s) \leq z\}} p(s)$.

A.1. First-Order Stochastic Dominance

First-order stochastic dominance requires that, if under one lottery the probability to obtain at least a particular monetary amount is weakly higher for all amounts and strictly higher for at least one amount than under the alternative lottery, then the decision maker must prefer the former lottery over the latter.

Definition 1 (First-order Stochastic Dominance)**.** *For any two lotteries $L_i, L_j \in \mathcal{L}(\mathcal{X}, \mathcal{S})$ the following holds: If $1 - F_i(z) \geq 1 - F_j(z)$ for all $z \in \mathcal{X}$ and $1 - F_i(z') > 1 - F_j(z')$ for some $z' \in \mathcal{X}$, then $L_i \succ L_j$.*

An example for why first-order stochastic dominance may well be violated under regret theory was given in Section 2.

A.2. Transitivity

Transitivity requires a decision maker's pairwise choices to be consistently linked with each other in the sense that if a first lottery is preferred over a second and the second lottery is preferred over a third, then the first lottery must also be preferred over the third.

Definition 2 (Transitivity)**.** *For any three lotteries $L_i, L_j, L_k \in \mathcal{L}(\mathcal{X}, \mathcal{S})$ the following holds: $[L_i \succ L_j \wedge L_j \succ L_k] \Longrightarrow L_i \succ L_k$.*

[34] The choice problems used to illustrate potential axiom violations are examples from our actual study. For a complete overview of these choice problems see Appendix B.3.

[35] Strictly speaking, the lottery L_i is an *act* in the sense of Savage (1954).

Consider the three lotteries depicted in Table 5, which are based on Loomes et al. (1991).[36] Here, in the pairwise choice between L_3 and L_4, it may well be that a regret-averse decision maker chooses L_4 in order to avoid the post-decisional regret of receiving only €5 and missing out on €14 that she would experience if she had chosen L_3 and state 2 had been realized. Likewise, in the pairwise choice between L_4 and L_5, the same decision maker might choose L_5 in order to avoid the regret associated with receiving only €3 and missing out on €9 in case that she had chosen L_4 and state 3 had been realized. In the pairwise choice between L_3 and L_5, however, the decision maker might opt for L_3 in order to avoid the regret of receiving only €9 and missing out on €24 that she would experience if she had chosen L_5 and state 1 had been realized. In this example, we would have $L_5 \succ L_4$, $L_4 \succ L_3$ and $L_3 \succ L_5$ – a violation of the transitivity axiom.[37]

	$s = 1$	$s = 2$	$s = 3$
L_3	€24	€5	€5
L_4	€14	€14	€3
L_5	€9	€9	€9
Prob.	40%	30%	30%

Table 5: Lotteries L_3, L_4 and L_5 depicted in the action-state matrix.

A.3. Consistency

Consistency requires that, if a first and a second lottery both represent one and the same probability distribution over the set of feasible payoffs (i.e., if the two lotteries are stochastically equivalent) and the first lottery is preferred over a third lottery, then the second lottery must also be preferred over the third lottery.

Definition 3 (Consistency). *For any three lotteries $L_i, L_j, L_k \in \mathcal{L}(\mathcal{X}, \mathcal{S})$ the following holds: If $\sum_{\{s\in\mathcal{S}|x_i(s)=x\}} p(s) = \sum_{\{s\in\mathcal{S}|x_j(s)=x\}} p(s)$ for all $x \in \mathcal{X}$, then $L_i \succ L_k \Longleftrightarrow L_j \succ L_k$.*

Consider the lotteries L_6, L_7 and L_8 depicted in Table 6, which are taken from Starmer and Sugden (1993).[38] In terms of probability distributions, L_6 is equivalent to L_7. Hence, if L_6 is chosen in the pairwise choice between L_6 and L_8, then consistency requires L_7

[36] Here, the difference to Loomes et al. (1991) is that we double the amount of all payoffs and choose the payoffs' currency to be €.

[37] Presenting the three pairwise choice problems L_3 vs. L_4, L_4 vs. L_5, and L_3 vs. L_5 (with one-half of the payoffs in £) to 100 subjects, Loomes et al. (1991) find that 21% of their subjects exhibit the cyclical choice pattern $L_5 \succ L_4$, $L_4 \succ L_3$ and $L_3 \succ L_5$.

[38] Compared to Starmer and Sugden (1993), we once again triple the amount of all payoffs and choose the payoffs' currency to be €.

to be chosen in the pairwise choice between L_7 and L_8. A regret-averse decision maker, however, may perceive the pairwise choice between L_6 and L_8 as starkly different from the pairwise choice between L_7 and L_8. Once again, the reason for this is rooted in the juxtaposition of outcomes and the associated scope for experiencing post-decisional regret: While the scope for experiencing ex post regret when choosing L_8 rather than L_6 is rather small (in state 1 the decision maker obtains only €21 under L_8 and would have gotten €33 under L_6), the scope for experiencing ex post regret when choosing L_8 instead of L_7 might be perceived as rather large (in state 2 the decision maker obtains only €0 under L_8 and would have gotten €33 under L_7). Hence, for a regret-averse decision maker, we might well observe $L_8 \succ L_6$ and $L_7 \succ L_8$.[39]

	$s = 1$	$s = 2$	$s = 3$
L_6	€33	€0	€0
L_7	€0	€33	€0
L_8	€21	€0	€21
Prob.	45%	45%	10%

Table 6: Lotteries L_6, L_7 and L_8 depicted in the action-state matrix.

A.4. Branch Independence

Branch independence requires that, if a first and a second lottery yield a given payoff $x \in \mathcal{X}$ with equal probability and the first lottery is preferred over the second lottery, then the preference must not change if the payoff $x \in \mathcal{X}$ is interchanged with some other payoff $y \in \mathcal{X}$.

Definition 4 (Branch Independence). *For any four lotteries $L_i, L_j, L_k, L_m \in \mathcal{L}(\mathcal{X}, \mathcal{S})$ and arbitrary $x, y \in \mathcal{X}$ the following holds: If there exist $\tilde{\mathcal{S}}, \hat{\mathcal{S}} \subsetneq \mathcal{S}$ such that $\sum_{s \in \tilde{\mathcal{S}}} p(s) = \sum_{s' \in \hat{\mathcal{S}}} p(s')$, $x_i(s) = x$ and $x_k(s) = y$ for all $s \in \tilde{\mathcal{S}}$, $x_i(s) = x_k(s)$ for all $s \in \mathcal{S} \backslash \tilde{\mathcal{S}}$, $x_j(s') = x$ and $x_m(s') = y$ for all $s' \in \hat{\mathcal{S}}$ and $x_j(s') = x_m(s')$ for all $s' \in \mathcal{S} \backslash \hat{\mathcal{S}}$, then $L_i \succ L_j \Longleftrightarrow L_k \succ L_m$.*

Consider the lotteries L_9, L_{10}, L_{11} and L_{12} depicted in Table 7. Here, lottery L_9 pays out €15 in states 1 and 2, which have a combined occurrence probability of 0.5, and L_{10} pays out €15 in state 3, which occurs with probability 0.5. Hence, if lottery L_9 is chosen in the pairwise choice between L_9 and L_{10}, then branch independence requires L_{11} to be chosen in the pairwise choice between L_{11} and L_{12}, where the payoff of €15 in states 1

[39] Presenting the two pairwise choice problems L_6 vs. L_8 and L_7 vs. L_8 (with one-third of the payoffs in £) to 90 subjects, Starmer and Sugden (1993) find that 32% of their subjects exhibit the choice pattern $L_8 \succ L_6$ and $L_7 \succ L_8$.

and 2 under L_9 and in state 3 under L_{10} has been replaced by a payoff of €0. While the scope for experiencing ex post regret when choosing L_9 rather than L_{10} is rather small (in state 2 the decision maker obtains only €15 under L_9 and would have gotten €24 under L_{10}), the scope for experiencing ex post regret when choosing L_{11} instead of L_{12} might be perceived as rather large (in state 2 the decision maker obtains only €0 under L_{11} and would have gotten €24 under L_{12}). Hence, for a regret-averse decision maker, we might well observe $L_9 \succ L_{10}$ and $L_{12} \succ L_{11}$.

	$s = 1$	$s = 2$	$s = 3$
L_9	€15	€15	€15
L_{10}	€0	€24	€15
L_{11}	€0	€0	€15
L_{12}	€0	€24	€0
Prob.	20%	30%	50%

Table 7: Lotteries L_9, L_{10}, L_{11} and L_{12} depicted in the action-state matrix.

B. Supplementary Material to the Experiment

B.1. Instructions

Note: The text below shows the instructions of Treatment M. Instructions displayed here are a translation into English. Original instructions were in German and are available from the authors upon request.

Welcome to this experiment!

Today you will take part in an economic experiment. You can earn a substantial amount of money in this experiment. The amount of this money depends on your own decisions and on chance. Therefore, it is very important that you read the following explanations carefully.

Absolutely no communication with the other participants is allowed during the experiment. Please stop any conversations with your neighbors now and remove everything from your table that you do not need for the experiment. Anyone disobeying this rule will be excluded from the experiment and all payments.

All your income in this experiment will be calculated directly in Euros. At the end, we will pay you the total amount of Euros earned during the experiment in cash.

Today's experiment consists of **4 parts in total (Part I, II, III and IV)**. In each of these parts you can earn money. At the end of the experiment, all the money amounts from each part will be added up. In addition, you will receive **5 Euros for showing up on time** for this experiment.

At the beginning of each part you will receive detailed instructions for that part. The decisions you will make in one part will have no effect on the other parts.

On the next screen, the exact procedure of Part I of this experiment will be described. During the instructions, we will ask you to repeatedly answer some comprehension questions on the computer. These questions should make it easier for you to familiarize yourself with the decision situation.

The following applies to the entire experiment: Your decisions are anonymous. None of the other participants in the experiment will receive information about your identity during or after the experiment.

Should you have any questions at any point in the experiment, please raise your hand. We will then come to you and answer your questions.

PART I: Instructions

Part I of the experiment consists of **a total of 3 sections (Sections A, B, and C)**. In each of these sections, you will make a series of choices.

At the end of the experiment, exactly **ONE of your decisions from ONE of the three sections** will be randomly selected by the computer. This decision will then determine the amount of money you earn in Part I of the experiment. **Each of your decisions from the entire Part I** can be selected with the **same probability**. You will learn which decision the computer randomly drew at the end of the entire experiment.

In the following, the **procedure of Section A** is described. The procedure of **Sections B and C** is explained in each case **directly before they begin**. Then you will also learn how exactly the decisions from the respective section are paid if they are drawn at random and thus become relevant for payment at the end of the experiment.

Important: For all sections, there are no right or wrong choices. We are only interested in what you prefer.

All three sections in Part I of today's experiment are about lotteries. To illustrate what a lottery is, imagine the following gamble: A number between 1 and 100 is rolled. Each number is equally likely. There is a monetary amount assigned to each of these numbers between 1 and 100. These amounts are between 0 Euro and 60 Euro. So there are no negative amounts of money and you cannot lose money in any case.

Example of a lottery: If one of the numbers from 1 to 30 is rolled, the lottery pays 8 Euros. If one of the numbers from 31 to 70 is rolled, then the lottery pays 37 Euros. If one of the numbers from 71 to 100 is rolled, then the lottery pays 0 Euros.

Example of another lottery: If one of the numbers from 1 to 100 is rolled, then the lottery pays 11 Euros.

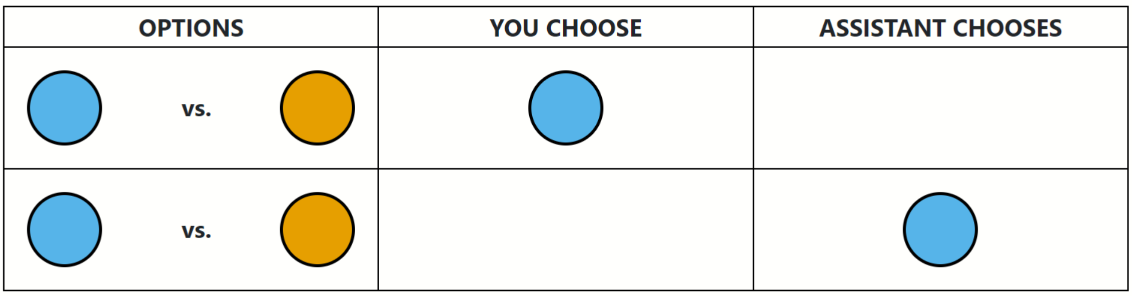
PART I - Section A: Choice Assistants

In **Section A**, you will be presented with **four** different, so-called **"Choice Assistants", one after the other**. A choice assistant is an **abstract DECISION SCHEME** that sometimes observes one or more initial choices between lotteries by you, and uses these to determine which lottery to choose in a subsequent decision. How a Choice Assistant works is represented by **colored balls** that represent **different lotteries**. The colors of the balls have no meaning in themselves, they only serve to distinguish different lotteries.

Your **task in this section** of the experiment is to determine for each Choice Assistant whether you want to **let the Choice Assistant make a decision for you**, or whether you want to **make the decision yourself**.

Important: Choose exactly the Choice Assistant whose decision scheme you feel **makes sense**. In this way, you can ensure that at the end of the experiment, the Choice Assistant makes a **decision in your favor without you having to make the decision yourself**. You are completely free to decide which and how many of the Choice Assistants should be used.

Example 1 for the display of a possible Choice Assistant:



Explanation of the Choice Assistant

You prefer BLUE over ORANGE. From this, the Choice Assistant concludes that you would prefer BLUE over ORANGE and therefore selects BLUE for you.

Example for Illustration:

For this example, do not think about amounts of money, but about types of ice cream.

- Imagine that there are the following possible ice cream sundaes:

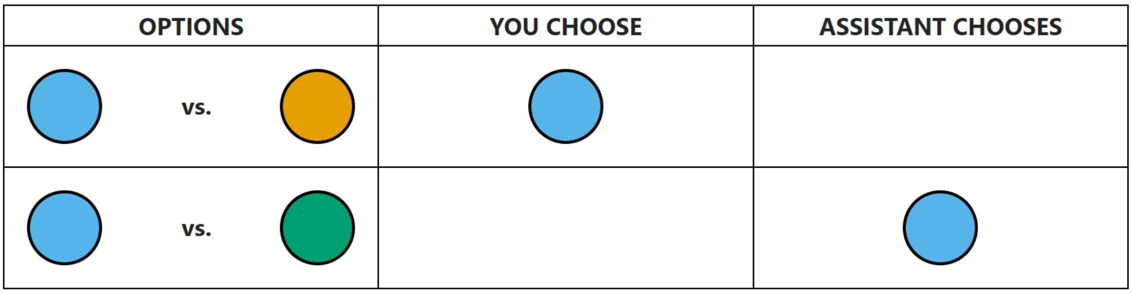
  - BLUE sundae: Contains 1 scoop of latte macchiato ice cream.
  - ORANGE sundae: Contains 1 scoop of walnut ice cream.

- Imagine you have a choice between the BLUE sundae and the ORANGE sundae. Suppose you like latte macchiato ice cream better than walnut ice cream, so you choose the BLUE sundae.
- From this, the Choice Assistant concludes that if you were to choose again between the BLUE sundae and the ORANGE sundae, you would prefer the BLUE sundae and therefore selects BLUE for you.

You may want to use this Choice Assistant. The Choice Assistant uses the decision you made and would choose exactly the same as you if you made the same decision.

Example for Clarification: If you like latte macchiato ice cream better than walnut ice cream, it can be concluded that you will also like latte macchiato ice cream better than walnut ice cream in the future.

Example 2 for the display of a possible Choice Assistant:



Explanation of the Choice Assistant

You prefer BLUE to ORANGE. From this, the Choice Assistant concludes that you would prefer BLUE over GREEN and therefore selects BLUE for you.

Example for Illustration:

For this example, think not about amounts of money, but about types of ice cream.

- Imagine that there are the following possible ice cream sundaes:
  - BLUE sundae: Contains 1 scoop of stracciatella ice cream.
  - ORANGE sundae: Contains 1 scoop of caramel ice cream.
  - GREEN sundae: Contains 1 scoop of wild berry ice cream.
- Imagine you have a choice between the BLUE sundae and the ORANGE sundae. Suppose you like stracciatella ice cream better than caramel ice cream, so you choose the BLUE sundae.

- From this, the Choice Assistant concludes that if you had to choose between the BLUE sundae and the GREEN sundae, you would prefer the BLUE sundae and therefore selects BLUE for you.

You may not want to use this Choice Assistant. Both the blue lottery and the orange and green lotteries may contain different probabilities for different amounts of money. Just because you prefer the blue lottery over the orange lottery, you would not necessarily prefer the blue lottery over the green lottery.

Example for Clarification: Just because you like stracciatella ice cream better than caramel ice cream does not necessarily mean that you also like stracciatella ice cream better than wild berry ice cream.

While you make your choice regarding the Choice Assistants, you don't know what specific lotteries the colored balls stand for. The lotteries can be very different, some are risky, others involve safe payoffs, some tend to be lower amounts, others tend to be higher amounts.

In summary: A choice assistant is an abstract decision scheme that observes one or more initial choices between lotteries by you and uses them to determine which lottery to choose in a subsequent decision. So you want to select exactly the Choice Assistants that will **IN EVERY CASE** make the decision that is best for you. On the other hand, it may be worth making decisions yourself if the Choice Assistant does not necessarily choose the best lottery for you, as shown in the example above.

Payment

Each of your decisions for or against a Choice Assistant in Section A will have the same probability of becoming payoff relevant as any other decision you make in Part I of this experiment. Underlying each decision for or against a Choice Assistant are specific lotteries represented by the colored balls. If one of the decisions from this section is selected for payoff, there are two possibilities:

- If you decided not to use the Choice Assistant, then the associated lottery decision will be displayed at the end of the experiment and you will have to make the lottery decision yourself.

- If you have decided to apply the Choice Assistant, then you do not have to make an additional decision at the end of the experiment. Instead, you will be shown which lottery the Choice Assistant has chosen for you.

At the end of the experiment, the computer will randomly roll a number between 1 and 100. This will then determine the outcome of the lottery chosen by you or by the Choice Assistant.

PART I - Section B: Lottery Decisions

In **Section B**, you will make a total of **20 decisions between two lotteries each**. In each of these lotteries you can receive certain amounts of money with certain probabilities. The amounts of money in the following lotteries range from 0 Euros to 60 Euros. The probabilities for the individual amounts are between 0% and 100%.

Your **task in this section** is to choose the **lottery you prefer** in each case. Each of these choices will be shown to you on a separate screen. Each time you can choose either the **upper lottery** or the **lower lottery**.

Example of the display of a possible lottery decision:

	1 — 30	31 — 70	71 — 100
○	**€8**	**€17**	**€0**
○	**€0**	**€9**	**€9**
	30%	40%	30%

In order to play out a lottery, the computer randomly rolls a number between 1 and 100. For this, the lotteries assign a monetary amount to each number between 1 and 100. The **top line of the table** shown summarizes **number ranges**. The **probability** that the randomly drawn number falls into a certain number range is shown in the **bottom row of the table**.

In this example, the upper lottery pays 8 Euros for a number between 1 and 30 (30% probability), 17 Euros for a number between 31 and 70 (40% probability) and 0 Euros for a number between 71 and 100 (30% probability). The lower lottery, on the other hand, pays 0 Euros for a number between 1 and 30 (30% probability), 9 Euros for a number between 31 and 70 (40% probability) and 9 Euros for a number between 71 and 100 (30% probability).

Payment

Each of your lottery choices in Section B will have the same probability of becoming payoff as any other choice you make in Part I of this experiment. If any of the decisions in this section is selected for payoff, at the end of the experiment the computer will roll a **random number between 1 and 100**, and you will receive the amount of money that the lottery you selected assigns to the rolled number.

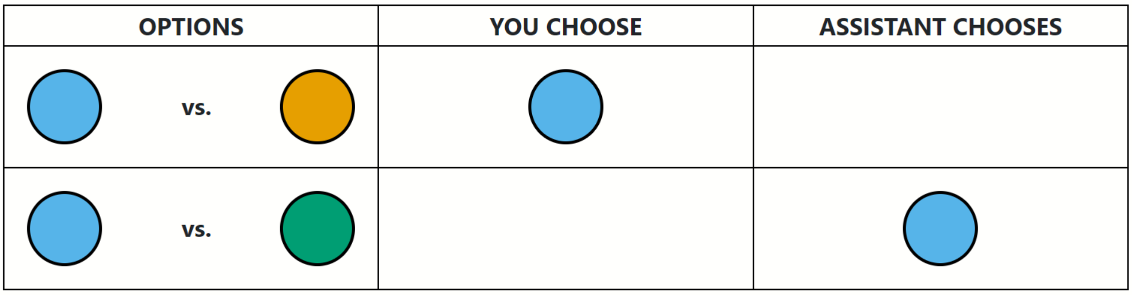
Assume that you have chosen the upper lottery in the example. If the random number is between 1 and 30, then you will receive a cash amount of 8 Euros. If the random number is between 31 and 70, then you will receive 17 Euros, and if the random number is between 71 and 100, then you will receive 0 Euros.

PART I - Section C: Revision Opportunity

In Section A, you determined whether or not you wanted a Choice Assistant to make a decision for you. In Section B, you made lottery decisions. In doing so, it is possible that you selected a Choice Assistant in Section A that could have been applied to decisions in Section B as well.

You now have the opportunity in **Section C** to **re-evaluate your choices from the first two Sections A and B**. We will show you again your decisions on the **Choice Assistants from Section A** and at the same time the **matching lotteries from Section B** for which the Choice Assistant could have made a decision. This way you can view your decisions from Sections A and B together. You have the possibility to compare if you have chosen a Choice Assistant and at the same time made a different choice in the lottery decisions than the Choice Assistant would have made. You do not have to make this comparison yourself. Instead, an information page will show you both graphically and verbally which choices you made in Section A and B, and which choice the Choice Assistant would have made for you.

Example: Here you see again a Choice Assistant that served as an example in the instructions for Section A. Assume that you have decided that this Choice Assistant **should not make a decision for you**:



Also, here you see the lottery decision again that served as an example in the instructions to Section B. Assume that you have selected the **upper lottery** in this decision:

	1 – 30	31 – 70	71 – 100
◉	€8	€17	€0
○	€0	€9	€9
	30%	40%	30%

Last, imagine you were also facing the following lottery decision. Suppose you chose the **lower lottery** in this decision:

	1 – 30	31 – 70	71 – 100
○	€8	€17	€0
◉	€11	€25	€4
	30%	40%	30%

The **information page** on these decisions would then look like this:

In the upper part of the screen you will see the choice you made in Section A regarding a Choice Assistant. In the lower part you see the respective matching lottery choices from Section B. Next to each of them is a verbal list of your choices and the choice that the Choice Assistant would have made. There are **two such information pages** for each Choice Assistant.

After these information pages you can then decide on a next screen whether you want to change your choice concerning the Choice Assistant or not. At the same time, you can decide whether you want to change your choice regarding the lotteries or not. **You are completely free to change either none of your choices, only individual choices, or even all of the choices displayed.**

In total, you **will be given four opportunities to adjust your choices**. Each of these possibilities refers to one of the four Choice Assistants from Section A. Once again it should be emphasized here: You are completely free to decide whether to make adjustments or not, and if so, which decisions to adjust.

Payment

Each of your decisions for or against changing your previous choice is as likely to become payoff relevant as any other decision you make in Part I of this experiment. If any of the choices in Section C are selected for payoff, that choice will be paid off in the same way as described earlier in Section A and Section B, respectively.

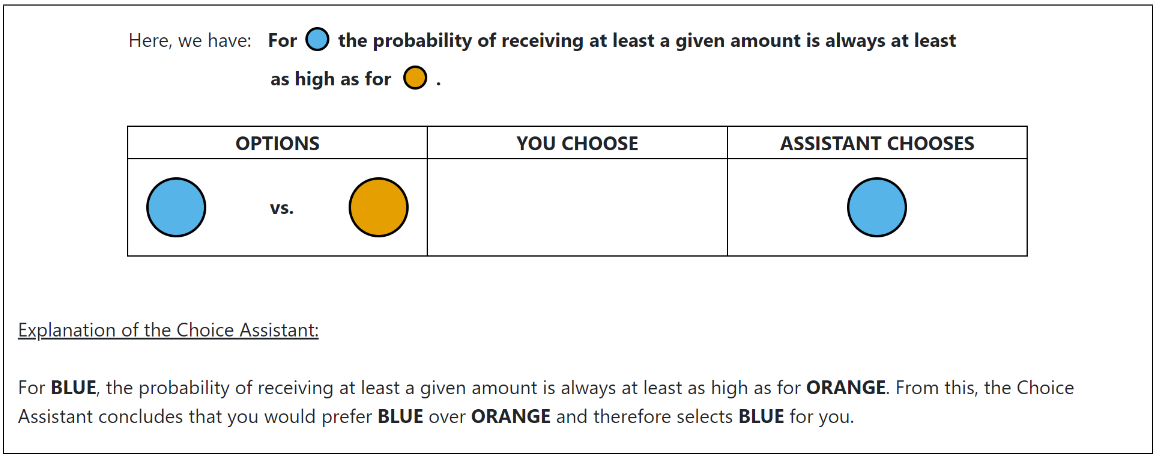
Important: The decisions from Section C are independent. Thus, they do not overwrite any decision from Sections A and B. Therefore, both the original decision from Section A or B can be selected for payment and the possibly re-evaluated decision from Section C can be selected. So if the possibly re-evaluated choice regarding a Choice Assistant becomes relevant for payoff, and you have decided to (now) make the decision yourself, then the lottery decision will be displayed to you at the end of the experiment and you will make a decision yourself. If you have (now) decided to use the Choice Assistant, then at the end of the experiment you will be shown which lottery the Choice Assistant has chosen for you.

If the possibly re-evaluated choice regarding a lottery becomes relevant for the payoff, then the lottery (now) chosen by you will be played out in each case.

B.2. Axiom Descriptions

Note: The text below shows the description of axioms on the decisions screens in the first stage of the experiment, when preferences over axioms were elicited. Descriptions displayed here are a translation into English. Original descriptions where in German and are available from the authors upon request.

Choice Assistant for FOSD



Explanation of the Choice Assistant

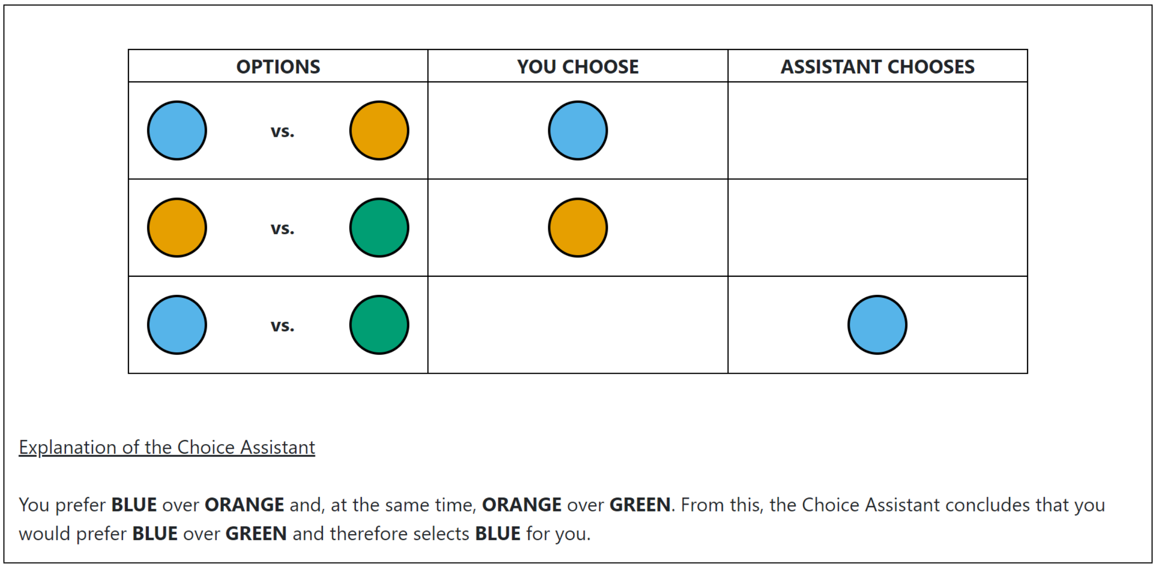
With **BLUE**, the probability of receiving at least a certain amount is always at least as high as with **ORANGE**. From this, the Choice Assistant concludes that you would prefer **BLUE** over **ORANGE** and therefore selects **BLUE** for you.

Example for Illustration:

For this example, do not think about amounts of money, but about types of ice cream.

- Imagine that there are the following possible ice cream sundaes:
  - **BLUE sundae:** A fair coin is tossed. Heads it contains 1 scoop of chocolate ice cream, tails it contains 2 scoops of chocolate ice cream.
  - **ORANGE sundae:** Contains 1 scoop of chocolate ice cream.
- From this, the Choice Assistant concludes that given the choice between the **BLUE** and **ORANGE** sundae, you would prefer the **BLUE** sundae and therefore selects **BLUE** for you.

Choice Assistant for TRANS



Explanation of the Choice Assistant

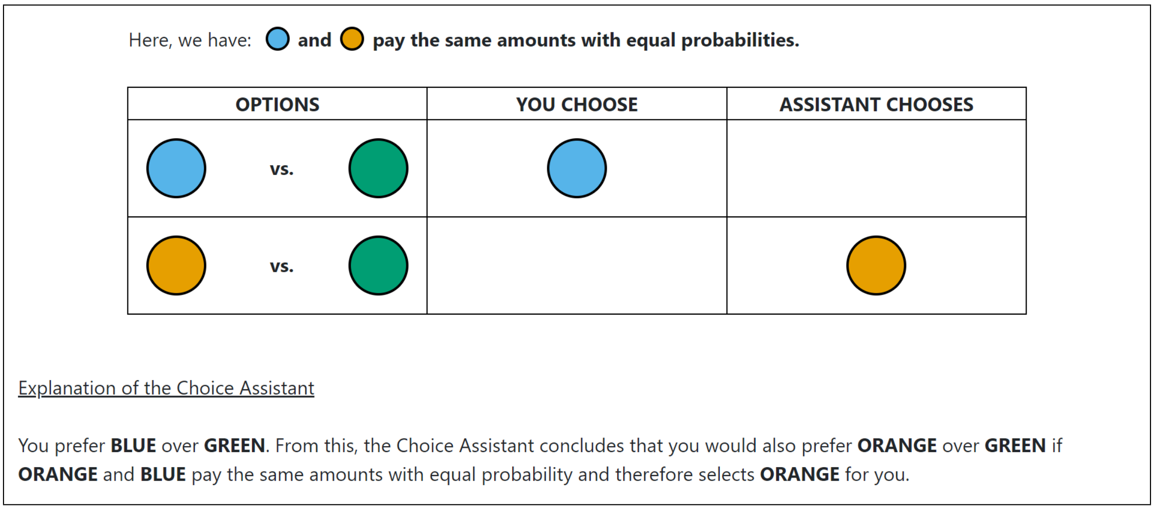
You prefer **BLUE** to **ORANGE** and at the same time **ORANGE** to **GREEN**. From this, the Choice Assistant concludes that you would prefer **BLUE** over **GREEN** and therefore selects **BLUE** for you.

Example for Illustration:

For this example, do not think about amounts of money, but about types of ice cream.

- Imagine that there are the following possible ice cream sundaes:
  - **BLUE sundae:** Includes 1 scoop of yogurt ice cream.
  - **ORANGE sundae:** Includes 1 scoop of pistachio ice cream.
  - **GREEN sundae:** Includes 1 scoop of cherry ice cream.
- Imagine you have a choice between the **BLUE** sundae and the **ORANGE** sundae. Suppose you like yogurt ice cream better than pistachio ice cream, so you choose the **BLUE** sundae.
- Also, imagine that you have a choice between the **ORANGE** sundae and the **GREEN** sundae. Suppose you like pistachio ice cream better than cherry ice cream and therefore choose the **ORANGE** sundae.
- From this, the Choice Assistant concludes that if you had to choose between the **BLUE** sundae and the **GREEN** sundae, you would prefer the **BLUE** sundae and therefore selects **BLUE** for you.

Choice Assistant for CONS



Explanation of the Choice Assistant

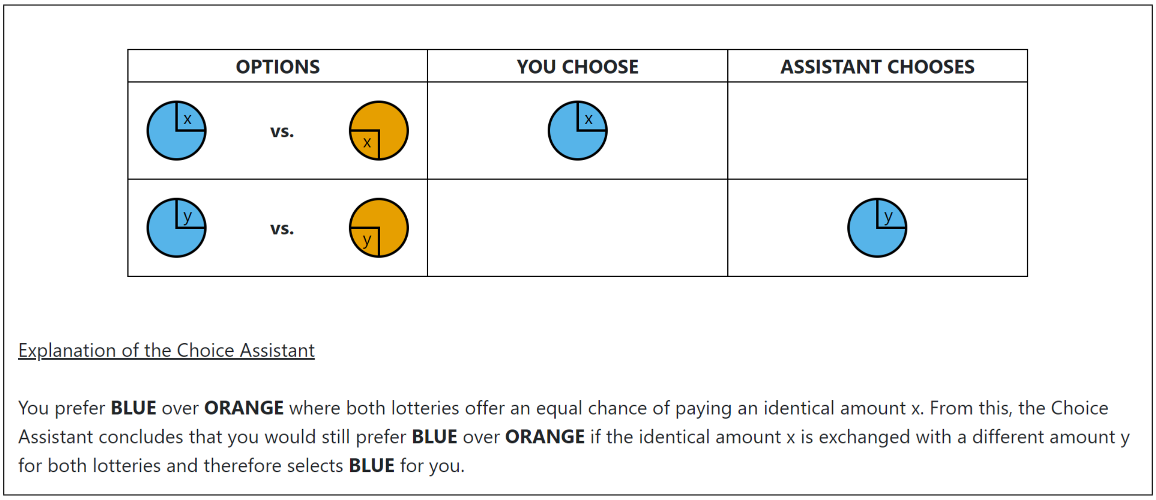
You prefer **BLUE** to **GREEN**. From this, the Choice Assistant concludes that you would also prefer **ORANGE** over **GREEN** if **ORANGE** paid out the same amounts with the same probabilities as **BLUE**, and therefore selects **ORANGE** for you.

Example for Illustration:

For this example, do not think about amounts of money, but about types of ice cream.

- Imagine that there are the following possible ice cream sundaes:
  - **BLUE sundae:** A fair coin is tossed. If heads, it contains 1 scoop of strawberry ice cream; if tails, it contains 1 scoop of raspberry ice cream.
  - **GREEN sundae:** Includes 1 scoop of hazelnut ice cream.
  - **ORANGE sundae:** A fair coin is tossed. Heads it includes 1 scoop of raspberry ice cream, tails it includes 1 scoop of strawberry ice cream.
- Imagine you have a choice between the **BLUE** sundae and the **GREEN** sundae. Suppose you like both strawberry ice cream and raspberry ice cream better than hazelnut ice cream, so you choose the **BLUE** sundae.
- From this, the Choice Assistant concludes that given the choice between the **ORANGE** sundae and the **GREEN** sundae, you would prefer the **ORANGE** sundae and therefore selects **ORANGE** for you.

Choice Assistant for BRANCH



OPTIONS	YOU CHOOSE	ASSISTANT CHOOSES
x vs. x	x	
y vs. y		y

Explanation of the Choice Assistant

You prefer **BLUE** over **ORANGE** where both lotteries offer an equal chance of paying an identical amount x. From this, the Choice Assistant concludes that you would still prefer **BLUE** over **ORANGE** if the identical amount x is exchanged with a different amount y for both lotteries and therefore selects **BLUE** for you.

Explanation of the Choice Assistant

You prefer **BLUE** over **ORANGE**, with both lotteries paying an identical payout x with an equal chance. From this, the Choice Assistant concludes that you would continue to prefer **BLUE** over **ORANGE**, even if the identical amount x were exchanged for a different amount y in both lotteries, and therefore selects **BLUE** for you.

Example for Illustration:

For this example, do not think about amounts of money, but about types of ice cream.

- Imagine that there are the following possible ice cream sundaes:
  - **BLUE sundae:** A fair coin is tossed. On tails it contains 1 scoop of vanilla ice cream, on heads it contains 1 scoop of lemon ice cream.
  - **ORANGE sundae:** A fair coin is tossed. On tails it includes 1 scoop of lemon ice cream, on heads it includes 1 scoop of banana ice cream.
- Imagine you have a choice between the **BLUE** sundae and the **ORANGE** sundae. Suppose you like vanilla ice cream better than banana ice cream, so you choose the **BLUE** sundae.
- From this, the Choice Assistant concludes that you would still prefer the **BLUE** sundae over the **ORANGE** sundae, even if you replace the 1 scoop of lemon ice cream (x) with 1 scoop of mango ice cream (y) in both sundaes, and therefore selects **BLUE** for you.

B.3. Overview of Choice Problems

	$s=1$	$s=2$	$s=3$	$s=4$
L_1	€0	€30	€9	€0
L_2	€9	€9	€0	€30
Prob.	18%	20%	42%	20%

Problem 1 (FOSD I).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_1$	€0	€39	€9	€0
$\widehat{L}_2$	€9	€9	€0	€36
Prob.	20%	20%	40%	20%

Problem 2 (FOSD II).

	$s=1$	$s=2$	$s=3$
L_6	€33	€0	€0
L_8	€21	€0	€21
Prob.	45%	45%	10%

Problem 3 (CONS I.1).

	$s=1$	$s=2$	$s=3$
L_7	€0	€33	€0
L_8	€21	€0	€21
Prob.	45%	45%	10%

Problem 4 (CONS I.2).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_6$	€0	€0	€0	€42
$\widehat{L}_8$	€0	€24	€0	€24
Prob.	50%	10%	20%	20%

Problem 5 (CONS II.1).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_7$	€0	€0	€42	€0
$\widehat{L}_8$	€0	€24	€0	€24
Prob.	50%	10%	20%	20%

Problem 6 (CONS II.2).

	$s=1$	$s=2$	$s=3$
L_3	€24	€5	€5
L_4	€14	€14	€3
Prob.	30%	40%	30%

Problem 7 (TRANS I.1).

	$s=1$	$s=2$	$s=3$
L_4	€14	€14	€3
L_5	€9	€9	€9
Prob.	30%	40%	30%

Problem 8 (TRANS I.2).

	$s=1$	$s=2$	$s=3$
L_3	€24	€5	€5
L_5	€9	€9	€9
Prob.	30%	40%	30%

Problem 9 (TRANS I.3).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_3$	€20	€6	€6	€0
$\widehat{L}_4$	€15	€15	€2	€0
Prob.	32%	24%	24%	20%

Problem 10 (TRANS II.1).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_4$	€15	€15	€2	€0
$\widehat{L}_5$	€10	€10	€10	€0
Prob.	32%	24%	24%	20%

Problem 11 (TRANS II.2).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_3$	€20	€6	€6	€0
$\widehat{L}_5$	€10	€10	€10	€0
Prob.	32%	24%	24%	20%

Problem 12 (TRANS II.3).

	$s=1$	$s=2$	$s=3$
L_9	€15	€15	€15
L_{10}	€0	€24	€15
Prob.	20%	30%	50%

Problem 13 (BRANCH I.1).

	$s=1$	$s=2$	$s=3$
L_{11}	€0	€0	€15
L_{12}	€0	€24	€0
Prob.	20%	30%	50%

Problem 14 (BRANCH I.2).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_9$	€18	€18	€18	€0
$\widehat{L}_{10}$	€0	€22	€18	€0
Prob.	10%	30%	40%	20%

Problem 15 (BRANCH II.1).

	$s=1$	$s=2$	$s=3$	$s=4$
$\widehat{L}_{11}$	€0	€0	€18	€0
$\widehat{L}_{12}$	€0	€22	€0	€0
Prob.	10%	30%	40%	20%

Problem 16 (BRANCH II.2).

	$s=1$	$s=2$	$s=3$
L_A	€20	€6	€6
L_B	€15	€15	€2
Prob.	40%	30%	30%

Problem 17 (TRANS Inc.1).

	$s=1$	$s=2$	$s=3$
L_B	€15	€15	€2
L_C	€10	€10	€10
Prob.	40%	30%	30%

Problem 18 (TRANS Inc.2).

	$s=1$	$s=2$	$s=3$	$s=4$
L_D	€30	€0	€30	€0
L_E	€60	€0	€0	€0
Prob.	50%	10%	20%	20%

Problem 19 (CONS Inc.).

	$s=1$	$s=2$	$s=3$	$s=4$
L_F	€6	€6	€0	€24
L_G	€0	€28	€6	€0
Prob.	10%	20%	40%	30%

Problem 20 (BRANCH Inc.).

B.4. Incentivization of Axiom Choices and Preference Input

The incentivization procedures were the same for original and revised axiom choices as well as for original and revised lottery choices. Lottery choices were incentivized in the standard manner; i.e., if a given lottery choice turned out to be payoff relevant, a subject was paid a realization from the lottery she selected. This realization was determined by another random draw from the computer.

With regard to the incentivization of (both original and revised) axiom choice, if a subject stated that she wants a given axiom to make decisions on her behalf and if this axiom choice was selected as the payoff-relevant decision at the end of the experiment, then the axiom was applied to a pairwise choice situation where it had implications. Any information necessary to apply the axiom – i.e., preference statements from the individual with regard to other pairwise choice situations – was elicited throughout Stage 2, where the original lottery choices were made. The subject then was paid a realization of the lottery 'chosen' by the axiom. (For details see Appendix B.4.) If the subject did not select the axiom to make choices on her behalf and this decision was selected as payoff relevant, then the subject made the relevant lottery choice on her own.

Regarding the incentivization of revision decisions, subjects were explicitly told that they can change any of their previously made choices or leave them as they were. While the revision opportunity for each axiom occurred on a single screen, any decision associated with that screen (irrespective of whether the decision was to revise a previously made choice or to leave a previously made choice unchanged) had an independent chance of being selected for payment. The subject's original choices were not overturned by the revision opportunity but still could be chosen for payment.

To clarify how the information necessary to apply the axiom was elicited, consider the example of TRANS. Suppose that in Stage 1 a subject selects the TRANS axiom to make decisions on her behalf. Then, in reference to Figure X, in Stage 2 this subject faces the pairwise choice between L_A and L_B in Problem 17 as well as the pairwise choice between L_B and L_C in Problem 18. Importantly, in Stage 2 the subject does not face the pairwise choice between L_A and L_C. Suppose further that this individual chooses L_A in Problem 17 (i.e., $L_A \succ L_B$) and L_B in Problem 18 (i.e., $L_B \succ L_C$). Also, suppose that the subject's selection of the TRANS axiom in the Stage 1 turns out to be the payoff relevant decision. The subject then would be shown the pairwise choice between L_A and L_C and she would be informed that, based on her lottery decisions in the second stage, the TRANS axioms prescribed the choice of lottery L_A. The monetary payoff of lottery L_A would randomly be determined by the computer and paid out to the subject. If, in contrast, the subject did not select the TRANS axiom in the first stage and this decision is determined as payoff relevant, then the subject would make the choice between L_A and L_C herself.[40]

[40] For the record, it could also happen that a subject selected the TRANS axiom and still had to make the choice between L_A and L_C herself. This happened if, in the pairwise choice between L_A and L_B and in the pairwise choice between L_B and L_C in Stage 2, she preferred both L_A and L_C over L_B or if she preferred L_B over both L_A and L_C. In these cases the TRANS axiom "has no bite" and makes no prescription which lottery to choose.

B.5. Post-Experimental Tests

Risk Attitudes. Risk attitudes were elicited with the "bomb" risk elicitation task (BRET) by Crosetto and Filippin (2013) using the ready-to-use oTree software module from Holzmeister and Pfurtscheller (2016). Subjects play one round of the BRET. They decide how many boxes of a 8×8 grid to collect, one of which contains a bomb. Between pressing the "Start" and "Stop" button, the computer would collect one box each second, starting in the upper left corner and proceeding row by row. Earnings increase by €0.30 with each box collected, but are zero if the bomb is also collected. We use the number of collected boxes as our measure of an individual's risk attitude.

Regret Aversion. Regret aversion was assessed in two different ways. For the first regret measure, subjects answer two questions about the amount of regret they feel in a specific situation described to them. There are 10 answer options ranging from no regret at all to extreme regret. We use the arithmetic mean over the two questions as our main measure for regret aversion. The questions read:

- Imagine you usually play the lottery every month and always choose your date of birth as the numbers. This month, however, you have forgotten to hand in your lottery ticket. You have just found out that your exact numbers have been drawn and that you would have won €50 if you had submitted your ticket. How much do you regret not having submitted your lottery ticket?
- Imagine it's the last soccer match in the championship. Your team is awarded a penalty shortly before the final whistle. If the penalty is converted, your team wins the game and the championship. If the penalty is missed, the game ends in a draw and your team does not win the championship. You step up to take the penalty and decide to shoot into the left corner. Unfortunately, the goalkeeper has also chosen the left corner and is able to save your shot. How much do you regret choosing the left corner?

For the second regret measure, subjects choose between two lotteries, were they either win €5 for sure (option A) or €80 with a probability of 4% and €0 with a probability of 96% (option B). Then they are asked, whether they want to prevent that the result of the lottery they have not chosen is displayed to them. In order to do so, the subjects indicate with which probability they want to have the result not shown, by specifying a number between 0% and 100%. We use the probability given by individuals as an additional measure for regret aversion. However, this measure is only valid for subjects that choose the safe option A and is therefore not used in regression analysis.

Cognitiv Reflection Ability. The subject's propensity to override an intuitive, but incorrect, response with a more analytical correct response was measured using the cognitive reflection test, using seven questions in total. For each correct answer, subjects earn €0.30. We use the average number of correct answers as our measure of an individual's cognitive reflection ability.

The three original CRT questions taken from Frederick (2005) read:

- A bat and a ball together cost 110 cents. The bat costs 100 cents more than the ball. How much does the ball cost? (intuitive answer: 10 cents; correct answer: 5 cents).
- If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? (intuitive answer: 100 min; correct answer: 5 min).
- In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? (intuitive answer: 24 days; correct answer: 47 days)

The additional four CRT-2 questions taken from Thomson and Oppenheimer (2016) read:

- If you're running a race and you pass the person in second place, what place are you in? (intuitive answer: first; correct answer: second)
- A farmer had 15 sheep and all but 8 died. How many are left? (intuitive answer: 7; correct answer: 8)
- Emily's father has three daughters. The first two are named April and May. What is the third daughter's name? (intuitive answer: June; correct answer: Emily)
- How many cubic feet of dirt are there in a hole that is 3' deep x 3' wide x 3' long? (intuitive answer: 27; correct answer: none)

C. Differences in the Experimental Design compared to Nielsen and Rehbeck (2022)

Different Axioms

Next to FOSD, TRANS, CONS and BRANCH, NR also include the canonical choice axioms textitmixture independence and *independence of irrelevant alternatives*. We include only those axioms from NR that apply to pairwise choice and for which correlation-sensitive preferences (such as regret theory) predict systematic violations once the correlation structure of the lotteries in question is appropriately specified.

Furthermore, to control for potential experimenter demand effects or other underlying drivers of axiom selection, NR included six so-called control axioms, which prescribe the exact reverse implication of the six canonical choice axioms of main interest, as well as six rather meaningless distractor axioms. To streamline our experiment and to avoid choice fatigue, we refrained from including control and distractor axioms. Instead, we rather take as given the insight of NR that axiom selection is not driven by experimenter demand effects, avoidance of responsibility or algorithm aversion but reflects a manifestation of genuine preferences over axioms.

Different Depictions of Axioms

To make the axioms under consideration easily understandable, we followed NR and used pictorial logic statements to illustrate each axiom, with colored circles representing otherwise unspecified lotteries. However, our depiction of FOSD, CONS and BRANCH differs from NR. Only the pictorial logic statement to depict TRANS is identical in both studies.

Our depiction of FOSD is logically different from NR. Specifically, in accordance with the standard definition of first-order stochastic dominance, our depiction of FOSD is based exclusively on a property of the (cumulative) probability distributions of the lotteries in question and does not require any previous decision based on which the axiom then is applied. In contrast, as depicted in Figure 14, the application of FOSD in NR requires an initial choice between two lotteries which then serves as an input for the choice between two mixture lotteries that randomize over the two initial lotteries with different mixing probabilities. While our depiction of FOSD requires spelling out the dominance relationship between two lotteries, it might be considered as simpler than the depiction in NR as it does not require understanding mixture lotteries.

The pictorial logic statement for CONS in NR shows two identical decisions, see Figure 15. We, in contrast, represent in our pictorial logic statement of CONS the two lotteries with identical probability distributions over payoffs with different colors, see Figure **??**.

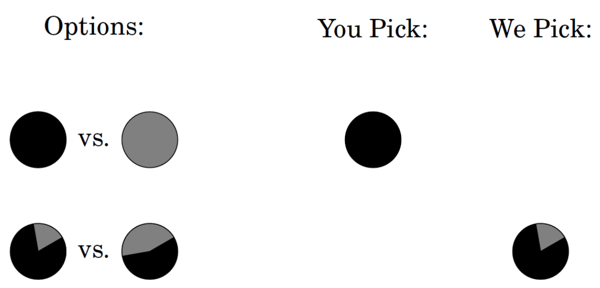


Figure 14: FOSD in NR

The reason is that the two lotteries with identical probability distributions over outcomes are not identical but different Savage acts; i.e., the juxtaposition of outcomes differs in comparison to an identical alternative lottery (the green circle in our pictorial logic statement). Note that the difference in juxtaposition of outcomes is observable only if information regarding the lotteries' correlation is provided.

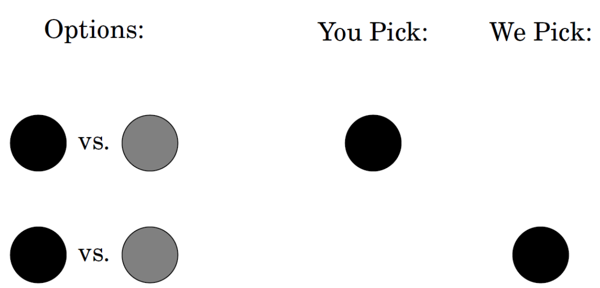


Figure 15: CONS in NR

As shown in Figure 16, not only the depiction of FOSD, but also the pictorial logic statement to explain BRANCH in NR involves mixture lotteries. Specifically, the choice between two mixture lotteries that both play out a given common lottery with the same probability is used as an input for the choice between two other mixture lotteries which are identical to the first two mixture lotteries except for the initial common lottery being replaced by a different common lottery. Our pictorial logic statement to explain BRANCH refrains from invoking the notion of mixture lotteries by indicating (within the colored circles representing lotteries) that a given outcome (denoted by x) which is paid out with the same probability under the initial two lotteries is replaced by a different outcome (denoted by y).

Different Lottery Choices

The decision problems used by us as well as by NR are inspired by existing evidence reporting relatively high choices in violation of the targeted axiom. We relied on evidence that reported high violation rates of canonical axioms for lottery choices displayed in the

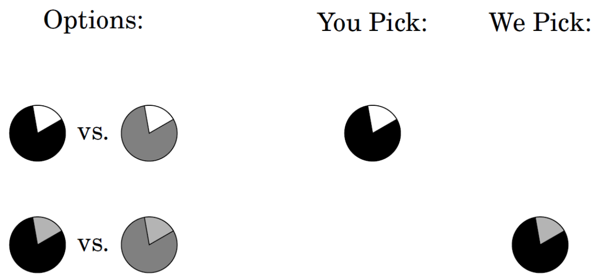


Figure 16: BRANCH in NR

matrix format, where choices that violate the axiom in question are potentially triggered by juxtaposition effects. NR, on the other hand, relied partly on studies reporting high violation rates for display formats not containing information on how the lotteries' outcomes are juxtaposed/correlated. This point can be best illustrated for the case of FOSD. All four questions asked by NR to target FOSD followed the structure in Birnbaum and Martin (2003). For example, one choice problem asked by them is the following:

10%	chance of	\$2	5%	chance of	\$2
5%	chance of	\$16	5%	chance of	\$3
85%	chance of	\$19	90%	chance of	\$19
	Lottery A			**Lottery B**	

Lottery B dominates Lottery A in the sense of first-order stochastic dominance. A line-wise comparison of the two lotteries may trick a subject into choosing Lottery A.

The choice problems used in our experiment rely on a particular juxtaposition of outcomes in order to trigger a violation of FOSD. Consider our Problem 1 (FOSD I) described in Appendix B.3. The fear of the high potential post-decisional regret in state $s = 4$ may lead a subject to choose the dominated option L_2. When this choice problem is displayed in the format used by NR, as we do in Treatment R, it takes the following form:

38%	chance of	€0	42%	chance of	€0
42%	chance of	€9	38%	chance of	€9
20%	chance of	€30	20%	chance of	€30
	Lottery L_1			**Lottery** L_2	

With this display format it is rather obvious that Lottery L_1 dominates Lottery L_2. Not surprisingly, in Treatment R, none of our subjects chose the dominated lottery and thus none violated FOSD.

To conclude, one might argue that the choice problems we use are designed to trigger juxtaposition effects – or more generally context effects – that lead to choices in violation of the targeted canonical axiom. The choice problems used by NR, on the other hand, are designed to trick subjects into making lottery choices that violate the targeted canonical axiom; i.e.,they work akin to optical illusions. These violations, by design, are rather mistakes than a manifestation of true preferences.

Different Structures for the Revision Opportunity

We modified the design of the third stage in the experiment by NR, where subjects have an opportunity to revise their axiom preferences and lottery choices, in two central aspects: the scope and the nature of the revision opportunity.

First, regarding the scope of the revision opportunity, we do not restrict the opportunity to revise one's choices to the case where a subject's stated axiom preferences and her subsequent lottery choices turned out to be inconsistent. Instead, we allow subjects to revise *all* their axiom preferences and lottery choices. Of particular interest here to us is the case where a subject's lottery choices are necessarily consistent with her previously stated axiom preferences because the subject did not express a preference for the given axiom to make choices on her behalf in the first place. We believe that a subject violating an axiom and then sticking to her lottery choices in this case is highly indicative of an intentional violation.

Second, with regard to the nature of the revision opportunity, we implement "badge revisions" for each canonical axiom rather than independent revisions to underline the axiomatic character of our choice assistants. In NR, each revision decision was made independent of any other revision decisions. That is, if a subject violated a given axiom on multiple occasions, this subject had as many revision opportunities *with regard to the same axiom*. In particular, a subject that violated an axiom more than once could stick with the axiom in one instance and renounce the same axiom in another instance. In order to highlight each axiom's nature as a universally valid guiding principle, we impose badge revisions in which a subject has to decide whether to revise her decisions in the light of *all* the lottery choices that are related to a given axiom.[41]

While primarily meant to widen the scope of our analysis and to highlight the axioms' inherent character, these two modifications have the additional benefit of making the experiment more symmetric across subjects. In NR, with revisions regarding one and the same axiom being independent and with the revision opportunity being feasible only in case of lottery choices that are inconsistent with a selected axiom, the number of revision decisions ranged from 2 to 22. In our experiment, each subject faces the same number of four revision decisions.

[41] The reason for NR to opt for independent revision decisions rather than for badge revisions was to reduce the cognitive load and to avoid choice fatigue in their experiment. We do not believe that badge revisions will necessarily increase cognitive load and choice fatigue significantly in our experiment as we have significantly fewer axiom choices (4 instead of 18) and lottery choices (20 instead of 33).

Different Wordings

First of all, our study was conducted in the German language, whereas the study by NR was conducted in the English language. This already implies modifications and differences in wordings.

More specifically, while axioms were presented in the spirit of algorithms that are capable of making choices on a subject's behalf in both studies, the wording used to refer to axioms throughout the experiment was different. Specifically, while NR labeled axioms as "rules", we referred to axioms as "choice assistants" (*Auswahlassistenten*). With our subject pool consisting mostly of German students and with Germans being widely regarded as sticklers for rules and order, we wanted to avoid that our subjects feel that they were expected to follow a rule in the sense of following a regulation or a law.

Furthermore, we opted for a somewhat more neutral wording for the revision opportunity in Stage 3. We did not directly tell subjects that their "choices were inconsistent with [the] rule" (NR, p.45 in the Online Appendix). Instead, we only reminded subjects of the lottery choices they had made in Stage 2 and told them what option the corresponding choice assistant would have chosen. Hence, in our experiment, subjects had to draw the conclusion themselves whether their lottery choices were consistent with an axiom's prescription or not.