Similarity and Contrast in Decision Making Under Risk and Uncertainty

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Vollständiger Abdruck der von der Fakultät für Wirtschafts- und Organisationswissenschaften der Universität der Bundeswehr München zur Erlangung des akademischen Grades eines

Doktors der Wirtschafts- und Sozialwissenschaften (Dr. rer. pol.)

genehmigten Dissertation.

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Die Dissertation wurde am 14.03.2022 bei der Universität der Bundeswehr München eingereicht und durch die Fakultät für Wirtschafts- und Organisationswissenschaften am 29.06.2022 angenommen. Die mündliche Prüfung fand am 13.07.2022 statt.

> “*Uncertainty and expectation are the joys of life. Security is an insipid thing.*”
>
> William Congreve

Acknowledgments

In preparing this thesis, I received support from many different people. I am deeply grateful to every one of them.

First and foremost, I thank Friedrich L. Sell, who gave me the opportunity to write this dissertation under his supervision. He provided me with excellent support, which did not subside after his retirement, even though work did not get less. I profited from his most valuable comments, his critical feedback, and his great experience, both with regard to writing my dissertation and my professional life. I hope there are many more joint research projects and lunch breaks ahead of us.

I am also grateful to Stefan D. Josten, my second supervisor. He was always available and extremely generous with his time. We had illuminating discussions regularly. Working at his chair, he gave me all freedom for my research and implementing my ideas.

Furthermore, I owe special gratitude to Johannes Pfeifer, whom I was fortunate to have met. His most valuable feedback, comments, and suggestions helped improve this thesis a lot. Additionally, he taught me how to use LaTeX for writing my dissertation – an exhausting operation as I turned out not to be a natural. His patience with me was admirable.

I also want to thank Beate Sauer. She introduced me to the in-house life of the university, the administration, and all the practical matters essential to a beginner. I also got precious advice from her for my dissertation.

Then I thank Saskia Schiele, Martin Pfotenhauer, and Martin Sperr, my colleagues from the chair of statistics, who I frequented on a regular basis with all kinds of questions on mathematics and statistics. Their willingness to always take their time for me was exceptional. Next, I want to thank my colleague

Lorenz Schönherr. We were often confronted with similar challenges, and I benefited a lot from his encouragement and our constant mutual exchange of experience.

I would also like to thank the student assistants who accompanied me throughout the years and provided me with great support. Tanja Angenend, Jennifer Dikme, Antonia Gottmann, Lena Schlausch, and Tabea Schulte helped me with numerous research assignments, designed figures and tables, and successfully completed many more tasks.

Eventually, I would like to thank my parents, Esther and Hubert. They encouraged me to write this dissertation and always believed in me. Furthermore, they kept me free from many everyday life obligations, help for which a 30-year-old son should actually have been too embarrassed to ask for.

Last but certainly not least, I thank Mona, my partner. She supported me through all the ups and downs of a postgraduate's life. Although under great stress due to the simultaneous passing of her exams, she was a permanent and reliable help. She did final proofreading on numerous occasions and always was a patient listener in countless talks.

Abstract

Decision theories like skew-symmetric additive models and similarity judgments assume that the similarity or contrast between specific pairs of payoffs shapes an agent's decision making process when faced with a choice between two lotteries. This rationale experienced a revival in economic theory with the recent introduction of salience theory, which – similarly to its skew-symmetric additive relatives – predicts the correlation between lotteries to affect agents' choices.

This thesis investigates the role of similarity and contrast in decision making under risk and uncertainty based on implications derived from skew-symmetric additive models such as salience theory and from similarity judgments. Employing a laboratory experiment with decision problems presented in two different display formats, it is investigated whether the change of a common consequence shared by two perfectly correlated lotteries affects subjects' choices. Under both display formats and in contrast to the prediction of salience theory, subjects' choices shift systematically when altering the common consequence. A second experiment shows that recent evidence in support of salience-predicted correlation effects resulted from changes in the display format rather than the correlation between lotteries. In a third experiment involving a setup that allows studying correlation effects without confounding changes in the display format, no significant salience-predicted correlation effects can be found. Furthermore, in a horse-race between display format and potential salience effects, the former are quantitatively more important. Finally, by building on predictions derived from similarity judgments, the role of similarity and contrast is examined within a broader context, independently of the correlation between lotteries. However, altering the juxtaposition between payoffs in order to guarantee varying pair-wise payoff comparisons does not significantly affect subjects' choices.

Kurzfassung

Entscheidungstheorien wie schief-symmetrisch additive Modelle und Ähnlichkeitsurteile nehmen an, dass bei der Wahl zwischen zwei Lotterien die Ähnlichkeit oder der Kontrast zwischen bestimmten Paaren von Auszahlungen menschliches Entscheidungsverhalten beeinflusst. Dieses Prinzip erfuhr in der Wirtschaftstheorie eine Wiederbelebung durch die Salienztheorie, die – ähnlich wie ihre schief-symmetrisch additiven Verwandten – vorhersagt, dass die Korrelation zwischen Lotterien die Wahl der Akteure beeinflusst.

Die vorliegende Arbeit untersucht die Rolle von Ähnlichkeit und Kontrast im Zuge von Entscheidungsfindungen unter Risiko und Unsicherheit auf der Grundlage von schief-symmetrisch additiven Modellen wie der Salienztheorie sowie von Ähnlichkeitsurteilen. Mithilfe eines Laborexperiments, das Entscheidungsprobleme in zwei unterschiedlichen Darstellungsformen präsentiert, wird untersucht, ob die Veränderung einer gemeinsamen Konsequenz zweier perfekt korrelierter Lotterien die Wahl der Probanden beeinflusst. Konträr zu den Vorhersagen der Salienztheorie ändert sich die Wahl der Probanden in beiden Darstellungsformen systematisch im Zuge der Veränderung der gemeinsamen Konsequenz. Ein zweites Experiment zeigt, dass die jüngsten Belege für die von der Salienztheorie vorhergesagten Korrelationseffekte auf Änderungen der Darstellungsform und nicht der Korrelation zwischen den Lotterien zurückgehen. Ein drittes Experiment, das störende Änderungen der Darstellungsform ausschließt, findet ebenfalls keinen Hinweis für Korrelationseffekte. Darüber hinaus übertreffen in einem direkten Wettbewerb Effekte der Darstellungsform jedwede potenziellen Salienz-Effekte. Abschließend werden Vorhersagen von Ähnlichkeitsurteilen in einem breiteren Kontext untersucht, unabhängig von der Korrelation zwischen den Lotterien. Die Neuordnung von Auszahlungsbeträgen, welche sich verändernde paarweise Auszahlungsvergleiche gewährleistet, hat jedoch keinen signifikanten Einfluss auf das Entscheidungsverhalten der Probanden.

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Introduction

In capitalistic, free-market societies, competition between economic agents is meant to spawn an improvement and increase of the variety of goods and services as well as procedures for more efficient and cost-saving production. As Hayek (1969) clarifies, the principle of competition is reasonable only if the ultimate winners are not a foregone conclusion. That is, the fundamental factors causing the competitors' actions are unknown. Hence, it is precisely uncertainty about which commodities or production techniques turn out superior that makes competition meaningful in the first place.

Following Blümle (1980), uncertainty is constitutive for competitive markets, but at the same time, the market economy is best suited to deal with and consolidate uncertainty. He argues that there is less risk in a decentralized economy for getting the overall scheme of things wrong. In the case of a centrally managed economy's uniform objective, errors tend to balance less as they are not stochastically independent. Furthermore, Blümle (1980) states that a lack of alternatives means a lack of experience making due corrections more difficult. Thus, while individual uncertainty about goals may be greater in market economies, overall economic uncertainty may be less.

Having emphasized the great importance of uncertainty in the free-market economy, some clarification with regard to definition is necessary. Terminology is not always used consistently in the literature. The most common definition of uncertainty, which is also used in this thesis, is based on Knight (1921). He distinguishes between uncertainty and risk, with the latter involving precisely known outcomes and probabilities of occurrence. In contrast, uncertainty lacks this measurable nature and includes incidents in which the possible outcomes or the respective probabilities (or both) are not detectable without a doubt. In many cases, agents form subjective beliefs about these outcomes or probabilities, which therefore is often referred to as "subjective uncertainty" in the relevant literature. By contrast, objective uncertainty serves as a synonymous phrase for risk. The most extreme form of uncertainty, where agents have no information about outcomes or probabilities, is called "total ambiguity". With regard to probabilities, this form of uncertainty is best known from Ellsberg (1961) urns that involve differently colored balls with unknown proportions. Outcomes then depend on the color of an eventually drawn ball.

In real-life applications, the boundaries between those definitions are often blurred. For example, career planning involves a great deal of uncertainty (see, e.g., Barth et al. 2017; Grove et al. 2019; R. Stinebrickner and T. R. Stinebrickner 2013). A young researcher at the start of her academic career can look up the odds of getting a professorship and will find that in Germany, about 1 of 22 applications is on average successful (Bundesbericht Wissenschaftlicher Nachwuchs 2021), which may be perceived as risk or objective uncertainty. However, the young researcher's confidence in becoming a professor most likely not only depends on those numbers but also on her self-assessment concerning her competencies and academic potential. Therefore, her career planning also involves subjective uncertainty. Alternatively, investment behavior and the stock market are domains highly affected by uncertainty (see, e.g., Bolton et al. 2019; Ebert et al. 2020; Grenadier and N. Wang 2007). For example, during the global COVID-19 pandemic, there was lots of uncertainty about future economic development due to, e.g., the threat posed by new variants of the virus. At the beginning of the pandemic, when practically everything was unknown and the stock market collapsed, the situation might even be considered close to total ambiguity.

Due to its far-reaching impact on various fields of application and, in particular, its constitutive role for the free-market economy, decision making under risk and uncertainty is a branch of science as old as the history of economic thought itself. Given that economic theory has been heavily influenced by neoclassical economics and its postulate of the *Homo economicus*, i.e., the perfectly rational economic agent, it is hardly surprising that the economic "workhorse" model of decision making under risk and uncertainty, *expected utility theory* (Bernoulli 1954; Neumann and Morgenstern 1947), is normative in character. The theory posits a set of four axioms for rational behavior.[1] These axioms are necessary to prove that an agent faced with a choice between risky or uncertain alternatives behaves as if she maximizes the expected value of a utility function defined over the potential outcomes.

[1]These axioms are completeness, transitivity, continuity, and independence. The assumption of completeness guarantees that decision makers have a well-defined preference relation for any pair of lotteries. Furthermore, transitivity ensures that preference relations are consistent with one another, i.e., if lottery A is at least as good as lottery B and lottery B is at least as good as lottery C, it follows that C cannot be preferred to A. The continuity axiom precludes lexicographic preferences meaning that very small changes in probabilities do not alter a preference relation. Finally, the independence axiom states that an element shared by two offered lotteries should not affect a rational agent's decision (Mas-Colell et al. 1995).

Subjects, however, systematically violate the axioms postulated by expected utility theory in real-world applications and laboratory experiments, highlighting its shortcomings in predicting and explaining actual choice behavior. Probably the most famous evidence against expected utility theory is the Allais paradox (Allais 1953), which contradicts the independence axiom. Over the years, researchers discovered many more so-called anomalies in decision making under risk and uncertainty, i.e., systematically observed behavior that refutes expected utility theory and the assumption of a perfectly rational economic agent. For example, people purchase insurance while participating in risky gambles (Friedman and Savage 1948). Also, agents' decisions are sensitive to subtle differences in framing, i.e., the specific presentation, formulation, and connotation of a choice problem – without any changes to the probabilities and outcomes being made (see, e.g., Ellingsen et al. 2012; Ropret Homar and Knežević Cvelbar 2021; Tversky and Kahneman 1981). Such framing effects even lead agents to prefer stochastically dominated options, thus challenging the basic principles of rationality (Birnbaum 2004).

Due to the vast number of detected anomalies in decision making under risk and uncertainty, so-called descriptive decision theories evolved which – in opposition to expected utility theory – do not impose normative constraints on choice behavior that are considered rational. Instead, these theories gear toward empirical research, often in the form of laboratory experiments that reveal systematic human choice patterns. Therefore, descriptive decision theories aim to describe, model, and reproduce the persistent anomalies reported in the empirical literature. Their goal is not to equip individuals with good advice on handling risk and uncertainty rationally but to predict and explain actual human decision making. The "gold standard" among descriptive theories is prospect theory (Kahneman and Tversky 1979; Tversky and Kahneman 1992), which was the starting point and benchmark for many more theories to come. Prospect theory is a context-independent decision theory, meaning that agents are supposed to evaluate a lottery independently of potential alternatives. The theory presumes that decision makers overweight small and underweight high probabilities in combination with a utility function that – starting from a reference point – is concave in the domain of gains and convex in the domain of losses.[2] However, potential criticism of the model aims at the lack of a psychological underpinning and the model's partially arbitrary basic properties.

By contrast, several other decision theories are founded on empirical insights from psychological research, transferring those findings into economic theory. An example is the family of decision theories with which this dissertation is primarily concerned – so-called skew-symmetric additive (*SSA*) models and

[2] See Sell (2020) for an application of prospect theory to the area of personal income distribution.

similarity judgments. These theories are context-dependent in the sense that a decision maker's evaluation of a lottery can be affected by the introduction of another lottery. Specifically, they presume that the similarity or contrast between lotteries' payoffs affects an agent's decision making process. Consequently, the juxtaposition of outcomes is supposed to induce specific pairs of comparison, thereby influencing a decision maker's preferences. For instance, the so-called regret theory (Loomes and Sugden 1982) from the class of *SSA* models argues that – in addition to the levels of utility directly received from potential outcomes – agents anticipate a feeling of regret (rejoicing) whenever their decision would have led to a better (worse) outcome had they chosen the alternative option. The theory therefore predicts correlation effects, meaning that the stochastic dependency between lotteries affects choice behavior. Recently, *SSA* models have come back into focus due to the introduction of salience theory (Bordalo et al. 2012b) which presumes that a higher contrast between lotteries' payoffs attracts a greater deal of the decision maker's attention. The theory is based on the psychological literature dealing with agents directing their limited cognitive capabilities on subsets of the available information (see, e.g., Mather and Sutherland 2011; Taylor and Thompson 1982).

Salience theory has undoubtedly had the greatest theoretical influence in economic research on decision making under risk and uncertainty in the past ten years. Yet, the empirical literature investigating predictions derived from the model is still young. Therefore, even though considerable support for salience theory's implications has been found, the supposedly confirming results are not yet set in stone. This is especially true because a bigger part of those investigations contradicts former empirical evidence on *SSA* models obtained in the context of regret theory.

The intended contribution of this dissertation is threefold. First, I derive novel predictions on systematic choice behavior under risk and uncertainty from *SSA* models such as salience theory as well as similarity judgments, i.e., decision theories founded on the assumption that contrast and similarity shape agents' preferences. Second, I identify where recent empirical evidence supporting salience theory contradicts the former findings on regret theory and which plausible explanations can reconcile this discrepancy. Third, I conducted three incentivized experiments – one laboratory and two online – to examine these theoretical considerations on the role of contrast and similarity in decision making under risk and uncertainty.

Chapter 1, which is conditionally accepted for publication by the *Journal of Economic Psychology*, investigates a central property of *SSA* models, the so-called sure-thing principle (Savage 1954). This principle declares that choices among two lotteries should be independent of states of the world in which both yield the same outcome. A violation of the principle implies the Allais paradox – also known as the common consequence effect – in the context of two perfectly correlated lotteries. In the lab experiment, I test for the sure-thing principle by examining the common consequence effect under subjective uncertainty and with correlated lotteries. Real-world events facilitate an easy-to-understand correlation structure between outcomes. Additionally, I control for the role of display formats by presenting each choice problem once in a coalesced format where subevents resulting in the same outcome are merged and once in an event-splitting[3] format that clearly reveals the state space and the underlying correlation structure to subjects.

The idea behind this chapter springs from novel experimental findings based on salience theory conflicting with former evidence on correlated versions of the Allais paradox. Bordalo et al. (2012b) investigate the Allais paradox under subjective uncertainty with correlated lotteries. They find no evidence for a common consequence affecting decision makers' choices – in line with *SSA* models. This contradicts earlier findings from Tversky and Kahneman (1992) for the very same employed choice problems, where more than half of their respondents exhibited Allais-type behavior, i.e., a common consequence effect. Because both author groups apparently made use of the same event-splitting display format, presentation effects are unable to resolve the conflicting findings. The results in the present study conform with Tversky and Kahneman (1992) as I find a significant Allais paradox in both display formats, which contradicts the rationale underlying *SSA* models. However, since I find a reduction of Allais-type preferences in the event-splitting design, the approach to control for display formats facilitates reconciling the findings of Bordalo et al. (2012b) with Tversky and Kahneman (1992).

Chapter 2 evolved from the findings presented in Chapter 1. The fact that salience theory did not perform well in the lab experiment on the Allais paradox under subjective uncertainty contrasts with recent studies confirming predictions derived from the model. Therefore, the goal of Chapter 2 is to retrace what causes this conflicting evidence, particularly with regard to the potential effect of the display format. In that sense, it is convenient to look at past experimental findings on regret theory, given its close relationship to salience theory (Herweg and D. Müller 2021). This former literature suggests that initially suspected correlation effects in line with regret theory actually resulted from event-splitting effects[4], i.e., the choice of the display format (Starmer and Sugden 1993). As all major recent empirical studies on salience theory also involved event-splitting, it is possible that similar display format effects

[3]Event-splitting means that an event leading to a particular outcome is artificially split into subevents.
[4]An event-splitting effect occurs when an agent's evaluation of an outcome changes due to splitting the associated event of disbursement into subevents.

confounded the analysis and caused the supposed confirmation of salience theory. Therefore, the first online experiment presented in Chapter 2 involves a repetition of two prominent recent experimental studies supporting salience-predicted correlation effects. It is observed that the supposed salience effects disappear when controlling for simultaneous changes in the display format while altering the correlation structure. Furthermore, I show that choice patterns previously attributed to the salience mechanism can be induced by keeping the correlation structure constant and only varying the display format.

The second online experiment presented in Chapter 2 is based on a generic choice problem designed to derive predictions from salience theory that are testable without the need to alter the display format. All choices are of binary form and presented both in a gain and a loss frame which also allows inference on salience theory's required value function. While salience theory can encompass general value functions, I show that it requires adopting a value function similar to prospect theory to explain the obtained choice pattern. However, even with this less parsimonious value function, there is no evidence for salience-predicted correlation effects – conforming with the results of the first experiment of Chapter 2.

Chapter 3 examines the effect of the juxtaposition between lotteries' payoffs on choices from a broader perspective, independently of the correlation between lotteries. The chapter summarizes findings on violations of first-order stochastic dominance (FOSD) accumulated in the course of the same experiment presented in Chapter 1. The investigation is based theoretically on similarity judgments, a theory closely related to *SSA* models. The theory also predicts juxtaposition effects but does not rely on the statistical dependency of the available lotteries. It is examined whether similarity judgments can explain FOSD violations for single-attribute lotteries. This is of interest because juxtaposition effects have been demonstrated to cause FOSD violations in the multi-attribute case, i.e., lotteries with multidimensional outcomes. Therefore, anomalies regarding FOSD might, in general, originate from juxtaposition effects, as suggested by *SSA* models and similarity judgments. However, when presenting subjects a well-established decision problem to induce FOSD violations, no change in choice behavior is observed due to altering the juxtaposition of payoffs – in line with the findings of Chapter 1 and Chapter 2.

I conclude with a summary of the key insights gained through my dissertation and give a brief outlook for potential future research in this field.

A few remarks to style; each chapter serves as an independent, self-contained unit. Furthermore, even though all chapters are single-authored, I make use of the plural in the further course of this thesis, thereby following the recommendation of Thomson (1999) to employ this style in economics.

Chapter 1

An Experimental Investigation of the Allais Paradox with Subjective Probabilities and Correlated Outcomes

Decision theories like skew-symmetric additive models assume that individuals adhere to Savage's sure-thing principle. The present chapter investigates that prediction in an incentivized lab experiment using Allais-type choice problems with subjective probabilities. Real-world events are employed to implement an easy-to-understand correlation structure between outcomes. Additionally, we control for the role of display formats by presenting each choice problem once in a coalesced format and once in an event-splitting format that clearly reveals the state space and the underlying correlation structure to subjects. We find the Allais paradox to be present in both display formats, which contradicts the rationale of skew-symmetric additive models. Due to significant event-splitting effects, Allais-type preferences are more pronounced in the coalesced format. The obtained event-splitting effects suggest that subjects assign a higher value to a lottery when the event of disbursement of its upside payoff is split into subevents. That holds both for situations in which event-splitting helps unveiling the state space and also when this is not the case. Previous findings on correlated versions of the Allais paradox can at least partially be explained by event-splitting rather than correlation.

1.1 Introduction

Ever since the famous work of Allais (1953) challenged expected utility theory (EUT) as a descriptive decision theory, economists have tried to understand what drives human decision making in Allais-type choice situations. The eponymous Allais (common consequence) paradox consists of two binary choice problems $j \in \{1, 2\}$ between two lotteries, R^j (risky) and S^j (safe), with nonnegative payments.[1] While the risky lottery contains a higher upside payoff, the safe lottery has a higher probability of winning its upside payoff. Within each problem j, the lotteries R^j and S^j share a common consequence, i.e., an identical payoff x^j occurring with equal probability p. The only difference across problems is the payoff x^j of this common consequence. The paradox derives from EUT predicting that altering a common consequence shared by two lotteries should not change their relative desirability, while empirically, it usually does. A commonly employed demonstration of the paradox dates back to Kahneman and Tversky (1979). It is depicted in Figure 1.1, involving precisely defined probabilities and hence objective uncertainty. The common consequence is disbursed with a probability of $p = 0.66$ and involves $x^1 = \$2400$ and $x^2 = \$0$ concerning the choice between lotteries R^j and S^j.

Choose between R^j and S^j.

R^1:	\$2500	with prob.	0.33	S^1:	\$2400	with certainty	
	\$2400		0.66				
	\$0		0.01				
R^2:	\$2500	with prob.	0.33	S^2:	\$2400	with prob.	0.34
	\$0		0.67		\$0		0.66

Figure 1.1: A variant of the Allais paradox introduced by Kahneman and Tversky (1979).

According to EUT, a decision maker should either consistently choose the risky lotteries (R^1, R^2) or the safe ones (S^1, S^2), because after factoring out the respective common consequence, the decision maker faces exactly the same two lotteries in both problems.[2]

Empirical choice patterns inconsistent with EUT are not per se grounds for its rejection. Frequent errors in decision making may follow from subjects being close to indifferent in both problems (Conlisk 1989) –

[1] Considering a set of potential outcomes, a lottery is defined as a vector of probabilities assigning a probability to each possible outcome.

[2] That is: R^j = \$2500 with prob. 0.33 and \$0 with prob. 0.01 versus S^j = \$2400 with prob. 0.34.

making violations of EUT the result of *random* error. However, experimental evidence shows that subjects *systematically* choose S^1R^2 more frequently than R^1S^2, with S^1R^2 often being the modal response, therefore contradicting EUT.

Various researchers have come up with ideas rationalizing the choice pattern behind the Allais paradox, also referred to as the common consequence effect. Yet, a satisfactory and definite explanation is still missing. So-called skew-symmetric additive (*SSA*) models (see, e.g., Bell 1982; Loomes and Sugden 1982, 1987) have recently come into focus in the form of the salience theory of choice under risk (Bordalo et al. 2012b).[3] This theory presumes that the contrast between the offered lotteries' payoffs in a specific state of the world evokes a decision maker's attention. Similar to its *SSA* relatives, the salience theory entails specific implications concerning choices among lotteries once correlation is introduced.[4] Subsequent empirical studies have found great support for the predictions obtained from salience theory (see, e.g., Bordalo et al. 2012b; Dertwinkel-Kalt and Köster 2020; Frydman and Mormann 2018). Preferences over a set of lotteries appear to be sensitive to the formation of the state space, which conveys whether and to what extent these lotteries are correlated.

The present chapter investigates the common consequence effect under subjective uncertainty with correlated lotteries using an incentivized lab experiment. Thereby, we test for the prediction of the class of *SSA* models that agents adhere to Savage (1954)'s sure-thing principle. The principle declares that choices among two lotteries should be independent of states in which both yield the same outcome. Therefore, the Allais paradox is supposed to be nonexistent when the involved lotteries are perfectly correlated, meaning that they disburse the common consequence in the same state. We employ two different Allais-type choice settings with outcomes linked to future uncertain real-world events to implement an easy-to-understand correlation structure for subjects: the temperature at a specific time and location and the results of a political poll at a given date. Furthermore, we control for the role of display formats, namely for so-called event-splitting effects. The literature on *SSA* models suggests that a large extent of initially supposed confirmation of correlation effects – so-called juxtaposition effects – actually stems from modified display formats. To make the correlation between lotteries explicit, experimenters have often split events

[3]Herweg and D. Müller (2021) have recently highlighted the great overlap between salience theory and one of the initial *SSA* models, regret theory. They show that salience theory is a special case of generalized regret theory (Loomes and Sugden 1987) while original regret theory (Loomes and Sugden 1982) is a special case of salience theory. In related work, Lanzani (forthcoming) established an axiomatization for salience theory that also allows for a direct comparison with regret theory.

[4]Note that the presentation of the second choice problem in Figure 1.1 does not communicate any correlation structure to subjects and may hence be interpreted as a choice between two independently distributed lotteries, R^2 and S^2. In the first problem, the zero variance of the certain outcome in S^1 implies that correlation is undefined.

into subevents. Later research showed that event-splitting itself and hence the choice of display format substantially influence decision making (see, e.g., Harless 1992; Starmer and Sugden 1993).[5] Therefore, we present each choice problem once in an event-splitting format that makes the correlation between lotteries more explicit and once in a coalesced format, where events that share the same outcome are merged. The reliance on real-world events brings the advantage that correlation is nevertheless also evident to subjects in the coalesced format.

Our main finding is that the Allais paradox is still present, even if we make the state space and hence correlation more transparent as we do in the event-splitting display format. In the coalesced display format, we obtain a significant common consequence effect for both choice settings, but only for the political poll setting also in the event-splitting format. In both choice settings, the share of Allais-type preferences is higher in the coalesced format, where the correlation is less "salient". However, our results suggest that this diverging choice behavior over display formats rather follows from event-splitting effects than from explicitly communicating the correlation structure to subjects. In the event-splitting display format, where the upside of the safe lottery and (if the common consequence is zero) the downside of the risky lottery are displayed more often, subjects choose the risky lottery less frequently. However, this also holds when the safe lottery involves a sure gain and therefore an undefined correlation, in which case displaying the state space does not reveal any correlation information to subjects. Overall, our findings are not in line with *SSA* models such as salience theory but indicate that the choice of the display format can crucially affect decision making under subjective uncertainty.

Our results expand the vast experimental literature on the Allais paradox. A large number of studies have dealt with the common consequence effect in the context of risk, i.e., objective probabilities. Researchers have investigated the common consequence effect with varying payoffs, probabilities, and display formats (see, e.g., Fan 2002; Huck and W. Müller 2012; Incekara-Hafalir et al. 2021; Starmer 1992). In contrast, there are only a few examinations of the Allais paradox in the context of subjective uncertainty (Bordalo et al. 2012b; MacCrimmon and Larsson 1979; Tversky and Kahneman 1992; Wu and Gonzalez 1999).[6] Few of these investigations have been incentivized, and none have controlled for the role of display formats. Using an event-splitting display format, they opted for a lottery presentation not commonly employed when investigating the common consequence effect with objective probabilities. As can be seen in the version of

[5] See, e.g., Borie and Jullien (2020) and Kerekov (2022) for recent evidence on description-dependent preferences.

[6] Schneider and Schonger (2019) conducted an empirical examination of the Allais paradox in a coalesced presentation format that combined subjective and objective uncertainty.

the Allais paradox in Figure 1.1, for any lottery, each payoff is linked to its total probability of occurrence and therefore only displayed once. To the best of our knowledge, we are the first to investigate the common consequence effect under subjective uncertainty, consistently employing the techniques developed in the context of risk.

Within the strand of literature on correlation effects, Bordalo et al. (2012b) and Frydman and Mormann (2018) are the two papers closest to our work. They both investigate the common consequence effect in the domain of risk and with correlated lotteries. The findings of Bordalo et al. (2012b) suggest that subjects' preferences over perfectly correlated lotteries are not affected by a common consequence. While they employ a matrix event-splitting display format that makes the state space perfectly clear, their results may still actually stem from event-splitting effects, for which they did not control. Frydman and Mormann (2018) provide supplementary support for salience theory by testing for the Allais paradox with objective probabilities and correlated lotteries using a pie-chart display format. Additionally, they present subjects with a zero correlation and an intermediate correlation variant of the choice problem that involves the null outcome as the common consequence. They find that subjects' tendency toward exhibiting the Allais paradox decreases with correlation. Again, event-splitting effects might explain the decreasing share of Allais-type preferences from zero correlation to perfect correlation, yet not the drop from zero to intermediate correlation as no additional event-splitting took place. While the results of the present chapter show that event-splitting is a major driver of supposed correlation effects, the findings of Frydman and Mormann (2018) suggest that there still remains a role for the correlation information conveyed by the state space.

Bordalo et al. (2012b) also investigate the Allais paradox under subjective uncertainty with correlated lotteries and again find no evidence for a common consequence affecting choices. The presentation design involves a matrix event-splitting display format that reveals the state space and, thereby, the common consequence. As Bordalo et al. (2012b) argue, it is the salience of the allowed states of the world that subsequently shapes risk preferences. This contradicts earlier findings by Tversky and Kahneman (1992) for the very same question, where more than half of their respondents exhibited Allais-type behavior, i.e., a common consequence effect. Because they presumably employed the same kind of display format, presentation effects are unable to resolve the conflicting findings. The findings in the present study conform with Tversky and Kahneman (1992) as we find a significant common consequence effect in both display formats. However, since we find a reduction of Allais-type preferences in the event-splitting display format, we contribute to reconciling the findings of Bordalo et al. (2012b) with Tversky and Kahneman (1992).

Lastly, our results add to the literature on framing effects by controlling for two different display formats. Previous studies in the context of risk found that decision makers tend to evaluate a lottery higher if the mentioning of its upside payoff increases due to splitting the corresponding event of disbursement into subevents (see, e.g., Birnbaum 2004, 2007). Humphrey (2001) suggests that the effect also works in the reverse direction with the lottery's downside. At the opposite end of the spectrum, Humphrey (1995) has shown that event-splitting effects are also present under total ambiguity where subjects had no information about the underlying probabilities due to the usage of Ellsberg urns. We add to this literature by investigating event-splitting effects employing real-world events and hence subjective probabilities as opposed to risk and total ambiguity. We find that event-splitting effects are present under subjective uncertainty as well and work in a similar manner as indicated by previous evidence.

The remainder of this chapter is structured as follows: Section 1.2 gives a summary of the *SSA* approach and derives our research hypotheses. Section 1.3 depicts the experimental design and procedure. Section 1.4 presents the results, and Section 1.5 concludes.

1.2 Skew-symmetric additive models and research hypotheses

Following the subjective expected utility theory introduced by Savage (1954), a decision maker's object of choice is a so-called act. For a finite state space, an act is defined as a function that maps a state $s \in \mathbb{S} = \{s_1, \ldots, s_n\}$ to an outcome $x \in X$ with an agent's evaluation of an act being additive over the states of the world. The *SSA* representation is a generalization of Savage's theory that also adheres to the sure-thing principle but no longer to transitivity (Fishburn 1988). With the binary relation $f \succ g$ indicating a decision maker's strict preference of act f over act g, *SSA* models present as follows:[7]

$$f \succ g \Leftrightarrow \sum_{i=1}^{n} \phi(f(s_i), g(s_i)) \cdot \pi_i > 0. \tag{1.1}$$

The function ϕ maps $X \times X$ into $\mathbb{R}$ and is skew-symmetric, i.e., $\phi(x, y) = -\phi(y, x)$, while $\pi_i = \pi(s_i)$ is a finitely-additive probability measure with $\sum_{i=1}^{n} \pi_i = 1$ (Fishburn 1990).[8] The skew-symmetric function ϕ embodies an agent's essential decision making process, which depends on the similarity/dissimilarity of

[7] For an infinite state space representation of the *SSA* model, see, e.g., Fishburn (1990).

[8] For a utility function $u : X \rightarrow \mathbb{R}$ and $\phi(x, y) = u(x) - u(y)$, the *SSA* model reduces to the subjective expected utility theory of Savage (1954).

the incorporated payoffs linked to a certain state.[9] The predictions derived from the *SSA* model in this chapter depend on the respective correlation structure between the involved lotteries, which – assuming the minimal state space – translates into different particular pairs of acts. As a consequence, varying correlation structures between a pair of lotteries would require specifying several acts. For ease of reading and because we sometimes only refer to the probability distributions over outcomes, we stick to denoting the objects of choice as lotteries while clarifying the underlying correlation.

The *SSA* approach's explanation for the common consequence effect is based on the claim that a decision maker interprets both presented lotteries, i.e., both probability distributions over outcomes as independent. The perceived state space then equals the product space of the lotteries' marginal distributions over outcomes. Concerning the first problem in Figure 1.1 with $x^1 = \$2400$, the perceived state space is $\mathbb{S}^1 = \{(2500, 2400); (2400, 2400); (0, 2400)\}$, while in the second problem with $x^2 = \$0$, it is $\mathbb{S}^2 = \{(2500, 2400); (0, 2400); (2500, 0); (0, 0)\}$. The greatest outcome dissimilarity in $\mathbb{S}^1$ is $(0, 2400)$, while in $\mathbb{S}^2$ it is $(2500, 0)$. Hence, the *SSA* model's psychological feature of how dissimilarity between payoffs affects decision making primarily applies to the minimum payoff of lottery R^1 and the maximum payoff of lottery S^1 under $\mathbb{S}^1$, while the opposite is true under $\mathbb{S}^2$. As a consequence, this procedure can account for subjects' shifting preferences due to altering the common consequence.[10]

However, the prognosis suddenly changes when the lotteries are no longer independently distributed. In the case of perfectly correlated lotteries, the class of *SSA* models makes the same prediction as EUT: Inconsistent preferences concerning both common consequence versions of the choice problem must be the result of random error. Figure 1.2 presents a variant of the Allais paradox with perfectly correlated lotteries $R(x^j)$ and $S(x^j)$ within a payoff matrix involving a hence fixed juxtaposition of payoffs, for which Bordalo et al. (2012b) found no indication for a common consequence effect.

In contrast to the initial presentation of the two choice problems in Figure 1.1, the state space $\mathbb{S}^j = \{(0, 2400); (2500, 2400); (x^j, x^j)\}$ is now invariant to the common consequence x^j. According to the

[9] How and why the similarity/dissimilarity between payoffs is supposed to affect an agent's decision making process depends on the respective *SSA* model's psychological underpinning. For instance, salience theory assumes that the contrast in outcomes draws an agent's attention. Hence, a greater dissimilarity between the available acts' payoffs linked to a particular state will inflate a decision maker's perceived likelihood of that state.

[10] For independently distributed lotteries, the *SSA* model predicts the Allais-type choice pattern S^1R^2 if ϕ is convex (Loomes and Sugden 1987).

Probability	0.01	0.33	0.66
payoff of $R(x^j)$	\$0	\$2500	x^j
payoff of $S(x^j)$	\$2400	\$2400	x^j

Figure 1.2: A correlated variant of the Allais paradox from Kahneman and Tversky (1979) adopted from Bordalo et al. (2012b).

SSA representation as given by Equation 1.1, the preference relation between both lotteries obtains as

$$\begin{aligned} &R(x^j) \succ S(x^j) \Leftrightarrow \\ &0.01 \cdot \phi(0, 2400) + 0.33 \cdot \phi(2500, 2400) + 0.66 \cdot \phi(x^j, x^j) > 0. \end{aligned} \tag{1.2}$$

For two identical payoffs as input factors with a hence perfect similarity, the skew-symmetry of ϕ implies that $\phi(x^j, x^j) = 0$. Consequently, the state (x^j, x^j), revealed by the juxtaposition of payoffs, cancels out in the comparison between both lotteries, leaving a decision maker's preference relation unaffected. Due to this so-called juxtaposition effect, the systematic shift in choices that characterizes Allais-type preferences (S^1R^2 more frequent than R^1S^2 for $x^1 = \$2400$ and $x^2 = \$0$) shall hence no longer come to pass with subjects adhering to the sure-thing principle.[11] Thus, the subsequent hypothesis for *SSA* models follows as:

Hypothesis 1.1. *In the context of two perfectly correlated lotteries that disburse a common consequence in the same state of the world, subjects adhere to the sure-thing principle and do not exhibit systematic Allais-type violations of EUT.*

In addition, we conjecture that the selection of the display format has a significant influence on choice behavior in correlated versions of the Allais paradox. The matrix display format in Figure 1.2 makes the state space explicit due to event-splitting. Compared to the initial coalesced presentation in Figure 1.1, the event of disbursement of the safe lottery's upside payoff \$2400 is split in both problems. The same applies to the risky lottery's downside payoff \$0 when the common consequence is \$0. As outlined in Section 1.1, empirical evidence obtained from, e.g., Birnbaum (2004, 2007) suggests that subjects assess a higher value to a lottery if its upside appears more often, even if the overall probability of the outcome

[11] The psychological rationale of *SSA* models is closely related to decision theories based on similarity judgments (see, e.g., Leland 1994; Rubinstein 1988). In contrast to the *SSA* representation, these models' predictions, however, do not depend on the statistical dependence of the available alternatives.

remains constant. These so-called event-splitting effects also seem to work with splitting the event linked to a lottery's downside (Humphrey 2001). Therefore, Hypothesis 1.2 states:

Hypothesis 1.2. *In perfectly correlated Allais-type choice settings, subjects choose the risky lottery less frequently compared to a coalesced display format if the correlation structure is made explicit by event-splitting.*

1.3 The experiment

1.3.1 Design

We examine both research hypotheses in the context of subjective uncertainty and a within-subjects design. To create a setting with subjective probabilities, we employ real-world events, which accommodate correlation structures more naturally. Subjects may find it easier to understand the state space and – if following *SSA* decision models – subsequently adhere to the sure-thing principle, i.e., exhibit behavior consistent with Hypothesis 1.1.

We constructed two Allais-type choice settings with two correlated lotteries, respectively, again using the notation from Figures 1.1 and 1.2. Each setting is based on – from the perspective at the time of the experiment – future uncertain real-world events and involves two choice problems $j \in \{1, 2\}$ between lotteries R^j (risky) and S^j (safe).[12] The lotteries share a common consequence x^j whose payout depends on the same real-world event in order to guarantee perfect correlation. As before, the risky lottery R^j contains a higher upside, while the safe lottery S^j has a higher probability of winning. As each setting incorporates two choice problems due to the change of the common consequence when testing for the Allais paradox, we get four basic choice problems in total. To investigate Hypothesis 1.2, we employ two different display formats for each of the four basic problems. One format contains event-splitting to make the state space and correlation structure more transparent. The other format is of a coalesced design, where each payoff of a lottery is only mentioned once because the respective states of disbursement are merged. Thus, subjects faced eight problems in total.

The experiment was administered with German-speaking subjects. All subsequent depictions of choice problems are therefore translations. We employed identical payoffs for both choice settings: €20 for the

[12] In the actual experiment, we denoted the lotteries as A and B.

The lotteries R^j and S^j disburse payoffs depending on the temperature (T) in degrees Celsius measured by the weather station Munich-City on this year's Christmas Day (December 25, 2019) at 6:00 p.m. Choose between R^j and S^j.

	$T < 2°C$	$2°C \leq T < 2.5°C$	$2.5°C \leq T$
Lottery R^j	€20	€0	x^j
Lottery S^j	€18	€18	x^j

Figure 1.3: Temperature choice setting in the matrix event-splitting display format.

risky lottery's upside and €18 and €0 for the two different variants of the common consequence.[13] In our first choice setting, we used the temperature measured in Celsius at a particular destination, date, and time in the future – a source of uncertainty that has also been deployed by, e.g., Fox and Tversky (1995). We binned the continuous variable into three discrete states of the world. Figure 1.3 displays the temperature choice setting in the event-splitting matrix display format, which was presented once with the common consequence being $x^1 =$ €18 and once being $x^2 =$ €0.

To aid subjects' evaluation of the likelihood of the three employed states, a table illustrating the minimum and maximum daytime temperature on December 25 in the last ten years was prefixed before each choice problem. The table is depicted in Appendix 1.A. The coalesced display format is presented in Figure 1.4 for both versions of the common consequence, but without the introductory explanation.

The second choice setting is based on the outcome of a political poll at a given date in the future. In Germany, almost every Sunday, opinion research institutes publish polls asking a representative sample of voters how they would vote if the federal election – which results in the formation of the German government – was held on that day. The "political choice setting" involves a choice problem between two lotteries that disburse payoffs contingent on future poll results of the CDU/CSU political party alliance of then-incumbent chancellor Angela Merkel.[14] To again aid the evaluation of each state's likelihood, we presented subjects with a table of past poll results of the CDU/CSU from INSA-Consulere (2022) together with each choice problem. The table is depicted in Figure 1.5, together with the coalesced display format of the two basic choice problems, once with the common consequence $x^1 =$ €18

[13] The exchange rate between the Euro and the US-Dollar on the day when the experiment took place was: 1 Euro = 1.12 US-Dollar.

[14] The alliance consists of two independent political parties, the Christian Democratic Union of Germany (CDU) and the Christian Social Union in Bavaria (CSU).

R^1:	€20	if the temperature is less than 2°C	S^1:	€18	as a sure gain (for any temperature)
	€0	if the temperature is greater than or equal to 2°C and less than 2.5°C			
	€18	if the temperature is equal to or greater than 2.5°C			
R^2:	€20	if the temperature is less than 2°C	S^2:	€18	if the temperature is less than 2.5°C
	€0	if the temperature is greater than or equal 2°C		€0	if the temperature is greater than or equal to 2.5°C

Figure 1.4: Temperate choice setting for both versions of the common consequence in the coalesced display format. The first and the second choice problem $j \in \{1, 2\}$ involve lotteries R^j and S^j which share the common consequence $x^1 =$ €18 and $x^2 =$ €0, respectively.

and once with $x^2 =$ €0. The event-splitting display format was, in this case, conducted within a verbal display format and is illustrated in Appendix 1.B.

1.3.2 Organization

The experiment took place at the "Munich Experimental Laboratory for Economic and Social Sciences" on December 12, 2019, i.e., before the future uncertain events.[15] The experimental instructions can be found in Appendix 1.C. In total, we recruited 101 subjects, 59 of which were female, and 42 were male. The average age was 27.31 years (median 23 years), and 84 subjects were students. We also asked them whether they had attended a lecture in economics or statistics in the past five years, which 73 respondents confirmed. The experiment involved a computer questionnaire containing 29 decision problems, divided into two parts, including different experimental investigations and pretests for future experiments. The first part of the questionnaire involved 27 choice problems, including the eight problems handoff interest in the current study.[16] Incentivization was implemented via the random-lottery procedure (Starmer and Sugden 1991). After completing the questionnaire, for each subject, one of the 27 choice problems was randomly selected and played for real money based on the preceding response. The second part of the

[15]Ultimately, the CDU/CSU poll results in the first "INSA voting intentions poll" in 2020 (January 6, 2020) were 29%. The temperature on December 25, 2019 at 6:00 p.m. in Munich-City turned out to be 4.9°C.

[16]Similar to, e.g., Humphrey (2001) and Starmer and Sugden (1998), choice problems not relevant for the present study dealt with other hypotheses. They are presented in Appendix 1.D. The obtained data for these problems are available upon request.

The following table shows the results of the CDU/CSU for the past “INSA voting intentions polls” (participants of this representative poll were asked which party they would vote for if the federal election took place on the next Sunday).

Date	Poll results of the CDU/CSU
2019-10-22	27.0%
2019-10-29	26.0%
2019-11-04	25.5%
2019-11-12	25.5%
2019-11-18	25.0%
2019-11-25	26.5%
2019-12-02	26.5%
2019-12-09	28.0%

The lotteries R^j and S^j disburse payoffs in dependence of the results of the CDU/CSU at the first published “INSA voting intentions poll” in 2020 (publication to be expected in the first calendar week). Choose between R^j and S^j.

R^1:	€20	if the results of the CDU/CSU are above 27.5%	S^1:	€18	as a sure gain (for any results of the CDU/CSU)
	€18	if the results of the CDU/CSU are between 25% and 27.5%			
	€0	if the results of the CDU/CSU are below 25%			
R^2:	€20	if the results of the CDU/CSU are above 27.5%	S^2:	€18	if the results of the CDU/CSU are above 27.5% or below 25%
	€0	if the results of the CDU/CSU are equal to or below 27.5%		€0	if the results of the CDU/CSU are between 25% and 27.5%

Figure 1.5: Political choice setting for both versions of the common consequence in the coalesced display format. The first and the second choice problem $j \in \{1, 2\}$ involve lotteries R^j and S^j which share the common consequence $x^1 = €18$ and $x^2 = €0$, respectively.

questionnaire contained two choice problems played for real money, yet this was unknown to participants before completing part 1. Subjects received a €10 show-up fee in cash at the beginning and additional earnings later via bank transfer. The experiment was conducted in four consecutive sessions in groups of (almost) equal size.

The order of the 27 choice problems in the first part of the questionnaire was randomized to prevent priming effects. Yet, it was ensured that the 8 inter-related problems that only vary with respect to the common consequence or the display format were placed further away from each other. Within a given choice problem, the order in which the available lotteries were presented was also randomized. As some of our choice problems involved reading accompanying text, we screened out subjects that did not pay attention throughout the entire experiment with a little brainteaser. It is shown in Appendix 1.D, along with the other employed choice problems. Ultimately, 94 subjects passed the screening question, forming the basis for our empirical analysis.

1.4 Results

1.4.1 Common consequence effects

We begin our analysis by examining Hypothesis 1.1. Decision making consistent with *SSA* models would imply that subjects' choices are insensitive to a common consequence in Allais-type choice tasks involving perfect correlation. Inconsistent choices are expected to be the result of random error as opposed to the typically observed tendency of S^1R^2 choices being more frequent than R^1S^2. Table 1.1 shows for both Allais-type choice settings the distribution of choice combinations R^1R^2, S^1S^2, R^1S^2, and S^1R^2 across subjects. The top panel presents the results for the temperature choice setting for both display formats when varying the common consequence from $x^1 = €18$ to $x^2 = €0$. The bottom panel shows the same for the political poll choice setting. The results cell corresponding to row "Coalesced" pertaining to the political poll setting and column S^1S^2, for example, shows that in the political setting with the coalesced display format, 51 of the 94 subjects chose the safe lottery when $x^1 = €18$ and also when $x^2 = €0$. The last column p denotes the probability for observing at least as many S^1R^2 responses as actually obtained under the null hypothesis that S^1R^2 responses occur with a smaller frequency than R^1S^2 responses (one-sided binomial test).

Except for the temperature choice setting in the event-splitting display format, all problem pairs exhibit a significantly higher frequency of S^1R^2 than R^1S^2 responses at the 5% level. Thus, when changing the common consequence from $x^1 = €18$ to $x^2 = €0$, the relative attractiveness of the risky lottery increases systematically. This is a clear violation of Hypothesis 1.1 that Allais-type choice behavior should be absent with perfect correlation. Remarkably, systematic common consequence effects not only hold for the coalesced display format but at least in the political choice setting also for the event-splitting format.[17]

[17] The fact that in the temperature setting, we cannot reject the null hypothesis even though all violations of EUT are of the Allais-type indicates a lack of statistical power. Considering that only four people exhibited a shift in choice behavior, it

Table 1.1: Common consequence effects for both choice settings and display formats

Problem pairs	Choice pattern (n=94): R^1R^2	S^1S^2	R^1S^2	S^1R^2	p
			Temperature		
Coalesced	4	57	4	29	<0.001
Event-splitting	0	90	0	4	0.063
			Political Poll		
Coalesced	8	51	7	28	<0.001
Event-slitting	7	64	7	16	0.047

Notes: Each problem pair consists of a specific choice setting and display format with the common consequence x^j being $x^1 = €18$ in the first and $x^2 = €0$ in the second problem. The p-value corresponds to a test of the hypothesis that S^1R^2 responses occur with a greater frequency than R^1S^2 responses, using a one-sided binomial test.

The finding of a common consequence effect in the event-splitting display format shows that conveying the state space to subjects via event-splitting is insufficient to induce subjects to behave in line with *SSA* models' predictions. If subjects were to adhere to the sure-thing principle, it should be particularly visible when the correlation structure is easily understandable, as is the case in the context of real-world events.

However, it is noteworthy that our analysis does not account for choice-specific error rates. Allowing for the possibility of subjects having EUT preferences but erroneously choosing the wrong lottery with different probabilities in both choice problems would prevent a rejection of the sure-thing principle based solely on the disparity of the S^1R^2 and the R^1S^2 choice pattern.[18]

1.4.2 Event-splitting effects

The results in Table 1.1 suggest that the display format has a substantial influence on decision making. Fewer subjects exhibit the Allais-type choice pattern S^1R^2 in the event-splitting than the coalesced display format, both in the temperature and the political setting ($p < 0.001$ and $p = 0.02$, two-sided z-tests, respectively). We now investigate Hypothesis 1.2 on the role of event-splitting. Table 1.2 presents for

is impossible to reject the null with the given sample size (a posthoc power analysis provides a probability of zero to reject the null at a significance level of 5%, even if the true probability that a shift in choice behavior is of the Allais-type was equal to 1).

[18]For example, let subjects' probability (fraction) to prefer the risky lottery be $\alpha \in [0, 1]$, while the probability of erroneously choosing the wrong lottery is p in the first and q in the second problem. Because the first problem involves a safe option, it might be simpler and hence $q > p$. As preferences satisfy the sure-thing principle and mistakes are choice-specific, the relative frequency of the SR to the RS choice pattern is $\frac{SR}{RS} = \frac{p(1-q)+(1-\alpha)(q-p)}{q(1-p)-(1-\alpha)(q-p)}$. The term increases in $(1-\alpha)$, i.e., the fraction that prefers the safe lottery. Moreover, $\lim_{\alpha \to 0} \frac{SR}{RS} = \frac{q(1-p)}{p(1-q)}) > 1$. Therefore, if the safe option is clearly more attractive – as suggested in both the temperature and the political setting – one might observe a higher frequency of SR compared to RS choices despite subjects obeying the sure-thing principle. I thank an anonymous referee for pointing this out.

Table 1.2: Event-splitting effects for the four basic choice problems

Problem	Number of subjects ($n = 94$) choosing the risky lottery (R^j), when display format is: Coalesced	Split	p
Temperature			
$x^1 = €18$	8	0	0.002
$x^2 = €0$	33	4	<0.001
Political Poll			
$x^1 = €18$	15	14	0.4
$x^2 = €0$	36	23	0.008

Notes: The p-value corresponds to a test of the proportion of risky lottery choices being lower in the event-splitting than in the coalesced display format, using a one-sided paired z-test.

each basic choice problem the number of subjects preferring the risky lottery, once for the coalesced and once for the event-splitting display format. For example, the row pertaining to the common consequence $x^1 = €18$ and the temperature choice setting shows that for this choice problem, 8 of the 94 subjects chose the risky lottery in the coalesced format, but zero when instead the event-splitting display format was used. The last column presents the p-values for observing at least as many risky lottery choices in the event-splitting display format as actually obtained under the null hypothesis that choices of the risky lottery occur with a greater frequency in the event-splitting display format (one-sided z-test).

Our results support Hypothesis 1.2 that the share of risky lottery choices decreases when moving from a coalesced to an event-splitting format. Except for the political choice setting with $x^1 = €18$, we observe significant event-splitting effects at the 5% level in all problems. Hence, the effect is present both for the matrix (temperature setting) and for the verbal display format (political setting). However, concerning both versions of the common consequence, event-splitting effects appear more robust (smaller p-values) in the temperature setting than in the political setting. This pattern might be influenced by the difference in the display formats when conducting the event-splitting. In the matrix representation, the correlation structure is conveyed more clearly than under the verbal portrayal. Hence, the higher salience of the state space in the matrix display format potentially explains the greater tendency for an event-splitting effect in the temperature compared to the political setting.[19]

[19] For the role of display format effects in the context of *SSA* models, see, e.g., Ostermair (2021).

Also, in both settings, event-splitting effects seem more pronounced when the common consequence is $x^2 = €0$, potentially because only in this case, event-splitting applies to both lotteries. The safe lottery's upside payoff is presented in two subevents, making it look more attractive for subjects. In contrast, it is the risky lottery's downside payoff that appears twice, potentially discouraging decision makers from choosing the lottery. That event-splitting can be employed both for making a lottery look more appealing and also for making it look worse, is in line with findings from Humphrey (2001).

A different explanation for event-splitting effects being more pronounced when the common consequence is €0 relates to the fact that when it equals €18, event-splitting solely applies to a certain outcome. Subjects' tendency to assess a higher value to a lottery if its upside payoff is displayed more often might attenuate when facing a sure gain.[20] However, even if that were true, the significant event-splitting effect concerning the temperature choice problem involving $x^j = x^1 = €18$ shows that event-splitting effects remain when applied to a payoff disbursed with certainty. This is noteworthy because, here, event-splitting does not convey additional information about the correlation to subjects. The observed reduction of risky lottery choices can therefore not be attributed to a higher salience of the allowed states of the world as Bordalo et al. (2012b) did for their findings concerning correlated versions of the Allais paradox.

Eventually, the larger event-splitting effects for the choice problems involving the common consequence $x^2 = €0$ may also explain why the Allais paradox appears to be more robust in the coalesced display format. If the reduction of risky lottery choices is smaller when $x^1 = €18$ compared to when $x^2 = €0$, then event-splitting effects asymmetrically affect choice behavior. As a consequence, there may be a greater drop in S^1R^2 compared to R^1S^2 responses.

1.5 Conclusion

Recent experimental evidence indicates that a subject's tendency to exhibit the common consequence effect depends on whether the involved lotteries are correlated (Bordalo et al. 2012b; Frydman and Mormann 2018). These findings are in line with the predictions of *SSA* models such as salience theory that adhere to Savage's sure-thing principle.

In this chapter, we investigate whether the Allais paradox is present in the context of subjective uncertainty and perfectly correlated lotteries using real-world events. When doing so, we controlled for event-splitting effects by varying between event-splitting and coalesced display formats. Our results indicate

[20]For example, when applied to certain options, Humphrey (2000) also finds an erratic pattern of event-splitting effects.

that a change of a common consequence shared by two lotteries systematically affects choice behavior. We observe the typical Allais-type choice pattern both in the coalesced and the event-splitting display format, which is inconsistent with the predictions of *SSA* decision models. Our findings show that it is insufficient to convey the correlation structure between both lotteries through event-splitting to resolve the Allais paradox. Our second finding is that event-splitting itself affects human decision making. When applied to a sure gain, a larger share of subjects prefers a certain payoff when it appears more often, although no additional correlation information is conveyed. This finding is in line with the extensive literature on event-splitting effects (Birnbaum 2004, 2007; Keller 1985).

Event-splitting might – at least partially – also be responsible for previous findings indicating that Allais-type preferences vanish in the context of perfect correlation. However, we cannot rule out the possibility that a clearer state space contributes to the decrease in risky lottery choices once the display format involves event-splitting and both lotteries contain a zero outcome. Future research could focus on further disentangling event-splitting and correlation effects. The recent findings of Frydman and Mormann (2018), which are in line with salience theory and cannot – as a whole – be explained by event-splitting effects, reinforce this kind of reasoning.[21]

Our results also contribute to understanding the real-world implications of event-splitting effects. As pointed out by Johnson et al. (1993), framing has a substantial influence on insurance purchases. They experimentally showed that subjects perceive the likelihood of a particular risk as greater when split into subrisks. Humphrey (2006) argues that splitting risks leads someone into believing to receive a higher coverage. Hence, insurance companies may charge higher premiums when mentioning the most detailed subrisks. As our results document event-splitting effects in the context of real-world events, they rationalize these findings.

[21] Yet, we are unaware of any research investigating the potentially varying effects of the way event-splitting is executed. For example, event-splitting might affect decision making differently depending on in which proportions probabilities are split. This could also be the subject of future research.

Appendix

1.A Table and pretext presented to subjects with each choice problem of the temperature choice setting

The following table shows the maximum and the minimum daytime temperature on Christmas Day (December 25) in Munich in degrees Celsius (°C) in the past ten years:

Year	Maximum daytime temperature	Minimum daytime temperature
2009	11.1	3.0
2010	-2.4	-6.7
2011	4.9	0.6
2012	16.3	4.2
2013	16.7	4.3
2014	8.6	2.2
2015	14.8	7.1
2016	10.5	5.6
2017	6	-2.5
2018	2.2	-2.1

Source: Kachelmann (2021)

1.B Political choice setting in its event-splitting display format for both versions of the common consequence

Choose between R^j and S^j:

R^1:	€20	if the results of the CDU/CSU are above 27.5%	S^1:	€18	if the results of the CDU/CSU are above 27.5%
	€18	if the results of the CDU/CSU are between 25% and 27.5%		€18	if the results of the CDU/CSU are between 25% and 27.5%
	€0	if the results of the CDU/CSU are below 25%		€18	if the results of the CDU/CSU are below 25%
R^2:	€20	if the results of the CDU/CSU are above 27.5%	S^2:	€18	if the results of the CDU/CSU are above 27.5%
	€0	if the results of the CDU/CSU are between 25% and 27.5%		€0	if the results of the CDU/CSU are between 25% and 27.5%
	€0	if the results of the CDU/CSU are below 25%		€18	if the results of the CDU/CSU are below 25%

1.C Experimental instructions

1.C.1 Introductory instructions

Dear participant,

We would like to welcome you to our experiment. The subject of our study is human decision making in situations under uncertainty. We kindly ask you to answer the following questionnaire. It will be processed individually, without any cooperation or interaction with other participants. The questionnaire consists of two sub-blocks, which in turn consist of so-called decision problems. At the beginning of each sub-block, the concrete structure and procedure will be explained to you.

Please note that as soon as you have finished working on a decision problem and have switched to the next decision problem by clicking on the "Next" button, it is no longer possible to correct previous answers. Therefore, there is no "back" function by which you can revise the answer to a previous decision problem.

IMPORTANT: For all decision problems, unless explicitly stated otherwise, there are neither correct nor incorrect answers, but they depend solely on your individual preferences.

Throughout the experiment, you cannot communicate with other participants, use mobile phones, or start other programs on the computer. If you violate this rule, we will, unfortunately, have to exclude you from the experiment and all its payouts. If you have a question, please press the red button next to your seat. An advisor will then come to your seat to quietly answer your question. If the question is relevant to all participants, he will answer it and repeat it out loud.

At the beginning of the questionnaire, we ask you to give a few more details about yourself. In particular, we need your name to assign your processing to you and pay out the amount of money you have earned.

1.C.2 Instructions for the experiment's first part

In this part of the questionnaire, we ask you to complete a total of 27 decision problems in succession.

A decision problem can contain different tasks. Usually, this is the choice between two lotteries, i.e., the choice in which of two different gambles you wish to participate. Another possibility is the question of how much one would have to pay you for you to refrain from playing a certain lottery (winning chance) or how much you would be willing to pay to abstain from playing a certain lottery (losing chance).

After completing the questionnaire, you will be assigned one of the 27 decision problems as a real gamble to be played by you on the basis of your previous decision, with the corresponding amounts of money.

We would like to point out once again that a correction of a decision made is only possible as long as you have not yet switched to the next decision problem. As soon as you switch to the next decision problem by clicking the "Next" button, your answer is final.

1.C.3 Instructions for the experiment's second part

In this part of the questionnaire, we ask you to work on a total of 2 decision problems in succession. Both decision problems will be played by you afterward – based of the decision you make now.

1.D Remaining choice problems employed in the questionnaire

Part I: Choice problem 1

A random number generator is programmed to deliver one of three possible conditions, 1, 2, or 3, each with the same probability of one-third. Lotteries A and B disburse payoffs depending on the draw of the random number generator.

	Condition 1	Condition 2	Condition 3
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
Lottery A	15€	10€	0€
Lottery B	25€	0€	0€

Choose between lottery A and lottery B.

Part I: Choice problem 2

A random number generator is programmed to deliver one of three possible conditions, 1, 2, or 3, each with the same probability of one-third. Lotteries A and B disburse payoffs depending on the draw of the random number generator.

	Condition 1	Condition 2	Condition 3
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
Lottery A	15€	10€	0€
Lottery B	0€	0€	25€

Choose between lottery A and lottery B.

Part I: Choice problem 3

A random number generator is programmed to deliver one of three possible conditions, 1, 2, or 3, each with the same probability of one-third. Lotteries A and B disburse payoffs depending on the draw of the random number generator.

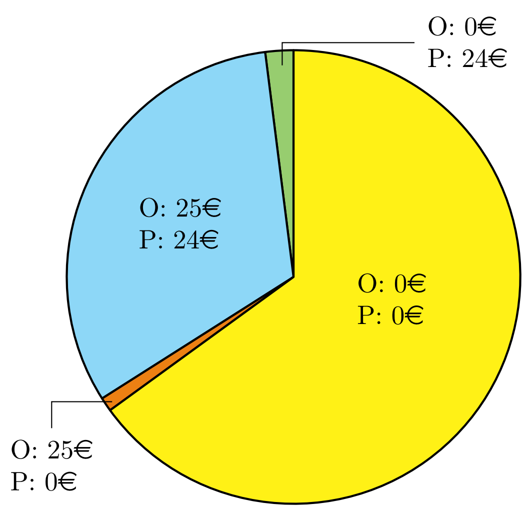
	Condition 1	Condition 2	Condition 3
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
Lottery A	15€	10€	0€
Lottery B	0€	25€	0€

Choose between lottery A and lottery B.

Part I: Choice problem 4

The two lotteries O and P disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries O and P disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Yellow: 65%
Blue: 32%
Brown: 1%
Green: 2%

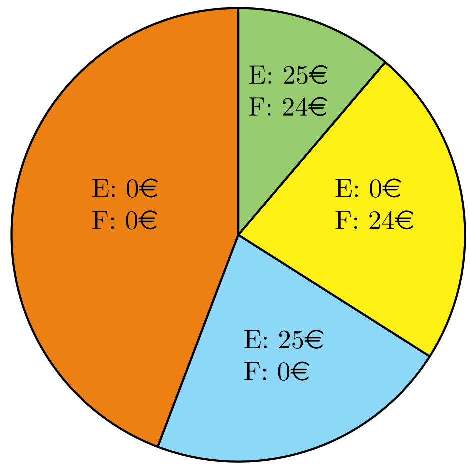


Choose between lottery O and lottery P.

Part I: Choice problem 5

The two lotteries E and F disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries E and F disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Yellow:	22.78%
Blue:	21.78%
Brown:	44.22%
Green:	11.22%

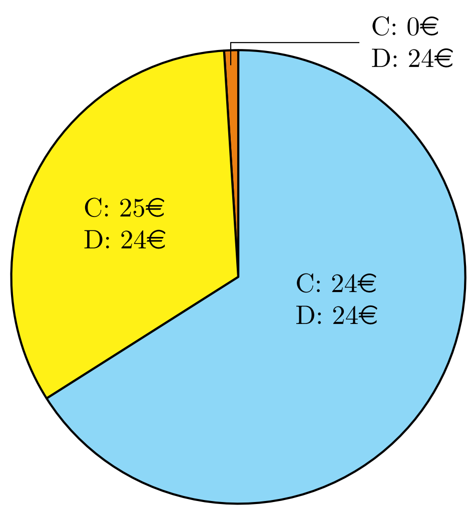


Choose between lottery E and lottery F.

Part I: Choice problem 6

The two lotteries C and D disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries C and D disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Yellow:	33%
Blue:	66%
Brown:	1%

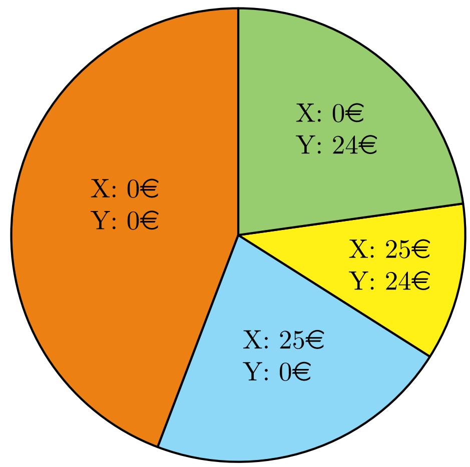


Choose between lottery C and lottery D.

Part I: Choice problem 7

The two lotteries X and Y disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries X and Y disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Green: 22.78%
Blue: 21.78%
Brown: 44.22%
Yellow: 11.22%

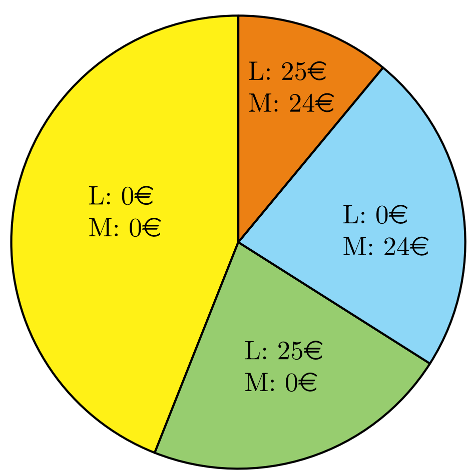


Choose between lottery X and lottery Y.

Part I: Choice problem 8

The two lotteries L and M disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries L and M disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Green: 22%
Blue: 23%
Brown: 11%
Yellow: 44%

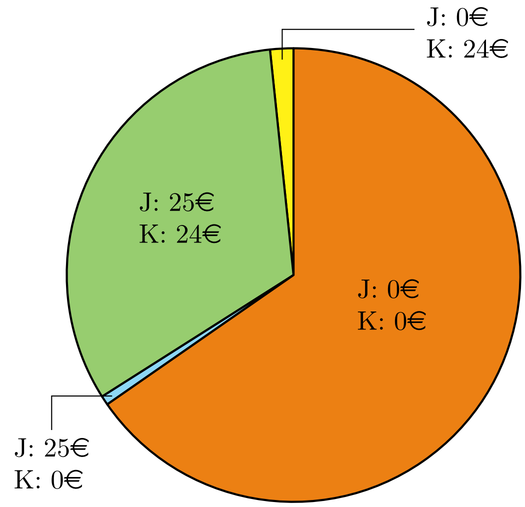


Choose between lottery L and lottery M.

Part I: Choice problem 9

The two lotteries J and K disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries J and K disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Brown: 65.34%
Green: 32.34%
Blue: 0.66%
Yellow: 1.66%

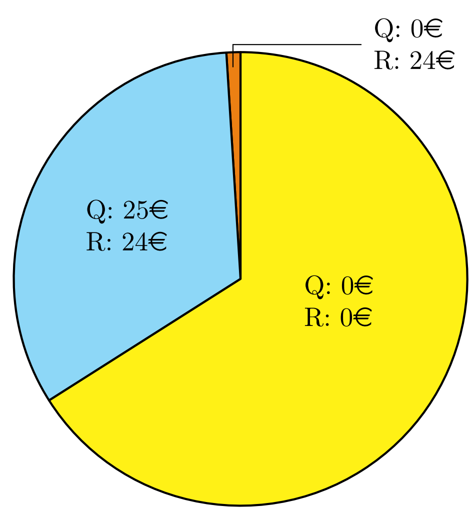


Choose between lottery J and lottery K.

Part I: Choice problem 10

The two lotteries Q and R disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries Q and R disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Yellow: 66%
Blue: 33%
Brown: 1%

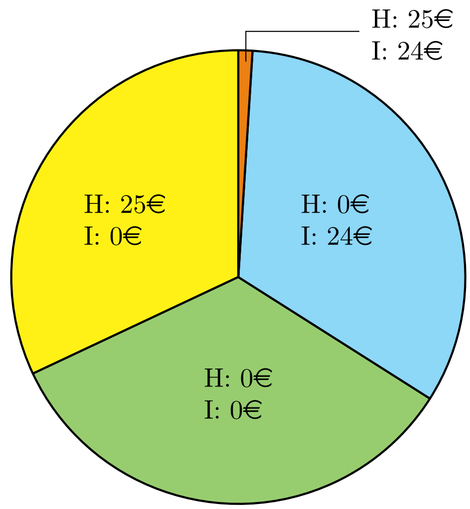


Choose between lottery Q and lottery R.

Part I: Choice problem 11

The two lotteries H and I disburse payoffs depending on the outcome of a random number generator. Think of the random number generator as a wheel of fortune with several differently-colored and differently-sized fields. Depending on which field the pointer of the wheel of fortune stops in after its rotation, the lotteries H and I disburse payoffs. The proportional area of the fields and thus the probabilities that the wheel of fortune stops at them as well as the corresponding payoffs of both lotteries can be represented as follows:

Brown: 1%
Green: 34%
Blue: 33%
Yellow: 32%



Choose between lottery H and lottery I.

Part I: Choice problem 12

There are two available lotteries, A and B, whose possible payoffs are linked to the random drawing of a ball from two separate urns, each containing 100 balls. The urn used for lottery A contains 5 blue, 5 white and 90 red balls. Lottery A pays 14€ if the drawn ball is a blue one, 12€ if it is white and 96€ if it is a red ball. In the urn used for lottery B, there are 85 green balls, 5 black balls, and 10 yellow balls. Lottery B pays 96€ if the drawn ball is a green one, 90€ if it is black and 12€ if a yellow ball is drawn. The following figure shows the two lotteries in tabular form:

Urn/Lottery A	**Urn/Lottery B**
05 blue balls to win 14€	85 green balls to win 96€
05 white balls to win 12€	05 black balls to win 90€
90 red balls to win 96€	10 yellow balls to win 12€

Choose between lottery A and lottery B.

Part I: Choice problem 13

There are two available lotteries, A and B, whose possible payoffs are linked to the random drawing of a ball from two separate urns, each containing 100 balls. The urn used for lottery A contains 90 red, 5 blue, and 5 white balls. Lottery A pays 96€ if the drawn ball is a red one, 14€ if it is blue and 12€ if it is a white ball. In the urn used for lottery B, there are 85 green balls, 5 black balls, and 10 yellow balls. Lottery B pays 96€ if the drawn ball is a green one, 90€ if it is black and 12€ if a yellow ball is drawn. The following figure shows the two lotteries in tabular form:

Urn/Lottery A	**Urn/Lottery B**
90 red balls to win 96€	85 green balls to win 96€
05 blue balls to win 14€	05 black balls to win 90€
05 white balls to win 12€	10 yellow balls to win 12€

Choose between lottery A and lottery B.

Part I: Choice problem 14

There are two available lotteries, A and B, whose possible payoffs are linked to the random drawing of a ball from two separate urns, each containing 100 balls. The urn used for lottery A contains 85 red, 5 further red, 5 white, and 5 blue balls. Lottery A pays 96€ if the drawn ball is a red one, 12€ if it is white and 14€ if it is a blue ball. In the urn used for lottery B, there are 85 green balls, 5 yellow balls, 5 further yellow balls, and 5 blue balls. Lottery B pays 96€ if the drawn ball is a green one, 12€ if it is yellow, and 90€ if a black ball is drawn. The following figure shows the two lotteries in tabular form:

Urn/Lottery A	**Urn/Lottery B**
85 red balls to win 96€	85 green balls to win 96€
05 red balls to win 96€	05 yellow balls to win 12€
05 white balls to win 12€	05 yellow balls to win 12€
05 blue balls to win 14€	05 black balls to win 90€

Choose between lottery A and lottery B.

Part I: Choice problem 15

With lottery X, you win 10€ with 80% probability and get nothing with 20% probability (no win = 0€). Please write in the field below the minimum amount you would have to be paid to give up the chance to play the lottery (we call this amount your “minimum selling price”).

If this decision problem is assigned to you as a real gamble, any amount between 0.01€ and 10€, accurate to the cent, will be determined by a random mechanism (for all amounts, the probability of being drawn is the same). If this amount is greater than or equal to your specified minimum selling price, you will be paid the amount. Should the amount be lower than your minimum selling price, you will play lottery X.

Part I: Choice problem 16

With lottery Y, you lose 10€ with 80% probability and get nothing with 20% probability (no loss = 0€). Please write in the field below the maximum amount you would be willing to pay to avoid playing the lottery (we call this amount your “maximum avoidance willingness”).

If this decision problem is assigned to you as a real gamble, any amount between 0.00€ and 9.99€, accurate to the cent, will be determined by a random mechanism (for all amounts, the probability of being drawn is the same). If the amount is lower or equal to your specified maximum avoidance willingness, you will have to pay the amount. If the amount is greater than your maximum avoidance willingness, you will play lottery Y.

Part I: Choice problem 17

Imagine you have the choice between a sure win of 6€ and playing a lottery with the chance to win 10€.

Please write in the box below the minimum probability with which the lottery would have to disburse the 10€ so that you would be willing to play the lottery instead of choosing to receive 6€ with certainty. Please write this probability as a percentage (values between 0 and 100).

If this decision problem is assigned to you as a real gamble, any percentage value between 1% and 100% will be determined by a random mechanism afterward (for all percentages, the probability of being drawn is the same). If this percentage is greater than or equal to the probability you specified, you will play the lottery in such a way that you can win 10€ with the probability determined by the random mechanism. If the percentage drawn is smaller than your specified probability, you will receive 6€.

Part I: Choice problem 18

Imagine you have to choose between a sure loss of 6€ and playing a lottery with the possibility to lose 10€.

Please write in the box below the maximum probability of losing the 10€ when playing the lottery so that you would be willing to play the lottery instead of choosing the sure loss of 6€. Please write this probability as a percentage (values between 0 and 100).

If this decision problem is assigned to you as a real gamble, any percentage value between 0% and 99% will be determined by a random mechanism afterward (for all percentages, the probability of being drawn is the same). If this percentage is less than or equal to the probability you specified, you play the lottery in such a way that you can lose 10€ with the probability determined by the random mechanism. If the percentage drawn is greater than your specified probability, you will lose 6€ for sure.

Part II: Choice problem 1

The two lotteries A and B are available for selection.

A:	8.50€	with 75%	**B:**	6€	as a sure gain
	0€	with 25%			

Choose between lottery A and lottery B.

Part II: Choice problem 2

The two lotteries A and B are available for selection.

A:	8.50€	with 3%	**B:**	6€	with 4%
	0€	with 97%		0€	with 96%

Choose between lottery A and lottery B.

Screen-out-question

A man buys a coin with a collector's value for €60. After one year, he sells the coin for €70. Very soon, he regrets his sale and repurchases it for €80.
Finally, after one more year, he decides to ultimately sell the coin and receives €90 for it.

How much profit did the man make in total with all his purchases and sales of the coin? (If this choice problem gets selected at random for you to play it for real money after completing the questionnaire, you will receive €10 if you have answered the question correctly.)

☐ €20

☐ €15

Chapter 2

Investigating the Empirical Validity of Salience Theory: The Role of Display Format Effects

As predicted by the salience theory of choice under risk, the correlation between lotteries has been shown to affect subjects' preferences. We conduct two online experiments challenging this perception. In our first experiment, we show that prominent recent experimental findings in support of salience-predicted correlation effects were driven by changes of the display format rather than the salience of payoffs: i) salience effects vanish when controlling for simultaneous changes in the display format when varying the correlation structure. ii) choice patterns previously attributed to the salience mechanism can be induced by keeping the correlation structure constant and only varying the display format. In our second experiment, we find that in a horse-race between display format and salience effects, the former are quantitatively more important. In a setup that allows studying correlation effects without confounding changes of the display format, we are unable to detect significant salience-predicted correlation effects.

2.1 Introduction

Salience theory of choice under risk (Bordalo et al. 2012b) is a prominent yet parsimonious approach to explain many behavioral anomalies in decision making under risk.[1] Because a decision maker's focus is directed toward salient states of the world, the way lotteries are correlated is predicted to influence subjects' choice behavior. Recently, Herweg and D. Müller (2021) have shown mathematically that salience theory is a special case of generalized regret theory (Loomes and Sugden 1987).[2] Thus, many theoretical predictions on choice behavior overlap between these two theories. At the same time, many experimental findings on regret theory also apply to salience theory. Importantly, the early literature has shown that the effect of correlation between lotteries on choice behavior (which causes a so-called "juxtaposition effect")[3] is usually overestimated if changes in the display format confound the analysis. Choice behavior initially ascribed to correlation effects was subsequently found to be caused by event-splitting (see, e.g., Starmer and Sugden 1993). Event-splitting effects occur when, for the purpose of displaying the state space, events are split into subevents and therefore the lotteries' payoffs associated with the event get displayed twice. Subjects tend to consider the joint probability of these subevents to be *higher* compared to the underlying single event, therefore overweighting the lotteries' corresponding payoffs (Birnbaum 2004, 2007).

In this chapter, we argue that similar event-splitting effects have confounded the recent experimental evidence put forth in support of salience theory. The experimental studies of Bordalo et al. (2012b), Bruhin et al. (2018), Dertwinkel-Kalt and Köster (2020, henceforth: DKK), and Frydman and Mormann (2018) investigate salience-predicted correlation effects by repeatedly presenting subjects the same decision problems with modified state spaces, all involving some degree of event-splitting. This simultaneous change in the correlation structure and the display format makes it almost impossible to disentangle the relative contribution of salience and event-splitting effects for explaining the obtained choice patterns.

To fix ideas, consider the decision problem adopted from DKK and presented in Figure 2.1, which involves the choice between a pair of lotteries, A and B, that disburse payoffs depending on the outcome of a wheel of fortune with 100 fields. The turn of the wheel determines the probabilities of all outcomes

[1] Salience theory can account for, e.g., the Allais (1953) paradox and the reflection and the fourfold pattern of risk attitudes (e.g., Baucells and Villasís 2010; Harbaugh et al. 2010; Tversky and Kahneman 1992). Moreover, it accommodates preference reversals (Lichtenstein and Slovic 1971) that prospect theory (Kahneman and Tversky 1979; Tversky and Kahneman 1992) is unable to explain. Salience theory's psychological underpinning also provides a rationale for decision making in diverse areas such as the formation of asset prices (Bordalo et al. 2013), the endowment effect (Bordalo et al. 2012a), investor behavior (Frydman and B. Wang 2020), judicial decisions (Bordalo et al. 2015), and tax evasion (Fochmann and Wolf 2019).

[2] The original regret theory (Loomes and Sugden 1982), in turn, is a special case of salience theory. Both salience theory and regret theory belong to the class of skew-symmetric additive models (Fishburn 1988, 1990).

[3] The effect describes a shift of agents' preferences due to changes of the juxtaposition of the involved lotteries' outcomes.

and the correlation between the two lotteries. Salience theory argues that decision makers perceive a state as salient if there is a large contrast between the associated payoffs and subsequently overweight the probability of a highly salient state. Figure 2.1(a) displays the case of perfectly negatively correlated lotteries. Here, the state $(40, 104)$ is most salient as it exhibits the greatest contrast between payoffs. Subjects should therefore assign a higher subjective probability to it than the true 36 out of 100. This favors lottery B because its upside payoff of 104 is getting overweighted, as is A's downside payoff of 40. Figure 2.1(b) displays the opposite case of a perfectly positive correlation. Here, the state $(90, 54)$ and therefore the upside and downside payoffs of lotteries A and B, respectively, exhibit the highest salience. As a consequence, salience theory predicts lottery A to have a higher appeal when the correlation is positive than when it is negative.

DKK find strong support for this prediction in a lab experiment. However, comparing panels (a) and (b) shows that making the positive correlation transparent to subjects involves event-splitting: lottery A disburses its upside payoff in 64% of the cases, yet the event is split into two subevents in panel (b) (and similarly for lottery B's downside payoff). Hence, the experimental evidence for the higher attractiveness of lottery A under positive correlation might, in fact, be driven by event-splitting effects, i.e., subjects' perceiving the joint probability of the two subevents in panel (b) as greater than the single event in panel (a), regardless of the underlying correlation. To control for this possible confounder, we employ a natural extension of the experimental setup: introducing a third decision problem that employs the same event-splitting technique for the negative correlation as shown in panel (c). Suppose salience and therefore correlation was the true cause of the observed decision patterns of DKK. In that case, the choice patterns should be identical when letting subjects choose between positively and negatively correlated lotteries *both* involving event-splitting, i.e., choosing between (b) and (c) instead of (a) and (b).

We conducted two incentivized online experiments to investigate the empirical validity of salience theory. In Experiment 1, we show that there is no evidence for salience-predicted correlation effects when accounting for the display format in the studies of DKK and Frydman and Mormann (2018). For DKK's study on preferences for relative skewness, we implement the additional event-splitting treatment presented in Figure 2.1(c) and observe no salience effect when comparing the treatment of panel (b) versus (c). In contemporary, independent work, Dertwinkel-Kalt and Köster (2021) report the same when controlling for event-splitting in their initial design. Interestingly, they then find no effect on choice behavior, while the present study finds a choice reversal relative to the initially presumed correlation effect. However, DKK present the subevents separated from each other as opposed to side by side in the present study.

Negative correlation

Fields of a wheel of fortune	1-64	65-100
Lottery A	90	40
Lottery B	54	104

(a)

Positive Correlation

Fields of a wheel of fortune	1-36	37-72	73-100
Lottery A	90	40	90
Lottery B	104	54	54

(b)

Negative correlation split

Fields of a wheel of fortune	1-36	37-64	65-100
Lottery A	90	90	40
Lottery B	54	54	104

(c)

Figure 2.1: Exemplary decision problem illustrating the challenge to separate event-splitting and correlation effects. Lotteries A and B disburse payoffs depending on the turn of a wheel of fortune with 100 fields. Panel (a) shows a negative correlation between the two lotteries without event-splitting. Panel (b) shows a positive correlation, simultaneously employing event-splitting to make the correlation structure transparent. Panel (c) incorporates the same form of event-splitting for the negative correlation case from panel (a). The original decision problem is adopted from DKK and involves comparing (a) and (b). Comparing (b) and (c) allows controlling for event-splitting.

These distinct approaches to implement the event-splitting may explain the differences in results, an interpretation consistent with the second part of Experiment 1. We repeat the study of Frydman and Mormann (2018), maintaining their changes of the display format but keeping the correlation between lotteries constant across all decision problems. Because the results are very similar to the originally observed choice patterns, although it cannot be caused by correlation, we conclude that display format effects are the driver. The fact that this happens despite Frydman and Mormann (2018)'s design partially controlling for event-splitting shows the subtle influence of the exact way the split proportions are presented to subjects. At the same time, the findings from Experiment 1 highlight the need to investigate correlation effects within a framework that abstains from potentially confounding changes in the display format.

Experiment 2 removes event-splitting as a confounder from the equation by keeping the display format constant. To do so, subjects worked on binary decision problems involving three equally likely states of the world. Because each problem was presented both in a gain and a loss frame, the setup also allows inference on salience theory's required value function. While salience theory can encompass general value functions, most applications assume a linear one in order to generate the reflection of risk attitudes. Recently, Dertwinkel-Kalt et al. (2020) have introduced the possibility of a salient thinker possessing a concave value function in the domain of gains. We show that, in order to explain our observed choice behavior, salience theory needs to implement a value function similar to the one in prospect theory: concave in the domain of gains and convex in the domain of losses. However, even with this less parsimonious value function, we are unable to detect salience-predicted correlation effects – in line with the results of Experiment 1.

In terms of findings, the present chapter is most closely related to the empirical literature on juxtaposition effects in the context of regret theory. While early studies on regret theory found great support for juxtaposition effects (see, e.g., Battalio et al. 1990; Starmer 1992; Starmer and Sugden 1989), it was later realized that controlling for event-splitting rendered the effect of correlation between lotteries on choice behavior insignificant (see, e.g., Harless 1992; Humphrey 1995; Starmer and Sugden 1993). Our findings reconcile this earlier literature with the recent experimental evidence in support of salience theory (Bordalo et al. 2012b; Bruhin et al. 2018; Frydman and Mormann 2018). Our work is also related to the experimental literature reporting mixed results regarding the empirical validity of salience theory (see, e.g., Alós-Ferrer and Ritschel forthcoming).

Recently, Bordalo et al. (2012b) and Dertwinkel-Kalt and Köster (2015) have argued that causality between event-splitting and correlation runs in the opposite direction, i.e., that changes in the correlation between lotteries explain event-splitting effects. Bordalo et al. (2012b) illustrate how the salience mechanism can account for experimental evidence concerning a correlated version of the Allais paradox where correlation is conveyed by a matrix display format incorporating event-splitting. Similar to earlier findings by Birnbaum and Schmidt (2010), Allais reversals subside under perfect correlation, which Bordalo et al. (2012b)'s salience theory can explain by the common consequence becoming nonsalient. The present chapter not only shows that event-splitting effects arise regardless of the correlation between lotteries, but also that such event-splitting effects tend to be stronger than salience-induced correlation effects. In an experimental setup where the direction of event-splitting effects counters the salience-predicted correlation effect, the former dominate.

The experimental framework employed in the present chapter builds on Leland (1998), who introduced the idea to invoke equally likely states to investigate juxtaposition effects but did not pursue the idea via an empirical investigation. Experimental studies like Birnbaum and Diecidue (2015) and Baillon et al. (2015) subsequently employed such a design to examine intransitive choices. The present chapter differs from these studies by testing whether preferences concerning the same pair of lotteries reverse when changing the correlation.

Lastly, our findings corroborate and expand the experimental literature on event-splitting effects (e.g., Birnbaum 2004, 2007; Humphrey 2000; Keller 1985). Consistent with this literature, we find that event-splitting concerning a lottery's upside payoff increases its attractiveness for a decision maker. We present incentivized evidence both for the domain of gains and losses.

The remainder of this chapter is structured as follows: Section 2.2 provides a summary of salience theory, while Section 2.3 presents the experimental design and results. Section 2.4 discusses the findings and concludes.

2.2 Salience theory of choice under risk

Salience theory employs a state-dependent utility approach (for an in-depth presentation, see Bordalo et al. (2012b)). A decision problem is linked to a set of possible states of the world, $\mathbb{S}$, where a state $s \in \mathbb{S}$ is defined with known and objective probability π_s and $\sum_{s\in\mathbb{S}} \pi_s = 1$. A lottery L_i disburses payoff x_s^i in state s. As both of our experiments only involve binary decision problems, we restrict ourselves to situations where two lotteries L_i and L_j are available for selection, i.e., the choice set is $\mathbb{C} = \{L_i, L_j\}$. The decision maker is a "local thinker", which means she overweights (underweights) the probabilities of states that are comparatively salient (nonsalient). The salience of a state s is determined by a continuous and bounded salience function $\sigma(x_s^i, x_s^j)$ that has the lotteries' payoffs as input factors. It satisfies the following three properties (Bordalo et al. 2012b):

(i) Ordering: If for states $s, \tilde{s} \in \mathbb{S}$ it holds that $[x_s^{min}, x_s^{max}]$ is a subset of $[x_{\tilde{s}}^{min}, x_{\tilde{s}}^{max}]$, then $\sigma(x_s^i, x_s^j) < \sigma(x_{\tilde{s}}^i, x_{\tilde{s}}^j)$

(ii) Diminishing sensitivity: If $x_s^i, x_s^j > 0$, then for any $\varepsilon > 0$ it holds that $\sigma(x_s^i + \varepsilon, x_s^j + \varepsilon) < \sigma(x_s^i, x_s^j)$

(iii) Reflection: For any two states $s, \tilde{s} \in \mathbb{S}$ where $x_s^i, x_s^j, x_{\tilde{s}}^i, x_{\tilde{s}}^j > 0$ we get $\sigma(x_s^i, x_s^j) < \sigma(x_{\tilde{s}}^i, x_{\tilde{s}}^j)$ if and only if $\sigma(-x_s^i, -x_s^j) < \sigma(-x_{\tilde{s}}^i, -x_{\tilde{s}}^j)$

Higher values assigned by the salience function correspond to a higher level of salience. A state s is more salient when the payoffs of L_i and L_j in s differ more strongly (ordering) and the closer the payoff average is to zero (diminishing sensitivity). It is the magnitude of payoffs that matters, not their sign (reflection). As a state's salience depends on the contrast between both lotteries' disbursed payoffs, the correlation between lotteries, i.e., which state of the world is linked to which payoff, is crucial. For the case of two lotteries, the salience function is symmetric, i.e., $\sigma(x_s^i, x_s^j) = \sigma(x_s^j, x_s^i)$. Furthermore, if the payoffs in s are identical, s has the lowest possible degree of salience due to *zero contrast.* This property was formalized by Frydman and Mormann (2018) and is implicit in Bordalo et al. (2012b) when accounting for the Allais paradox.

The local decision maker works with distorted subjective probabilities with a higher salience rank leading to a higher distorted probability. Denote with $k_s \in \{1, \ldots, |\mathbb{S}|\}$ the salience rank of a state s. States that are equally salient receive the same rank, and the ranking has no jumps. The probability weighting of a generic state s is the result of multiplying π_s with a decision weight ω_s:

$$\omega_s = \frac{\delta^{k_s}}{\sum_{r \in \mathbb{S}} \delta^{k_r} \cdot \pi_r}. \tag{2.1}$$

Here, $\delta \in (0, 1]$ captures a decision maker's degree of local thinking. The lower δ, the higher the level of local thinking and therefore the overweighting of probabilities of salient states.[4] The local thinker's overall evaluation of a lottery L_i is then denoted as $V(L_i)$ and calculated as

$$V(L_i) = \sum_{s \in \mathbb{S}} \pi_s \cdot \omega_s \cdot v(x_s^i) \tag{2.2}$$

with $v(x)$ representing a decision maker's value function in order to evaluate the lotteries' payoffs relative to the reference point of zero.[5] In the evaluation process of both L_i and L_j, we receive an identical probability distortion for each state due to the symmetry property of the salience function. Hence, for $L_i \succ L_j$, it must hold that $V(L_i) > V(L_j)$, which is equal to:

$$\sum_{s \in \mathbb{S}} \pi_s \cdot \omega_s \cdot [v(x_s^i) - v(x_s^j)] > 0. \tag{2.3}$$

2.3 Two experiments on the empirical validity of salience theory

We pursue a two-fold approach to examine salience-predicted correlation effects. In Experiment 1, we investigate whether previous experimental evidence of DKK and Frydman and Mormann (2018) supporting salience theory is robust to controlling for display format effects. In Experiment 2, we create an analytical framework that does not require changes in the display format to illustrate a modified correlation between lotteries. We employ this design in the domain of gains and losses. Additionally, we implement a treatment where event-splitting effects work in the opposite direction of salience-predicted correlation effects.[6]

[4] Classic expected utility maximization is nested for $\delta = 1$ and hence $\omega_s = 1$, in which case the subjective probabilities coincide with the objective ones.

[5] Applications usually assume a linear value function to generate the reflection of risk attitudes. A concave value function in the loss domain would create a preference for a moderate and certain loss (Bordalo et al. 2012b).

[6] We pre-registered both experiments on the AEA RCT Registry (AEARCTR-0007919).

Both experiments were conducted online on July 5 in 2021, and employ a within-subjects design. Participants were recruited from the subject pool of the "Munich Experimental Laboratory for Economic and Social Sciences" (MELESSA). In both experiments, subjects had to work on a series of decision problems involving the choice between two lotteries. To ensure incentive compatibility, for each subject, one decision problem was selected at random to be played for real money after completion of the experiment (Azrieli et al. 2018; Starmer and Sugden 1991). Earnings were paid out via bank transfer. Based on DKK, all decision problems were denoted in the experimental currency Taler, with 4 Taler = 1 Euro. Because Experiment 2 also contained problems in a loss frame, subjects were paid an additional participation fee of 17 Euro. The average payoff in Experiment 1 (2) was 18 Euro (17 Euro). The sequence of decision problems and the ordering of lotteries within each problem were randomized at the subject level. For Experiment 1 (2) we recruited 149 (150) German-speaking subjects, of which 93% (81%) were students and 66% (66%) were female.[7] The average participant's age was 24 years (25 years). For further information on both experiments, please see the respective implementation sections. Appendix 2.C and Appendix 2.D provide a translation of the experimental instructions.

2.3.1 Experiment 1: Controlling for display format effects

2.3.1.1 Research hypotheses

The role of correlation between lotteries for human decision making under risk has been investigated in the context of regret theory. Experimental evidence showed the juxtaposition of outcomes within a payoff matrix to strongly affect decision makers' preferences (Starmer 1992; Starmer and Sugden 1989). However, to illustrate a modified correlation structure, it was often necessary to split events into subevents and therefore change the display format. It was later recognized that these event-splitting effects were the real driver behind the presumed juxtaposition effects (see, e.g., Humphrey 1995; Starmer and Sugden 1993). When the event of disbursement of a lottery's upside payoff is split into subevents, the lottery appears more attractive to decision makers because they overestimate the joint probability of the subevents (Birnbaum 2004, 2007).

The fact that regret theory and salience theory share many similarities (Herweg and D. Müller 2021) shows the need to control for changes in the display format when investigating salience-predicted correlation

[7] This is larger than the pre-registered number of 130 subjects for each experiment due to a lower than expected drop-out rate. Because usually 5% to 15% of registered participants are no shows, we initially enrolled 152 subjects.

effects. Recent experimental evidence supporting salience theory's predictions regarding correlation effects all involve event-splitting (DKK; Bordalo et al. 2012b; Bruhin et al. 2018; Frydman and Mormann 2018). We hypothesize that event-splitting effects instead of correlation may be the actual choice determinant. Therefore, putative correlation effects will vanish when properly controlling for event-splitting:

Hypothesis 2.1. *When properly controlling for event-splitting, salience-predicted correlation effects will not show up in experimental data.*

At the same time, if changes of the display format are responsible for the experimental findings on salience theory, we expect to obtain similar results when maintaining the changes in the display format without introducing correlation between lotteries. This setup allows investigating potential display format effects beyond pure event-splitting. Therefore, we formulate Hypothesis 2.2:

Hypothesis 2.2. *Shifts in choice behavior consistent with salience theory persist when keeping the changes of the display format while introducing uncorrelated lotteries.*

2.3.1.2 Implementation: Revisiting the experimental findings of DKK and Frydman and Mormann (2018)

To investigate Hypothesis 2.1, we repeat DKK's study on preferences for relative skewness. Due to their usage of a matrix display format, illustrating and controlling for event-splitting as a potential confounder for salience-predicted correlation effects is straightforward. DKK derive and experimentally verify predictions on how a local thinker's preferences are shaped by i) the level of absolute skewness $S^{abs}(L_A)$ of a lottery L_A (its third standardized central moment) and ii) relative skewness $S^{rel}(L_A, L_B)$, i.e., how skewed two lotteries L_A and L_B are relative to each other.[8]

The experiment on relative skewness involves binary choices between Mao (1970)-pairs of lotteries. Mao-pairs of lotteries have the same mean and variance, while their absolute level of skewness only differs in its sign (left- and right-skewed). The joint distribution of a Mao-pair can be parametrized by one parameter $\eta \in (0, 1)$, with $\eta = 0$ denoting a perfect negative and $\eta = 1$ a perfect positive correlation. Relative skewness between two lotteries L_A and L_B depends on their difference in third moments and third cross-moments, with L_A being skewed relative to L_B if and only if $S^{rel}(L_A, L_B) > 0$. Relative skewness between a Mao-pair's left- and right-skewed lottery is an increasing function of the correlation η.

[8] Context-independent models such as prospect theory can only accommodate the predictions on absolute skewness but not relative skewness.

Table 2.1: Mao-pairs employed by DKK

Left-skewed lottery	Right-skewed lottery	Variance	Skewness S^{abs}	Rel. skewness S^{rel}	
				$\eta = 0$	$\eta = 1$
(120, 90%; 0, 10%)	(96, 90%; 216, 10%)	1296	±2.7	-2.7	-1.5
(135, 64%; 60, 36%)	(81, 64%; 156, 36%)	1296	±0.6	-0.6	1.0
(40, 90%; 0, 10%)	(32, 90%; 72, 10%)	144	±2.7	-2.7	-1.5
(45, 64%; 20, 36%)	(27, 64%; 52, 36%)	144	±0.6	-0.6	1.0
(80, 90%; 0, 10%)	(64, 90%; 144, 10%)	576	±2.7	-2.7	-1.5
(90, 64%; 40, 36%)	(54, 64%; 104, 36%)	576	±0.6	-0.6	1.0

Notes: First two columns: payoffs and probabilities of the left- and right-skewed lotteries in the Mao-pairs. Middle columns: variance and skewness S^{abs} of the lotteries. Final columns: Relative skewness S^{rel} for perfect negative ($\eta = 0$) and positive correlation ($\eta = 1$) between the lotteries. The table is adopted from DKK, with units omitted.

For a local thinker, salience theory predicts the attractiveness of lotteries in a Mao-pair to depend on the sign of relative skewness. Crucially, there exist cases where for $\eta = 0$ a local thinker will prefer the absolutely right-skewed lottery due to it being skewed *relative* to the left-skewed lottery (negative S^{rel}), while the preference relation reverses when the correlation becomes sufficiently positive and relative skewness becomes positive as well. Based on the corresponding threshold value it follows that S^{rel} can only reverse sign, if $|S^{abs}| < \frac{2}{3}\sqrt{3} \approx 1.15$. For absolute skewness values above this value, a local thinker will always prefer the right-skewed lottery, regardless of η.

Table 2.1 depicts the six employed binary decision problems between Mao-pairs. Presenting every problem both under perfectly negative ($\eta = 0$) and positive correlation ($\eta = 1$) between lotteries equals a total of twelve choices. There are two types of decision problems, making use of the relationship between η and S^{rel}. First, for the three pairs involving lotteries with an absolute skewness of ±0.6, the left-skewed lottery is skewed relative to the right-skewed one under $\eta = 1$, while the opposite is true under $\eta = 0$. Here, salience theory predicts correlation effects to arise. Second, in the three problems involving lotteries with $S^{abs} = \pm 2.7$, the right-skewed lottery is skewed relative to the left-skewed lottery under both correlation structures so that no correlation effects should arise.

Consistent with these predictions, the study of DKK yields a highly significant increase of left-skewed lottery choices under $\eta = 1$ compared to $\eta = 0$ for the first type of problems and no significant correlation effect for the second type (for convenience, the original results of DKK are presented in Appendix 2.B.1). Subjects were presented with a matrix display format to illustrate correlation between both lotteries and the turn of a wheel of fortune with 100 fields generated randomness. For example, the last row of Table 2.1 corresponds to Figures 2.1(a) (negative correlation: $\eta = 0$) and 2.1(b) (positive correlation: $\eta = 1$), respectively. As outlined in the introduction, only panel (b) depicting the positive correlation involves event-splitting: The events related to the left-skewed lottery's upside payoff as well as the right-skewed lottery's downside payoff get split into subevents. If subjects consider the sum of the subevents' probabilities as greater than the single event, this will boost the attractiveness of the left-skewed lottery compared to the right-skewed lottery. Therefore, it is impossible to tell whether the observed shifts in choice behavior are caused by the change in correlation structure or the event-splitting (or both). Testing Hypothesis 2.1 that switches in choice behavior are not caused by the correlation structure is straightforward: present subjects also with a decision problem under a negative correlation but with event-splitting. These additional 6 choices bring the total to 18 binary decision problems in our experimental design. Comparing the choice between the positive and negative correlation structures with event-splitting, i.e., panels (b) and (c) of Figure 2.1 allows to isolate the effect of the correlation structure.

In order to investigate Hypothesis 2.2, we repeat the study of Frydman and Mormann (2018), but again control for display format effects – which are more subtle in this case. Their experiment investigates salience-predicted correlation effects within an Allais-type decision problem. The problem involves a risky lottery $(\$25, 0.33; \$0, 0.01; \$z, 0.66)$ and a safe one $(\$24, 0.34; \$z, 0.66)$ that share a common consequence $(\$z, 0.66)$. The common consequence z could take two different values in their experiment, $z = \$24$ and $z = \$0$. If $z = \$24$, the safe lottery pays out \$24 with certainty, and the correlation between both lotteries is undefined. Hence, varying levels of correlation only apply to the case when $z = \$0$. Figure 2.2 depicts the four different employed versions of the decision problem. In each version, both lotteries disburse payoffs depending on the same turn of a wheel of fortune. A pie chart display format is used to illustrate the correlation structure between the lotteries. Panel D depicts the case where $z = \$24$. Due to the in this case undefined correlation, there is only one possible way to illustrate the problem when employing the minimal state space. By contrast, Panel A, B, and C show different correlation structures between both lotteries (full, intermediate, and zero correlation, respectively) for when $z = \$0$. Salience theory then predicts a decision maker's likelihood to choose the risky lottery when $z = \$0$ to decrease with correlation. Hence, the share of subjects who exhibit the Allais paradox (i.e., who choose the risky lottery when $z = \$0$ and the safe lottery when $z = \$24$) should decline when the correlation increases.

Consistent with this prediction of salience theory, Frydman and Mormann (2018) show experimentally that the share of subjects choosing the risky lottery when $z = \$0$ declines with correlation. Hence, combined with the results concerning Panel D, fewer subjects exhibit the Allais paradox with higher levels of correlation between both lotteries when $z = \$0$. In contrast to DKK, these correlation effects

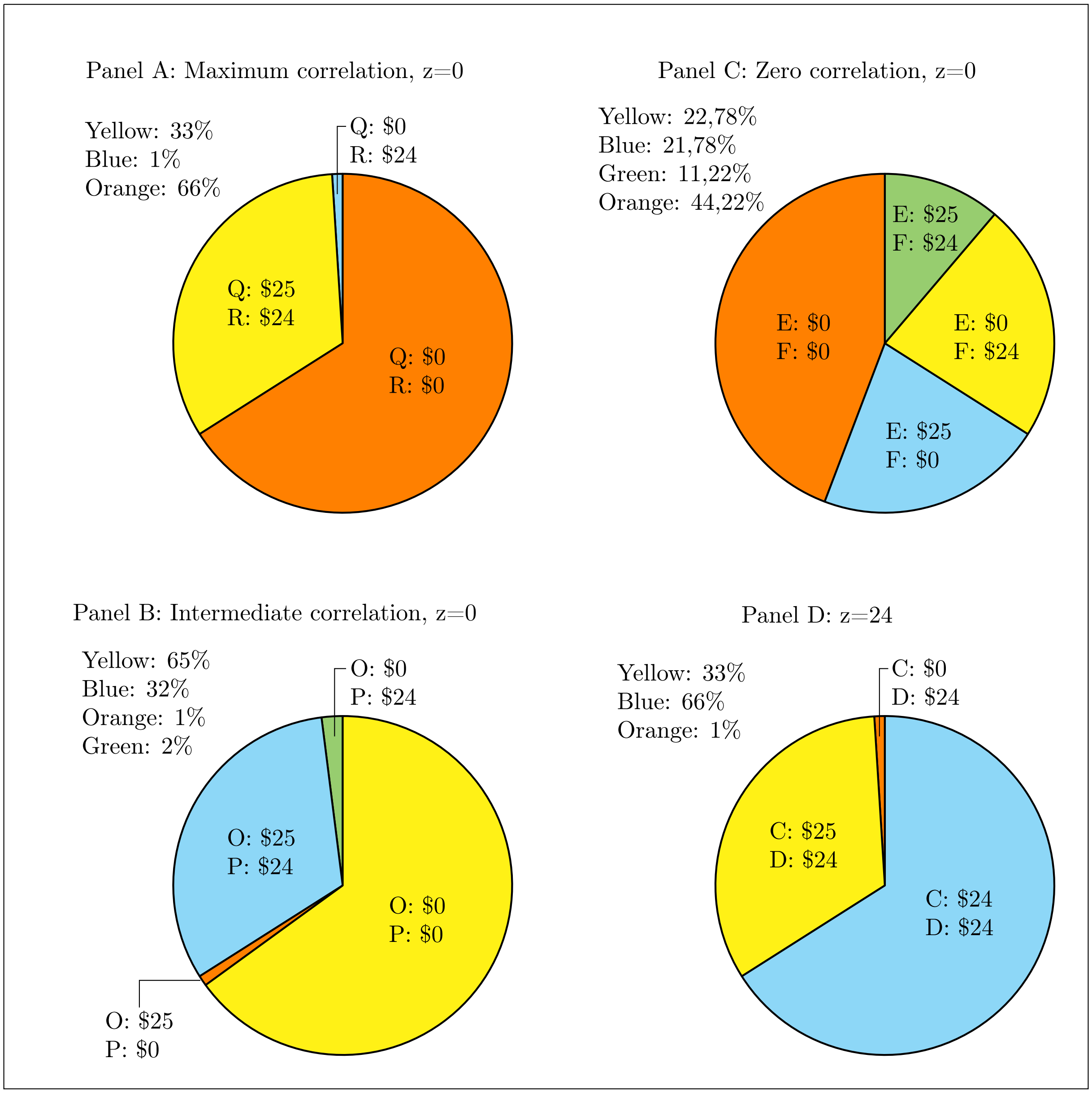


Figure 2.2: Pie charts employed by Frydman and Mormann (2018) in their Allais-type setting. Panels A, B, and C represent the full, intermediate, and zero correlation cases between the involved lotteries when the common consequence is $z = \$0$. Panel D represents the case where $z = \$24$.

cannot be purely attributed to event-splitting because the design partially controls for it. While the step from an intermediate to full correlation indeed involves event-splitting, the step from zero to intermediate correlation is not associated with any further splitting of events. Nevertheless, the last step involves a change in the display format as well because the proportions change. While the probabilities of the states ($\$25, \$24$) and ($\$0, \$0$) are larger than under zero correlation, the ones of ($\$0, \$24$) and ($\$25, \$0$) are smaller. If subjects, for example, employ a heuristic of comparing the most attractive events of each lottery regardless of the correlation, this would explain the shift in choice behavior from zero to intermediate correlation.[9]

To test whether the presumed correlation effects are again caused by display format effects, we repeat the experimental design and maintain the changes in the display format, but with a crucial modification: We keep the correlation constant. To do so, we employ the same four decision problem variants from Panel A, B, C, and D, but with lotteries that are uncorrelated due to being linked to distinct wheels of fortune, indicated by two differently-colored pie charts. We then examine whether the share of observed Allais paradoxes still declines in a similar manner when moving from the problem based on Panel C to the one based on Panel B and also when moving from B to A. This will only be the case if not correlation, but the specific representation of the decision problems causes the shifts in preferences. Figure 2.3 depicts an English translation of the decision problem based on Panel B (the intermediate correlation case of Frydman and Mormann (2018)) as presented to subjects. Together with the 18 decision problems based on DKK, Experiment 1 involved 22 problems in total.

2.3.1.3 Results

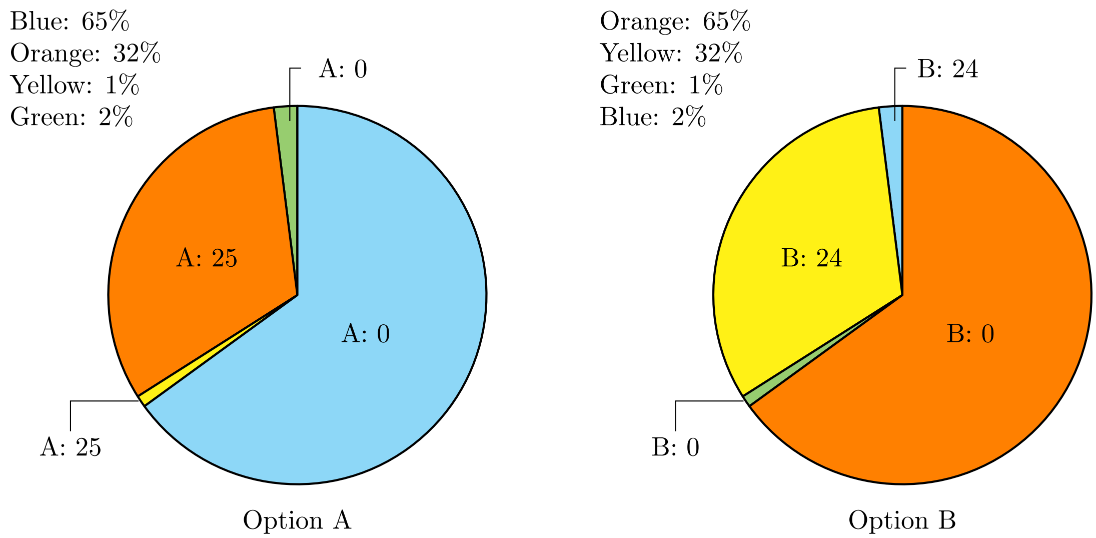
Figure 2.4 displays our results for the test of Hypothesis 2.1 using the study on preferences for relative skewness from DKK. The left and right parts of the figure report the pooled results for the decision problems involving lotteries with an absolute level of skewness of $|S^{abs}| = 0.6$ and 2.7, respectively. Solid bars report the share of right-skewed lottery choices under the positive correlation $\eta = 1$, hatched bars under the negative correlation $\eta = 0$. The first group of bars presents the results for the original display format of DKK, where event-splitting is only conducted for the positive correlation case. The second group presents results for the treatment where event-splitting is also consistently applied to the negative correlation.[10]

Confirming the results of DKK, we find a similar choice pattern when employing their original display format. First, subjects more often choose the right-skewed lottery under the negative compared to the positive correlation when $|S^{abs}| = 0.6$. The difference in shares of right-skewed lottery choices is 0.181

[9] See, e.g., Guo (2019), who proposes a model where agents' choices are based on the foci of all lotteries, i.e., the specific events yielding a relatively high payoff with a relatively high probability compared to all other possible events.

[10] The reference case of the positive correlation is the same across both pairs of bars.

Decision problem
Shown below are two wheels of fortune, each with differently sized and color-coded fields. The probability of a wheel of fortune coming to a stop in a certain field after it has been spun is indicated in each case at the edge. The payouts of the two Options A and B depend on the field in which the wheel of fortune assigned to them comes to a stop.



Choose between Option A and Option B.

Figure 2.3: Uncorrelated version of Panel B employed when repeating the study on correlation effects from Frydman and Mormann (2018). As the actual experiment employed the experimental currency Taler (4 Taler = 1 Euro), the shown payoffs were multiplied by four for comparability.

and hence quantitatively larger than in DKK by 5.4 percentage points.[11] Second, for $|S^{abs}| = 2.7$ there is no significant difference in choices induced by the switch from a negative to a positive correlation. Both findings are prima facie consistent with the predictions of salience theory regarding correlation effects.

However, the picture looks quite different when isolating the pure correlation effect by consistently applying event-splitting to both the negative and the positive correlation case. The second group of bars, depicting the consistent event-splitting treatment, shows that the choice pattern even reverses for

[11] We follow DKK and Frydman and Mormann (2018) in conducting OLS regressions to compute the required paired t-tests. The dependent variable takes a value of 1 if subjects shift from a choice of the right-skewed lottery under the negative correlation to a choice of the left-skewed lottery under positive correlation. It takes a value of -1 for the reverse shift and zero for no shift. Hence, the mean of the dependent variable also denotes the average shift in right-skewed lottery choices from negative to positive correlation. Regressing the dependent variable on a constant yields the required t-test and allows to cluster the standard errors at the subject level.

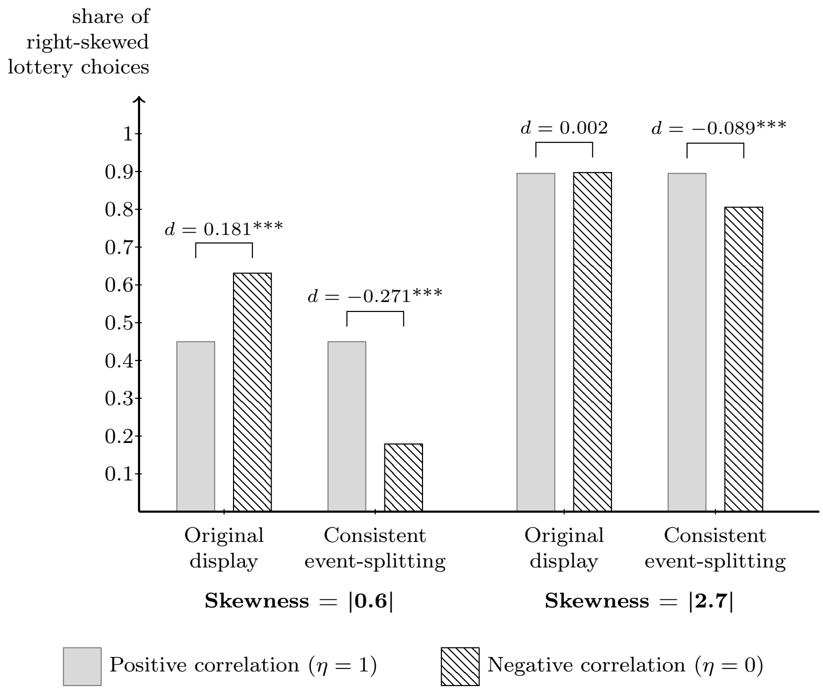


Figure 2.4: Preferences for relative skewness when controlling for event-splitting. The left panel presents the pooled results of the decision problems involving lotteries with an absolute skewness of $|S^{abs}| = 0.6$, the right one for $|S^{abs}| = 2.7$. Solid bars depict the share of right-skewed lottery choices under the positive correlation ($\eta = 1$), hatched bars under the negative correlation ($\eta = 0$). Original display refers to DKK's presentation with event-splitting only applying to the positive correlation case, consistent event-splitting to the treatment with event-splitting regardless of the correlation. d reports the difference between right-skewed lottery choices under negative and positive correlation within each treatment, with p-values based on paired t-tests with standard errors clustered at the subject level. Significance level: * Significant at 5%; **: 1%; ***: 0.1%.

$|S^{abs}| = 0.6$. 27% fewer subjects chose the right-skewed lottery under the negative compared to the positive correlation. While this finding is in line with Hypothesis 2.1, it runs contrary to salience-predicted correlation effects. A similar effect is found for the lotteries with an absolute level of skewness of 2.7 – albeit with a smaller magnitude of only 8.9 percentage points. For both levels of absolute skewness, the decrease in right-skewed lottery choices when consistently applying event-splitting is highly significant.

These findings indicate that the way event-splitting is executed plays an important role in decision making.[12] In contemporary, independent work, Dertwinkel-Kalt and Köster (2021) also investigated the robustness of their results when controlling for event-splitting. Consistent with our results, they also find that salience-predicted correlation effects subside when controlling for event-splitting. However, they only

[12] We obtained very similar results in an unincentivized pilot study ($N = 106$).

find an insignificant difference in choices in the event-splitting treatment, not a reversal in choice behavior. We conjecture that this difference is driven by their format not displaying subevents next to each other and that this subtle difference in display formats affects subjects' preferences very differently.[13] When presenting the subevents next to each other, subjects might find it easier to assess the overall probability in the wheel of fortune. While the way probabilities are disclosed to subjects is another example for display format effects, it does not have a bearing on the absence of evidence for salience-predicted correlation effects.

We can also only conjecture why there is no significant event-splitting effect in the original display format case when the absolute level of skewness equals 2.7. Two possible explanations come to mind. First, in this case, the left-skewed lottery's upside is only slightly larger than the right-skewed lottery's downside. Splitting the two might – if anything – only induce a comparatively mild event-splitting effect. Second, the left-skewed lotteries of the Mao-pair involve a zero-outcome. Subjects might therefore be especially hesitant to pick this lottery due to aversion to zero (Incekara-Hafalir et al. 2021).

Figure 2.5 displays the results of our test of Hypothesis 2.2 based on Frydman and Mormann (2018). The left part of Figure 2.5 pictures the original results of Frydman and Mormann (2018). It shows the share of subjects exhibiting the Allais paradox, i.e., the share of subjects who prefer the safe lottery for $z = \$24$ (Panel D of Figure 2.2) and the risky lottery under the respective maximum, intermediate, and zero correlation structures when $z = \$0$ (Panels A to C). Consistent with salience theory, the share of observed Allais paradoxes significantly declined at each step from zero correlation (Panel C) via intermediate correlation (Panel B) to maximum correlation (Panel A). Importantly, only the last step involved event-splitting, i.e., event-splitting was controlled for during the first step and cannot explain shifts in choice behavior.

The right side of Figure 2.5 presents our results where we shut off any correlation effects by employing two distinct wheels of fortune. Because the correlation remains constant at zero, salience theory predicts no shifts in choice behavior. Nevertheless, we observe a choice pattern that is very similar to the one obtained by Frydman and Mormann (2018). First, the share of Allais paradoxes significantly drops at each step when moving from the problem representation of Panel C via Panel B to Panel A – with effect size magnitudes also being similar to the ones reported in Frydman and Mormann (2018) for the correlated lottery case. Second, the greatest decline in Allais-type preferences is caused by event-splitting when

[13] Appendix 2.B.2 provides a detailed comparison of the setups.

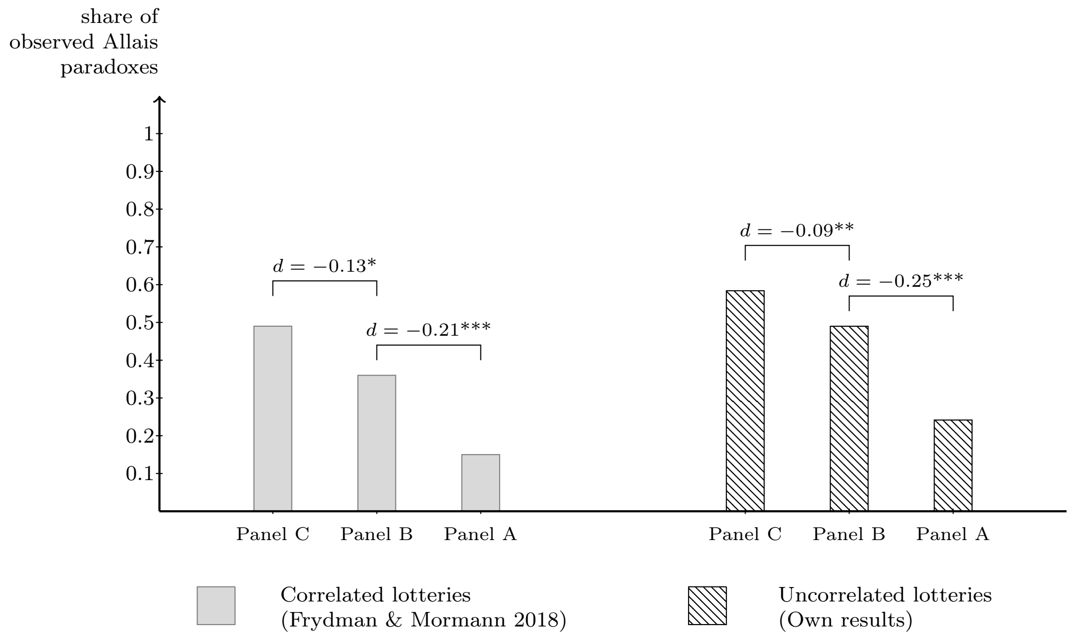


Figure 2.5: Share of observed Allais paradoxes for different display formats for the common consequence $z = \$0$ (Panel A, B, or C). Left part: results of Frydman and Mormann (2018)'s presentation of correlated lotteries within the same pie chart. Right part: presentation of the lotteries by two distinct pie charts, i.e., as uncorrelated. d reports the difference between two treatments, with p-values based on paired t-tests. Significance level: * Significant at 5%; **: 1%; ***: 0.1%.

moving from Panel B to A. These results again suggest that it is a change of the display format that affects choice behavior rather than correlation. This is in line with our Hypothesis 2.2 that the associated changes of the display format alone are sufficient to replicate choice patterns in line with salience theory. However, we can only speculate about the causes of the additional drop in Allais-type choices when moving from Panel C to B. For example, it may be that the exact proportions by which events are split affect human decision making under risk.

Summarizing, the results of Experiment 1 show that variations in the experimental display format may crucially affect subjects' choices. Confirming Hypothesis 2.1, we find evidence for event-splitting effects as the actual cause for the findings of DKK, which were initially attributed to salience-predicted correlation effects. In line with Hypothesis 2.2, we receive similar results as Frydman and Mormann (2018) when repeating their design with the associated changes in the display format while keeping the correlation constant. The common denominator for both parts of Experiment 1 is that subjects' choices are sensitive to changes in the display format, which in turn can easily confound the investigation of correlation effects.

2.3.2 Experiment 2: Testing for extracted salience effects

When controlling for display format effects as a confounder, the results of Experiment 1 yielded no evidence for salience-predicted correlation effects. The contrast between payoffs did not significantly affect decision makers' choices as presumed by salience theory. Rather, the display format and, in particular, artificially splitting states had a significant effect on choice behavior that was sufficient to explain behavior previously attributed to salience effects. Our findings suggest that choice behavior is sensitive to even the slightest changes of the display format, which may confound the effect that is under investigation. As display format effects might also contravene a correlation effect, the findings of Experiment 1 do not rule out the possibility of a salience-predicted correlation effect with absolute certainty. In this section, we employ an experimental design that has the following properties:

(i) Salience rankings between states follow from ordering, diminishing sensitivity, reflection, and zero contrast and therefore hold for any admissible salience function.

(ii) Predictions derived from salience theory hold for any degree of local thinking ($0 < \delta < 1$).

(iii) The display format remains unchanged when altering the correlation structure.

(iv) Choice behavior contradicting predictions obtained from a salience model with linear utility allows inference on the curvature of the value function required in the domain of gains and losses.

2.3.2.1 Experimental framework

Consider a scenario with three equally likely states of the world with a decision problem between two available lotteries, once in the domain of gains and once in the domain of losses.[14] For the gain frame, the two available lotteries are $L_R = (x_1, \frac{1}{3}; x_4, \frac{1}{3}; x_5, \frac{1}{3})$ and $L_S = (x_2, \frac{1}{3}; x_3, \frac{1}{3}; x_5, \frac{1}{3})$, with

$$x_1 > x_2 > x_3 > x_4 > x_5 = 0, \tag{A1}$$

$$x_1 + x_4 = x_2 + x_3. \tag{A2}$$

Thus, both lotteries have the same expected value, while the risky lottery L_R is a mean-preserving spread of the safe lottery L_S so that L_S second-order stochastically dominates L_R. For the loss frame, the corre-

[14] The idea to invoke equally likely states in order to investigate juxtaposition effects builds on Leland (1998), yet, he did not conduct an empirical investigation.

Table 2.2: Correlation structures S_1 and S_6 between lotteries L_R and L_S

	S_1			S_6		
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
L_R	x_1	x_4	x_5	x_1	x_4	x_5
L_S	x_5	x_2	x_3	x_3	x_5	x_2
Salience Ranking	1	3	2	3	2	1

sponding problem consists of the lotteries $L_{R'} = (-x_1, \frac{1}{3}; -x_4, \frac{1}{3}; x_5, \frac{1}{3})$ and $L_{S'} = (-x_2, \frac{1}{3}; -x_3, \frac{1}{3}; x_5, \frac{1}{3})$.

Consider an expected utility maximizer employing objective probabilities ($\delta = 1$). If she strictly prefers L_S over L_R, she must exhibit a strictly concave value function in the domain of gains. Following the reflection of risk attitudes (e.g., Baucells and Villasís 2010), i.e., the empirically robust phenomenon that subjects reverse preferences when moving from the gain to the loss frame, one would expect a decision maker who prefers L_S over L_R to simultaneously prefer $L_{R'}$ over $L_{S'}$. Appendix 2.A.1 proves that:

Lemma 1. *Any expected utility maximizer strictly prefers L_S over L_R if and only if her value function is strictly concave in the domain of gains.*

Lemma 2. *Any expected utility maximizer strictly prefers $L_{R'}$ over $L_{S'}$ if and only if her value function is strictly convex in the domain of losses.*

Because the lotteries could disburse their payoffs in any of the three states of the world, there are $3! = 6$ possible correlation structures for each frame, which we label as S_i with $i = 1, \dots, 6$. Of particular interest for reasons outlined in Proposition 2 below are the two correlation structures denoted as S_1 and S_6, which are shown in Table 2.2.[15]

We additionally impose that

$$x_3 + x_4 \geq \ x_1 \ . \tag{A3}$$

In that case, a clear salience ranking for all six correlation structures can be established purely based on the general properties of salience theory: ordering, diminishing sensitivity, and zero contrast. From the salience function's property of reflection immediately follows that the same rankings hold for the loss frame. The bottom row of Table 2.2 presents the rankings for S_1 and S_6.

Denote the difference in the valuation of lotteries L_R and L_S for correlation structure i as $V(L_R^i) - V(L_S^i)$. Assuming a linear value function $v(x) = x$ with a degree of local thinking $0 < \delta < 1$ as Bordalo et al. (2012b),

[15] The four remaining correlation structures $S_2, \dots, S_5$ are relegated to Appendix 2.B.3.

the valuation differences for $i = \{1, 6\}$ are given by:[16]

$$V\left(L_R^1\right) - V\left(L_S^1\right) = \frac{(1-\delta^2)\cdot x_1 - (\delta-\delta^2)\cdot x_3}{1+\delta+\delta^2} > 0 \tag{2.4}$$

$$V\left(L_R^6\right) - V\left(L_S^6\right) = \frac{-(1-\delta^2)\cdot x_2 + (\delta-\delta^2)\cdot x_4}{1+\delta+\delta^2} < 0 \tag{2.5}$$

Thus, a local thinker with linear utility will choose L_R for correlation structure S_1. The reason is the state containing the upside payoff x_1 of L_R and the downside payoff x_5 of L_S being most salient. In contrast, under S_6 the preference relation reverses because now the state containing the downside payoff x_5 of L_R and the upside payoff x_2 of L_S is most salient. The loss frame involves the same salience rankings so that the inequalities reverse: for S_1 the state $(-x_1, x_5)$ is most salient, leading the decision maker to overweight the downside of $L_{R'}$ and the upside of $L_{S'}$. In contrast, under S_6, the opposite holds with the state $(x_5, -x_2)$ being most salient. We summarize the predictions of salience theory with respect to the gain and loss frame in the following proposition:

Proposition 1 (Preferences with linear v)**.** *A local thinker with $0 < \delta < 1$ will prefer*

(a) the risky lottery L_R over the safe lottery L_S under correlation structure S_1 in the domain of gains.

(b) the safe lottery L_S over the risky lottery L_R under correlation structure S_6 in the domain of gains.

(c) the safe lottery $L_{S'}$ over the risky lottery $L_{R'}$ under correlation structure S_1 in the domain of losses.

(d) the risky lottery $L_{R'}$ over the safe lottery $L_{S'}$ under correlation structure S_6 in the domain of losses.

We close this section by pointing out an important consequence of relaxing the linearity assumption of the value function and, instead, restricting $v(x)$ to be strictly increasing with $v(0) = 0$.[17]

Proposition 2 (Valuation differences with nonlinear v)**.** *In the domain of gains, a local thinker with $0 < \delta < 1$ will – for any strictly increasing value function with $v(0) = 0$ – assign the highest valuation difference $V(L_R^i) - V(L_S^i)$ for all $i \in \{1, \ldots, 6\}$ to S_1 and the lowest to S_6. In the loss frame, the reverse will hold.*

Appendix 2.A.2 proves Proposition 2.

[16] The valuation difference is a function of the degree of local thinking δ, which may be heterogeneous across individuals. Because all propositions hold for any degree of local thinking $0 < \delta < 1$, such potential heterogeneity would not affect our results.

[17] Note that the proposition allows for heterogenous curvatures across subjects.

2.3.2.2 Research hypotheses

In this section, we operationalize the theoretical predictions of Section 2.3.2.1. As in Frydman and Mormann (2018), we assume subjects' choices are stochastic, with the probability of a particular choice increasing in the valuation difference. Moreover, we presuppose that if a local thinker strictly prefers a lottery, the choice probability is greater than 0.5. Individual choices then give rise to an overall choice pattern where the majority of subjects would show behavior in accordance with salience theory. In the case of a linear value function, Proposition 1 generates the following expected choice behavior:

Hypothesis 2.3. *(Local-thinkers with linear value function) A majority of subjects will choose*

(a) the risky lottery L_R under correlation structure S_1 in the domain of gains.

(b) the safe lottery L_S under correlation structure S_6 in the domain of gains.

(c) the safe lottery $L_{S'}$ under correlation structure S_1 in the domain of losses.

(d) the risky lottery $L_{R'}$ under correlation structure S_6 in the domain of losses.

Rejection of any of these hypotheses is either a rejection of salience-predicted correlation effects or the auxiliary hypothesis that the value function is linear. If one is willing to maintain that salience-predicted correlation effects exist, then the observed behavior allows for inference on the curvature of the value function in the domain of gains and losses. For example, if subjects prefer the safe lottery L_S under S_1 despite the salience mechanism with a linear value function favoring L_R (Proposition 1(a)), the value function must be sufficiently concave in the domain of gains for salience theory to accommodate the observed choice behavior. If subjects exhibit the reflection of risk attitudes and – in the loss frame – a majority chooses the risky lottery $L_{R'}$ under S_1, salience theory's value function needs to be sufficiently convex in the domain of losses for convexity to overturn the salience effect that increases the attractiveness of the safe lottery $L_{S'}$ (Proposition 1(c)).

Similarly, Proposition 2 results in a clear prediction of a local thinker's choice behavior in the case of a nonlinear value function. Because correlation structures S_1 and S_6 have the largest valuation difference, we should also observe the largest difference in choice behavior due to salience effects.

Hypothesis 2.4. *(Local-thinkers with nonlinear value function) A higher share of subjects will choose*

(a) the risky lottery L_R under correlation structure S_1 than under S_6 in the domain of gains.

(b) the risky lottery $L_{R'}$ under correlation structure S_6 than under S_1 in the domain of losses.

Table 2.3: Taler payoffs employed in Experiment 2

	Payoffs					Expected value of L_R & L_S
	x_1	x_2	x_3	x_4	x_5	
Set 1	17	13	12	8	0	8.3
Set 2	48	34	31	17	0	21.6
Set 3	67	46	44	23	0	30

Notes: Rows show the three sets of payoffs satisfying assumptions (A1)-(A3) used in the decision problems presented to subjects in Experiment 2.

Finally, we investigate the relative strengths of event-splitting and salience-predicted correlation effects. Experiment 1 on preferences for relative skewness showed event-splitting to have strong effects that could lead to a reversal in choice behavior. We now formally test this by deliberately introducing event-splitting effects that should work in the opposite direction as the salience-predicted correlation effects. In that case, we expect event-splitting effects to dominate.

Hypothesis 2.5. *When event-splitting effects work in the opposite direction as salience-predicted correlation effects, the former tend to be quantitatively more important.*

2.3.2.3 Implementation

Table 2.3 shows the three different sets of payoffs, each satisfying Assumptions (A1)-(A3), that are employed in the experiment. The last column displays the expected values for L_R and L_S. For each set of payoffs, subjects are presented with four different decision problems between the risky lottery and the safe lottery: The gain (L_R and L_S) and the loss ($L_{R'}$ and $L_{S'}$) frame, each presented under correlation structures S_1 and S_6.

To investigate Hypotheses 2.3 and 2.4, we let the lotteries in each of the twelve problems disburse their payoffs following a random draw of one out of three balls stored in a nontransparent urn. A matrix display format with proportionate columns makes the correlation transparent. The top panel of Figure 2.6 shows the decision problem for payoff set 1 in the gain frame under correlation structure S_1 as presented to subjects.

The investigation of Hypothesis 2.5 instead employs a dice roll to introduce randomness in order to allow for an event-splitting treatment. The state space is a function of the roll of a fair six-sided die. To generate payoff probabilities of one third, each payoff is linked to two different sides of the die. Naturally,

Decision problem

There are three balls (ball 1, ball 2, ball 3) in a nontransparent urn. One of these three balls is drawn at random, and the probability of a draw is exactly one third for each ball.

Options A and B pay the following amounts of money depending on which ball is drawn.

	Ball 1	Ball 2	Ball 3
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
Option A	17	8	0
Option B	0	13	12

Please choose between Option A and Option B.

(a) Baseline

Decision problem

Options A and B pay the following amounts of money depending on which number is rolled on a single roll of a fair die.

Number	⚀	⚁ or ⚂	⚃ or ⚄	⚅
Probability	$\mathbf{\frac{1}{6}}$	$\mathbf{\frac{1}{3}}$	$\mathbf{\frac{1}{3}}$	$\mathbf{\frac{1}{6}}$
Option A	0	17	8	0
Option B	12	0	13	12

Please choose between Option A and Option B.

(b) Event-splitting treatment

Figure 2.6: Decision problem derived from payoff set 1 under correlation structure S_1 employed in Experiment 2 to test salience-predicted correlation effects. Top panel: Baseline display format only showing the three events. Bottom panel: Event-splitting treatment showing subevents.

this creates two different display formats. First, one can merge the two sides as being one state of the world. This is the non-event-splitting treatment. Second, one can split particular states into sub-states by displaying the two sides of the die separately. This is the event-splitting treatment, which allows the construction of an event-splitting effect that works in the opposite direction of the salience-predicted correlation effect. Consider again the example of payoff set 1 under correlation S_1 in the gain frame. We split the state (x_5, x_3) linked to the downside payoff of the risky lottery L_R, which should make the risky lottery less attractive to decision makers. This contrasts with the presumed salience effect, according to which S_1 favors the risky lottery. Under S_6 we split the state (x_1, x_3) where L_R realizes its greatest gain. Thus, event-splitting makes the risky lottery appear more attractive to decision makers, while salience theory predicts decision makers to favor the safe lottery.[18] The bottom panel of Figure 2.6 depicts the decision problem constructed from payoff set 1 under correlation structure S_1 in the gain frame with the event-splitting treatment.[19]

To aid visual perception of the probabilities and extract a "pure" event-splitting effect, the column widths of the matrix were proportional to the underlying probabilities of the (sub-)states. This avoids the problem noted in Keller (1985) that matrix column widths not proportional to the reported probability can amplify the effects of event-splitting.[20]

2.3.2.4 Results

We begin our analysis by examining Hypothesis 2.3, which predicts that – when assuming local thinkers with a linear value function – the majority of subjects should switch between choosing the risky lottery and the safe lottery when varying the correlation structure due to different payoffs becoming more salient. Table 2.4 displays the number of subjects choosing the risky lottery in the twelve decision problems derived from payoff sets 1, 2, and 3, as well as the total over all sets for the baseline without event-splitting. Turning to the results for the gain frame in the left part of the table, a significant majority of subjects prefer the safe over the risky lottery under both correlation structures. While this choice behavior is consistent with salience theory's predictions for correlation structure S_6 (Hypothesis 2.3(b)), it contradicts the theory with respect to S_1 (Hypothesis 2.3(a)).

[18] While the safe lottery is also affected by the event-splitting, the split is the same across both correlation structures, allowing to isolate the event-splitting effect on the risky lottery.

[19] Appendix 2.B.4 presents the problem under S_6. In the loss frame, we conduct the same splits, because again, event-splitting and salience-predicted correlation effects oppose each other.

[20] For example, DKK's matrix design did not involve lengths proportionate to the underlying probabilities.

Table 2.4: Choice behavior in the baseline treatment of Experiment 2

	Gain frame			*Loss frame*		
Correlation	Risky	Safe	%Risky	Risky	Safe	%Risky
			Payoff set 1			
S_1	41	109	0.27***	87	63	0.58
S_6	48	102	0.32***	91	59	0.61*
			Payoff set 2			
S_1	39	111	0.26***	86	64	0.57
S_6	44	106	0.29***	83	67	0.55
			Payoff set 3			
S_1	39	111	0.26***	87	63	0.58
S_6	49	101	0.33***	85	65	0.57
			Sum over all sets			
S_1	119	331	0.26***	260	190	0.58**
S_6	141	309	0.31***	259	191	0.58**

Notes: For the gain (loss) frame, asterisks denote the significance level for a test of the hypothesis that safe (risky) lottery choices occur with a greater frequency than choices of the risky (safe) lottery using the binomial distribution. Significance level: * Significant at 5%; **: 1%; ***: 0.1%.

The right part of Table 2.4 presents the results for the loss frame, where salience theory predicts the opposite choice behavior: a majority of subjects should prefer the risky lottery under correlation S_6 and the safe one under S_1. However, most subjects in our experiment preferred the risky lottery $L_{R'}$, regardless of the underlying correlation structure. Thus, while the observed choice behavior was consistent with the reflection of risk attitudes, it did not square well with the predictions of salience theory. Concerning both correlation structures S_1 and S_6, our findings are significant when considering the total over all sets, which is in line with Hypothesis 2.3(d) but contradicts Hypothesis 2.3(c).

Overall, results from both the loss and gain frame are at odds with Hypothesis 2.3 that – based on the assumption of a local thinker with linear utility – a majority of subjects should choose the respective lottery with the more attractive salient payoff. By Lemma 1, an expected-utility maximizer who employs the undistorted probabilities strictly prefers the safe lottery L_S in the gain frame if and only if her value function is strictly concave. A local thinker deviates from this procedure by overweighting the probabilities of the most salient payoffs. Hence, for salience theory to be consistent with subjects choosing the safe lottery in the gain frame under S_1, despite the risky lottery's upside payoff being salient, local thinkers require a sufficiently concave value function in the domain of gains to counteract the salience effect.

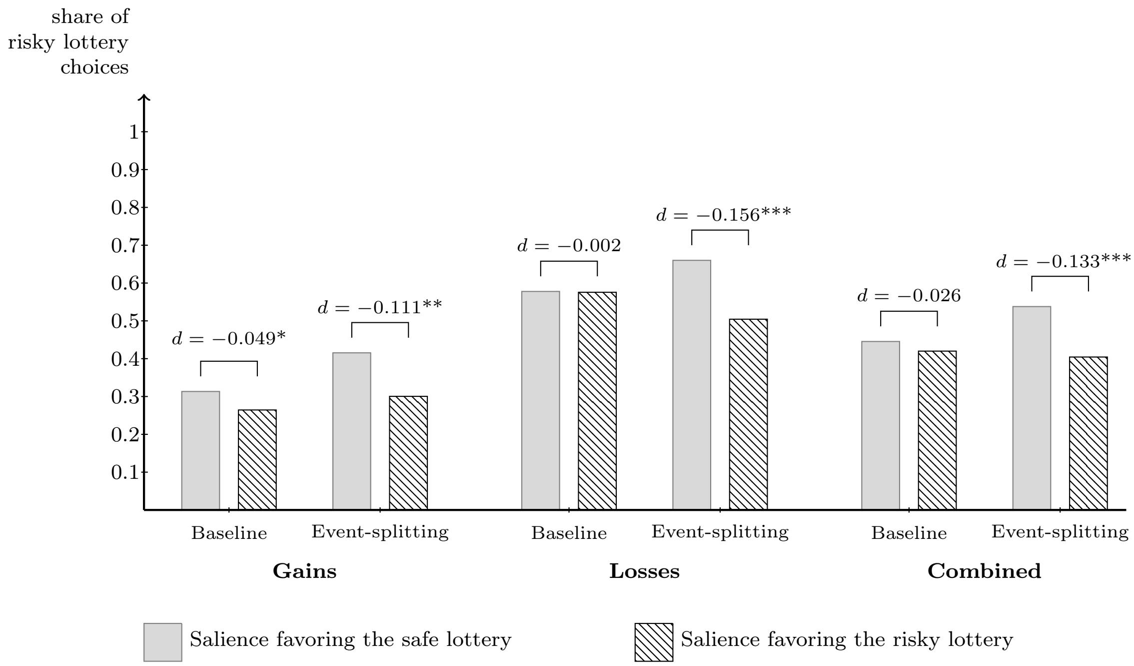


Figure 2.7: Share of risky lottery choices in Experiment 2. Results across decision problems are pooled for the gain frame, the loss frame, and both combined. Solid bars show the share of risky lottery choices for correlation structures where the salience mechanism favors the safe lottery (S_6 for the gain frame, S_1 for the loss frame), hatched bars for correlation structures favoring the risky lottery (the opposite case). "Baseline" denotes the baseline display format only showing the three events, while "Event-splitting" denotes the event-splitting treatment showing subevents. d reports the differences in shares of risky lottery choices within each treatment, with p-values based on paired t-tests with standard errors clustered at the subject level. Significance level: * Significant at 5%; **: 1%; ***: 0.1%.

Similarly, explaining the choice of the risky lottery in the loss frame under S_1 requires a convex value function in the domain of losses to counteract the risky lottery's downside payoff being salient (see also Lemma 2). Thus, to explain the overall choice pattern observed in Table 2.4, salience theory requires a value function similar to the one employed by prospect theory: concave in the domain of gains and convex in the domain of losses.

If we assume such a nonlinear value function, Hypothesis 2.4 makes clear predictions: a higher share of subjects should choose the risky over the safe lottery under correlation structures where the salience mechanism favors the risky lottery than under structures where it favors the safe one. Figure 2.7 presents the pooled share of risky lottery choices across the gain frame, the loss frame, and all decision problems combined. Solid bars represent the share of pooled risky lottery choices for correlation structures favoring the safe lottery (S_6 for the gain frame, S_1 for the loss frame), hatched bars for correlation structures favoring the risky lottery (the opposite case). Considering the baseline display format to investigate Hypothesis 2.4, we find no salience-predicted correlation effect, neither in the total results nor the individual gain/loss frames. For the combined choices and the loss frame, there is no significant difference in risky lottery choices across the relevant correlation structures.[21] While we find a significant effect in the gain frame, it has the wrong sign.[22] Hence, the results indicate that the juxtaposition of payoffs does not materially affect subjects' preferences as predicted by salience theory.

The absence of a statistically significant salience effect, of course, does not preclude the existence of a salience mechanism. It may still be hidden by a combination of low statistical power and small effect size. In a last step, we investigate Hypothesis 2.5 on the relative size of salience and event-splitting effects. If event-splitting effects have a much larger quantitative effect size, then any set involving them will most likely be futile for uncovering salience effects because any hidden signal will be drowned out for realistic sample sizes. Figure 2.7 contrasts the results of the baseline treatment showing the three states display format with the ones of the event-splitting treatment showing subevents. In that case, more than 10 percentage points fewer subjects chose the risky lottery under correlation structures where the salience mechanism actually favors the risky lottery than under correlation structures where salience favors the safe lottery. All of the differences in choice behavior are now highly significant and in the opposite direction than predicted by salience theory. Hence, for the gain frame, the loss frame, and both combined, the results support Hypothesis 2.5 that event-splitting effects dominate a potential salience-predicted correlation effect leading subjects to behave in opposition to salience theory.

In summary, the results of Experiment 2 indicate that event-splitting materially affects decision making under risk, while no salience-predicted correlation effects were detectable. Any hope of uncovering such effects is complicated in experiments involving event-splitting, because event-splitting effects tend to be stronger than potential salience effects, making it hard to detect any signal reliably.

[21] Similarly as in Experiment 1, we conduct OLS regressions to compute the required paired t-tests. The dependent variable again is an indicator that equals 1 when subjects shift from choosing the risky lottery under the correlation structure favoring the risky lottery to choosing the safe lottery under the correlation structure favoring the safe lottery. The indicator equals -1 for the reverse shift, and 0 otherwise. The mean dependent variable thus corresponds to the average shift in risky lottery choices due to a change of the correlation. Regressing the dependent variable on a constant yields the required t-test and allows to cluster the standard errors at the subject level.

[22] The significant coefficient ($p = 0.039$) most likely reflects the multiple comparisons problem and would vanish with a Bonferroni correction of $p^* < \frac{\alpha}{2}$.

2.4 Conclusion

Summarizing, we find no evidence for salience theory's presumed rationale that the contrast between payoffs steers a decision maker's focus toward salient states of the world, subsequently shaping her risk preferences. We have shown in this chapter that prominent recent experimental findings in support of salience-predicted correlation effects were driven by changes in the display format rather than the salience of payoffs. Our first experiment showed that the salience effect found by DKK vanishes when controlling for event-splitting and that display format effects are sufficient to explain the results of Frydman and Mormann (2018). Our findings show that subjects' observed choices are sensitive to even relatively minor changes in the display format. One example was the proportions by which event-splitting was conducted. Our second experiment employed a design that did not require altering the display format to test for salience-predicted correlation effects. For salience theory to be consistent with the observed choice behavior, the typically adopted linear value function needs to be replaced with a prospect theory-type value function. However, even when allowing for such an adjustment, we are still unable to detect statistically and economically significant salience-predicted correlation effects. Furthermore, in a horse-race between event-splitting effects and potential salience-predicted correlation effects, the former are found to quantitatively dominate.

Turning to real-life applications, the effect of event-splitting has been highlighted for the insurance industry (Dertwinkel-Kalt and Köster 2015; Humphrey 2006; Johnson et al. 1993). Insurance companies can charge higher premiums when reporting the most detailed subrisks. Our results show that the underlying mechanism is not the specification of particular correlation structures making payoffs salient but rather the splitting of events into subevents.

Of course, our results do not imply that other forms of salience and the attraction of attention do not affect choices under risk. For example, Bazley et al. (forthcoming) have shown experimentally that colors affect subjects' risk preferences, while Lacetera et al. (2012) provide evidence for the left-digit bias and limited attention in wholesale used-car transactions. Future research should investigate competing theoretical explanations for how a subject's focus might influence her preferences. For example, Guo (2019) proposed that subjects' choices are based on the foci of all lotteries, which renders the correlation between lotteries irrelevant but allows the display format to affect choices.

Appendix

2.A Proofs

2.A.1 Proof of Lemma 1

Assumption (A1) that $x_1 > x_2 > x_3 > x_4 > x_5 = 0$ implies we can write both x_2 and x_3 as a convex combination of x_1 and x_4:

$$x_2 = \alpha \cdot x_1 + [1 - \alpha] \cdot x_4 \tag{2.6}$$

$$x_3 = \beta \cdot x_1 + [1 - \beta] \cdot x_4 \tag{2.7}$$

for appropriate $0 < \alpha, \beta < 1$. Combining this with assumption (A2) that $x_1 + x_4 = x_2 + x_3$, we obtain:

$$\begin{aligned} x_1 + x_4 = \alpha \cdot x_1 + [1 - \alpha] \cdot x_4 + \beta \cdot x_1 + [1 - \beta] \cdot x_4 \\ \Leftrightarrow \alpha + \beta = 1 \end{aligned} \tag{2.8}$$

If an expected utility maximizer with value function v exhibits the preference relation $L_S \succ L_R$, it must hold that:

$$\begin{aligned} v(\alpha \cdot x_1 + [1 - \alpha] \cdot x_4) + v(\beta \cdot x_1 + [1 - \beta] \cdot x_4) > v(x_1) + v(x_4) \\ \Leftrightarrow v(\alpha \cdot x_1 + [1 - \alpha] \cdot x_4) + v([1 - \alpha] \cdot x_1 + \alpha \cdot x_4) > v(x_1) + v(x_4) \end{aligned} \tag{2.9}$$

With

$$v(x_1) + v(x_4) = \alpha \cdot [v(x_1) + v(x_4)] + [1 - \alpha] \cdot [v(x_1) + v(x_4)] \tag{2.10}$$

we get

$$v(\alpha \cdot x_1 + [1 - \alpha] \cdot x_4) + v(\alpha \cdot x_4 + [1 - \alpha] \cdot x_1) > \alpha \cdot v(x_1) + [1 - \alpha] \cdot v(x_4) + \alpha \cdot v(x_4) + [1 - \alpha] \cdot v(x_1) \tag{2.11}$$

which shows that v must be a strictly concave function in the domain of gains.

The proof for Lemma 2 works along the same lines, but in the loss domain with inequalities reversed due to $-x_1 < -x_2 < -x_3 < -x_4 < x_5 = 0$. □

2.A.2 Proof of Proposition 2

Assuming a local thinker ($0 < \delta < 1$) with any strictly increasing value function that fulfills $v(0) = 0$, her valuation difference between L_R and L_S is the highest under correlation structure S_1 and the smallest under S_6 (in the loss frame, all inequalities reverse):

$$\begin{aligned} &[V(L_R^1) - V(L_S^1)] - [V(L_R^2) - V(L_S^2)] \\ &= \frac{\delta \cdot [v(x_2) - v(x_3)] \cdot (1-\delta)}{1+\delta+\delta^2} > 0 \end{aligned} \tag{2.12}$$

$$\begin{aligned} &[V(L_R^2) - V(L_S^2)] - [V(L_R^3) - V(L_S^3)] \\ &= \frac{(1-\delta) \cdot v(x_1) + (1-\delta^2) \cdot [v(x_3) - v(x_4)]}{1+\delta+\delta^2} > 0 \end{aligned} \tag{2.13}$$

$$\begin{aligned} &[V(L_R^3) - V(L_S^3)] - [V(L_R^4) - V(L_S^4)] \\ &= \frac{(\delta-\delta^2) \cdot [v(x_1) - v(x_2)] + (1-\delta) \cdot v(x_4)}{1+\delta+\delta^2} > 0 \end{aligned} \tag{2.14}$$

$$\begin{aligned} &[V(L_R^4) - V(L_S^4)] - [V(L_R^5) - V(L_S^5)]^* \\ &= \frac{\delta^2 \cdot [v(x_1) - v(x_2)] - \delta \cdot [v(x_1) - v(x_4) - v(x_3)] + [v(x_2) - v(x_3) - v(x_4)]}{1+\delta+\delta^2} \lesseqgtr 0 \end{aligned} \tag{2.15}$$

$$\begin{aligned} &[V(L_R^5) - V(L_S^5)] - [V(L_R^6) - V(L_S^6)] \\ &= \frac{(1-\delta) \cdot v(x_4) + (\delta-\delta^2) \cdot [v(x_1) - v(x_3)]}{1+\delta+\delta^2} > 0 \end{aligned} \tag{2.16}$$

* Concerning correlation structures S_4 and S_5, the value function needs to be specified in order to determine which difference in evaluation between L_R and L_S is greater. However, we can show that the difference is still greater under S_4 compared to S_6:

$$\begin{aligned}&[V(L_R^4) - V(L_S^4)] - [V(L_R^6) - V(L_S^6)]\\&= \frac{(1-\delta^2)\cdot[v(x_2)-v(x_3)]}{1+\delta+\delta^2} > 0\end{aligned} \tag{2.17}$$

□

2.B Figures

2.B.1 Results of DKK concerning their experiment on preferences for relative skewness

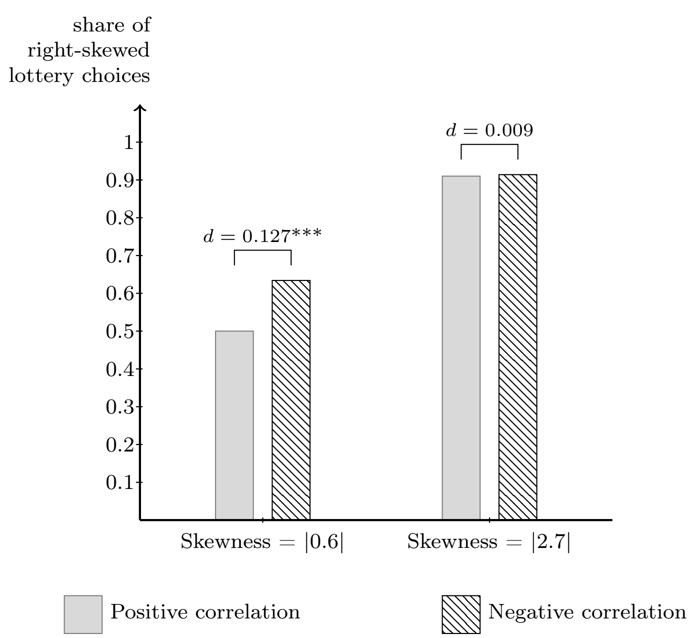


Figure 2.8: Original results on preferences for relative skewness reported by DKK. The share of choices of the right-skewed lottery is presented for the positive and the negative correlation, both for decision problems with lotteries involving an absolute level of skewness of ±0.6 and ±2.7. Additionally, the figure reports results of paired t-tests with standard errors being clustered at the subject level. Significance level: * Significant at 10%; **: 5%; ***: 1%.

2.B.2 Different possible event-splitting treatments when replicating the study on preferences for relative skewness of DKK

	Event-splitting treatment: Subevents located next to each other			**Event-splitting treatment:** Subevents dislocated from each other		
Fields of a wheel of fortune	1-36	37-64	65-100	1-28	29-64	65-100
Left-skewed lottery	90	90	40	90	40	90
Right-skewed lottery	54	54	104	54	104	54
		(a)			(b)	

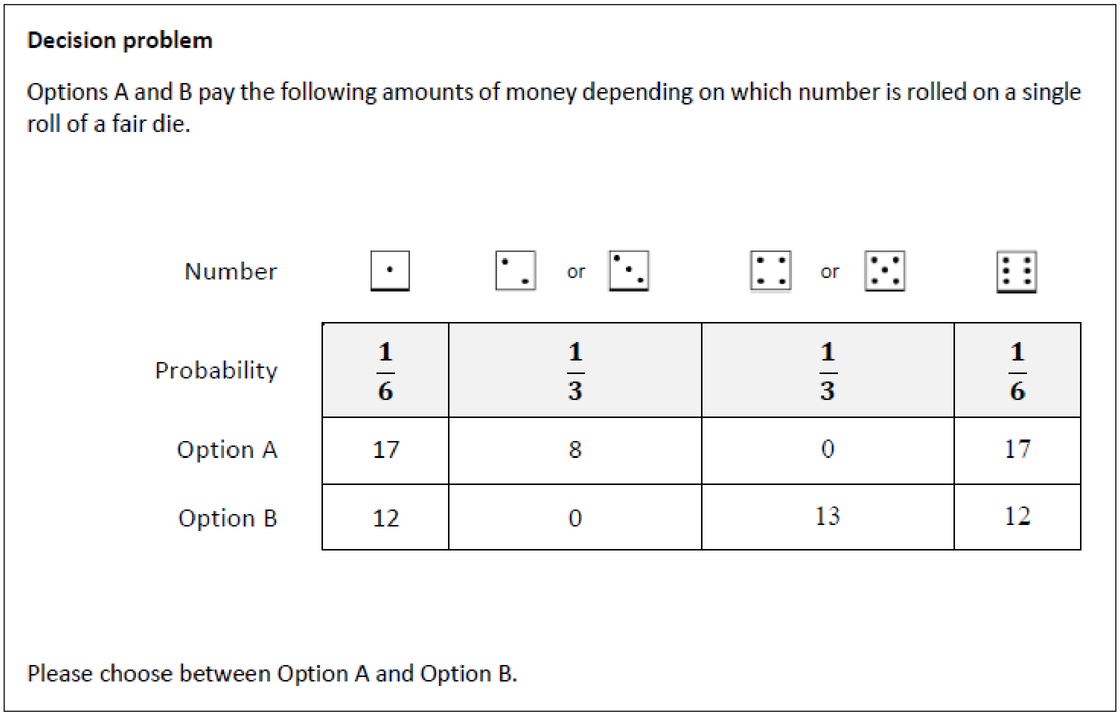
Figure 2.9: Different implementations of event-splitting. Panel (a) reports the event-splitting treatment employed in the present study that locates subevents next to each other. Panel (b) reports the one of Dertwinkel-Kalt and Köster (2021).

2.B.3 Correlation structures $S_2, \ldots, S_5$ and corresponding salience rankings

	S_2			S_3			S_4			S_5		
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
L_R	x_1	x_4	x_5	x_1	x_4	x_5	x_1	x_4	x_5	x_1	x_4	x_5
L_S	x_5	x_3	x_2	x_2	x_3	x_5	x_2	x_5	x_3	x_3	x_2	x_5
Salience Ranking	1	3	2	2	1	3	3	2	1	2	1	3

Figure 2.10: Correlation structures S_2 to S_5 between lotteries L_R and L_S. The row "Salience Ranking" presents a correlation structure's associated salience ordering.

2.B.4 Decision problem constructed from set 1 in the gain frame under correlation structure S_6 (event-splitting treatment)



Decision problem

Options A and B pay the following amounts of money depending on which number is rolled on a single roll of a fair die.

Number	⚀	⚁ or ⚂	⚃ or ⚄	⚅
Probability	$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$
Option A	17	8	0	17
Option B	12	0	13	12

Please choose between Option A and Option B.

Figure 2.11: Decision problem constructed from set 1 in the gain frame under correlation structure S_6. The event-splitting treatment contravenes a supposed salience effect, thereby favoring Option A.

2.C Experimental instructions for participants of Experiment 1

Information about the experiment

Welcome to this experimental study. It is not possible to draw any conclusions about you personally. The results of this survey will be published as part of a scientific publication (in aggregated form). It is guaranteed that the collected data will not be passed on to unauthorized third parties. In the following, please focus exclusively on your participation in the study and exclude potential sources of interference.

Please read the following instructions carefully. It is important that you fully understand the instructions in order to successfully complete the experiment. If you have any questions at any time, please call 089/6004 4287 (make a note of the number if necessary, there is no option to move back and forth between questions within the survey).

As part of this experiment, you will be able to earn a currency (Taler) constructed for this occasion, which will be converted to Euro at the end of the experiment. The conversion rate is **1 Euro = 4 Taler**. So, for example, if you earn 30 Taler, you will receive 7.50 Euro at the end of the experiment.

In total, you will work on 22 so-called decision problems. Here you always have to decide between two available options, A and B. These decisions only concern your personal preferences, there are no right or wrong answers!

At the end of the experiment, you will be assigned one of the 22 decision problems as a payoff-relevant game. **According to your previously made decision**, either Option A or Option B will be played for you with the corresponding amounts of money and a random number generator. Your won amount will then be paid to you via bank transfer.

The options used in the decision problems pay amounts of money (in Taler) depending on the spinning of a wheel of fortune. On the following pages we show you three examples. Please study them carefully so that you can answer the following decision problems which are potentially payoff-relevant.

10% CONTINUE

Example 1:

Decision Problem

A wheel of fortune with a total of 100 fields is spun. For each field there is an equal probability that the wheel of fortune will stop on it.

Option A and Option B pay the following amounts of money depending on which field the wheel of fortune comes to a stop on:

	Fields 1-90	Fields 91-100
Option A	120	0
Option B	96	216

Please choose between Option A and Option B.

Option A ○ Option B ○

If the wheel of fortune stops on the fields 1-90 (which corresponds to a 90% probability) you will receive exactly 120 Taler with Option A and exactly 96 Taler with Option B. If the wheel of fortune stops on the fields 91-100 (this corresponds to a 10% probability), you will receive exactly 0 Taler with Option A and exactly 216 Taler with Option B.

Example 2:

Decision Problem

A wheel of fortune with a total of 100 fields is spun. For each field there is an equal probability that the wheel of fortune will stop on it.

Option A and Option B pay the following amounts of money depending on which field the wheel of fortune comes to a stop on:

	Fields 1-36	Fields 37-72	Fields 73-100
Option A	90	40	90
Option B	104	54	54

Please choose between Option A and Option B.

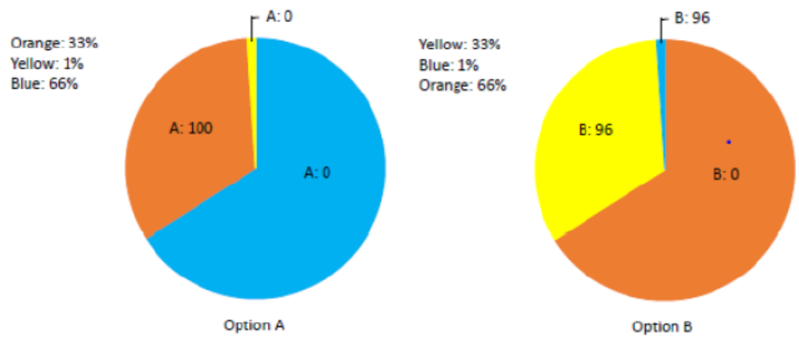
Option A ○ Option B ○

If the wheel of fortune stops on fields 1-36 (which corresponds to a 36% probability), Option A will pay you exactly 90 Taler and Option B will pay you exactly 104 Taler. If the wheel of fortune stops on the fields 37-72 (which corresponds to a 36% probability), Option A will give you exactly 40 Taler and Option B will give you exactly 54 Taler. If the wheel of fortune stops on the fields 73-100 (which corresponds to a 28% probability), Option A will give you exactly 90 Taler and Option B will give you exactly 54 Taler.

Example 3:

Decision problem

Shown below are two wheels of fortune, each with differently sized and color-coded fields. The probability of a wheel of fortune coming to a stop in a certain field after it has been spun is indicated in each case at the edge. The payouts of the two Options A and B depend on the field in which the wheel of fortune assigned to them comes to a stop.



Please choose between Option A and Option B?

Option A ○ Option B ○

If the left wheel of fortune stops on the orange field (this corresponds to a probability of 33%), you will receive exactly 100 Taler with Option A. If the left wheel of fortune stops on the yellow field (probability of 1%) or the blue field (probability 66%), you will receive 0 Taler with Option A.

If the right wheel of fortune stays on the yellow field (probability 33%), you will get exactly 96 Taler with Option B. If the right wheel of fortune stops on the blue field (probability 1%), Option B will also pay you 96 Taler. If the wheel of fortune stops on the orange field (probability 66%), you will receive 0 Taler with Option B.

2.D Experimental instructions for participants of Experiment 2

Information about the experiment

Welcome to this experimental study. The results of this survey will be published as part of a scientific publication (in aggregated form). It is not possible to draw any conclusions about you personally. It is guaranteed that the collected data will not be passed on to unauthorized third parties. In the following, please focus exclusively on your participation in the study and exclude potential sources of interference.

Please read the following instructions carefully. It is important that you fully understand the instructions in order to successfully complete the experiment. If you have any questions at any time, please call 089/6004 4287 (make a note of the number if necessary, there is no option to move back and forth between questions within the survey).

You will receive 17 Euro for your participation in this experiment.

Furthermore, you can earn or lose a currency (Taler) constructed for this occasion. This will be converted into Euro at the end of the experiment. The conversion rate is **1 Euro = 4 Taler**. For example, if you win 30 Taler, at the end of the experiment you will receive 17 Euro plus a profit of 7.50 Euro, i.e., 24.50 Euro. If you lose 30 Taler, for example, you will receive 17 Euro minus a loss of 7.50 Euro, i.e., 9.50 Euro.

In total, you will work on 24 so-called decision problems. Here you will always have to decide between two options available for selection, A and B. These decisions only concern your personal preferences, there are no right or wrong answers! For options that involve potential losses, the payoff amounts are marked with a minus sign.

At the end of the experiment, you will be assigned one of the 24 decision problems as a real payoff-relevant game. **According to your previously made decision**, either Option A or Option B will be played for you with the corresponding money amounts and a random number generator. Your total amount won will then be paid out to you via bank transfer.

On the following pages we show you three examples of the decision problems used. Please study them carefully so that you can then answer the decision problems that are potentially relevant to the payoff.

10% CONTINUE

Example 1:

Decision problem

There are three balls (ball 1, ball 2, ball 3) in a nontransparent urn. One of these three balls is drawn at random, and the probability of a draw is exactly one third for each ball.

Options A and B pay the following amounts of money depending on which ball is drawn.

	Ball 1	Ball 2	Ball 3
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
Option A	48	17	0
Option B	31	0	34

Please choose between Option A and Option B.

Option A ○ Option B ○

If ball 1 is drawn (this corresponds to a probability of one third), you will receive exactly 48 Taler with Option A and exactly 31 Taler with Option B. If ball 2 is drawn (probability of one third), you will receive exactly 17 Taler with Option A and exactly 0 Taler with Option B. If ball 3 is drawn (probability of one third), you will receive exactly 0 Taler with Option A and exactly 34 Taler with Option B.

Example 2:

Decision problem

There are three balls (ball 1, ball 2, ball 3) in a nontransparent urn. One of these three balls is drawn at random, and the probability of a draw is exactly one third for each ball.

Options A and B include the following losses depending on which ball is drawn.

	Ball 1	Ball 2	Ball 3
Probability	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
Option A	-17	-8	0
Option B	0	-13	-12

Please choose between Option A and Option B.

Option A ○ Option B ○

If ball 1 is drawn (which corresponds to a probability of one third), you suffer a loss of exactly 17 Taler with Option A and you receive exactly 0 Taler with Option B. If ball 2 is drawn (probability of one third), you will suffer a loss of exactly 8 Taler with Option A and a loss of exactly 13 Taler with Option B. If ball 3 is drawn (probability of one third), Option A will give you exactly 0 Taler and Option B will give you a loss of exactly 12 Taler.

Example 3:

Decision problem

Options A and B pay the following amounts of money depending on which number is rolled on a single roll of a fair die.

Number	⚀	⚁ or ⚂	⚃ or ⚄	⚅
Probability	$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$
Option A	67	23	0	67
Option B	44	0	46	44

Please choose between Option A and Option B.

Option A ○ Option B ○

If the number 1 is rolled (which corresponds to a probability of one sixth), Option A will give you exactly 67 Taler and Option B will give you exactly 44 Taler. If either the number 2 or 3 is rolled (this corresponds to a probability of one third), Option A will give you exactly 23 Taler and Option B exactly 0 Taler. If either 4 or 5 is rolled (one-third chance), Option A will give you exactly 0 Taler and Option B will give you exactly 46 Taler. If the number 6 is rolled (probability of one sixth), Option A will give you exactly 67 Taler and Option B will give you exactly 44 Taler.

Chapter 3

Juxtaposition Effects Do Not Explain Single-attribute First-order Stochastic Dominance Violations

We experimentally investigate whether juxtaposition effects can account for subjects choosing a first-order stochastically dominated single-attribute lottery as suggested by similarity judgments. We rely on a decision problem proven to induce dominance violations when moving from a transparent to a nontransparent frame that disguises the dominance relation. Adding another variant of the nontransparent frame involving a modified juxtaposition of outcomes, we examine whether the particular pairs of apposed outcomes had caused previous dominance violations. In line with pre-existing findings, we observe a sharp increase in violations when moving from the transparent to the nontransparent frame. However, when modifying the juxtaposition of outcomes, we find a precise null effect on the frequency of dominance violations.

3.1 Introduction

Obeying first-order stochastic dominance (FOSD) is a key principle of rational financial and economic decision making. A lottery L_A first-order stochastically dominates a lottery L_B if, for any payoff x, L_A's probability of disbursing at least x is never less than L_B's, while for minimum one x, L_A's probability of disbursing at least x is higher than L_B's.[1] Although FOSD implies that for a decision maker with monotonically increasing preferences, a dominant option is unequivocally better than its alternative, there is substantial empirical evidence of subjects systematically choosing the dominated option once the dominance relation is not immediately transparent (see, e.g., Birnbaum 2005, 2006, 2008). As an example, Figure 3.1 presents a decision problem from Birnbaum (2005), where it is not obvious at first glance that lottery L_A dominates lottery L_B. The two lotteries do not contain the exact same payoffs and also involve different probabilities, making it difficult to compare the underlying cumulative distribution functions and to detect dominance. As a consequence, subjects frequently prefer L_B over L_A.

Lottery L_A	**Lottery** L_B
90 red balls to win \$96	85 green balls to win \$96
05 blue balls to win \$14	05 black balls to win \$90
05 white balls to win \$12	10 yellow balls to win \$12

Figure 3.1: Decision problem adopted from Birnbaum (2005). Lotteries L_A and L_B disburse monetary payoffs depending on the draw of a ball from two separate urns. Even though lottery L_A first-order stochastically dominates lottery L_B, subjects frequently prefer L_B over L_A.

In this chapter, we experimentally investigate whether juxtaposition effects explain FOSD violations in the context of single-attribute lotteries.[2] The juxtaposition of outcomes can affect subjects' preferences if choices are the result of similarity judgments (see, e.g., Leland 1994). Presuming decision makers to compare pairs of outcomes when choosing between two lotteries, descriptive decision theories based on similarity judgments account for FOSD violations if pairs that favor the dominant lottery are considered sufficiently similar. Subsequently, subjects neglect them in the decision making process, leaving those as

[1] Or, put more formally: $F_A(x) \leq F_B(x)$ for all x with strict inequality at some x, where $F_A(x)$ and $F_B(x)$ denote both lotteries' cumulative distribution functions, respectively.

[2] Single-attribute lotteries involve one-dimensional outcomes, typically in the form of monetary payoffs as presented in Figure 3.1.

Lottery L_A	**Lottery** L_B
05 blue balls to win $14	85 green balls to win $96
05 white balls to win $12	05 black balls to win $90
90 red balls to win $96	10 yellow balls to win $12

Figure 3.2: Decision problem adopted from Birnbaum (2005) with a different juxtaposition of payoffs. As a consequence, similarity judgments no longer predict a choice of the first-order stochastically dominated lottery L_B.

the relevant pairs of outcomes that favor the dominated lottery. Presenting subjects the same decision problem in the frames of Figures 3.1 and 3.2, we investigate whether the frequency of FOSD violations is sensitive to the juxtaposition and hence the associated pairs of outcomes as suggested by similarity judgments.

Recently, Dertwinkel-Kalt and Köster (2015) have shown that salience theory (Bordalo et al. 2012b) can account for FOSD violations by a very similar rationale when relaxing the model's dependence on the correlation between the involved lotteries. However, despite these attempts to explain FOSD violations via similarity judgments, we are aware of only one study experimentally investigating the role of juxtaposition effects in the context of single-attribute lotteries. Leland (1998) does find supporting evidence for the juxtaposition of outcomes inducing FOSD violations as predicted by similarity judgments. His results may alternatively be driven by event-splitting effects, though (see, e.g., Ostermair 2021).[3] For multi-attribute lotteries, Diederich and Busemeyer (1999) show that the juxtaposition of outcomes generates FOSD violations. They employ lotteries involving monetary payoffs and unpleasing bursts of noise so that a convenient juxtaposition of outcomes disguises the transparency of the dominance relation. However, it is unclear whether these results translate to the single-attribute case. For single-attribute lotteries, as presented in Figures 3.1 and 3.2, subjects might not be able to detect dominance regardless of the juxtaposition of outcomes.

[3] Birnbaum and Martin (2003) also investigate the effect of changes of the juxtaposition on FOSD violations. However, they thereby refer to the positioning of both lotteries and not to a change of the respective pairs of outcomes.

3.2 Similarity judgments and first-order stochastic dominance

Decision theories based on similarity judgments have been proposed by, e.g., Rubinstein (1988) and Leland (1994). Although both models have a very similar mode of operation, we subsequently focus on Leland (1994)'s application as Rubinstein (1988) confines himself to pairs of simple lotteries, each involving only one nonzero outcome. Following Leland (1994), there are two lotteries L_A and L_B available for selection, both having the same number of outcomes $i = 1, 2, \ldots, n$, i.e.,

$L_A = \{x_{A1}, p_{A1}; x_{A2}, p_{A2}; \ldots; x_{An}, p_{An}\}$ and

$L_B = \{x_{B1}, p_{B1}; x_{B2}, p_{B2}; \ldots; x_{Bn}, p_{Bn}\}$,

where for both lotteries each outcome $x_i \in X$ and each probability $p_i \in [0, 1]$ with $\sum_i p_i = 1$. When choosing between the two lotteries, a decision maker is supposed to follow a succession of three steps, moving to the next step whenever a decision cannot be reached based on the current step.

Step 1: If there is a clear appeal to preference based on an expected utility procedure, then the respective lottery will be chosen.

Step 2: The decision maker pairwisely compares the lotteries' outcomes and probabilities for all i to detect dominance. Agents choose lottery L_A if it is favored ($x_{Ai} \geq x_{Bi}$ and $p_{Ai} \geq p_{Bi}$ with at least one inequality) in any comparison and inconsequential ($x_{Aj} = x_{Bj}$ and $p_{Aj} = p_{Bj}$ with $j \neq i$) in the others.

Step 3: The decision maker evaluates both lotteries based on similarity judgments involving the transitive binary relations $>^x$ and $>^p$ ("greater than and dissimilar") for outcomes and probabilities, respectively. Similarity relations read as $\sim^x$ and $\sim^p$, which are, however, not necessarily transitive.[4] Similar to step 2, decision makers again pairwisely compare the lotteries' outcomes and probabilities for all i, yet now according to their similarity and dissimilarity. Decision makers choose lottery L_A if it is favored (e.g., $x_{Ai} >^x x_{Bi}$ and $p_{Ai} \sim^p p_{Bi}$) in any comparison and inconsequential ($x_{Aj} \sim^x x_{Bj}$ and $p_{Aj} \sim^p p_{Bj}$ with $j \neq i$) in the others.

If the choice cannot be resolved within these three steps, it is made at random (Leland 1994) or the procedure is otherwise unspecified (Rubinstein 1988). To demonstrate how similarity judgments, i.e.,

[4] For example, if $x_f > x_g > x_h$ it could be that $x_f \sim^x x_g$ and $x_g \sim^x x_h$ but $x_f >^x x_h$ (Leland 1998).

step 3, can explain FOSD violations, consider the example from Figure 3.1 again.[5] If there is no clear appeal to preference, then the selection process is relegated to step 3 as both lotteries are dominant in at least one pairwise comparison, therefore not enabling a choice based on step 2. When applying the concept of similarity judgments, certain comparisons may be considered sufficiently similar and hence irrelevant for the decision making process. For example, in the first pairwise comparison, both lotteries involve the same outcome ($96), with the dominant lottery L_A having a slightly higher probability of winning (90% compared to 85%). Therefore, the comparison is considered inconsequential if 85% $\sim^p$ 90%. In the second comparison, both lotteries involve the same probabilities (5%), with the dominant lottery L_A having a considerably lower outcome ($14 compared to $90). Hence, if $90 $>^x$ $14, then the decision maker considers this comparison to be in favor of L_B. Consequently, she will prefer L_B over L_A as in the third pairwise comparison, L_B is again either considered better or at least equally good as L_A because both lotteries involve the same outcome ($12) and L_A contains a lower probability than L_B (5% compared to 10%).

To sum up, similarity judgments can explain a choice of the dominated lottery L_B if a decision maker perceives the probabilities 90% and 85% to be sufficiently similar. Then, the first outcome and probability comparison is considered inconsequential while the substantial payoff-difference in the second comparison ($14 vs. $90) favors L_B and the third comparison is either inconsequential or also in favor of L_B. Hence, the juxtaposition of both lotteries' outcomes enables pairwise comparisons favoring the dominated lottery. To see that it is the juxtaposition of outcomes that benefits the dominated lottery in Figure 3.1, consider our own portrayal of the decision problem in Figure 3.2. Here, the new juxtaposition prevents a preference for L_B as it causes L_A to be favored in the third pairwise comparison (90% chance to win $96 vs. 10% chance to win $12). This is necessarily true if we assume that $90 $>^x$ $14, which is what we did to account for a choice of the dominated lottery L_B in the presentation format of Figure 3.1.[6] As $[14, 90]$ is a subset of $[12, 96]$, i.e., the payoffs $12 and $96 generate an even greater dissimilarity than $14 and $90, it must then hold that $96 $>^x$ $12. Thus, when similarity judgments predict a choice of the dominated lottery in the presentation format of Figure 3.1, they no longer do so concerning Figure 3.2.[7]

[5] We employ this specific example from Birnbaum (2005) as Dertwinkel-Kalt and Köster (2015) have already proven in this context how the salience mechanism can account for FOSD violations by a very similar rationale. Subsequently, our obtained results apply both to similarity judgments and reasoning based on salience effects.

[6] Theoretically, similarity judgments could explain a choice for L_B in the presentation format of Figure 3.1 solely based on the third outcome comparison and 10% $>^p$ 5%. In that case, the second comparison might as well be inconsequential due to $90 $\sim^x$ $14. In the further course of this chapter, however, we neglect this very counterintuitive possibility since it would imply that agents are basically indifferent to the payoffs involved in the decision problem.

[7] The same is true for Dertwinkel-Kalt and Köster (2015)'s modified salience model. The pairwise comparison of outcomes

Lottery L_A	**Lottery** L_B
85 red balls to win $96	85 green balls to win $96
05 red balls to win $96	05 yellow balls to win $12
05 white balls to win $12	05 yellow balls to win $12
05 blue balls to win $14	05 black balls to win $90

Figure 3.3: Transparent version of Birnbaum (2005)'s decision problem as proposed by Dertwinkel-Kalt and Köster (2015). Splitting the outcomes this way facilitates comparison of both lotteries' underlying cumulative distribution functions, thereby making it evident that lottery L_A first-order stochastically dominates lottery L_B.

3.3 Experimental design

We examined the obtained prediction of a juxtaposition effect concerning the lottery presentations of Figures 3.1 and 3.2 in an incentivized lab experiment using a within-subjects design. To better assess the obtained effect and the frequency of FOSD violations, we, as a benchmark, included another variant of the decision problem in which the dominance relation between both lotteries becomes apparent through an appropriate splitting of outcomes. Figure 3.3 presents this transparent version as suggested by Dertwinkel-Kalt and Köster (2015), where FOSD violations should no longer be an issue.[8]

The experiment was conducted at the "Munich Experimental Laboratory for Economic and Social Sciences" on December 12 in 2019, with payoffs denoted in Euro. Appendix 1.C depicts a translation of the experimental instructions. We recruited 101 subjects, divided into four consecutive sessions of

resulting in the highest level of salience is $(14, 90)$ in Figure 3.1, which favors the dominated lottery L_B. However, in the case of the new juxtaposition presented in Figure 3.2, the pairwise comparison of $(96, 12)$ attracts the highest salience, therefore favoring the dominant lottery L_A.

[8]Dertwinkel-Kalt and Köster (2015) demonstrate that their modified version of salience theory predicts no FOSD violations when the decision problem is presented as in Figure 3.3. However, when applying similarity judgments, the explanation for the absence of FOSD violations is less handy. Choosing the dominant lottery L_A can only be explained by some sort of appeal to preference in step 1 as neither step 2 nor step 3 are sufficient. It would be different if the pairs of outcomes were $(96, 96)$, $(96, 90)$, $(14, 12)$, and $(12, 12)$, in which case a choice of L_A would follow from step 2. Hence, picking up on the suggested transparent variant of Dertwinkel-Kalt and Köster (2015) has two advantages: First, if subjects have a clear preference for the dominant lottery L_A, this would disclose the necessity for amending theories based on similarity judgments as subjects still obey FOSD if it is obvious, yet not accounted for by steps 2 and 3 of the decision making process. Second, one might be inclined to explain a missing juxtaposition effect from Figure 3.1 to Figure 3.2 by the fact that in both frames, the dominated lottery L_B offers the better outcome in more pairwise comparisons (two compared to one). Hence, choosing the lottery that wins more pairwise comparisons of outcomes may be considered a fourth step in decision making. However, if that were the case, then a considerable frequency of people would still need to violate FOSD in the presentation format of Figure 3.3 since both lotteries win the same number of comparisons here.

(almost) equal size. Each individual completed a questionnaire consisting of two parts with overall 29 decision problems, including further experimental investigations and pretests. The decision problems handoff interest in this study were placed in the questionnaire's first part, which involved 27 problems in total. Incentivization was guaranteed by randomly drawing one of the 27 decision problems to be payoff-relevant (Azrieli et al. 2018). To sort out inattentive participants, we employed a brainteaser as a screen-out-question, illustrated in Appendix 1.D. In total, 94 subjects solved the brainteaser, providing the basis for our examination. To counteract the hazard of subjects trying to make consistent choices, we placed the three variants of the decision problem as presented in Figures 3.1, 3.2, and 3.3 further away from each other, namely as question numbers 2, 8, 22 (22, 8, 2) for sessions 1 and 2 (3 and 4), respectively. Within each problem representation, we randomized which of both lotteries was presented at the left or right side.

3.4 Results

The bars in Figure 3.4 display the shares of FOSD violations, i.e., the shares of choices of lottery L_B for all three variants of the decision problem. In the case of the transparent dominance relation presented in Figure 3.3, we find only a very small rate of violations equaling 5.3%. In line with previous findings of Birnbaum (2005), the rate strongly increases to 42.6% when employing the presentation format of Figure 3.1 ($p < 0.001$, two-tailed t-test). However, as opposed to the rationale of similarity judgments and modified salience theory, we find no subsequent decrease in FOSD violations once we change the juxtaposition of outcomes as demonstrated in Figure 3.2 ($p = 0.7$, two-tailed t-test). In fact, the rate of violations even slightly further increases to 44.7%. Conducting a posthoc power analysis, we would have been able to detect an effect size of 0.29 with a probability of 80% at a significance level of 5% (two-tailed t-test). This effect size corresponds to a difference in shares of violations of 15.4%, which is less than half of the detected difference in shares of violations between the original juxtaposition of Birnbaum (2005) presented in Figure 3.1 and the transparent representation format of Figure 3.3.[9]

[9] The sequence of the three variants of the decision problem within the employed questionnaire also enables a between-subjects design as sessions 1 and 2 first answered the problem under the juxtaposition of Figure 3.2, whereas sessions 3 and 4 first answered the problem under the presentation format of Figure 3.1. The results are similar to the within-subjects design: 46.8% (48.9%) of subjects violate FOSD under the presentation format of Figure 3.1 (3.2). As the number of subjects in each group is now half as large as in the within-subjects design, a posthoc power analysis indicates that a distinctively greater effect size of 0.58 would have been necessary to detect the effect with a probability of 80% at a significance level of 5%. This corresponds to a difference in shares of violations of 29.5%, which, however, is still smaller than the detected difference between the original juxtaposition of Figure 3.1 and the transparent presentation format of Figure 3.3 in the within-subjects design.

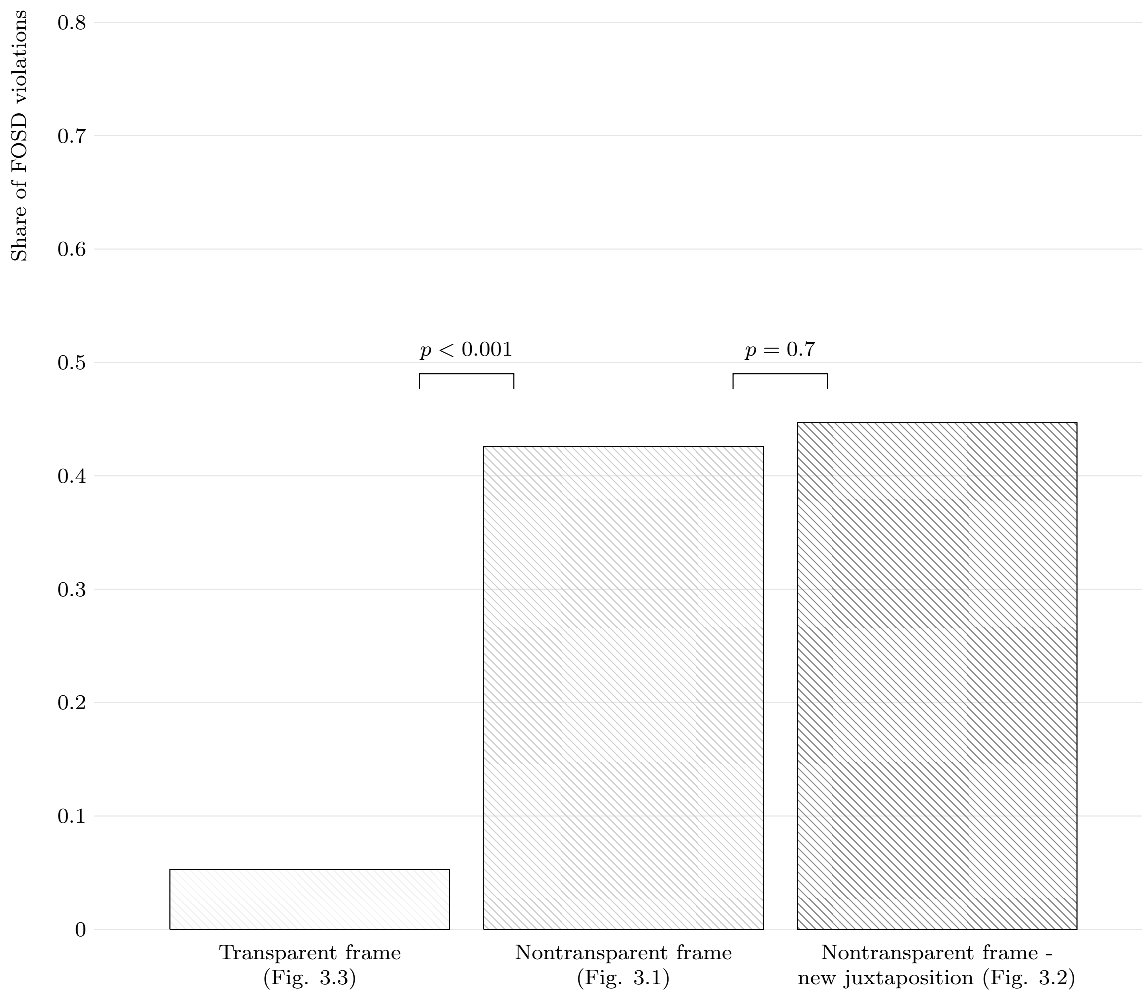


Figure 3.4: Share of the $n = 94$ subjects who violated FOSD in each of the three variants of the employed decision problem. The left bar represents the share of FOSD violations in the transparent frame of Figure 3.3 as proposed by Dertwinkel-Kalt and Köster (2015). The middle bar denotes the share of FOSD violations in the original nontransparent presentation format of Birnbaum (2005) displayed in Figure 3.1. The right bar indicates the share of FOSD violations in the nontransparent frame with a modified juxtaposition of outcomes as shown in Figure 3.2. p-values are based on two-sided paired t-tests regarding the differences in shares of FOSD violations.

3.5 Conclusion

Our experimental results do not indicate that – in the context of single-attribute lotteries – the frequency of FOSD violations is sensitive to the juxtaposition of outcomes . This is remarkable insofar that juxtaposition effects are responsible for FOSD violations in the multi-attribute case where they mask the dominance relationship (Diederich and Busemeyer 1999). Hence, it appears that the juxtaposition of outcomes only induces FOSD violations when veiling the transparency of one lottery dominating the other but not because of subjects comparing pairs of juxtaposed outcomes. Future research could investigate whether there are situations in which the juxtaposition of outcomes does induce FOSD violations in the single-attribute case as well. For example, juxtaposition effects might play a role when the involved lotteries contain a higher number of outcomes such that the transparency of the dominance relation varies with the sequence by which outcomes are presented.

Of course, our results do not give rise to the notion that when evaluating a set of lotteries, decision makers do not make specific outcome comparisons at all. For example, Guo (2019)'s focus theory offers a rationale for FOSD violations that is related to similarity judgments. Decision makers are supposed to compare the lotteries' so-called foci, which are those events that offer the best mix of a high payoff and a high probability.[10] Which outcomes and probabilities get compared is independent of their juxtaposition and therefore in line with our obtained results.

[10] For instance, Zhu et al. (2021) apply the theory in the context of the newsvendor problem.

Conclusion

The introduction to this dissertation argued for the importance of uncertainty as the basis for any competition in the free-market economy. In turn, competition between private enterprises is supposed to dissolve this uncertainty and reveal which products consumers appreciate, which production techniques are most efficient, and so forth. With regard to science, this dissertation has proved that the competition of theories and research approaches is also the best way to gain new insights and further enhance the understanding of the world we live in, and, thereby, reduce uncertainty vis-à-vis to (the explanation of) agents' decision making process. Since my findings contradict a considerable body of recent empirical literature that has originated with the aim of verifying salience theory, this thesis also shows the need not to reach conclusions on supposed evidence too early.

The research agenda I pursued through this dissertation is as follows: In Chapter 1, I examined to what extent the effectiveness of *SSA* models to predict agents' choice behavior in correlated Allais-type decision problems depends on the employed display format. In a corresponding lab experiment, subjects systematically exhibited the common consequence effect in all display formats, leading *SSA* models to perform poorly. However, these findings conflict with the experimental literature on the most recent *SSA* model, salience theory. Those studies found great support for the model and its prediction for juxtaposition effects caused by the correlation between lotteries. In Chapter 2, I presented evidence from an online experiment in which I repeated two previous studies allegedly confirming salience-predicted correlation and juxtaposition effects. I modified their initial problem representation, thereby controlling for display format effects. As a result, the supposed salience effects either occurred independently of the correlation or vanished entirely. The examination of new predictions gained from salience theory in a second online experiment aligned with these results as I found no indication for salience-predicted correlation or juxtaposition effects. In Chapter 3, I investigated predictions derived from similarity judgments on the frequency of first-order stochastic dominance violations due to the juxtaposition of payoffs. In contrast to *SSA* models, similarity judgments predict juxtaposition effects independently of the correlation between lotteries, which therefore increases the possibility for them to occur. However, altering the juxtaposition between payoffs had again no effect on subjects' choices, yielding a precise null result. The findings presented in these three chapters complement one another, bringing this dissertation to a round figure. All conducted experiments contradict the rationale of salience theory, *SSA* models, and similarity judgments, according to which the similarity or contrast between payoffs shapes attitudes toward risk and uncertainty.

Provided that no further research twist rehabilitates salience theory, a few words need to be said concerning the integration of limited attention and salience into economic theory. My findings reject salience theory's conjecture that the contrast between payoffs attracts an agent's attention, subsequently influencing her main focus in a way that depends on the juxtaposition of the involved lotteries' outcomes. However, it should be emphasized that this does not refute the notion that, in general, salience plays a major role in decision making under risk and uncertainty. The idea of integrating salience and limited attention into economic theory is still young, with new modeling approaches emerging.[11] Hence, upcoming theories might find different and improved ways to model the effect of salience on decision behavior.

While this dissertation intends to contribute to a better comprehension of a series of well-established puzzles in choice under risk and uncertainty, it also raises some new questions. In future work, I intend to shed more light on the fundamentals behind event-splitting effects. Building on the results presented in Chapter 2, I plan to investigate to what extent the exact proportions by which events are split affects human choice behavior. Next, I want to analyze whether it is actually the splitting of events or only the more frequent mention of the associated payoffs that influence decision making. Working on these topics will hopefully further enhance our understanding of what constitutes human decision making under risk and uncertainty.

[11] For example, Guo (2019) suggests a modeling approach where agents' choices are based on the foci of all lotteries, i.e., the particular events yielding a comparatively high payoff with a comparatively high probability relative to all other potential events.

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