Regret Theory and Salience Theory: Total Strangers, Distant Relatives or Close Cousins?*

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Two non-expected-utility-theory approaches to model decision making under risk are regret theory (Loomes and Sugden, 1982; Bell, 1982) and salience theory (Bordalo, Gennaioli, and Shleifer, 2012). While the psychological underpinning of these two approaches is different, the models share the assumption that within-state comparisons of outcomes across choice options are a key determinant of choice behavior. We investigate the overlap between the two theories and show that salience theory is a special case of regret theory. Moreover, we trace out the relationship between diminishing sensitivity of the salience function and concavity of the choiceless utility function with regard to behavioral implications.

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1. Introduction

The analysis of decision making under risk has always been and still is a core topic in microeconomics. The neo-classical workhorse model is *expected utility theory* (EUT), which was first introduced into the scientific discourse by Bernoulli (1738). As was shown two centuries later by von Neumann and Morgenstern (1947), EUT rests on the assumption that a decision maker's preferences satisfy a small set of (at least apparently) appealing properties, so-called axioms, which makes EUT hard to criticize from a normative point of view. From a positive perspective, however, already Allais (1953) pointed out that EUT fails to predict a significant share of observed individual choices and, as a consequence, also average behavior in a variety of choice situations.

Given the descriptive difficulties of EUT, it is hardly surprising that over the years plenty "competing" alternative theories for decision making under risk have been proposed. It seems safe to say that the most prominent of these non-EUT alternatives is *prospect theory* as proposed by Kahneman and Tversky (1979), which rests on the three main building blocks of probability weighting, reference dependence, and loss aversion. Other non-EUT alternatives, which are widely recognized in economics, are, for example, disappointment theory (Loomes and Sugden, 1986; Bell, 1985), generalized expected utility theory (Machina, 1982), rank-order theory (Quiggin, 1982; Yaari, 1987), and expectation-based loss aversion (Kőszegi and Rabin, 2007). All these theories of choice under risk are *prospect-based* theories, meaning that the utility value assigned to a given risky choice option, a so-called prospect, is determined by the properties of this prospect alone. Notably, all of the aforementioned non-EUT alternatives rationalize the classic Allais paradoxes by relaxing the independence axiom as introduced by von Neumann and Morgenstern (1947).

With regret theory Bell (1982) and Loomes and Sugden (1982, 1987a) quite early proposed "[a] bold alternative to the[se] alternatives" (Bleichrodt and Wakker, 2015, p.493)—"bold" because they relaxed the transitivity axiom rather than the independence axiom.[1] Regarding the pairwise choice between two prospects, regret theory posits that, after uncertainty about the true state of the world has been resolved, the utility derived from receiving the chosen alternative's outcome in that state depends not only on this outcome alone, but also on the outcome that the other prospect, which was not chosen, would have yielded in the realized state of the world. If the decision maker had done better by choosing differently, she suffers from regret.[2] If

[1]A fairly similar model was contemporaneously proposed by Fishburn (1982).

[2]As noted by Bleichrodt and Wakker (2015, p.494), "the linguistic and psychological concepts of

she had done worse by choosing differently, she rejoices. The anticipation of these ex post feelings of regret and rejoicing, which arise from within-state comparison of outcomes across choice options, is hypothesized to be factored into ex ante decision making. More precisely, it is presumed that the decision maker has a desire ex ante to avoid ex post feelings of regret. Notably, regret theory assumes that the decision maker perceives the occurrence probabilities of the different states of the world correctly and without any distortion.

Thirty years after the introduction of regret theory, with salience theory as proposed by Bordalo, Gennaioli, and Shleifer (2012) a new contender entered the competition for the title of a viable theory for choice under risk. Starting out from the observation that the assumptions imposed on prospect theory's probability weighting function were primarily inspired by the empirical regularities that Kahneman and Tversky (1979) sought to explain, Bordalo, Gennaioli, and Shleifer (2012) propose a novel parsimonious approach of probability weighting which is based on the widely acknowledged idea from the psychological literature that salience exerts a directional pull on attention.[3] Specifically, with regard to pairwise choice under risk, salience theory posits that a decision maker's attention is drawn to those states of the world in which the respective payoff combination of the two feasible prospects stands out (i.e., is salient). This directional influence on attention is hypothesized to lead to the decision maker placing disproportionally much (little) weight on (i.e., over-weighing (under-weighing) the occurrence probability of) those states of the world in which the outcomes of the two prospects are very different (rather similar).

While the respective psychological motivation underlying regret theory and salience theory is different, the two theories share that within-state comparisons of outcomes are a key determinant of choice behavior. Given this similarity, it is not surprising that both theories have a large overlap when it comes to their explanatory potential. Both regret theory and salience theory can explain the common consequence effect and the common ratio effect, which go back to Allais (1953).[4] Furthermore, both theories can rationalize the reflection effect identified by Kahneman and Tversky (1979), the preference reversal phenomenon documented by Grether and Plott (1979), as well as the inherent instability of risk attitudes (as reflected in the simultaneous preference for gambling and insurance or in the so-called four-fold pattern in Tversky and Kahneman (1992)). Given the significant overlap in choice patterns

regret have existed for ages and have been studied in psychology for over a century [...]." For references on this statement, see Zeelenberg and Pieters (2007).

[3]Smith and Mackie (2007, p.63) define salience as "the ability of a cue to attract attention in its context".

[4]Notably, both theories predict these effects to be driven by correlation effects (or, more precisely, juxtaposition effects) rather than by probability effects.

that can be explained by both regret theory and salience theory, we believe it to be desirable (if not even imperative) to aim for a thorough analytical comparison of these two theories.[5]

The paper is structured as follows: In Section 2, we describe the general structure of the choice problem under consideration and explain both regret theory and salience theory. We define a generalized notion of salience theory that encompasses the prominent notions introduced by Bordalo, Gennaioli, and Shleifer (2012). Section 3 contains our first main result: salience theory is a special case of general regret theory (Loomes and Sugden, 1987a). In Section 4, we carve out the relation of salience theory and the original (more restrictive) formulation of regret theory (Loomes and Sugden, 1982) in more detail. Specifically, we show that salience theory is a special case of original regret theory if the assumption of regret aversion is relaxed. In order to derive this finding, we build heavily on the recent axiomatic foundation of original regret theory proposed by Diecidue and Somasundaram (2017); i.e., we show that salience theory satisfies all the axioms imposed by Diecidue and Somasundaram (2017). Furthermore, we find that predictions under salience theory which are driven by salience theory's assumption of diminishing sensitivity can also be derived under reasonable specifications (i.e., specifications that allow for regret aversion) of original regret theory. In Section 5, we discuss the implications of our findings for future theoretical and experimental research. Section 6 concludes.

2. Two Context-Dependent Theories for Pairwise Choice under Risk

Consider a decision maker who faces the choice between two risky choice options (or, prospects) L^x and L^y. The prospects L^x and L^y can be described based on the finite state space $\mathcal{S} = \{1, \ldots, S\}$, where the occurrence probability of state s is $\pi_s \in (0, 1)$. The S different states of the world are mutually exclusive such that $\sum_{s=1}^{S} \pi_s = 1$. Let $\Pi = (\pi_1, \ldots, \pi_S)$ denote the vector of occurrence probabilities. Prospect L^i $(i = x, y)$ assigns to each state of the world $s \in S$ a monetary consequence (i.e., an increment or a decrement of the decision maker's wealth). Hence, $L^x = (x_1, \ldots, x_S) \in \mathbb{R}^S$ and $L^y = (y_1, \ldots, y_S) \in \mathbb{R}^S$. We summarize this pairwise choice situation as $\langle \mathcal{S}, \Pi, L^x, L^y \rangle$.[6]

[5] Loomes and Sugden (1982) show that regret theory can explain the common ratio, common consequence, isolation, and reflection effects as well as the simultaneous preferences for gambling and insurance. That regret theory can also rationalize the preference reversal phenomenon is shown by Loomes and Sugden (1983). Bordalo, Gennaioli, and Shleifer (2012) show that all the aforementioned choice patterns can be explained by salience theory.

[6] Throughout the paper, we restrict attention on pairwise choice problems, which, we believe, captures the true spirit in which Loomes and Sugden (1982, 1987a) proposed regret theory and Bordalo, Gennaioli, and Shleifer (2012) proposed salience theory. We comment on this limitation in Section 6.

With our focus on purely monetary consequences, in all that follows we impose the rather uncontroversial assumption that the decision maker's preferences over *pure consequences* are monotonic in the following sense: Suppose that the decision maker faces an exogenously imposed change of her initial wealth position in which she has no say at all (i.e., there is no decision to make). Then the decision maker weakly prefers the exogenous change to be the amount x rather than the amount y if and only if x is at least as large as y.[7]

2.1. Regret Theory

We consider regret theory as defined by Loomes and Sugden (1982, 1987a). Suppose the decision maker chooses prospect L^x. If state $s \in \mathcal{S}$ realizes, she obtains outcome x_s. She knows she would have received y_s if she had chosen differently, namely prospect L^y. According to regret theory, given the choice of prospect L^x, in state s the decision maker therefore has a composite experience based on obtaining x_s and missing out on y_s. The Benthamite or Bernouillian utility associated with this composite experience based on obtaining x_s and missing out on y_s is denoted by $M(x_s, y_s)$, where $M : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$.

Regret theory postulates that the value assigned to choosing prospect L^x is given by

$$V^{RT}(L^x) = \sum_{s=1}^{S} \pi_s \; M(x_s, y_s). \tag{1}$$

In consequence,

$$L^x \succeq L^y \iff \sum_{s=1}^{S} \pi_s \; \Psi(x_s, y_s) \geq 0, \tag{2}$$

where the function $\Psi : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$ is defined as $\Psi(x, y) \equiv M(x, y) - M(y, x)$. In order to explain certain EUT anomalies and to be consistent with the underlying psychological foundation, Loomes and Sugden (1987a) require the function $\Psi(\cdot, \cdot)$ to display the following properties:

Assumption 1. *The function $\Psi(\cdot, \cdot)$ satisfies the following properties:*

(SS) Skew symmetry: For all $x, y \in \mathbb{R}$, $\Psi(x, y) = -\Psi(y, x)$.[8]

[7] Formally, we assume that there exists a rational (i.e., complete, reflexive, and transitive) preference ordering $\succeq_{PC}$ on the set of pure consequences $\mathbb{R}$, such that the following hold: $x \succeq_{PC} y$ if and only if $x \geq y$. Our analysis can readily be extended to allow for non-monetary outcomes. Then, a rational preference ordering over all possible pure consequences is required.

[8] With $\Psi(x, y) = M(x, y) - M(y, x)$, skew symmetry holds by construction. However, as we build the upcoming analysis on the function $\Psi(x, y)$ without alluding to its particular construction, we treat skew symmetry as a property in its own right. Furthermore, note that skew symmetry implies $\Psi(x, x) = 0$.

(OPC) Ordering of pure consequences: For all $x, y \in \mathbb{R}$, $x \geq y$ if and only if $\Psi(x, y) \geq 0$.[9]

(I) Increasingness: For all $x, y, z \in \mathbb{R}$, $\Psi(x, y) \lesseqgtr 0$ if and only if $\Psi(x, z) \lesseqgtr \Psi(y, z)$.

(C) Convexity: For all $x, y, z \in \mathbb{R}$, if $\Psi(x, y) > 0$ and $\Psi(y, z) > 0$ and $\Psi(x, z) > 0$, then $\Psi(x, z) > \Psi(x, y) + \Psi(y, z)$.[10]

Strictly spoken, as outlined by Loomes and Sugden (1987a), the most basic definition of of a regret-theoretic representation of preferences would require the function $\Psi(\cdot, \cdot)$ to satisfy only (SS). The properties (OPC), (I), and (C), however, not only seem reasonable but also imply that regret theory can account for the observed choice behavior incompatible with EUT, which inspired regret theory in the first place. In particular, the convexity requirement (C) embodies the commonly accepted idea of regret aversion in the sense that experiencing two separate regretful outcomes pains the decision maker less than experiencing a single regretful outcome of the same overall magnitude. This is the reason why property (C) is also called *regret-aversion* (Loomes, Starmer, and Sugden, 1991). Therefore, we make the full set of properties listed in Assumption 1 part of the following definition of *generalized regret theory*.

Definition 1 (Generalized Regret Theory)**.** *The decision maker acts in accordance with generalized regret theory if there is a function $\Psi : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$ that satisfies (SS), (OPC), (I), and (C), such that for any pairwise choice situation $\langle S, \Pi, L^x, L^y \rangle$ the following holds:*

$$L^x \succeq L^y \iff \sum_{s=1}^{S} \pi_s \; \Psi(x_s, y_s) \geq 0. \tag{3}$$

In their seminal contribution Loomes and Sugden (1982) consider a simpler (and, thus, more restrictive) form of regret theory.[11] Specifically, they assume that $\Psi(x, y) = Q(c(x) - c(y))$, where the strictly increasing function $c : \mathbb{R} \to \mathbb{R}$ denotes "choiceless utility"; i.e., $c(x)$ denotes the purely hedoncic pleasure experienced from obtaining x

[9]Not restricting their focus on purely monetary consequences, Loomes and Sugden (1987a, p.273) defined property (OPC) as follows: "There is a complete, reflexive and transitive preference relation $\succeq$ on the set [of pure outcomes] X such that for all $[x, y \in X : x \succeq y \iff \Psi(x, y) \geq 0]$. Our focus on purely monetary consequences, paired with the assumption of monotonicity of preferences regarding pure consequences, allows us to restate this definition equivalently in the more convenient version above.

[10]When restricting attention to monetary outcomes, property (I) can also be stated as $\Psi(x, y)$ being strictly increasing in its first argument. As noted by Loomes, Starmer, and Sugden (1991, footnote #6), this property is implied by property (C). Here, to facilitate comparability with the original contributions, we state the full set of properties as listed in Loomes and Sugden (1987a).

[11]According to Bleichrodt and Wakker (2015) this more tractable representation is the most popular special case used in the literature on regret theory.

without having made a choice that led to obtaining x. Hence, under original regret theory choice is assumed to be determined only by differences in choiceless utilities. The function $Q : \mathbb{R} \to \mathbb{R}$, which is also referred to as regret function, is assumed to display the following properties:

Assumption 2. *The function $Q : \mathbb{R} \to \mathbb{R}$ is continuous and satisfies the following properties:*

(SS') Skew symmetry: For all $\Delta \in \mathbb{R}$, $Q(\Delta) = -Q(-\Delta)$.[12]

(I') Increasingness: For all $\Delta \in \mathbb{R}$, $Q(\Delta)$ is strictly increasing.

(C') Convexity: For all $\Delta \in \mathbb{R}_{>0}$, $Q(\Delta)$ is strictly convex.

As before, the most basic definition of original regret theory would not impose the convexity requirement (C′) to be satisfied. As is carefully argued by Loomes and Sugden (1982), property (C′) is needed for original regret theory to capture the observed empirical regularities, which is why we include property (C′) in the following definition of *original regret theory*.[13]

Definition 2 (Original Regret Theory)**.** *The decision maker acts in accordance with original regret theory if there is a strictly increasing function $c : \mathbb{R} \to \mathbb{R}$ and a continuous function $Q : \mathbb{R} \to \mathbb{R}$ that satisfies (SS'), (I'), and (C'), such that for any pairwise choice situation $\langle S, \Pi, L^x, L^y \rangle$ the following holds:*

$$L^x \succeq L^y \iff \sum_{s=1}^{S} \pi_s \, Q(c(x_s) - c(y_s)) \geq 0. \tag{4}$$

2.2. Salience Theory

The key idea of salience theory is that the decision maker's attention is invariably drawn to states with salient (i.e., outstanding) payoff combinations and that this directional influence on attention blurs the perception of the objective occurrence probabilities of the different states of the world. More specifically, it is hypothesized that the objective occurrence probability of a state with a very salient (non-salient) payoff combination is inflated (deflated). When evaluating prospect L^x, the salience of a state s with payoff combination (x_s, y_s) is denoted by $\sigma(x_s, y_s)$, where the function $\sigma : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$ is the so-called salience function.

Bordalo, Gennaioli, and Shleifer (2012) propose two mechanisms, *rank-based salience theory* and *smooth salience theory*, for how differences in the salience of

[12]Note that skew symmetry implies $Q(0) = 0$.

[13]If $Q(\cdot)$ is linear, original regret theory coincides with EUT.

payoff combinations might translate into a blurred perception objective occurrence probabilities along the lines mentioned above. Here, we present a slightly more general version of this probability distortion which allows us to address both rank-based salience theory and smooth salience theory (and, at least potentially, other so far unexplored salience-based mechanisms of probability distortions) in a single analytical framework. Specifically, when evaluating lottery L^x, the decision weight attached to state s with outcome x_s under lottery L^x and y_s under lottery L^y is given by

$$\hat{\pi}_s^x = \frac{f(\sigma(x_s, y_s))}{\sum_{r=1}^{S} f(\sigma(x_r, y_r))\pi_r}\ \pi_s, \tag{5}$$

where $f(\cdot) : \mathbb{R} \to \mathbb{R}_{\geq 0}$ is a strictly increasing function.[14] Essentially, the idea is that the objective occurrence probability of state s is inflated (deflated) if the (f-transformed) salience of outcome combination (x_s, y_s) is higher (lower) than the average (f-transformed) salience of all possible outcome combinations $(x_1, y_1), \ldots, (x_S, y_S)$. Below we explain in detail how to translate rank-based salience theory and smooth salience theory into this framework.

The value that the decision maker attaches to prospect L^x then is given by

$$V^{ST}(L^x) = \sum_{s=1}^{S} \hat{\pi}_s^x\ v(x_s), \tag{6}$$

where $v : \mathbb{R} \to \mathbb{R}$ is a strictly increasing value function with $v(0) = 0$. In consequence,

$$L^x \succeq L^y \iff \sum_{s=1}^{n} [\hat{\pi}_s^x\ v(x_s) - \hat{\pi}_s^y\ v(y_s)] \geq 0. \tag{7}$$

According to Bordalo, Gennaioli, and Shleifer (2012) the salience function $\sigma(\cdot, \cdot)$ displays the following properties:

Assumption 3. *The function $\sigma(\cdot, \cdot)$ is continuous and bounded and satisfies the following properties:*

(S) Symmetry: For all $x, y \in \mathbb{R}$, $\sigma(x, y) = \sigma(y, x)$.

(MS) Minimal salience of states with identical payoffs: For all $x, y, z, z' \in \mathbb{R}$ with $x \neq y$, $\sigma(z, z) = \sigma(z', z') < \sigma(x, y)$.

[14] One might wonder why we allow for $f(\sigma) = 0$ as this entails that states with a strictly positive occurrence probability may be assigned a decision weight equal to zero. With $f(\cdot)$ being strictly increasing, this can only be the case for the least salient states. As will become clear after the statement of Assumption 3, the least salient states are those in which both prospects yield the same outcome. And as can be seen from equation (8), states with identical outcomes have no impact on the decision maker's choice between L^x and L^y. Therefore, it is without loss of generality to allow for $f(\sigma) = 0$.

(O) Ordering: For all $x, y, x', y' \in \mathbb{R}$, if $[\min\{x, y\}, \max\{x, y\}] \subset [\min\{x', y'\}, \max\{x', y'\}]$, then $\sigma(x, y) < \sigma(x', y')$.

(DS) Diminishing sensitivity: For all $x, y \in \mathbb{R}_{>0}$ with $x \neq y$, $\sigma(x+\varepsilon, y+\varepsilon) < \sigma(x, y)$ for all $\varepsilon > 0$.

(R) Reflection: For all $x, y, x', y' \in \mathbb{R}_{>0}$, $\sigma(x, y) < \sigma(x', y')$ if and only if $\sigma(-x, -y) < \sigma(-x', -y')$.

As noted by Bordalo, Gennaioli, and Shleifer (2012, p.1250), "[t]he key properties driving our explanation of anomalies are ordering and diminishing sensitivity," which reflect contrast and level effects, respectively. The reflection property (R) only plays a role in the explanation of the reflection effect. The properties (S) and (MS) are assumed implicitly throughout the analysis of pairwise choice in Bordalo, Gennaioli, and Shleifer (2012), which is why we made these properties explicit part of the following definition of salience theory.[15,16] Symmetry of the salience function implies that $\hat{\pi}_s^x = \hat{\pi}_s^y$; i.e., the decision weight attached to state s does not depend on which prospect the decision maker evaluates. Hence, we can define *generalized salience theory* as follows:

Definition 3 (Generalized Salience Theory)**.** *The decision maker acts in accordance with generalized salience theory if there is a strictly increasing function $f : \mathbb{R} \to \mathbb{R}_{\geq 0}$, a continuous and bounded function $\sigma : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$ that satisfies (S), (MS), (O), (DS), and (R), and a strictly increasing function $v : \mathbb{R} \to \mathbb{R}$ with $v(0) = 0$ such that*

$$L^x \succeq L^y \iff \sum_{s=1}^{S} \pi_s \; f(\sigma(x_s, y_s))[v(x_s) - v(y_s)] \geq 0. \tag{8}$$

With *smooth salience theory* and *rank-based salience theory*, Bordalo, Gennaioli, and Shleifer (2012, p.1251-1252, 1255) propose two formalizations of how a salience-biased perception of the odds translates into decision weights compatible with the general formulation in equation (5). Here, we briefly explain both these approaches.

Under smooth salience theory, when evaluation prospect L^x, the decision maker transforms the odds $\pi_{s'}/\pi_s$ into $\hat{\pi}_{s'}^x/\hat{\pi}_s^x$, where

$$\frac{\hat{\pi}_{s'}^x}{\hat{\pi}_s^x} = \delta^{[(-\sigma(x_{s'}, y_{s'})) - (-\sigma(x_s, y_s))]} \cdot \frac{\pi_{s'}}{\pi_s}, \tag{9}$$

[15] Bordalo, Gennaioli, and Shleifer (2012, p.1250) refer to the symmetry requirement (S) as "a natural property in the case of two lotteries [...]".

[16] At first glance, property (MS) might seem at odds with the definition of diminishing sensitivity in Definition 1 in Bordalo, Gennaioli, and Shleifer (2012, p.1249). Key here is that the definition of diminishing sensitivity in Bordalo, Gennaioli, and Shleifer (2012) does not require x and y to be different. As becomes clear from the proof of Lemma 2 on p.6 in the Web-Appendix of Bordalo, Gennaioli, and Shleifer (2012) as well as from the statement that the salience function $\sigma(x, y) = |x - y|/(|x| + |y| + \theta)$ satisfies diminishing sensitivity, the definition of diminishing sensitivity in Bordalo, Gennaioli, and Shleifer (2012) indeed (implicitly) requires x and y to be different.

with $\delta \in (0,1)$ denoting the (inverse) degree of the salience induced distortion.[17] Intuitively, if the outcome combination in state s' is more (less) salient than the outcome combination in state s, i.e., if $\sigma(x_{s'}, y_{s'}) > (<)\ \sigma(x_s, y_s)$, then the objective odds $\pi_{s'}/\pi_s$ are perceived as inflated (deflated). Furthermore, the salience-induced decision weights are required to sum to unity, i.e., $\sum_{s=1}^{S} \hat{\pi}_s^x = 1$. Together, these conditions can be solved for the n salience-induced decision weights. Specifically, fixing $s \in \{1, \ldots, S\}$, adding up condition (9) for all $s' = 1, \ldots, S$ yields the following:[18]

$$\sum_{s'=1}^{S} \frac{\hat{\pi}_{s'}^x}{\hat{\pi}_s^x} = \sum_{s'=1}^{S} \left(\delta^{\{-\sigma(x_{s'},y_{s'})-[-\sigma(x_s,y_s)]\}} \cdot \frac{\pi_{s'}}{\pi_s} \right) \iff \hat{\pi}_s^x = \frac{\delta^{-\sigma(x_s,y_s)}}{\sum_{s'=1}^{S} \delta^{-\sigma(x_{s'},y_{s'})} \pi_{s'}} \cdot \pi_s \tag{10}$$

To formalize how salience distorts the perception of objective occurrence probabilities under rank-based salience theory, let $\Gamma = \langle \mathcal{S}, L^x, L^y \rangle$ denote the probability-independent aspect of the pairwise choice problem under consideration. The salience rank of state s, which results in payoff combination (x_s, y_s), when evaluating prospect L^x is denoted by $k^x(\sigma(x_s, y_s)|\Gamma) \in \mathbb{N}_{>0}$. The salience ranking of the states $1, \ldots, S$ starts at 1, has no jumps, and $k^x(\sigma(x_s, y_s)|\Gamma) \lesseqgtr k^x(\sigma(x_{s'}, y_{s'})|\Gamma)$ if and only if $\sigma(x_s, y_s) \gtreqless \sigma(x_{s'}, y_{s'})$. Notably, the salience ranking is decision-problem specific; i.e, while the value of the salience function $\sigma(\cdot,\cdot)$ for outcome combination (x_s, y_s) does not depend on Γ, the assigned salience rank does. In analogy to smooth salience theory, the decision maker transforms the odds $\pi_{s'}/\pi_s$ according to (9) but with $\delta^{[(-\sigma(x_{s'},y_{s'}))-(-\sigma(x_s,y_s))]}$ being replaced by $\delta^{k^x(\sigma(x_{s'},y_{s'})|\Gamma)-k^x(\sigma(x_s,y_s)|\Gamma)}$. Together with the requirement of decision weights summing up to unity, this distortion of odds results in the following decision weight attached to state s:

$$\hat{\pi}_s^x = \frac{\delta^{k^x(\sigma(x_s,y_s)|\Gamma)}}{\sum_{s'=1}^{S} \delta^{k^x(\sigma(x_{s'},y_{s'})|\Gamma)} \pi_{s'}} \cdot \pi_s \tag{11}$$

As previously explained, symmetry of the salience function $\sigma(\cdot,\cdot)$ implies that $\hat{\pi}_s^x \equiv \hat{\pi}_s^y$ under both smooth and rank-based salience theory. Comparison of (10) and (11) with (5) allows for the following observation:

Proposition 1. *Generalized salience theory encompasses smooth salience theory (with $f(\sigma) = \delta^{-\sigma}$) and rank-based salience theory (with $f(\sigma) = \delta^{k(\sigma|\Gamma)}$).*

Proof. See Appendix A. □

[17] If $\delta = 1$, salience theory coincides with EUT.

[18] We are thankful to two of our master students, Maximilian Fiedler and Fabio Römeis, for presenting this nicely streamlined proof of the logic underlying Definition 2 in Bordalo, Gennaioli, and Shleifer (2012) in one of our master seminars.

As outlined before, both smooth and rank-based salience theory are based on the premise that differences in the salience of outcome combinations distort the decision maker's perception of odds. The advantage of rank-based salience theory is its analytical tractability in pairwise choice problems with only few outcome combinations, as in the analysis of the common consequence effect or the common ratio effect in Bordalo, Gennaioli, and Shleifer (2012). Here, rank-based salience theory (unlike smooth salience theory) allows for a crisp characterization of choice behavior in terms of the salience parameter δ. As, however, already noted by Bordalo, Gennaioli, and Shleifer (2012, p.1255), the discrete nature of rank-based salience theory leads to "states with similar [though not identical] salience obtain[ing] very different weights," which may create discontinuities in valuation. As later formally analyzed by Kontek (2016), these discontinuities in valuation under rank-based salience theory entail that a prospect's certainty equivalent may be not well defined. With the main findings in Bordalo, Gennaioli, and Shleifer (2012) holding under both formalizations, from our point of view, the answer to the question whether to apply smooth or rank-based salience theory is based on trading off analytical convenience and conceptual coherence.

3. The Main Result: General Regret Theory and Salience Theory

In order to compare the two theories, we define the function $\Psi^{ST} : \mathbb{R}^2 \to \mathbb{R}$ as follows

$$\Psi^{ST}(x, y) \equiv f(\sigma(x, y))[v(x) - v(y)], \tag{12}$$

with $f(\cdot)$, $\sigma(\cdot, \cdot)$ and $v(\cdot)$ satisfying the properties listed in Definition 3.

Theorem 1. *If the decision maker behaves according to generalized salience theory with functions $v(\cdot)$, $\sigma(\cdot, \cdot)$ and $f(\cdot)$, then the decision maker behaves according to generalized regret theory with function $\Psi(\cdot, \cdot) = \Psi^{ST}(\cdot, \cdot)$.*

Proof. To prove the statement, it is sufficient to show that the function $\Psi^{ST}(\cdot, \cdot)$ satisfies the (SS), (OPC), (I), and (C).

(i) $\Psi^{ST}(\cdot, \cdot)$ *satisfies (SS).*

Skew-symmetry follows immediately from $\sigma(\cdot, \cdot)$ satisfying (S):

$$\begin{aligned}
\Psi^{ST}(x, y) &= f(\sigma(x, y))[v(x) - v(y)] \\
&= -f(\sigma(y, x))[v(y) - v(x)] \\
&= -\Psi^{ST}(y, x)
\end{aligned}$$

(ii) $\Psi^{ST}(\cdot,\cdot)$ *satisfies (OPC).*

Ordering of pure prospects follows immediately from $v(\cdot)$ being strictly increasing and $f(\cdot)$ being weakly positive and strictly increasing:

$$\begin{aligned}
\Psi^{ST}(x,y) > 0 \quad &\iff \quad f(\sigma(x,y))[v(x)-v(y)] > 0 \\
&\iff \quad f(\sigma(x,y)) > 0 \;\wedge\; v(x)-v(y) > 0 \\
&\iff \quad x > y
\end{aligned}$$

$$\begin{aligned}
\Psi^{ST}(x,y) = 0 \quad &\iff \quad f(\sigma(x,y))[v(x)-v(y)] = 0 \\
&\iff \quad f(\sigma(x,y)) = 0 \;\vee\; v(x)-v(y) = 0 \\
&\iff \quad x = y
\end{aligned}$$

(iii) $\Psi^{ST}(\cdot,\cdot)$ *satisfies (I).*

Step 1: First, we establish the "$\Longrightarrow$" direction. To this end, note that $\Psi^{ST}(a_j,c_j) \gtreqless \Psi^{ST}(b_j,c_j)$ if and only if

$$f(\sigma(x,z))[v(x)-v(z)] \gtreqless f(\sigma(y,z))[v(y)-v(z)] \tag{13}$$

If $\Psi^{ST}(x,y)=0$, then, by (OPC), we have $x=y$, in which case $\Psi^{ST}(x,z) = \Psi^{ST}(y,z)$ holds trivially.

If $\Psi^{ST}(x,y) > 0$, then, by (OPC), $y < x$ and we have to distinguish three cases. First, suppose that $z \le y$. Then $0 \le v(y)-v(z) < v(x)-v(z)$ because $v(\cdot)$ is strictly increasing. Furthermore, by (O), $\sigma(y,z) < \sigma(x,z)$. As $f(\cdot)$ is weakly positive and strictly increasing, we have $0 \le f(\sigma(y,z)) < f(\sigma(x,z))$, such that (13) implies $\Psi^{ST}(x,z) > \Psi^{ST}(y,z)$. Second, suppose that $y < z \le x$. Then $v(y)-v(z) < 0 \le v(x)-v(z)$ because $v(\cdot)$ is strictly increasing. Furthermore, as $f(\cdot)$ is weakly positive and strictly increasing, $f(\sigma(y,z)) > 0$ and $f(\sigma(x,z)) \ge 0$, such that (13) implies $\Psi^{ST}(x,z) > \Psi^{ST}(y,z)$. Third, suppose that $x < z$. Then $v(y)-v(z) < v(x)-v(z) < 0$ because $v(\cdot)$ is strictly increasing. Furthermore, by (O), $\sigma(x,z) < \sigma(y,z)$. As $f(\cdot)$ is weakly positive and strictly increasing, $0 < f(\sigma(x,z)) < f(\sigma(y,z))$, such that (13) implies $\Psi^{ST}(x,z) > \Psi^{ST}(y,z)$.

If $\Psi^{ST}(x,y) < 0$, then, by (OPC), we have $x < y$. By reasoning in analogy to the case before, one can establish that $\Psi^{ST}(x,z) < \Psi^{ST}(y,z)$.

Step 2: Next, we establish the "$\Longleftarrow$" direction. To this end, note that

$$\begin{aligned}
&\left[\Psi^{ST}(x,z) > \Psi^{ST}(y,z) \implies \Psi^{ST}(x,y) > 0\right] \\
\iff &\left[\neg[\Psi^{ST}(x,y) > 0] \implies \neg[\Psi^{ST}(x,z) > \Psi^{ST}(y,z)]\right] \\
\iff &\left[\neg[x > y] \implies \Psi^{ST}(y,z) \geq \Psi^{ST}(x,z)\right] \\
\iff &\left[y \geq x \implies \Psi^{ST}(y,z) \geq \Psi^{ST}(x,z)\right],
\end{aligned}$$

where the third equivalence holds by (OPC) and the fourth equivalence holds by Step 1. Reversing the roles of x and y allows to immediately establish that $\Psi^{ST}(x,z) < \Psi^{ST}(y,z) \implies \Psi^{ST}(x,y) < 0$. Finally,

$$\begin{aligned}
&\left[\Psi^{ST}(x,z) = \Psi^{ST}(y,z) \implies \Psi^{ST}(x,y) = 0\right] \\
\iff &\left[\neg[\Psi^{ST}(x,y) = 0] \implies \neg[\Psi^{ST}(x,z) = \Psi^{ST}(y,z)]\right] \\
\iff &\left[\neg[x = y] \implies \Psi^{ST}(x,z) \neq \Psi^{ST}(y,z)\right] \\
\iff &\left[x \neq y \implies \Psi^{ST}(x,z) \neq \Psi^{ST}(y,z)\right],
\end{aligned}$$

where the third equivalence holds by (OPC) and the fourth equivalence holds by Step 1.

(vi) $\Psi^{ST}(\cdot,\cdot)$ *satisfies (C).*
By (OPC),

$$\begin{aligned}
&\Psi(x,y) > 0 \wedge \Psi(y,z) > 0 \wedge \Psi(x,z) > 0 \\
\iff &\quad z < y < x.
\end{aligned}$$

Furthermore,

$$\begin{aligned}
&\Psi^{ST}(x,z) > \Psi^{ST}(x,y) + \Psi^{ST}(y,z) \\
\iff &\quad [f(\sigma(x,z)) - f(\sigma(x,y))][v(x) - v(y)] \\
&\quad > [f(\sigma(y,z)) - f(\sigma(x,z))][v(x) - v(z)]
\end{aligned}$$

Hence, to establish convexity of $\Psi^{ST}(\cdot,\cdot)$ it is sufficient to show that the following holds:

$$\begin{aligned}
z < y < x \implies &[f(\sigma(x,z)) - f(\sigma(x,y))][v(x) - v(y)] \\
&> [f(\sigma(y,z)) - f(\sigma(x,z))][v(y) - v(z)] \quad (14)
\end{aligned}$$

To see that (14) holds, note the following: first, $v(x) - v(y) > 0$ and $v(y) - v(z) > 0$ by $v(\cdot)$ strictly increasing; second, $\sigma(x,z) > \max\{\sigma(x,y), \sigma(y,z)\}$ by (O); third, $f(\cdot)$ is strictly increasing.

□

Theorem 1 establishes that generalized salience theory is a special case of generalized regret theory: If a preference relation allows for a representation by generalized salience theory, then the same preference relation also allows for a representation by generalized regret theory. The result is established by equating the function $\Psi(x,y)$ with the function $\Psi^{ST}(x,y) = f(\sigma(x,y))[v(x) - v(y)]$ and showing that the assumptions imposed by salience theory guarantee that $\Psi^{ST}(x,y)$ satisfies the assumptions imposed by generalized regret theory. In a nutshell, property (S) of function $\sigma(\cdot,\cdot)$ immediately translates into property (SS) of function $\Psi^{ST}(\cdot,\cdot)$ and the property (O) of function $\sigma(\cdot,\cdot)$ ensures that function $\Psi^{ST}(\cdot,\cdot)$ satisfies the properties (I) and (C).[19] Finally, the assumptions imposed on the functions $v(\cdot)$ and $f(\cdot)$ guarantee that $\Psi^{ST}(\cdot,\cdot)$ displays property (OPC). Notably, to establish Theorem 1, only two of the properties imposed on the salience function $\sigma(\cdot,\cdot)$ are needed—symmetry and ordering. The second of salience theory's core assumptions, property (DS), is not needed *at all*. Hence, salience theory imposes more assumptions and, thus, has more predictive power than generalized regret theory. In particular, the assumption of diminishing sensitivity seems to be a key difference. We will investigate these issues further in Section 4.

According to Theorem 1, for any specification of generalized salience theory (i.e., for any specific functions $v(\cdot)$, $\sigma(\cdot,\cdot)$, and $f(\cdot)$), there is a corresponding function $\Psi(\cdot,\cdot)$ that predicts exactly the same behavior in any pairwise choice problem.[20] As outlined in Subsection 2.2, under smooth salience theory we have $f(\sigma) = \delta^{-\sigma}$. In consequence, even though the decision weights $\hat{\pi}_1, \ldots, \hat{\pi}_S$ are specific to the pairwise choice situation under consideration, the function $\Psi^{ST}(x,y) = \delta^{-\sigma(x,y)}[v(x) - v(y)]$ is not. More specifically, while the decision weight $\hat{\pi}_s$ attached to state $s \in \mathcal{S}$ according to (5) depends on the outcome combinations of all the other states $s' \neq s$ and therefore on the exact specification of the two prospects L^x and L^y, the salience-related part of function $\Psi^{ST}(x,y) = \delta^{-\sigma(x,y)}[v(x) - v(y)]$ depends only on the value of the salience function at outcome combination (x,y), which, for a given salience function $\sigma(\cdot,\cdot)$, is invariant to the exact specification of the choice problem. Clearly,

[19] In the light of footnote #9 it is not surprising that one and the same property of function $\sigma(\cdot,\cdot)$, namely (O), implies that $\Psi^{ST}(\cdot,\cdot)$ satisfies both (I) and (C). That property (O) of salience theory has similar implications than the property convexity of regret theory is already conjectured by Bordalo, Gennaioli, and Shleifer (2012).

[20] For example, a specification of salience theory could prescribe a function $v(\cdot)$ that satisfies the properties of a "typical" value function as stated in Bowman, Minehart, and Rabin (1999), the salience function $\sigma(x,y) = |x-y|/(|x|+|y|+\theta)$ with $\theta > 0$, as proposed by Bordalo, Gennaioli, and Shleifer (2012) and often used in subsequent applications, and function $f(\sigma) = \delta^{-\sigma}$ or $f(\sigma) = \delta^{k(\sigma|\Gamma)}$, which correspond to smooth or rank-based salience theory, respectively (cf. Proposition 1).

this resonates well with the usual understanding of general regret theory that there is a "universal" function $\Psi(\cdot,\cdot)$ that applies to each and every pairwise choice problem that one can think of.

The picture looks slightly different under rank-based salience theory. Here, as outlined in Subsection 2.2, also the salience rank $k(\sigma(x_s, y_s)|\Gamma)$ of state s itself is choice-problem specific (where $\Gamma = \langle \mathcal{S}, L^x, L^y \rangle$ captures the probability-independent aspect of the pairwise choice problem under consideration). In other words, with rank-based salience theory, not only the decision weight $\hat{\pi}_s$ assigned to state s but also the "absolute salience weight" of state s, $f(\sigma)$, is choice-problem specific. As a consequence, and in contrast to smooth salience theory, this choice-problem specificity does not vanish in pairwise comparison, such that under rank-based salience theory the function $\Psi^{ST}(x,y) = \delta^{k(\sigma(x,y)|\Gamma)}[v(x) - v(y)]$ is choice-problem specific. This clearly is a rather uncommon interpretation of the function $\Psi(\cdot,\cdot)$ in regret theory, which becomes particularly relevant when interpreting comparative static results or variations of experimental treatments that involve any changes in Γ, because such changes potentially affect the salience ranking. Changes in Π (i.e., in the probability distribution over states and, thus, the correlation between the two prospects), on the other hand, pose no such complication because the states' salience ranking is left unchanged (as long as all occurrence probabilities remain strictly positive); i.e., given Γ, the function $\Psi^{ST}(\cdot,\cdot)$ is invariant to changes in Π.

Before the backdrop of this seeming limitation of our Theorem 1 with regard to rank-based salience theory, we consider it warranted to emphasize two observations. First, while extensively relying on rank-based salience theory, Bordalo, Gennaioli, and Shleifer (2012, p.1255) acknowledge that the "assumption of rank-based discounting buys us analytical tractability, but our main results also hold if the distortion of the odds [...] is a smooth increasing function of the salience differences [...]." Second, and more importantly, the function $\Psi^{ST}(\cdot,\cdot)$ under rank-based salience theory is invariant in the classic scenarios of the common ratio effect and the common consequence effect (in both the stochastic independent version and the correlated version), which makes generalized regret theory and rank-based salience theory impossible to distinguish in these scenarios.[21]

[21] To be precise, this statement does not hold for (what Bordalo, Gennaioli, and Shleifer (2012) would refer to as) perfect negative correlation of the riskier and the safer prospect. The reason is that under perfect negative correlation a state with an intermediate salience rank becomes impossible, which changes the difference in salience ranks between states and, thus, the function $\Psi^{ST}(\cdot,\cdot)$. The qualitative predictions, however, are not affected by this discontinuity embodied in rank-based salience theory.

4. Further Insights: Original Regret Theory and Salience Theory

As we have shown in Section 3, all choice patterns that can be rationalized by salience theory can also be rationalized by generalized regret theory. Generalized regret theory imposes only few rather general assumptions and thus has clearly less structure than salience theory. In other words, while certain choice patterns are in accordance (i.e., can be rationalized) with both generalized regret theory and salience theory, their systematic occurrence is predicted only by salience theory.

According to Bleichrodt and Wakker (2015), the applied theoretical literature on regret theory often relies on the more tractable specification of original regret theory (cf. Definition 2 in Subsection 2.1) under which $\Psi(x,y) = Q(c(x)-c(y))$. This regret theoretic preference representation has more structure and therefore more predictive power (i.e., it is easier to falsify) than generalized regret theory. The purpose of this section is to compare (generalized) salience theory with original regret theory. In order to facilitate this comparison, we focus on salience representations with continuous functions $f(\cdot)$, $\sigma(\cdot,\cdot)$, and $v(\cdot)$. The following result states the main finding of this section.

Theorem 2. *If the decision maker behaves according to generalized salience theory with continuous functions $f(\cdot)$, $\sigma(\cdot,\cdot)$ and $v(\cdot)$, then the decision maker's preference ordering can also be represented as follows:*

$$L^x \succeq L^y \iff \sum_{s=1}^{S} \pi_s \, Q(c(x_s) - c(y_s)) \geq 0, \tag{15}$$

where the function $c : \mathbb{R} \to \mathbb{R}$ is strictly increasing and continuous and the function $Q : \mathbb{R} \to \mathbb{R}$ is strictly increasing, continuous and skew-symmetric.

Proof. See Appendix A. □

The proof of Theorem 2 is based on the axiomatic foundation of original regret theory provided by Diecidue and Somasundaram (2017).[22] According to Theorem 1 in Diecidue and Somasundaram (2017), a preference ordering satisfies *completeness*, *strong monotonicity*, *continuity*, *d-transitivity*, and *trade-off consistency* if and only if it allows for a utility representation as in (15).[23] Notably, the axiomatization in Diecidue and Somasundaram (2017) does not yield the function $Q(\cdot)$ to be necessarily

[22] The proof of Lemma 8 in Diecidue and Somasundaram (2017) contains a theoretical argument how one can derive the functions $c(\cdot)$ and $Q(\cdot)$ from a function $\Psi(\cdot,\cdot)$, which can also be used in theory to derive these functions from $\Psi^{ST}(\cdot,\cdot)$. The described technique, however, does not allow necessarily for obtaining a closed form solution.

[23] The axioms are all formally defined in the proof of Theorem 2. The axiom *d-transitivity* first appeared in Stoye (2011) as *transitive extension of monotonicity*.

strictly convex, such that, strictly spoken, Theorem 2 does not show salience theory to be a special case of original regret theory as defined in Definition 2. However, even if the function $Q(\cdot)$ identified by Theorem 1 in Diecidue and Somasundaram (2017) should not be strictly convex in the sense of property (C′), it still satisfies the less strict convexity requirement embodied by property (C). Therefore, in any case, salience theory is closely related to original regret theory.

As we establish in the proof of Theorem 2, any salience specification with continuous functions $v(\cdot)$, $\sigma(\cdot,\cdot)$, and $f(\cdot)$ satisfies the five axioms imposed by Diecidue and Somasundaram (2017) and, thus, also d-transitivity. In order to formally define d-transitivity, we first define *state-wise dominance* $\succeq_{SD}$: prospect L^x *state-wise dominates* prospect L^y, $L^x \succeq_{SD} L^y$, if $x_s \geq y_s$ for all $s \in \mathcal{S}$ and $x_{s'} > y_{s'}$ for some $s' \in \mathcal{S}$. Now, we can define d-transitivity as follows:

Definition 4 (d-transitivity)**.** *For all prospects L^x, L^y and $L^z \in \mathbb{R}^S$ it holds that:*

$$[L^x \succeq_{SD} L^y \wedge L^y \succeq L^z] \;\Rightarrow\; L^x \succ L^z \quad \textit{and} \quad [L^x \succeq L^y \wedge L^y \succeq_{SD} L^z] \;\Rightarrow\; L^x \succ L^z.$$

Clearly, d-transitivity distinguishes the action-based approaches of original regret theory and salience theory from EUT and most prospect-based non-EUT alternatives.[24] These latter theories assign to each prospect a real-valued utility level which depends only on the prospect itself but not on the specification of the alternative choice option(s). In consequence, EUT and most prospect-based theories necessarily are required to satisfy "traditional" transitivity because the real numbers themselves are transitive. In contrast, original regret theory and salience theory have to satisfy "only" d-transitivity rather than transitivity as they make the evaluation of a prospect contingent on the alternative choice option. Therefore, with violations of transitivity being well-known (though, maybe, not fully understood) in the literature on choice under risk and uncertainty (Loomes, Starmer, and Sugden, 1991; Starmer and Sugden, 1998), future experimental research that is interested in comparing prospect-based theories and action-based theories (such as regret theory or salience theory) should try to validate/falsify d-transitivity.

Notably, just like the proof of Theorem 1, the proof of Theorem 2 makes use of only one of the two key assumptions of salience theory, namely of ordering. Diminishing sensitivity is not needed. This observation raises the question whether we can identify behavior which, due to diminishing sensitivity of the salience function, is systematically predicted by salience theory but never systematically predicted by original regret theory. As it turns out, the answer to this question is "No." In

[24]EUT can be axiomatized based on completeness, monotonicity, continuity, and trade-off consistency (Köbberling and Wakker, 2003).

the following proposition, we establish the existence of specifications of generalized salience theory that are *identical* to a specification of original regret theory.

Proposition 2. *Suppose that the functions $v(\cdot)$ and $f(\cdot)$ are twice differentiable and satisfy $v(x) = -v(-x)$ for all $x \in \mathbb{R}$, $v''(\cdot) < 0$ for all $x \in \mathbb{R}_{>0}$, $v(\cdot) < \bar{v} \in (0, \infty)$ and $2f'(\xi) + f''(\xi)\xi > 0$. If $v(\cdot) \equiv c(\cdot)$, then the decision maker behaves according to generalized salience theory with functions $v(\cdot)$, $\sigma(x, y) = (|v(x) - v(y)|)/(2\bar{v})$ and $f(\cdot)$ if and only if the decision maker behaves according to original regret theory with functions $c(\cdot)$ and $Q(\Delta) = f\left((|\Delta|)/(2\bar{v})\right)\Delta$.*

Proof. See Appendix A. □

As can be seen from the proof of Proposition 2, it is the concavity of choiceless utility (in the domain of positive outcomes) that ensures that the corresponding salience function satisfies diminishing sensitivity. While many applications of original regret theory assume a linear choiceless utility function, Loomes and Sugden (1982, p.814) favor a concave function: "Our intuition is that $c(\cdot)$ is not linear but concave." Note, however, that global concavity of the choiceless utility function in our construction can only be assumed once the reflection property is dropped.[25]

Taking diminishing sensitivity of the salience function as given, what kind of choice behavior would be expected from a decision maker who adheres to salience theory? To answer this question, consider two distinct prospects L^x and L^y between which the decision maker is indifferent and where prospect L^x pays out a strictly higher positive amount in state s than prospect L^y; i.e., $L^x \sim L^y$ and $0 \leq y_s < x_s$. A uniform increase of x_s and y_s by the amount $\varepsilon > 0$ then makes L^y relatively more attractive than L^x, at least as long as the value function is not overly convex over the domain of gains.[26] Hence, letting $z_s L^x \equiv (x_1, \ldots x_{s-1}, z, x_{s+1}, \ldots, x_S)$ denote the prospect L^x with x_s being replaced by z, we would this decision maker's preference relation expect to satisfy the following "axiom":

Definition 5 (Diminishing marginal utility). *For all prospects L^x, $L^y \in \mathbb{R}^S$ and all $\varepsilon \in \mathbb{R}_{>0}$ it holds that:*

(DMU) $L^x \sim L^y \;\wedge\; 0 \leq y_s < x_s$ *for some* $s \in \mathcal{S} \;\Rightarrow\; (x_s + \varepsilon)_s L^x \prec (y_s + \varepsilon)_s L^y$

Whether a decision maker adheres to axiom (DMU) can easily be tested experimentally. If the decision maker's preference ordering should be found to satisfy

[25] Curvature of the choiceless utility function $c(\cdot)$ is not needed under original regret theory in order to capture the reflection effect (Bell, 1982; Loomes and Sugden, 1982).

[26] Clearly, the requirement of the value function $v(\cdot)$ being not too convex over the domain of gains is satisfied by all standard specifications as well as by a (piece-wise) linear specification for function $v(\cdot)$.

axiom (DMU), this has a direct implication for the curvature of the choiceless utility function $c(\cdot)$ in a original-regret-theoretic representation of the preference ordering. Specifically, if the preference ordeing satisfies the five axioms listed in Theorem 1 of Diecidue and Somasundaram (2017) and, in addition, axiom (DMU), then the preference ordering can be represented by original regret theory with a strictly concave choiceless utility function.[27] The implications of axiom (DMU) being found valid for a salience-theoretic representation of the preference ordering are less clear, because, based on choice data alone, it is impossible to disentangle the curvature of the salience function from curvature of the value function.[28]

This section further emphasizes that salience theory and original regret theory are closely related. Differences in predictions do not stem from fundamental differences of the two theories, but rather from differences in the particular assumptions imposed on functional forms. Salience theory always imposes (DS), which, for typical specifications of the value functions, implies that axiom (DMU) is satisfied. Applications of original regret theory, however, often opt for a linear choiceless utility function, which does not satisfy axiom (DMU). Therefore, we believe it insightful for future experimental work to test the importance of axiom (DMU).

5. Discussion

In their exposition of salience theory, Bordalo, Gennaioli, and Shleifer (2012) extensively compare salience theory with prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992), which they refer to as "the gold standard of behavioral theories of choice under risk" (Bordalo, Gennaioli, and Shleifer, 2012, p.1245). A comparison with regret theory, on the other hand, happens rather in the passing. This focus on the match-up salience theory versus prospect theory, together with the fact that much of the predictive power of both these theories is rooted in the assumption of a distorted perception of probabilities, led to the proclamation of the

[27]To see this, note that $L^x \sim L^y$ and $(x_s+\varepsilon)_s L^x \prec (y_s+\varepsilon)_s L^y$ together imply $Q(c(x_s+\varepsilon)-c(y_s+\varepsilon)) < Q(c(x_s)-c(y_s))$. With $Q(\cdot)$ being strictly increasing, the latter inequality is equivalent to $c(x_s+\varepsilon)-c(y_s+\varepsilon) < c(x_s)-c(y_s)$, which is satisfied for all x_s, y_s, and ε if and only if $c(\cdot)$ strictly concave.

[28]Instead of testing (DMU), Bordalo, Gennaioli, and Shleifer (2012) experimentally and theoretically investigate how a shift in all payoffs affects risk attitudes. They consider a simple choice situation with $S = 2$, a safe prospect $L^S = (x, x)$ and a risky prospect $L^R = (x + \frac{1-\pi}{\pi} l, x - l)$, with $l > 0$ and $x - l > 0$. The probability of $s = 1$ is $\pi \in (0, 1)$. Both prospects have the same mean x, which is varied across the treatments. They report (weak) evidence that risk seeking increases in x. This observation is in accordance with salience theory (and a linear value function) but not with original regret theory with a linear choiceless utility function. An increase of x, however, has opposing effects on the risk attitudes of a decision maker that behaves according to salience theory. The observed pattern is predicted by salience theory only if the salience function is convex. See Definition 3 and Lemma 1 of Bordalo, Gennaioli, and Shleifer (2012). Note, diminishing sensitivity (or property DMU) does not allow for a clear prediction in this choice situation.

agenda to "stringently pit the predictions of the two theories against each other" (Dhami, 2016, p.187). Before the backdrop of our analysis, we believe this "call to arms" to be somewhat misguided—or, better put, misguiding—for several reasons.

First and foremost, by now, the predictions of prospect theory and regret theory have been stringently put against each other for more than thirty years. In consequence, with salience theory being a special case of regret theory, any research project (whether theoretical or empirical in nature) with the aim to compare prospect theory and salience theory should make sure that the question under consideration has not yet been addressed under the label of regret theory. And even if this is not be the case, it should be carefully explained to what extent the analysis rests on aspects that are peculiar to the structure of salience theory or on aspects that are shared by salience theory and regret theory.

Second, instead of narrowly focusing on the comparison of prospect theory and salience theory, we believe it to be more insightful to take a step back and to re-examine the comparison of the two classes of theories to which prospect theory and salience theory belong to, respectively. Prospect theory belongs to the class of *prospect-based theories* whereas salience theory belongs to the class of *action-based theories*.[29] Under prospect-based theories the evaluation of a given prospect is fully determined by the properties of that particular prospect itself. Under action-based theories, in contrast, the evaluation of a given prospect depends also on the available alternative prospects. Specifically, an important determinant of a subject's decision between two prospects is how the outcomes of these prospects are juxtaposed, i.e., how a prospect's outcome in a given state compares to the alternative prospect's outcome in that particular state. A series of experimental studies from the 1980s confirmed the existence of significant juxtaposition effects, thereby providing support for action-based rather than prospect-based theories (Loomes and Sugden, 1987b; Loomes, 1988a,b; Starmer and Sugden, 1989). These predictions where challenged in the 1990s by studies which found these juxtaposition effects to be highly susceptible to the problem representation format (Battalio, Kagel, and Jiranyakul, 1990; Harless, 1992). Moreover, and more importantly, Starmer and Sugden (1993) and Humphrey (1995) argue that the evidence which had been interpreted as supportive for the occurrence of juxtaposition effects in fact may have been driven by event-splitting effects, i.e., by a distorted processing of probabilities, where "an event with given

[29] The distinction between the class of prospect-based theories and the class of action-based theories was introduced by Loomes and Sugden (1987b). Next to prospect theory, the former class encompasses expected utility theory (von Neumann and Morgenstern, 1947), disappointment theory (Loomes and Sugden, 1986; Bell, 1985), generalized expected utility theory (Machina, 1982), rank-order theory (Quiggin, 1982; Yaari, 1987), and expectation-based loss aversion (Kőszegi and Rabin, 2007). Next to salience theory, the latter class encompasses regret theory Loomes and Sugden (1982, 1987a) and skew-symmetric bilinear utility theory (Fishburn, 1982).

probability and given consequences is weighted more heavily if it is considered as two sub-events than if it is considered as a single event" (Starmer and Sugden, 1993, p.236). Such event-splitting effects are neither predicted by regret theory nor by salience theory but by classic prospect theory (Kahneman and Tversky, 1979).[30] In our perception, the debate between prospect-based and action-based theories has not reached a decisive conclusion yet. Therefore, we see little value in testing one particular prospect-based theory against one particular action-based theory.

Third, instead of solely focusing on the match-up prospect theory versus salience theory, we consider it just as fruitful to dig deeper into the differences between salience theory and regret theory. Salience theory imposes more assumptions than generalized regret theory. Therefore, there must exist choice situations where the former theory makes tighter predictions than the latter. Future theoretical work might aim at identifying these choice situations, which then can be stringently tested experimentally. Ultimately, however, an axiomatic approach seems most promising to carve out the precise differences between the two theories. The development of such an axiomatic foundation for salience theory may benefit from our findings as we have shown that salience theory is both a special case of generalized regret theory, which is axiomatized by Sugden (1993), and a special case of original regret theory (without the convexity requirement), which is axiomatized by Diecidue and Somasundaram (2017).

Finally, and related to the issue before, future experimental investigations may want to aim at identifying the psychological channel that underlies decision under risk. For example, under regret theory it is hypothesized that a decision maker's ex ante choice is affected by the fear of experiencing regret ex post. In consequence, if regret theory (and regret aversion in particular) is a key determinant of decision making under risk, then one might expect to observe a strictly positive ex ante willingness to pay for avoiding information that would lead to ex post regret.[31] Under salience theory, the willingness to pay for avoiding this kind of information would be expected to be zero. Under salience theory, on the other hand, it is hypothesized that the decision maker ex ante overweighs the occurrence probability of salient events. Hence, when moving from the realms of risk to the realms of uncertainty, one might investigate whether payoff variation affects truly elicited beliefs about occurrence probabilities according to the predictions of salience theory. Under regret aversion,

[30] In contrast to regret theory, salience theory works via probability distortions. In consequence, we believe it to be easier to augment salience theory in a theory-coherent way to accommodate event-splitting effects.

[31] First evidence that feedback on foregone risky alternatives enhances the salience of regret as decision motive is provided by Larrick and Boles (1995) and Humphrey, Mann, and Starmer (2005).

such variation of payoffs should have no effect on the assessment of the probabilistic environment.

6. Conclusion

In this paper we compare two non-EUT theories to model pairwise choice under risk—regret theory (Loomes and Sugden, 1982, 1987a) and salience theory (Bordalo, Gennaioli, and Shleifer, 2012). Bordalo, Gennaioli, and Shleifer (2012) offer two approaches to model salience-induced distortions in the perception of probabilities: rank-based salience theory, which favors analytical tractability in simple choice problems, and smooth salience theory, which favors conceptual coherence. To facilitate the exposition and the comparison of regret theory and salience theory, we present a "generalized" version of salience theory that encompasses both these approaches. Our key result shows that generalized salience theory is a special case of generalized regret theory. This insight is particularly compelling for the case of smooth salience theory. Here, for any specification of salience theory's salience function and value function, there exists a choice-problem-invariant specification of generalized regret theory that predicts identical behavior in any pairwise choice problem. Under rank-based salience theory, on the other hand, the resulting regret representation typically is decision-problem specific, because rank-based salience theory introduces a (rather subtle) dependence of the salience ranking on the states of the world which is absent under smooth salience theory. However, for choice problems that share the same non-probabilistic aspects (i.e., the same underlying state space and the same combination of outcomes in each state) the regret representation resulting under rank-based salience theory is invariant to changes in the probability distribution over the different states of the world. This has the important implication that regret theory and (both rank-based and smooth) salience theory are effectively impossible to distinguish in the choice problems that constitute the common consequence and common ratio Allais paradoxes. Overall, with the qualitative predictions of smooth and the rank-based salience theory being the same, we believe that our insights qualitatively apply to both formulations.

An obvious limitation of our analysis is the focus on pairwise choice. To some extent, however, this limitation is inherited from regret theory and salience theory themselves, both of which (at least in our reading) were proposed to explain observations made primarily in pairwise choice situations. As pointedly stated by Bleichrodt and Wakker (2015) "[a] limitation of regret theory, as of any intransitive theory of binary choice, is that it is unclear how to extend the theory to choices among three or more actions." Regarding regret theory, Loomes and Sugden (1982) made some first suggestions, which were further formalized by Loomes and Sugden (1987a) and axiomatized by Sugden (1993), for how regret or rejoicing experienced from receiving the outcome of the chosen alternative in a given state might depend on the outcomes of all rejected alternatives in that state. Quiggin (1994), on the other hand, advocated for the imposition of the axiom of the irrelevance of state-wise dominated alternatives, which implies that regret in a given state is determined only by the maximum outcome across choice options in that particular state. And yet another alternative approach is proposed by Hayashi (2008). Thus, even after more than thirty years, in our perception no clear consensus has emerged on how to extend regret theory beyond pairwise choice. Salience theory, which still is at a young age, so far has not moved beyond the proposal by Bordalo, Gennaioli, and Shleifer (2012) that a state's salience should depend on the comparison of the outcome of the prospect which is to be evaluated in that state with some representative measure for the alternative prospects' outcomes (e.g., the average outcome) in that state. Before this backdrop, we consider an extension of our analysis to choice among three or more prospects beyond the scope of this paper (if not even beyond our grasp), as such an endeavor raises broader questions that most likely will not have a theory-specific answer.

A. Appendix

Proof of Proposition 1. With regard to smooth salience theory, it is sufficient to note that $\delta \in (0,1)$ implies that $f(\sigma) > 0$ and $f'(\sigma) = -\delta^{-\sigma}\ln(\delta) > 0$ for all σ. With regard to rank-based salience theory, it is sufficient to note that $k(\sigma|\Gamma) \in \mathbb{N}_{>0}$ and that $k^x(\sigma(x_s, y_s)|\Gamma) \lesseqgtr k^x(\sigma(x_{s'}, y_{s'})|\Gamma)$ if and only if $\sigma(x_s, y_s) \gtreqless \sigma(x_{s'}, y_{s'})$ implies $f(\sigma(x_s, y_s)) \gtreqless f(\sigma(x_{s'}, y_{s'}))$ if and only if $\sigma(x_s, y_s) \gtreqless \sigma(x_{s'}, y_{s'})$. □

Proof of Theorem 2. We apply Theorem 1 of Diecidue and Somasundaram (2017).[32] In the following, $\succeq_{SD}$ denotes *state-wise dominance*: A prospect L^x *state-wise dominates* prospect L^y, i.e., $L^x \succeq_{SD} L^y$, if $x_s \geq y_s$ for all $s \in \mathcal{S}$ and $x_{s'} > y_{s'}$ for some $s' \in \mathcal{S}$.[33] Further, $\alpha_s L^x$ denotes the prospect L^x with outcome x_s replaced by $\alpha \in \mathbb{R}$.

Theorem 3 (Diecidue and Somasundaram, 2017)**.** *The following two statements are equivalent:*

1. *The preference relation $\succeq$ can be represented with a strictly increasing continuous choiceless utility function c and a strictly increasing skew symmetric*

[32] Theorem 1 of Diecidue and Somasundaram (2017) allows for subjective probabilities.

[33] Diecidue and Somasundaram (2017) refer to the $\succeq_{SD}$ relation as *strict dominance* rather than *state-wise dominance.*

continuous regret function Q; i.e.

$$L^x \succeq L^y \iff \sum_{s=1}^{S} \pi_s Q(c(x_s) - c(y_s)) \geq 0$$

2. *The preference relation $\succeq$ satisfies:*

   (i) Completeness: For all L^x, $L^y \in \mathbb{R}^S$, either $L^x \succeq L^y$ or $L^x \preceq L^y$.

   (ii) Strong monotonicity: For all L^x, $L^y \in \mathbb{R}^S$, if $x_s \geq y_s$ for all $s \in \mathcal{S}$ and $x_{s'} > y_{s'}$ for a state $s' \in \mathcal{S}$, then $L^x \succ L^y$.

   (iii) Continuity: For each $L^y \in \mathbb{R}^S$, the sets $\{L^x \in \mathbb{R}^S | L^x \succeq L^y\}$ and $\{L^x \in \mathbb{R}^S | L^x \preceq L^y\}$ are closed subsets of $\mathbb{R}^S$.

   (iv) Trade-off consistency: For all L^x, L^y, L^z, $L^w \in \mathbb{R}^S$ if $[\alpha_s L^x \sim \beta_s L^y \ \wedge \ \gamma_s L^x \sim \delta_s L^y \ \wedge \ \alpha_{s'} L^z \sim \beta_{s'} L^w] \implies \gamma_{s'} L^z \sim \delta_{s'} L^w$.

   (v) d-transitivity: For all L^x, L^y, $L^z \in \mathbb{R}^S$, if $[L^x \succeq_{SD} L^y \wedge L^y \succeq L^z] \implies L^x \succ L^z$ and if $[L^x \succeq L^y \wedge L^y \succeq_{SD} L^z] \implies L^x \succ L^z$.

According to Theorem 1 in Diecidue and Somasundaram (2017), in order to establish the result it is sufficient to show that a preference relation which allows for a salience-theoretic representation satisfies (i) completeness, (ii) strong monotonicity, (iii) continuity, (iv) trade-off consistency, and (v) d-transitivity. Hence, in all that follows, we assume that the preference relation allows for a representation according to Definition 3 and we denote $\Psi^{ST}(x, y) \equiv f(\sigma(x, y))[v(x) - v(y)]$

(i) Completeness: For any prospects $L^x \in \mathbb{R}^S$ and $L^y \in \mathbb{R}^S$, the choice between the two prospects is governed by the function $\sum_{s=1}^{S} \pi_s \Psi^{ST}(x_s, y_s)$. This function is either > 0 or < 0 or $= 0$. Hence, $L^x \succeq L^y$ or $L^x \preceq L^y$ and the preference relation satisfies completeness.

(ii) Strong monotonicity: For any prospects $L^x \in \mathbb{R}^S$ and $L^y \in \mathbb{R}^S$, if $x_s \geq y_s$ for all $s \in \mathcal{S}$ and $x_{s'} > y_{s'}$ for some $s' \in \mathcal{S}$, then $\sum_{s=1}^{S} \pi_s \Psi^{ST}(x_s, y_s) > 0$, because $f(\sigma(x_s, y_s)) \geq 0$ and $v(x_s) - v(y_s) \geq 0$ for all states and the inequalities are strict at least for state s'. Hence, as $\sum_{s=1}^{S} \pi_s \Psi^{ST}(x_s, y_s) > 0$ implies $L^x \succ L^y$, the preference relation satisfies strong monotonicity.

(iii) Continuity: For each prospect $L^y \in \mathbb{R}^S$, as the functions $f(\cdot)$, $\sigma(\cdot, \cdot)$, and $v(\cdot)$ are continuous, the sets $\{L^x \in \mathbb{R}^S \mid L^x \succeq L^y\}$ and $\{L^x \in \mathbb{R}^S \mid L^x \preceq L^y\}$ are closed. Thus, the preference relation satisfies continuity.

(iv) Trade-off consistency: Note that $\alpha_s L^x \sim \beta_s L^y$ is equivalent to

$$\sum_{r \neq s} \pi_r \Psi^{ST}(x_r, y_r) + \pi_s \Psi^{ST}(\alpha, \beta) = 0, \tag{A.16}$$

and $\gamma_s L^x \sim \delta_s L^y$ is equivalent to

$$\sum_{r \neq s} \pi_r \Psi^{ST}(x_r, y_r) + \pi_s \Psi^{ST}(\gamma, \delta) = 0, \tag{A.17}$$

From (A.16) and (A.17) it follows that

$$\Psi^{ST}(\alpha, \beta) = \Psi^{ST}(\gamma, \delta). \tag{A.18}$$

Moreover, $\alpha_{s'} L^z \sim \beta_{s'} L^w$ is equivalent to

$$\sum_{r \neq s'} \pi_r \Psi^{ST}(z_r, w_r) + \pi_{s'} \Psi^{ST}(\alpha, \beta) = 0. \tag{A.19}$$

By (A.18) and (A.19) it holds that

$$\sum_{r \neq s'} \pi_r \Psi^{ST}(z_r, w_r) + \pi_{s'} \Psi^{ST}(\gamma, \delta) = 0. \tag{A.20}$$

As (A.20) implies $\gamma_{s'} L^z \sim \delta_{s'} L^w$, the preference relation satisfies trade-off consistency.

(v) d-transitivity: Let $L^x \succeq_{SD} L^y$ and $L^y \succeq L^z$. $L^y \succeq L^z$ is equivalent to

$$\sum_{s=1}^{S} \pi_s \Psi^{ST}(y_s, z_s) \geq 0. \tag{A.21}$$

As $x_s \geq y_s$ for all $s \in \mathcal{S}$ by $L^x \succeq_{SD} L^y$, the three sets $\mathcal{S}_1 = \{s \in \mathcal{S} \mid y_s \geq z_s\}$, $\mathcal{S}_2 = \{s \in \mathcal{S} \mid x_s \geq z_s > y_s\}$, and $\mathcal{S}_3 = \{s \in \mathcal{S} \mid z_s > x_s\}$ partition the state space; i.e., the three sets are disjoint and $\mathcal{S}_1 \cup \mathcal{S}_2 \cup \mathcal{S}_3 = \mathcal{S}$. By $\sigma(\cdot, \cdot)$ satisfying (O), it follows that $\sigma(x_s, z_s) \geq \sigma(y_s, z_s)$ if $s \in \mathcal{S}_1$ and $\sigma(x_s, z_s) \leq \sigma(y_s, z_s)$ if $s \in \mathcal{S}_3$. Further, with $x_s \geq y_s$ for all $s \in \mathcal{S}$ and $v(\cdot)$ being strictly increasing, we have $0 \leq v(y_s) - v(z_s) \leq v(x_s) - v(z_s)$ if $s \in \mathcal{S}_1$, $v(y_s) - v(z_s) < 0 \leq v(x_s) - v(z_s)$ if $s \in \mathcal{S}_2$, and $v(y_s) - v(z_s) \leq v(x_s) - v(z_s) < 0$ if $s \in \mathcal{S}_3$. Together these observations imply that

$$\sum_{s \in \mathcal{S}_1} \pi_s \Psi^{ST}(x_s, z_s) \geq \sum_{s \in \mathcal{S}_1} \pi_s \Psi^{ST}(y_s, z_s) \tag{A.22}$$

$$\text{and} \quad \sum_{s \in \mathcal{S}_2} \pi_s \Psi^{ST}(x_s, z_s) > \sum_{s \in \mathcal{S}_2} \pi_s \Psi^{ST}(y_s, z_s) \tag{A.23}$$

$$\text{and} \quad \sum_{s \in \mathcal{S}_3} \pi_s \Psi^{ST}(x_s, z_s) \geq \sum_{s \in \mathcal{S}_3} \pi_s \Psi^{ST}(y_s, z_s). \tag{A.24}$$

If $\mathcal{S}_2 = \emptyset$, then $s' \in \mathcal{S}_1$ or $s' \in \mathcal{S}_3$, in which case the inequality in either (A.22) or (A.24) is strict because $x_{s'} > y_{s'}$ implies $\Psi^{ST}(x_{s'}, z_{s'}) > \Psi^{ST}(y_{s'}, z_{s'})$. Together (A.22), (A.23), and (A.24) thus imply

$$\sum_{s \in \mathcal{S}} \pi_s \Psi^{ST}(x_s, z_s) > \sum_{s \in \mathcal{S}} \pi_s \Psi^{ST}(y_s, z_s), \tag{A.25}$$

which, in turn, together with (A.21) implies

$$\sum_{s\in\mathcal{S}} \pi_s \Psi^{ST}(x_s, z_s) > 0. \tag{A.26}$$

Thus, $L^x \succ L^z$.

Analogously it can be shown that $[L^x \succeq L^y \wedge L^y \succeq_{SD} L^z] \;\Rightarrow\; L^x \succ L^z$. Hence, the preference relation satisfies d-transitivity. $\square$

Proof of Proposition 2. To prove the statement, we proceed in two steps. In Step 1, we show that the function $\sigma(\cdot,\cdot)$ satisfies the properties (S), (MS), (O), (DS), and (R). In Step 2, we show that the function $Q(\cdot)$ satisfies the properties (SS), (I), and (C).

Step 1: As the function $\sigma(\cdot,\cdot)$ obviously satisfies the properties (S), (MS), and (O), a formal proof is omitted. Property (DS) follows from the assumption of $v(\cdot)$ being strictly concave over the domain of positive outcomes. Formally, for $x > y > 0$ and $\varepsilon \geq 0$,

$$\frac{d}{d\varepsilon}\left\{v(x+\varepsilon) - v(y+\varepsilon)\right\} \;=\; v'(x+\varepsilon) - v'(y+\varepsilon) < 0, \tag{A.27}$$

where the strict inequality holds by $v''(x) < 0$ for $x > 0$. As (A.27) implies $\sigma(x+\varepsilon, y+\varepsilon) < \sigma(x,y)$ for all $\varepsilon > 0$, property (DS) is satisfied. Property (R) clearly follows from the assumption that $v(x) = -v(-x)$. In fact, this assumption implies a strong form of reflection, $\sigma(x_s, y_s) = \sigma(-x_s, -y_s)$ for $x_s, y_s > 0$.

Step 2: As the function

$$Q(\Delta) = f(|\Delta|)\Delta = \begin{cases} f(\Delta)\ \Delta & \text{for } \Delta \geq 0 \\ f(-\Delta)\ \Delta & \text{for } \Delta < 0 \end{cases} \tag{A.28}$$

clearly satisfies (SS) and (I), a formal proof is omitted. Furthermore, for $\Delta > 0$ we have $Q''(\Delta) = 2f'(\Delta) + \Delta f''(\Delta) > 0$, such that property (C) is satisfied. Continuity of $Q(\cdot)$ follows from continuity of $f(\cdot)$, $\sigma(\cdot,\cdot)$, and $v(\cdot)$. $\square$

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