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The Achilles' heel of Salience theory and a way to fix it

Barna Bakó [a], Gábor Neszveda [b,*]

[a] Department of Economics, Corvinus University of Budapest, Fővám tér 8, 1093 Budapest, Hungary
[b] MNB Department, Corvinus University of Budapest, Fővám square 8, 1093, Budapest, Hungary

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ABSTRACT

Salience theory has been successfully used to explain a wide range of empirical and experimental phenomena such as the Allais paradox, framing effect, the preference reversal phenomenon or the decoy and compromise effects. In this paper we show that salience theory carries a notable flaw and under certain circumstances it suggests that a salient thinker may prefer a dominated option even when a strictly dominant alternative is available to her. To solve this problem we propose a possible alteration of the theory and show how it accounts for the same phenomena as the salience theory.

1. Introduction

Salience theory (Bordalo et al., 2012a and Bordalo et al., 2013a) accounts for paradoxes such as the Allais paradox (Allais, 1953), the preference reversal phenomenon (Lichtenstein and Slovic, 1971) and the framing effect (Tversky and Kahneman, 1981), phenomena that the classical theory of expected utility cannot be made compatible with. Furthermore, salience theory provides an explanation for some regular quirks of non-binary decision making as well, such as the asymmetric dominance, also known as decoy effect (Huber et al., 1982) or the compromise effect (Simonson, 1989). According to salience theory decisions are not made in a vacuum, but rather in a comparative context and decision makers contrast the attributes of an option to the features of other available alternatives when facing a decision. An attribute of an option is being said to be salient if it stands out relative to its average level in the choice context. The premise of the theory is that salient characteristics get more focus and thus are disproportionately overweighted compared to other more average or less-salient features during the thought process. As a consequence the decision maker might choose an option which has more salient features. However, this choice might not necessary be the 'best' outcome one would expect based on the classical rational choice theory.[1] Remarkably, the theory, albeit simple, provides explanations for the paradoxes mentioned above and it has been applied for choices under risk (Bordalo et al., 2012a), asset pricing (Bordalo et al., 2013b), judicial decisions (Bordalo et al., 2015) or even for multi-attribute consumer choices (Bordalo et al., 2013a).

Yet, the theory carries a rather peculiar feature, which to our knowledge has never been addressed in the literature. It suggests that a salient thinker (sometimes referred to as local thinker) might be better off choosing a dominated alternative even when a strictly dominant option, i.e. an alternative which yields strictly higher payoffs than any other alternative in every state, is available. It is hard to believe that decision makers, no matter how much of a salient thinker they might be, would choose a dominated alternative when an obvious best option is available to them.[2]

In this article we address this issue of salience theory and suggest an alteration of it which tackles this problem. In order to do so we change focus from the decision makers' utility to her regret when measuring the value of a prospect in salience theory. More specifically, we consider regret as the main subject of a decision, and instead of focusing on the decision maker's utility she might gain by choosing an alternative we focus on her disutility she may experience when this option is not yielding the best attainable payoff of the prospect. The idea of using regret to explain human behaviour is not new. It was introduced simultaneously by Loomes and Sugden (1982) and Bell (1982) and has

* Corresponding author.
E-mail addresses: barna.bako@uni-corvinus.hu (B. Bakó), gabor.neszveda@uni-corvinus.hu (G. Neszveda).

[1] One might argue that decisions based on salience are rational given that information needed for a sound decision are limited and costly. This reasoning, however, assumes that decision makers allocate efficiently their attention to different features of a choice ex ante, while in salience theory and so as in this paper we assume that attention is being focused ex post on the salient attributes. For more on models with rationally inattentive decision makers see e.g. Matejka and McKay (2012) or Gabaix (2014).

[2] Another odd feature of the theory was presented by Kontek (2016), who shows that the lottery certainty equivalent is undefined for certain ranges of probabilities.

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been extensively investigated ever since. We use the specification of the model of Quiggin (1994) for regret which has been applied to explain many empirical phenomena with success, for instance, for understanding demand for insurance (Braun and Muermann, 2004), transportation choices (Chorus et al., 2014), or asset pricing (Qin, 2020). Considering the same context-dependent framework as salience theory we show that the theory we propose, the salient regret theory, overcomes the above mentioned problem of the salience theory and it accounts for the same phenomena, namely the Allais paradox, framing effect, preference reversal, asymmetric dominance and compromise effect.

2. Salience theory and the preference for a dominated alternative

In order to understand the oddity of the theory, let us first summarize its formal framework as proposed by Bordalo et al. (2012a).

Consider a choice problem with a choice set of $\{L_1, \ldots, L_N\}$, where L_i are risky prospects (lotteries) defined over a finite state space S with objective and known probabilities, π_s, for each $s \in S$ such that $\sum_{s\in S} \pi_s = 1$. The payoffs of state s are given with the payoff vector $x_s = (x_s^1, \ldots, x_s^N\}$. The decision maker chooses a lottery based on the lotteries' perceived values. These, however, are distorted to some extent from their intrinsic values because the lotteries' salient features are inflated at the expense of their less-salient attributes. The salience of a lottery in a given state is captured by a continuous and bounded function $\sigma(x_s^i, \mathbf{x}_s^{-i})$, where $\mathbf{x}_s^{-i}$ is the payoff vector for all lotteries except for lottery i in state s. More specifically, it is assumed that

$$\sigma(x_s^i, \mathbf{x}_s^{-i}) = \frac{|x_s^i - f(\mathbf{x}_s^{-i})|}{|x_s^i| + |f(\mathbf{x}_s^{-i})|} \quad (1)$$

where $f(\mathbf{x}_s^{-i}) = \frac{1}{N-1}\sum_{j\neq i} x_s^j$. Thus, a lottery's salience in state s depends on the magnitude of the difference between its payoff and the average payoff all other available lotteries yield in the same state.[3] According to the theory the salient thinker ranks the states for each lottery L_i based on the salience function's values such that a higher value implies a lower ranking, and distorts the decision weights of her value function in the following way

$$V^{LT}(L_i) = \sum_{s\in S} \pi_s^i v(x_s^i) \quad (2)$$

where $\pi_s^i = \pi_s \omega_s^i$, while $\omega_s^i = \frac{\delta^{k_s^i}}{\sum_{r\in S}\delta^{k_r^i}\pi_r}$ and k_t^i is the salience ranking of state $t \in S$ for lottery L_i and $\delta \in (0, 1]$. Furthermore, it is assume that $v(\cdot)$ is a strictly increasing and concave value function for which $v(0) = 0$.[4]

Now, let us demonstrate a surprising oddity of this framework with the following example. Consider four lotteries $\{L_1, L_2, L_3, L_4\}$ with the state space of $\{s_1, s_2\}$, both with equal probability as it is presented in the following table. Assume that $\delta = 0.7$ and $v(x_s^i) = x_s^i$. One can think of s_1 as a *bad* state, while s_2 as a *good* state. The penultimate column of the table ($V(L_i)$) shows the intrinsic value of a lottery that a rational decision maker would assign to the lottery, while the last column represents the amount that a local thinker would value the lottery for, after over- or underweighting its salient or less-salient payoffs, according to their salience given by $\sigma_{s_1}^i$ and $\sigma_{s_2}^i$.[5]

	x_1^i	x_2^i	$\sigma_{s_1}^i$	$\sigma_{s_2}^i$	$V(L_i)$	$V^{LT}(L_i)$
L_1	9	45	4/5	4/131	27	23.82
L_2	0	44	1	1/65	22	18.12
L_3	0	43	1	0	21.5	17.71
L_4	3	40	0	1/21	21.5	24.76

Notice that lottery L_1 is a strictly dominant alternative and it yields the highest payoffs in both states. Not surprisingly, a rational decision maker would prefer this lottery over any other alternative as we can see from the penultimate column of the table. Yet, a local thinker behaves differently. After distorting the odds based on the lotteries' salient payoffs as it is suggested by the theory and described in (2) she prefers lottery L_4 over any other option. As we can see from the table the bad state is salient for lotteries L_1, L_2 and L_3, while for lottery L_4 the good state gets the focus. Thus, the local thinker overweights L_1's low payoff and underweights its high payoff, while exactly the opposite happens for L_4. Intuitively, too much weight is being put on L_1's low payoff which makes the decision maker to choose L_4, a choice in which a dominated alternative is being preferred over a dominant one.

This result, though not driven by any particular odd assumption, is counter-intuitive. In order to prevent such an outcome we propose a simple alteration of the theory and we argue that by using a regret function as the value function we can eliminate this counter-intuitive result while retaining the explanatory power of the theory. The reason a dominated option might be chosen by the decision maker is that the salience function treats any difference from the average, being positive or negative, the same. Therefore, it might happen that a prospect's good state is salient because its value negatively differs the most from the state's average value. In other words a prospect's good state, and as a consequence the prospect itself, might be overvalued because the prospect has the worst outcome among the available prospects in the good state. This undesirable outcome can be prevented by using regret as the value function, since the regret attached to a dominant alternative is always zero and non-negative for any alternative choice. Thus, no matter how a salient thinker would under- or overvalue the regrets associated with an alternative's realizations, the dominant option would always be the best choice to make for the decision maker. In the following we will prove this result in a more general way.

3. Salient regret theory

We consider a choice problem similar to the one presented above, however, instead of assuming that the decision maker maximizes her value function given by expression (2) we assume that she is minimizing her regret accompanied with any choice that is not the best available option in the given state.

Following Quiggin (1994) we define regret (r_s^i) as a state dependent variable characterizing a lottery i in a given state s and we assume that it equals the difference between the payoff received by choosing the lottery in question and the highest possible payoff realization available in the given state. More precisely,

[3] In some applications it is assumed that the salience of a lottery in state s depends on the contrast between its payoff and the average payoff of all available lotteries in state s including lottery i (see e.g. Bordalo et al., 2013a or Bordalo et al., 2012b). Furthermore, in Bordalo et al. (2012a) the salience function is defined with an added positive constant to the denominator. Our result does not depend on the particular specification of the salience function.

[4] Notice, that we assume a more general value function than as it is in Bordalo et al. (2012a) and Bordalo et al. (2013a) where a linear value function is being considered.

[5] In this example we assume that a lottery's salience depends on the difference between the lottery's payoff and the average payoff of all the other lotteries in a given state. One can easily verify that the result holds true when the salience is calculated as the difference between the lottery's payoff and the total average in a specific state.

Definition 1 (*Regret Value*). $r_s^i \equiv x_s^H - x_s^i$, where x_s^H is the highest possible payoff in state s considering all available lotteries.

The problem of a rational decision maker who is minimizing the regret she might have by not receiving the highest possible payoff is given as follows

$$\min_i R(L_i) = \sum_{s \in S} \pi_s v(r_s^i) \tag{3}$$

A salient regret thinker, however, inflates the lotteries' most salient regrets and distorts the odds in the same way as it is suggested by the salient theory. Thus, in her case the value function is

$$R^{LT}(L_i) = \sum_{s \in S} \omega_s^i \pi_s v(r_s^i), \tag{4}$$

where ω_s^i is defined in expression (2).[6] Notice, that this regret-based evaluation relies on the exact same parameters as salience theory and there are no extra variables added to the original model.[7] We can state the following

Proposition 1. *Let L_i be a strictly dominant lottery. A salient regret thinker always prefers L_i to any other available lottery. I.e. if $x_s^i > x_s^j$, where $i \neq j$ for any s it follows that $L_i \succ L_j$.*

Proof. In case of L_i we have that $R^{LT}(L_i) = 0$ since L_i has the highest possible payoffs in each state by definition. On the other hand, for any $j \neq i$, $R^{LT}(L_j) > 0$, because at least in one state it is characterized with a positive regret value. Thus, a salient thinker prefers L_i over any other lottery. □

Proposition 1 implies that a salient regret thinker would always choose a strictly dominant lottery when that is available in the choice set.

Furthermore, we can state the following

Proposition 2. *Consider a binary choice set of $\{L_i, L_{-i}\}$. $\sum_{s \in S} \pi_s^i v(x_s^i) > \sum_{s \in S} \pi_s^{-i} v(x_s^{-i})$ iff $\sum_{s \in S} \pi_s^i v(r_s^i) < \sum_{s \in S} \pi_s^{-i} v(r_s^{-i})$.*

Proof. Having only two lotteries in the choice set we have that $k_s^i = k_s^{-i}$ and as a consequence $\omega_s^i = \omega_s^{-i}$, hence we can drop the superscripts in ω_s^i. From $\sum_{s \in S} \pi_s^i v(x_s^i) > \sum_{s \in S} \pi_s^{-i} v(x_s^{-i})$ we have that

$$\sum_{s \in S} \pi_s \omega_s (v(x_s^i) - v(x_s^{-i})) > 0. \tag{5}$$

Given that $v(\cdot)$ is strictly increasing, concave function and $v(0) = 0$ it follows that $v\left(\frac{x_s^i - x_s^{-i}}{2}\right) > \frac{v(x_s^i) - v(x_s^{-i})}{2}$ for all s, thus inequality (5) can be written as

$$\sum_{s \in S} \pi_s \omega_s v(x_s^i - x_s^{-i}) > 0. \tag{6}$$

Furthermore, inequality (6) is equivalent with

$$\sum_{s \in S} \pi_s \omega_s v((x_s^i - x_s^H) - (x_s^{-i} - x_s^H)) > 0$$

or

$$\sum_{s \in S} \pi_s \omega_s v((x_s^H - x_s^i) - (x_s^H - x_s^{-i})) < 0$$

which because of concavity leads to

$$\sum_{s \in S} \pi_s \omega_s (v(x_s^H - x_s^i) - v(x_s^H - x_s^{-i})) < 0$$

or

$$\sum_{s \in S} \pi_s \omega_s v(r_s^i) < \sum_{s \in S} \pi_s \omega_s v(r_s^{-i}). \quad \square$$

Proposition 2 implies that with any binary choice set salient regret theory yields the same result as salience theory and therefore it provides explanation for the Allais paradox, preference reversal and framing effect.

So far we have considered only binary choices, yet salience theory can account for phenomena observed with non-binary choices, such as the decoy and compromise effects (Bordalo et al., 2013a).

Consider a choice problem of two-attribute (e.g. quality and price) goods. According to salience theory an attribute of a good is considered salient if the good stands out in that attribute from the other goods available in the choice set. More specifically, a good's salient attributes are those which are the furthest from the reference good which is defined with the average values of the attributes. Let the choice set be $C = \{(q_s, p_s)\}_{s=1,\dots,N}$, where q_s stands for the quality, and p_s for the price of good $s = \{1, \dots, N\}$. Analogously to Bordalo et al. (2013a), we assume that the decision maker intrinsic utility is linear in attributes, both measured in dollars. Furthermore, we assume that she minimizes her regret function which is given by $r_s = (q^H - q_s) - (p^L - p_s)$, where $q^H \equiv \max\{q_1, \dots, q_N\}$ and $p^L \equiv \min\{p_1, \dots, p_N\}$, i.e., q^H is the highest quality and p^L is the lowest price available.

A salient thinker distorts the relative weight attached to the attributes in such a way that a salient attribute gets a higher weight, and the attribute which is close to the average level of the same attribute gets a lower weight. More specifically, the local thinker's (dis)utility of good s is

$$r_s^{LT} = \begin{cases} (q^H - q_s) - \delta(p^L - p_s) & \text{if } \sigma(q_s, \bar{q}) > \sigma(p_s, \bar{p}) \\ \delta(q^H - q_s) - (p^L - p_s) & \text{if } \sigma(q_s, \bar{q}) < \sigma(p_s, \bar{p}) \\ (q^H - q_s) - (p^L - p_s) & \text{if } \sigma(q_s, \bar{q}) = \sigma(p_s, \bar{p}) \end{cases} \tag{7}$$

where $\delta \in (0, 1]$

To show how salient regret theory can account for asymmetric dominance (decoy effect) let us consider a choice problem similar as in Bordalo et al. (2013a). Formally,

Proposition 3. *Assume a choice set of two available options, i.e. $C = \{(q_l, p_l), (q_h, p_h)\}$ and assume that $(q_h - q_l)(p_h - p_l) > 0$, that is, the high quality product neither dominates nor is dominated by the other available option. Furthermore, assume that $r_h^{LT} < r_l^{LT}$ only if $\sigma(q_h, \bar{q}) > \sigma(p_h, \bar{p})$, and the low quality good is being chosen by the decision maker otherwise. Let $C_d = C \cup (q_d, p_d)$ where (q_d, p_d) is a decoy good with $q_d < q_h$ and $p_d > p_l$. Moreover, let us assume that $q_l/p_l > q_h/p_h$. For any (q_d, p_d) satisfying*

$$q_d < p_d \frac{q_h}{p_h} - p_l \left(\frac{q_l}{p_l} - \frac{q_h}{p_h} \right) \tag{8}$$

(q_h, p_h) is quality salient.

Proof. First notice that $\sigma(\cdot, \cdot)$ defined in (1) is homogenous of degree zero. Thus, $\sigma(a_h, \bar{a}) = \sigma(a_h/\bar{a}, 1)$, where $a_h/\bar{a} > 1$. Therefore, we have that $\sigma(q_h, \bar{q}) > \sigma(p_h, \bar{p})$ if and only if $q_h/\bar{q} > p_h/\bar{p}$.

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[6] We use the same salience function as in Bordalo et al. (2012a) in order to reduce the number of changes compared to the original salience theory.

[7] Bordalo et al. (2020) propose a new model in which they define the value of an attribute as the difference between its observed value and a norm. Although this approach exhibits some similarities to our approach, there are several important differences as well. First, they introduce new norm parameters for each attribute independent from the choice set, while in this article we do not need any new parameter compared to the previous salience models. Second, Bordalo et al. (2020) introduce a new salience function which is not relative anymore, and as a consequence, all attributes can be salient at the same time, while we keep the original salience function which overweights certain attributes at the expense of the others.

Given that $q_l/p_l > q_h/p_h$ we have that the price attribute is salient in C, thus (q_l, p_l) is being chosen from C by the local thinker. If adding (q_d, p_d) (the decoy good) to the choice set makes quality salient, then (q_h, p_h) becomes preferred over (q_l, p_l) by the local thinker in C_d. Consider a decoy good for which

$$\frac{q_h}{p_h} > \frac{\bar{q}}{\bar{p}}$$

or

$$q_h p_l + q_h p_d > p_h q_l + p_h q_d.$$

From this we have that if the decoy good is designed in that way that satisfies

$$q_d < p_d \frac{q_h}{p_h} - p_l \left(\frac{q_l}{p_l} - \frac{q_h}{p_h} \right) \tag{9}$$

then the (q_h, p_h) is quality salient which guaranties that it is preferred to (q_l, p_l).

To show that the decoy (an asymmetrically dominated) good is never chosen over (q_h, p_h) consider the following. For any (q_d, p_d) satisfying (8) we have that $\frac{q_d}{p_d} < \frac{q_h}{p_h} < \frac{q_l}{p_l}$. If $p_d \geq p_h$, then (q_d, p_d) is dominated by (q_h, p_h). On the other hand, if $p_d < p_h$, quality is salient thus (q_h, p_h) is preferred to (q_d, p_d) if

$$(q^H - q_h) - \delta(p^L - p_h) < (q^H - q_d) - \delta(p^L - p_d)$$

or

$$q_h - q_d > \delta(p_h - p_d)$$

which is always satisfied whenever (9) holds. □

Proposition 3 suggests that if the decoy good's attributes (quality and price) are such that the average (reference) good's quality/price ratio is smaller than the quality/price ratio of the high quality good, then the quality of the high quality good is salient and thus the local regret thinker will overvalue it. Therefore, if the decoy (asymmetrically dominated) good is not exceptionally cheap and therefore attractive for the decision maker, she will choose the high quality good.

In the same vein it can be shown that decision makers may shift their choice from (q_l, p_l) to (q_h, p_h) after a (q_d, p_d) option is added to the choice set, for which $q_d > q_h$ and $p_d > p_h$ holds. This effect is known as the compromise effect in the literature (Simonson, 1989).

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