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A methodological approach to ratio bias

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Abstract

The ratio-bias (RB) phenomenon is considered to provide systematic evidence of irrationality. When judging the probability of a low-probability event, many people judge it as less likely when it is expressed as a ratio of small numbers (e.g., 1-in-10) than when it is expressed as a ratio of large numbers (e.g., 10-in-100). Four experiments show that the phenomenon is increased by the experimental paradigm, which misleads subjects regarding the aim of the task by inducing equal-ratio neglect. One factor is constant across the texts of the Experiment 1–3: a particular sentence that induces subjects to neglect the equal ratio and invites them to express feelings about the outcome of the target event rather than giving a rational answer. This intent is strengthened by the formulation of the question (Experiment 1), which explicitly asks the subject to express the *feeling* connected to the lotteries and the absence of a third option (Experiment 1, 4), the right one, which expresses the "indifference" between the two options. In Experiment 4, the task lacks only the third option, and, simply by adding the option that allows subjects to express the correct answer, the RB disappears.

Keywords: ratio bias, probability judgment.

1 Introduction

The ratio-bias (RB) phenomenon occurs when people judge an unlikely event as less likely or more surprising when its probability is presented in the form of an equivalent ratio of smaller (e.g., 1-in-20) versus larger (e.g., 10-in-200) numbers (Denes-Raj et al., 1995). The phenomenon, which is as robust as it is surprising, is of special interest because it seems to demonstrate that many people, "despite intellectually knowing better, prefer to behave in certain situations according to their intuitive impressions" (Pacini & Epstein, 1999b, p. 303). The phenomenon seems to provide compelling evidence for the existence of two independent processing modes that sometimes conflict with each other and often interact in a manner that produces compromises (Denes-Raj & Epstein, 1994; Denes-Raj et al., 1995; Kirkpatrick & Epstein, 1992; Pacini et al., 1998).

A typical experimental paradigm is a game of chance (Pacini & Epstein, 1999a,b) in which subjects indicate from which of two trays of red and white jellybeans, one "large" (e.g., 10 red out of 100 jellybeans) and one "small" (e.g., 1 red out of 10 jellybeans), they prefer to draw with the hope of obtaining a winning red jellybean. When the two trays offer equal probabilities of drawing a red jellybean, the rational decision is to report no tray preference. However, most subjects select the tray with the larger number of red jellybeans, and many, despite acknowledging they know better, are willing to pay small sums of money for the privilege of doing so (Kirkpatrick & Epstein, 1992) rather than having the selection made randomly. Subjects were instructed to indicate how they believed most people would behave (others-perspective) and how they believed they themselves would behave (self-perspective). According to these authors, judging others' behavior is more revealing because it circumvents subjects' desire to present themselves as rational people.

The ratio bias has been investigated in the health domain by Yamagishi (1997) and Pinto-Prades et al. (2006). Yamagishi (1997) gave subjects mortality rates for well-known causes of death, varying both the percentage incidence rate and the population frame (deaths per 100 or 10,000 people) within subjects. Ratings of risk were consistently higher with a frame of 10,000 than a frame of 100, regardless of the actual percentage incidence rate. Similarly, Pinto-Prades et al. (2006) investigated and replicated the ratio bias in the context of choices between medical treatments with a given probability of death.

Many studies on the RB (Denes-Raj & Epstein, 1994; Peters et al., 2006) have presented subjects with a choice between a 1-in-10 chance of success and a 9-in-100 chance of success as well as a choice between 1-in-10 and 7-in-100. They found that many individuals (61% and 40%, respectively) preferred the latter choice (the large urn) even though the former (the small urn) offered a greater probability of success.

The existence of the bias has also been confirmed in studies testing the effect of incentives (Kirkpatrick & Epstein, 1992; Dale et al., 2007). A recent study of risky

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judgments (Bonner & Newell, 2008) also provides support for the RB effect over a conflicting theory, the construal level theory (CLT). Given the statements "100 people die from cancer every day" and the equivalent "36,500 people die from cancer every year", construal level theory predicts that the former will result in higher risk judgments, whereas the ratio-bias effect predicts higher risk judgments for the latter statement. This study showed that the ratio bias effect seems to dominate construal level theory when the two are compared, although one-third of Bonner and Newell's subjects show the opposite effect. The latter result indicates that there are effects in both directions.

1.1 Explanations of the ratio bias phenomenon

The RB effect was originally studied by Piaget and Inhelder (1975) with an experimental paradigm called the *two-urn-choice task*. These authors discovered that children are incapable of proportional reasoning until 11 years of age and presumed that an integration of proportionality and chance schemes was necessary for a complete understanding of probability.

Moreover, the RB phenomenon was extensively investigated in the developmental literature, where it was considered a tendency to focus on magnitudes quantity rather than on the correct proportion of the data presented. Contrary to the view that adolescents do not show the effect, many studies show that adults exhibit the RB.[1]

Miller, Turnbull, and McFarland (1989) conducted a series of five studies to examine Kahneman and Miller's hypothesis that events became more "normal" and generate weaker reactions the more strongly they evoke representations of similar events. In these studies, they found that two events with the same low probability, but expressed with different absolute numbers (e.g., 1-in-20 and 10-in-200) elicited different levels of suspiciousness. In one of their vignettes (version A), a child who loves chocolate chip cookies selects a cookie (supposedly without peeking) from a jar containing 1 chocolate-chip cookie and 19 oatmeal cookies. In another version (B), the child selects a cookie from a jar containing 10 chocolate-chip cookies and 190 oatmeal cookies. In both versions, the child draws a chocolate-chip cookie. Subjects are asked how suspicious they would be that the child peeked into the jar before selecting the cookie. Although the objective probability of drawing a chocolate-chip cookie is the same in both scenarios, Miller et al. (1989) found that the subjects who read version A (1 chocolate-chip cookie among 19 oatmeal cookies) reported more suspicion than those who read version B. Miller and his associates explained their findings with the Norm Theory (NT): reactions to events depend not only on the events themselves but also on what the events bring to mind (Kahneman & Miller, 1986). They argued that the RB effect occurs because of the post-outcome processing of counterfactual alternatives, i.e., imagined other outcomes after an unusual outcome (Kahneman & Miller, 1986). If norms are computed only after the event, as they presume, then the RB effect can occur only in post-outcome judgements.

In contrast to the explanation of Miller et al. (1989), according to which the ratio bias phenomenon can be attributed to post-outcome processing (of counterfactual alternative scenarios), the cognitive-experiential self theory (CEST) of Kirkpatrick and Epstein (1992) predicts that the phenomenon can also be exhibited for pre-outcome processing.

According to the CEST, our behaviour is guided by the joint operation of two systems (*dual system theory*,[2]) with their relative influences being determined by the nature of the situation and the degree of emotional involvement (Denes-Raj & Epstein, 1994). This theory posits a distinction between two partially independent information-processing systems: the experiential and the rational systems. The experiential system operates in a manner that is preconscious, automatic, imagistic, associative, rapid, effortless, concrete, holistic, intimately associated with affect, highly compelling and minimally demanding of cognitive resources. Its schemas are primarily generalisations from emotionally significant intense or repetitive experience (Epstein, 2008). The experiential system, which has a much longer evolutionary history, represents events in the form of concrete exemplars rather than in abstract symbols; it is shaped by emotionally significant past experience, is outcome rather than process oriented and operates automatically outside, or on the fringes of conscious awareness (Epstein, 1990). In contrast to the automatic learning of the experiential system, the rational system is a reasoning system that operates in a manner that is conscious, abstract, analytical, affect-free, effortful and highly demanding of cognitive resources. It acquires its beliefs consciously from books, lectures and other explicit sources of information and from logical inference; it has a very brief evolutionary history. Like the experiential system, it learns from experience, but it does so not through automatically establishing associations but by logical inference. The two systems are assumed to operate in parallel and to be bidirectionally interactive. All behaviour is influenced by both systems (Epstein, 2008).

The basic assumption of fuzzy-trace theory (FTT; Reyna & Brainerd, 1995, 2008, 2011; Brainerd & Reyna, 2002, 2004; Reyna, 2008) is that people in general rely on

[1] See also the analogies between childhood egocentrism and the hindsight bias, as described by Royzman, Cassidy, and Baron (2003).

[2] For review, see Evans and Frankish (2009), Evans (2010), Evans and Over (1996), Sloman (1996).

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their memories for the vague gist of information in reasoning and decision making, even when they can remember the verbatim (e.g., quantitative) details of such information. In addition to encoding two kinds of memories, people retrieve what they know about ratios when that knowledge is cued, but applying that knowledge about ratios is interfered with when classes of objects or events being reasoned about overlap or are nested in one another. FTT presumes that the bias is connected with a phenomenon called *denominator neglect,* related to the class-inclusions problem.

In probability judgment, for example, the classes referred to in the numerator of a probability ratio (e.g., the number of patients who survived surgery) are also included in the denominator (e.g., the total number of patients who had the surgery, those who survived plus those who did not survive). The confusion created by overlapping classes, or processing interference, prompted theorists to label the cognitive illusions and judgment biases created by such confusion as "class-inclusion illusions". As a result of confusion created by overlapping or nested classes, people focus on salient gist, often comparisons between numerators, at the expense of focusing on denominators (Reyna & Brainerd, 2008). When a salient gist is available, it induces the failure to retrieve relevant knowledge and people are induced to focus on this salient gist[3] underweighting the denominators.

The main difference between CEST and FTT is related to high probability cases; consider the following vignette to make a comparison between the main theories about RB:[4]

"Case 1: People have to make a choice between Urn A (1 winning ticket among 10 tickets) and Urn B (10 winning ticket among 100 tickets)."

"Case 2: People have to make a choice between Urn A (9 winning ticket among 10 tickets) and Urn B (90 winning ticket among 100 tickets)."

According to the CEST, the RB is determined by the joint operation of two effects of the experiential system: the numerosity effect (the experiential system encodes and better comprehend numerosity than ratios because single numbers are more concrete than relations between number) and the small-numbers effect (the experiential system comprehend smaller numbers better than larger numbers, because the former are more concrete). People prefer the Urn B in the case 1, because, with low probability, the numerosity effect and the small numbers effect operates simultaneously, leading to RB responses. Instead, in the case 2 the RB doesn't occur because, in high probability, the numerosity effect and the small-numbers effect work in opposition to each other. The numerosity effect favours the large urn and the small-numbers effect favours the small one.

According to the FTT people prefer the Urn B in both cases, because of the denominator neglect; this happens because numerators and denominators are two overlapping classes and people focus on the salient, gist information (the numerators) and neglect the seemingly irrelevant information provided by the denominators.

2 A methodological hypothesis based on the analysis of the text

Numerous studies (Bagassi & Macchi, 2006; Hilton, 1995, 2000; Macchi & Bagassi, 2012; Politzer & Macchi, 2000; Sperber et al. 1995; Sperber & Mercier, 2011) have shown the importance of the formulation of the text in problems regarding the study of thinking and reasoning. We have therefore made an analysis of the texts[5] of certain problems, with a subsequent reformulation to show that the RB effect is less general than has been supposed.

In the present study, we analysed the texts of the main studies on this phenomenon[6] and have identified some elements that could influence the phenomenon, in particular those which activate the Experiential System and inhibit the Rational System.

We speculate that one of the key factors responsible for the inhibition of the Rational System is a particular sentence which is constant across all of these problems; this sentence induces subjects to neglect the equal ratio and invites them to express feelings about the outcome of the target event rather than giving a rational answer. This intent is strengthened by the way the question is formulated (as the subject is explicitly asked to express the *feeling* generated by lotteries) and by the absence of a third option, the correct one, which expresses "indifference" between the two options. Under these conditions the Rational System will be totally inhibited, leaving the field open to the Experiential System; the subjects in fact will only give "experiential" answers.

We examined the relationship between these elements and the RB effect through four studies. The modifications made to the relationship in these studies did not affect the crucial structure of the experimental paradigm because they did not alter either the statistical structure of the problem or the nature of the task, which is still a choice task. However, it is not in the scope of the present paper to compare the main RB theories (CEST and FTT) which do not differ at low probabilities.

[3]Gist representation are less precise than verbatim ones and are the "fuzzy trace".

[4]According to NT, people don't have a preference between Urn A and Urn B, because the RB occurs only in post-outcome judgments.

[5]In accordance with Grice' s cooperative principle and the principle of relevance of Sperber and Wilson (1986).

[6]Our analysis does not refer to Kahneman and Miller (1986).

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Our prediction was that when the texts of the problems do not explicitly encourage the activation or the inhibition of the two systems, answers tend to be more autonomous and reliable. If the RB is induced by the phrases indicated, which would favour the inhibition of a rational way to consider the options, their elimination should result in a decrease of the RB effect.

As opposed to other theories, our approach focuses on a methodology designed not to inhibit the Rational System a priori.

3 Experiment 1 (*Lottery*, *Machine* and *Transfusion* problems)

In the present study, we examined the RB effect in three tasks (*Lottery*, *Machine* and *Transfusion*) in which the structure of the problem was identical but the scenarios were described with a varying degree of detail and different emotional involvement. All the scenarios were derived from Denes-Raj, Epstein & Cole (1995). According to the authors, the first scenario ("Lottery") is described with vivid and personalised details, the second scenario ("Machine") is described in a mechanical and impersonal way and the third scenario ("Transfusion") is characterised by an intensely emotion-arousing context.

The critical aspects that emerged from the analysis of the texts are:

(1) The following phrases: "*Although you know that the proportions are identical, you may have the feeling that it is less likely that Ralph will get a winning number in one lottery than in the other*" (Lottery Task); "*Although the proportions are identical, you may feel that the chance of a red ball being selected is less in one scenario than in the other*" (Machine Task); and "*You know that the proportions are identical, but somehow you feel that the chance of transmission is greater in one sample than in the other*" (Transfusion Task). These statements are misleading regarding the aim of the task, encourage the activation of the Experiential System and inhibit the Rational System.

(2) The following questions[7]: "*How would you advise Ralph about which lottery, if either, you feel is more likely to produce a winning ticket*?" (Lottery Task); "*In which scenario would you feel there is less chance of the red ball being selected*?" (Machine Task), "*In which sample do you think there is a greater likelihood of HIV contamination?*" (Transfusion Task). These questions encourage the production of subjective answers and generate doubts about the equal probability of the target event.

(3) The set of possible answers (the first lottery vs. the second lottery) does not include the correct rational answer ("no preference") and does not allow subjects to judge both lotteries as having the same proportion of winning tickets.

For the Lottery Task, we studied the RB effect in the original version (i.e., the structure of the text is the same as in the original text used by Denes-Raj, Epstein & Cole, 1995) and in four different versions in which the text was modified by the methodological analysis discussed to study these three critical aspects both individually and jointly:

- A third response was introduced in the "No preference added" condition (1. The first lottery, 2. The second lottery, 3. **No preference**).
- The question in the "Question replaced" condition was modified as follows: "In which lottery would you (do you think that most people would) advise Ralph to take part?" and "In which lottery do you think (do you think that most people thought) that Ralph decided to take part?"
- The text in the "Phrase removed" condition was modified by removing the phrase "*Although you know that the proportions are identical, you may have the feeling that it is less likely that Ralph will get a winning number in one lottery than in the other.*"
- The text in the "All manipulations" condition was modified by replacing the questions, maintaining the three response options and removing the misleading phrase, to manipulate all the factors.
- As the structure of the three scenarios was identical, we decided to study the RB for the Machine and the Transfusion Tasks only in the control task and in the condition in which all three critical aspects were modified in the text (as in the fourth condition of the Lottery Task).
- The aim of this experimental paradigm was (a) to test the hypothesis that the existence of the RB phenomenon was due to how the proposed task was formulated and (b) to ascertain whether the RB phenomenon resulted from one of the three critical aspects or by the interaction of these elements.

We made the following predictions:

[7]The questions in the others-perspective version of the pre-outcome condition are the following: "How do you think that most people would advise Ralph about which lottery, if either, they thought was more likely to produce a winning ticket?" (Lottery Task); "In which scenario do you think that most people feel there is less of a chance of the red ball being selected?" (Machine Task), "In which situation do you think that most people think there is a greater likelihood of HIV contamination" (Transfusion Task).

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1. A stronger RB effect for the others-perspective than for the self-perspective in the control tasks, in line with the results of the study by Denes-Raj et al. (1995).

2. The Lottery Task: a significant decrease of the RB effect in the "Phrase removed" and "All manipulations" conditions was expected in both the others- and the self-perspective. The RB was not expected to decrease in the "No preference added" and "Question replaced" conditions. In our view, the key role in the activation/inhibition of Experiential System is played by the misleading sentence while the question and the set of possible answers only strengthen its effect.

3. The "Phrase removed" condition: the questions which, by asking people to express a feeling or a suspicion, had the potential to activate the Experiential System, were maintained but the misleading phrase which allows the "not necessary" inhibition of the Rational System was eliminated. This condition admits the possibility of the activation of both systems. It cannot be excluded that this condition is not sufficient to eliminate the bias in the others' perspective, since the subjects are asked to distinguish the self from the others perspective, thus providing the opportunity for expressing irrational tendencies, and attributing them to others.

4. The Machine and the Transfusion Tasks: a decrease of the RB phenomenon in the experimental condition (which is has the same structure as the "All manipulations" condition of the Lottery Task) was predicted.

3.1 Method

3.1.1 Subjects

A total of 665 university students of both sexes agreed to participate in this study. All were undergraduates aged between 19 and 30 years. In particular, 345 students participated in the Lottery Task, 160 in the Machine Task and 160 in the Transfusion Task.

3.1.2 Procedure

Subjects were assigned randomly to one of the three tasks and to one of the experimental conditions within each task (included the control task). In each condition, subjects were given one of two booklets, each presenting a pre- or a post-outcome version of the same scenario. We asked subjects to estimate their own responses (self-perspective) and how most people would respond (others-perspective). They were asked to give written answers. There was no time limit.

3.1.3 Lottery Task

The text of the Lottery pre-outcome control task was as follows (see the post-outcome version in Appendix 1 and the Machine and Transfusion Task in Appendix 2 and 3 respectively):

> Imagine two scenarios involving lotteries. In both cases, a winning number pays ten thousand dollars. Now imagine that Ralph Jones, a friend of yours, thinks of all the things he could buy with the money, like a new car, and all he can do with the money, such as take his dream vacation. These thoughts and images make Ralph desperately want to win the lottery. In one of the lotteries, a single winning number is selected from 1,000 numbers. In the other, 10 winning numbers are selected from 10,000 numbers. *Although you know the proportions are identical, you may have the feeling that it is less likely that Ralph will get a winning number in one lottery than in the other.*
>
> Ralph asks your advice about which lottery to buy. *How would you advise Ralph about which lottery, if either, you thought was more likely to produce a winning ticket? (If you cannot make a choice, skip this item, and check "not at all" in the next item).*
>
> - *The first lottery (1 winning number in 1,000)*
> - *The second lottery (10 winning numbers in 10,000)*
>
> To what extent do you believe that this is true?
> (Not at all) 0----1----2----3----4 (a great deal)
>
> *How do you think that most people would advise Ralph about which lottery, if either, they thought that was more likely to produce a winning ticket? (If you cannot make a choice, skip this item, and check "not at all" in the next item).*
>
> - *The first lottery (1 winning number in 1,000)*
> - *The second lottery (10 winning numbers in 10,000)*
>
> To what extent would most people believe that this is true?
> (Not at all) 0----1----2----3----4 (a great deal)

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Table 1: Results of Experiment 1—"*Lottery*" Scenario, all subject included (N=345).

	PREOUTCOME			POSTOUTCOME		
	EXB	UEB	OBJ	EXB	UEB	OBJ
Denes-Raj et al. (1995)						
"Self" perspective	18 (38%)	9 (19%)	20 (43%)	17 (34%)	11 (22%)	22 (44%)
"Others" perspective	22 (47%)	14(30%)	11 (23%)	29 (60%)	11 (23%)	8 (17%)
Control task (N=59)						
"Self" perspective	10 (32%)	7 (23%)	14 (45%)	11 (39%)	6 (22%)	11 (39%)
"Others" perspective	18 (58%)	10(32%)	3 (10%)	12 (43%)	10 (36%)	6 (21%)
"No preference added" condition (N= 51)						
"Self" perspective	10 (42%)	5 (21%)	9 (37%)	5 (18%)	5 (18%)	17 (74%)
"Others" perspective	17 (71%)	5 (21%)	2 (8%)	18 (75%)	5 (18%)	4 (7%)
"Question replaced" condition (N= 76)						
"Self" perspective	8 (22%)	10 (28%)	18 (50%)	5 (12.5%)	5 (12.5%)	30 (75%)
"Others" perspective	16 (44%)	10 (28%)	10 (28%)	25(62.5%)	7 (17.5%)	8 (20%)
"Phrase removed" condition (N= 95)						
"Self" perspective	5 (11%)	1 (2%)	40 (87%)	4 (8%)	2(4%)	43 (88%)
"Others" perspective	18 (40%)	16 (35%)	12 (25%)	21 (43%)	16 (33%)	12 (24%)
"All manipulations" condition(N= 64)						
"Self" perspective	1 (4%)	2 (6%)	28 (90%)	2 (6%)	1 (3%)	30 (91%)
"Others" perspective	4 (16%)	1 (4%)	26 (84%)	4 (12%)	1 (3%)	28 (85%)

EXB: number of subjects that answer in the Ratio Bias direction, **UEB**: number of subjects that answer in the Ratio Bias unexpected direction, **OBJ**: number of subjects that answer objectively.

3.1.4 Machine and Transfusion tasks

In the experimental condition ("All manipulations") of both tasks, the texts were modified, manipulating all three factors by replacing the questions, offering three response options and removing the misleading sentence responsible of the Rational System's inhibition, as in the "All manipulations" condition of the lottery task.

3.2 Results and discussion

As we can see in Table 1, the results of the control task substantially replicated those obtained by Denes-Raj et al. (1995). In "No preference added" condition, the introduction of a third answer did not appear to produce any significant differences like in "Question replaced" condition. In "Removed phrase" condition, the findings show an increase in the rate of objective answers compared to the control task in the self-perspective form of the pre-outcome version (from 45% to 87%; Chi-squared = 16.38, Bonferroni's p<.00125) and the post-outcome version (from 39% to 88%; Chi-squared = 20.06, Bonferroni's p<.00125). The phrase that was eliminated in the "Removed phrase" condition appears to be responsible for much of the bias. In the pre-outcome version of the others-perspective condition, the results show a decrease of the bias compared to the Control Task (from 58% to 40%) but not a a consequent increase of rational responses (Obj), infact we obtain a random distribution of ratings between Exb and Ueb (respectively 40% and 35%). The same patterns of response is obtained in the post-outcome form: there is not an increase of objective answers but there is a tendency toward the irrationality, which is comparable with a random choice rather than a tendency toward the bias.

In "All manipulations" condition, finally, the RB effect disappears. In fact, we can observe a strong increase in the rate of objective answers in both the self-perspective pre-outcome version (from 45% to 90%; Chi-squared =

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Table 2: Results of Experiment 1—"*Machine*" Scenario, all subject included (N=160).

	PREOUTCOME			**POSTOUTCOME**		
	EXB	UEB	OBJ	EXB	UEB	OBJ
Denes-Raj et al. (1995)						
"Self" perspective	13 (27%)	10 (21%)	25 (52%)	18(38%)	5 (38%)	25 (52%)
"Others" perspective	30 (64%)	10 (21%)	7 (15%)	25 (52%)	12 (52%)	11 (23%)
Control Task (N=80)						
"Self" perspective	14 (35%)	10 (25%)	16 (40%)	24 (60%)	6 (15%)	10 (25%)
"Others" perspective	16 (40%)	16 (40%)	8 (20%)	22 (55%)	14 (35%)	4 (10%)
"All manipulations" condition (N= 80)						
"Self" perspective	6 (15%)	6 (15%)	28 (70%)	5 (12.5%)	5 (12.5%)	30 (75%)
"Others" perspective	6 (15%)	5 (12.5%)	29 (72.5%)	7 (17.5%)	5 (12.5%)	28 (70%)

EXB: number of subjects that answer in the Ratio Bias direction, **UEB**: number of subjects that answer in the Ratio Bias unexpected direction, **OBJ**: number of subjects that answer objectively.

14.8, Bonferroni's p<.00125) and the post-outcome version (from 39% to 91%; Chi-squared = 18.09 Bonferroni's p<.00125) and for the others-perspective both in the pre-outcome version (from 10% to 84%; Chi-squared = 28.4, Bonferroni's p<.00125) and in the post-outcome version (from 21% to 85%; Chi-squared = 25.8, Bonferroni's p<.00125). The results of this experiment show that under these conditions the RB disappears and people produce objective answers. It is possible to hypothesize that, this time, rational responses are the result of inhibition of the Experiential System; however, even in the others perspective the bias does not occur, although in the literature (Alonso and Fernandez-Berrocal, 2003; Denes-Raj et al., 1995) it is used as a way to let express subjective irrational tendency, by attributing it to the others.

As we can see in Table 2, the results of the Machine Control Task replicated those obtained by Denes-Raj et al. (1995) only in part; in fact, they found a strong RB effect in the others-perspective condition, whereas we also observe a strong RB effect in the self- and others-perspectives of the post-outcome version. However, the results of the Transfusion Control Task (Table 3) confirmed those obtained by Denes-Raj et al. (1995).

In the Machine "All manipulations" condition, the findings show a significant increase in the rate of objective answers compared to the control task in the self-perspective (from 40% to 70%; Chi-squared = 8.2, p<.05) and the others-perspective (from 20% to 72.5%; Chi-squared = 22.2, p<.001) versions of the pre-outcome condition and in the self-perspective (from 25% to 75%; Chi-squared = 22.5, p<.001) and others- perspective versions of the post-outcome condition (from 10% to 70%; Chi-squared = 28, p<.001). In the Transfusion "All manipulations" condition the findings show a significant increase in the rate of objective answers with respect to the control task in the self-perspective (from 45% to 72.5%; Chi-squared = 6.8, p<.05) and others-perspective (from 20% to 75%; Chi-squared = 22.13 , p<.001) versions of the pre-outcome condition and in the self-perspective (from 45% to 92.5%; Chi-squared = 21.2, p<.001) and others-perspective (from 45% to 82.5%; Chi-squared = 12.2, p<.01) versions of the post-outcome condition.

As in the Lottery Task, people produced correct answers in the experimental versions of the Machine and Transfusion tasks and the RB phenomenon disappeared.

4 Experiment 2 (Jellybean)

In this study, we investigated the occurrence of the RB following textual versus pictorial presentation of large and small number ratios. According to Rudski and Volksdorf (2002), the use of textual vignettes may actually encourage the use of the rational system, and this potential influence can be circumvented through nonverbal presentation of the large and small number ratios. They state that differences in the prevalence of a RB would indicate that the presentation of the problem, and not just its informative content *per se*, alters the balance of automatic versus analytic cognition. According to Rudski and Volksdorf's results, when ratios were presented as textual

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Table 3: Results of Experiment 1—"*Transfusion*" Scenario, all subject included (N=160)

	PREOUTCOME			**POSTOUTCOME**		
	EXB	UEB	OBJ	EXB	UEB	OBJ
Denes-Raj et al. (1995)						
"Self" perspective	12 (25%)	8 (16%)	28 (58%)	9 (18%)	8 (16%)	33 (66%)
"Others" perspective	26 (54%)	11 (23%)	11 (23%)	24 (48%)	8 (16%)	18 (36%)
Control Task (N=80)						
"Self" perspective	15 (37.5%)	7 (17.5%)	18 (45%)	12 (30%)	10 (25%)	18 (45%)
"Others" perspective	28 (70%)	4 (10%)	8 (20%)	14 (35%)	8 (20%)	18 (45%)
"All manipulations" condition (N= 80)						
"Self" perspective	2 (5%)	9 (25%)	29 (72.5%)	1 (2.5%)	2 (5%)	37 (92.5%)
"Others" perspective	6 (15%)	4 (10%)	30 (75%)	4 (20%)	2 (7.5%)	33 (82.5%)

EXB: number of subjects that answer in the Ratio Bias direction, **UEB**: number of subjects that answer in the Ratio Bias unexpected direction, **OBJ**: number of subjects that answer objectively.

vignettes the RB was rarely observed. On the contrary, when ratios were presented as pictorial vignettes, the RB was significant. Thus, despite being informatively identical, pictorial presentation of the problem in their study resulted in more experiential choices than did textual presentation.

As in the previous studies, we performed an analysis of the Jellybean text (textual and pictorial), and we deemed one critical aspect. This critical aspect, common to both the formats, like in the previous study, is the phrase:

> Now, what makes your choice interesting is that for each time you choose, both trays will offer identical odds of selecting a black jellybean. Still, many (but not all) people have a preference for picking one of the trays.

From our methodological perspective, subjects could attribute a functional meaning to this statement, independently from its pictorial or textual presentation: the first phrase, stating that some people in the past have preferred one of the two trays, conveys that it is possible to have a preference rather than to have no preference, and the second phrase, stating that both trays offer identical odds, legitimates making a choice even if it is irrational.

We studied the RB effect in the original version (Rudski & Volksdorf, 2002) and in the pictorial and textual experimental conditions ("Phrase removed" condition) in which we eliminated the critical sentence.

According to the Rudski and Volksdorf' hypothesis that the RB effect was due to the pictorial presentation, we would expect the same findings in both the control and experimental conditions; on the contrary, our hypothesis predicts an increasing rate of rational answers in the experimental condition, independently from its pictorial or textual presentation.

4.1 Method

4.1.1 Subjects

A total of 163 university students of both sexes agreed to participate in this study. All were undergraduates aged between 19 and 25 years.

4.1.2 Procedure

Subjects were assigned randomly to the control task (N=83) or "Phrase removed" condition (N=80). In each condition, subjects were given the pictorial or the textual version of the same scenario. We asked them to estimate their own responses (self-perspective) and to give written answers.

The text of the control task:

> Suppose you are faced with two trays of jellybeans, one of which contained 10 beans and one with 100.In each condition, you must draw one jellybean without peeking, of course, from either tray. Should you pick a black jelly bean, you will win 5$, Should you pick a white jellybean, you will win nothing.

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> Now, what makes your choice interesting is that for each time you choose, both trays will offer identical odds of selecting a black jellybean. Still, many (but not all) people have a preference for picking one of the trays. Your job is to indicate whether you would prefer to pick from the large tray (100 beans), the small tray (10 beans) or if you have no preference.
>
> From which tray would you select your jellybean?

The pictorial problem consisted of two grids (1x10 and 10x10) placed next to each other. Black jellybeans were depicted as a dark circle within a square on the grid and white jellybeans by an unfilled circle (see Appendix 4).

Textual version

> Suppose you are faced with two trays of jellybeans, one of which contained 1 black and 9 white jellybeans, the other has 10 black and 90 white jellybeans.
>
> - *The first tray (1 black and 9 white jellybeans)*
> - *The second tray (10 black and 90 white jellybeans)*
> - *No preference*

4.2 Results and discussion

As can we see in Table 4, in the Control Task there is a strong RB effect in both the textual and the pictorial conditions. This result contradicts Rudski and Volksdorf's (2002) conclusion that the RB effect is apparent only in the pictorial version because this type of presentation is responsible for the activation of the experiential system. A possible explanation for this difference is that the two experiments have different designs: Rudski and Volksdorf's task asked each subjects to perform 18 trials, 9 textual and 9 pictorial, under nine different proportions of black jellybeans (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%). Our between-subjects design asked each subject to perform only one version (textual or pictorial), in accordance with our previous experimental design.

In " Phrase removed" conditions (pictorial and textual), the findings show a significant increase in the rate of objective answers with respect to the control tasks (from 26% to 77.5% in the textual condition and from 30% to 72.5% in the pictorial condition), and the RB phenomenon disappears in both the textual (Chi-squared = 22.63, p<.01) and the pictorial presentations (Chi-squared = 13.93, p<.01). As in Experiment 1, the formulation of the task was responsible for the RB phenomenon, and this effect is independent of the presentation format of the stimuli (textual vs. pictorial).

Table 4: Results of Experiment 2—"*Jeally Bean*" Scenario, all subject included (N=285).

Perspective	**EXB**	**UEB**	**OBJ**
Rudski & Volksdorf (2002)			
"Textual"	20 (33%)	10 (17%)	30 (50%)
"Pictorial"	34 (57%)	9 (15%)	17 (28%)
Control task (N= 83)			
"Textual"	27 (51%)	10 (23%)	16 (26%)
"Pictorial"	16 (53%)	5 (17%)	9 (30%)
"Phrase removed" condition (N=80)			
Textual"	5 (12.5%)	4 (10%)	31 (77.5%)
"Pictorial"	6 (15%)	5 (12.5%)	29 (72.5%)

EXB: number of subjects that answer in the Ratio Bias direction, **UEB**: number of subjects that answer in the Ratio Bias unexpected direction, **OBJ**: number of subjects that answer objectively.

5 Experiment 3 (Job)

In the present study, we examined the RB effect in a job context (Alonso and Fernandez-Berrocal, 2003). Besides confirming the phenomenon, Alonso and Fernandez-Berrocal (2003) showed that the RB effect is present in all perspectives and is greater in ratings of others than in self-ratings (82.9% vs. 34%) or in logical-person ratings (25.7%), replicating previous results in the literature.

As in our previous studies, our hypothesis is that some critical aspects of the formulation of the problem could be responsible for the bias. These critical aspects, which will be discussed in detail below, are two sentences: "*one of them would be you"* and "*As you can observe, the ratio between number of vacancies and candidates' number is 10% in the Type P and 10% in the Type Q"*. The aims of this experiment were (a) to verify and extend our previous findings in a realistic context and (b) to identify the role of the formulation of the task in the bias.

We controlled two sentences of the original text:

1. The phrase in parentheses, "(*one of them would be you)",* stating that the subject "would be one of" the 10 or 100 candidates, conveys that people must be admitted among the 10 or the 100 candidates before participating in the personnel selection; it is more difficult to be admitted to a group of 10 compared

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to a group of 100, and the second option is more probable than the first one.

2. The sentence "*As you can observe, the ratio between number of vacancies and candidates' number is 10% in the Type P and 10% in the Type Q*", stating that both jobs offer identical odds, induces a neglect of this aspect and legitimates, or asks for, a non-rational choice.

For this Task, we studied the RB effect in the original version (i.e., the structure of the text is the same as in the original text of Alonso and Fernandez-Berrocal, 2003) and in three different versions in which the text was modified from the methodological analysis discussed to study these two critical aspects both individually and together.

- In "Replaced phrase" condition the text of the control task was modified by replacing the phrase "*one of them would be you"* with the phrase "*one of them is you"*.
- In "Removed phrase" condition the text was modified by removing the phrase.
- In "All manipulations" condition we combined the two variations introduced in the previous conditions.

Based on literature about the RB (Kirkpatrick & Epstein, 1992; Denes-Raj, Epstein & Cole, 1995; Rudski & Volksdorf, 2002) and on our previous findings, we made the following predictions:

1. The RB effect will decrease across the "Replaced phrase" and "Removed phrase" conditions in both the others-perspective and the self-perspective;
2. The RB phenomenon will decrease in the "All manipulations" condition, in which the formulation of the task is adequate to communicate the aim of the task and the experimenter's intention.

5.1 Method

5.1.1 Subjects

A total of 196 university students of both sexes agreed to participate in this study. All were undergraduates and aged between 19 and 25 years.

5.1.2 Procedure

Subjects were assigned randomly to one of the four conditions (N=43 in the control task, N=40 in "Replaced phrase" condition, N=55 in "Removed phrase" condition, N=58 in "All manipulations" condition). Each subject received one of the 4 descriptions of a hypothetical situation that implied the election of one of two alternatives. Paralleling the strategy used by Alonso and Fernandez-Berrocal (2003), we asked subjects to estimate their own responses (self-perspective), how most people would respond (others-perspective) and how a completely logical person would respond (logical-perspective). They were asked to give written answers to the problem. There was no time limit.

The text of the control task:

> Imagine that you have finished your studies and you need to find a job. You are looking through the newspaper and you read an advert from a company that is looking for people like you. This company offers two types of job positions: Type P and Type Q. Both are of the same category, and you like them equally. Therefore, you quickly go to the company to present your application to work in either of them. Once there, they tell you that you cannot request both at the same time; you have to opt for one of them: P or Q.
>
> They also tell you that: For the Type P job, 1 people is needed, and only 10 candidates are admitted (one of them would be you). For the Type Q job, 10 people are needed, and only 100 candidates are admitted (one of them would be you).
>
> As you can observe, the ratio between number of vacancies and candidates' number is 10% in the Type P and 10% in the Type Q.
>
> Your task consists of estimating what most people choose in a real situation. We are also interested in your own preference. In addition, in your impression about how a completely logical person would react in this situation.
>
> What job type would you choose? Indicate it with an "X":
> __Type P __Type Q __No preference
>
> What job type do you believe most people would choose? Indicate it with an "X":
> __Type P __Type Q __No preference
>
> What job type do you believe a completely logical person would choose? Indicate it with an "X":
> __Type P __Type Q __ No preference

5.2 Results and discussion

As we can see in Table 5, the results of the Control Task substantially replicated those obtained by Alonso and Fernandez-Berrocal (2003). We can observe a strong RB effect for the others-perspective responses and a

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Table 5: Results of Experiment 3—"*Job*" Scenario, all subject included (N=196).

Perspective	EXB	UEB	OBJ
Alonso & Fernandez-Berrocal (2003)			
"Self"	34.30%	45.70%	20%
"Others"	82.90%	14.30%	2.90%
"Logical"	25.70%	37.10%	37.10%
Control Task (N= 43)			
"Self"	(17) 39.6%	(15) 34.8%	(11) 25.6%
"Others"	(34) 79.1%	(1) 2.3%	(8) 18.6%
"Logical"	(11) 25.6%	(4) 9.3%	(28) 65.1%
"Replaced phrase" condition (N= 40)			
"Self"	(12) 30%	(6) 15%	(22) 55%
"Others"	(10) 25%	(12) 30%	(18) 45%
"Logical"	(10) 25%	(4) 10%	(26) 65%
"Removed phrase" condition (N= 55)			
"Self"	(8) 14.55%	(3) 5.45%	(44) 80%
"Others"	(14) 25.45%	(8) 14.55%	(33) 60%
"Logical"	(5) 9.09%	(1) 1.82%	(49) 89.09%
"All manipulations" condition (N= 58)			
"Self"	(6) 10.34 %	(5) 8.63%	(47) 81.03%
"Others"	(4) 6.89%	(5) 8.63%	(49) 84.48%
"Logical"	(5) 8.63%	(1) 1.72%	(52) 89.65%

EXB: number of subjects that answer in the Ratio Bias direction, **UEB**: number of subjects that answer in the Ratio Bias unexpected direction, **OBJ**: number of subjects that answer objectively.

weaker effect for the self-perspective and the logical-perspective responses. The objective responses increase along the "Replaced phrase" and "Removed phrase" conditions; in the "Removed phrase" condition, the objective responses increase in the logical-perspective (from 65% to 89%, Chi-squared = 9.9, Bonferroni's p<.0011), self-perspective (from 25% to 80%, Chi-squared = 17.09, Bonferroni's p<.0011) and others-perspective versions (from 20% to 60%, Chi-squared = 21.91, Bonferroni's p<.0011). Finally, in "All manipulations" condition the phenomenon disappears and is it possible to observe a strong production of objective answers in the self-perspective (from 25% to 81.1%, Chi-squared = 27.43, Bonferroni's p<.0011), others-perspective (from 20% to 84.5%, Chi-squared = 28.12 , Bonferroni's p<.0011) and logical-perspective versions (from 65% to 90%, Chi-squared = 10.89 , Bonferroni's p<.0011). Also in this experiment, like in the previous ones, the formulation of the task was responsible for the RB phenomenon.

6 Experiment 4 (Folded tickets)

The present study (Kirkpatrick & Epstein, 1992) aimed to investigate the RB effect in a task in which there is not the misleading phrase[8], which is present in Experiments 1–3. In this task, people have to choose between two bowls with blank and winning (or losing) tickets. We studied the RB effect in the typical version (e.g., where the structure of the text is the same as in Kirkpatrick and Epstein, 1992). The vignette for the 10% win condition of the control task was as follows:

> Imagine that you are presented with two bowls of folded tickets. One bowl contains 1 ticket marked "winner" and 9 blank tickets.
>
> The other bowl contains 10 tickets marked "winner" and 90 blank tickets. You must draw one ticket (without peeking, of course) from either bowl: If you draw a ticket marked "winner", you win €8.00; otherwise, you win nothing and the game is over.

The vignette was identical for the 90% win condition except that the respective bowls were described as containing (a) 9 winners and 1 blank and (b) 90 winners and 10 blanks. The 10% lose and 90% lose conditions were identical to the respective win conditions except that the word "winners" was replaced by the word "losers" so that drawing a losing ticket meant that the subject would lose €8. In each condition, the question listed below the vignette is: "If you were given the choice, which bowl would you choose from?"[9]

Kirkpatrick and Epstein found that the proportion of subjects favouring one bowl over the other in the total sample was significantly different only in the 10% lose condition. They interpreted this result as a failure of the task to adequately tap experiential-system responding; the demand characteristics of the situation led many subjects to choose arbitrarily. From our point of view, their results confirm our hypothesis of the centrality of the target phrase to the bias. We hypothesise that the absence of the third, correct option creates an arbitrary

[8]The misleading phrase is the sentence of the Experiments 1, 2 and 3 that we removed because induces subjects to neglect the equal ratio (e.g., "Although you know that the proportion are identical…", p. 7).

[9]In the original task, there was another question: "How much would you be willing to pay for the privilege of choosing which bowl you will draw from rather than having the bowl picked for you? (Check the largest amount you would be willing to pay.)" The response alternatives were nothing, 1 cent, 5 cents, 10 cents, 25 cents, 50 cents, and $1 or more. The authors found that people were not willing to pay.

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distribution of the choices between the two categories of responses (EXB vs UEB). To check our hypothesis, we created an experimental condition in which a third option is introduced.

6.1 Method

6.1.1 Subjects

A total of 153 university students of both sexes agreed to participate in this study. All were undergraduates and aged between 19 and 30 years.

6.1.2 Procedure

Subjects were assigned randomly to the experimental conditions or the control task. We asked subjects to estimate their own responses (self-perspective). They were asked to give written answers to the problems. There was no time limit. The experimental condition and the control task were arranged in a 2 X 2 experimental design for odds (10% vs. 90%) and valence of outcome (win vs. lose), resulting in four versions. The dependent variable was choice of bowl (large vs. small). Subjects were given a brief paragraph to read that described one of the four versions. In the control task (N=94), subjects were given the original task of Kirkpatrick & Epstein (1992) and in the experimental condition (N=93), we modified the original task with the introduction of the third response (no preference).

6.2 Findings and discussion

A first interesting result is that about 50% of subjects in our control task spontaneously reported having no preference between the two bowls and making a choice only because they were obliged to do so. We found a substantial correspondence between our 10% condition's results and the 10% condition of Kirkpatrick & Epstein (1992), but not for the 90% condition, in which our subjects made choices coherent with the RB. Our explanation is that subjects who have already given the correct answer (no preference), when obliged to make a choice, produce answers in an irrational way. As we can see in Table 6, the indifference to the choice that subjects spontaneously expressed is confirmed by the results of the experimental condition, in which the RB effect is strongly reduced in the 10% win (from 44% to 0% biased responses) and lose conditions (from 81% to 10% biased responses) and in the 90% win (from 91% to 20% biased responses) and lose (from 71% to 9% biased responses) conditions. To compare our results and those of Kirkpatrick and Epstein (1992), we collapsed the unexpected RB responses and the objective responses in a unique category (unexpected RB responses), and we found that the unexpected responses strongly increased in the 10% win (Chi-squared = 13.68, p<.01) and lose conditions (Chi-squared =2 2.64, p<.01) and in the 90% win (Chi-squared = 16.49, p<.01) and lose (Chi-squared = 13.10, p<.01) conditions.

7 General discussion

The RB phenomenon was studied in four experiments (Kirkpatrick & Epstein, 1992; Denes-Raj, Epstein & Cole, 1995; Rudski & Volksdorf 2002; Alonso & Fernandez-Berrocal, 2003), and for each text problem investigated we made an analysis of the text; from this analysis, we identified some critical aspects that may be responsible for the phenomenon. In particular, we found two elements common to experiments 1–3: a particular sentence that invites subjects to *intentionally neglect the equal ratio* and the absence of a third, correct option that expresses "indifference" between the two options despite their different numerosity.

More precisely, in Experiment 1 we studied the phenomenon in the context of three different scenarios (Lottery, Machine and Transfusion) and four experimental conditions; our results (in particular in "All manipulations" conditions) show that the RB phenomenon decreases greatly when the critical aspects of the texts are manipulated. The same results were obtained in Experiment 2, independent of the presentation format (textual vs. pictorial), and in Experiment 3, in a job context, independent of the perspective assumed (self, others and logical). In Experiment 4, the task lacks only the "no preference" option, and, simply by adding the option that allows subjects to express the correct answer, we revealed that the vast majority of subjects do not commit the RB. We can conclude that subjects tend to satisfy the task's demands.

In light of the results obtained, we can reconsider other classic findings in the literature. In particular, when the question of the task does not refer explicitly to suspiciousness, as in the pre-outcome condition of study 1 of Miller et al. (1989), in which people must simply estimate the likelihood of a target event, subjects do not show the bias. However, when the text explicitly refers to suspiciousness (like in the post-outcome study 1 of Miller et al.), subjects make irrational responses. Furthemore, when subjects have to choose between two different probabilities (Peters et al. 2006) but the task asks for a judgment of attractiveness, subjects produce irrational answers.

Our results are consistent with other studies (Price & Matthews, 2009; Windschitl & Wells, 1998) which investigated the factors that influence associative-experiential processes of uncertainty informations vs. rule-based pro-

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Table 6: Results of Experiment 4, all subject included (N=187).

	10%			**90%**		
	EXB	UEB	OBJ	EXB	UEB	OBJ
Kirkpatrick et al., 1992						
Win condition	80 (49.4%)	82 (50.6%)		84 (52.5%)	76 (47.5%)	
Lost condition	104(65.4%)	55 (34.6%)		85 (45.9%)	72 (54.1%)	
Control Task (N=94)						
Win condition	10 (44%)	13 (56%)	15*	21 (91%)	3 (9%)	12*
Lost condition	21 (81%)	5 (19%)	10*	15 (71%)	6 (29%)	10*
Experimental condition (N=93)						
Win condition	0	2 (8%)	23 (92%)	5 (20%)	3 (12%)	17 (68%)
Lost condition	2(10%)	0	18 (90%)	2 (9%)	2 (9%)	19 (82%)

EXB: number of subjects that answer in the Ratio Bias direction, **UEB**: number of subjects that answer in the Ratio Bias unexpected direction, **OBJ**: number of subjects that answer objectively.
* subjects made as first answer "no preference" and only in a second moment they made a choice.

cessing. In particular, Price and Matthews found that how the relevant informations are presented affects the likelihood judgment. Windschitl and Wells also found that the distribution of alternative outcomes influences the perception of uncertainty through associative processing when the task asks a verbal estimation of the probability (certain, likely, impossible). Besides, according to Price and Matthews the RB is more likely to be observed when the numerator is more salient but they did not replicate the RB when the numerator and the denominator were given in a straightforward way.

Concerning the main theories about RB (CEST and FTT), our results confirm their previsions at low probability, because the construction of the text lead to the activation of the Experiential System, which is responsible of the proportion's neglect in favour to the numerator. Instead, when the text is relevant to the aim of the task and to the experimenter's intention, subjects evaluate the available data in a global way, considering the proportions and producing rational responses.

References

Alonso, D. & Fernandez-Berrocal, P. (2003). Irrational decisions: attending to numbers rather than ratios. *Personality and Individual Differences, 35*, 1537–1547

Bagassi, M. & Macchi, L. (2006). Pragmatic approach to decision making under uncertainty: the case of the disjunction effect. *Thinking and Reasoning, 12*, 329–350.

Bonner, C., & Newell, B. R. (2008). How to make a risk seem riskier: The ratio bias versus construal level theory. *Judgment and Decision Making, 3*, 411-416.

Brainerd, C. J. & Reyna, V. F. (2002), Fuzzy-trace theory and false memory. *Current Directions in Psychological Science,* 11, 164–169.

Brainerd, C. J. & Reyna, V. F. (2004), Fuzzy trace theory and memory development. *Developmental Review, 24*, 396–439.

Dale, D., Rudsky, J., Schwarz, A. & Smith, E. (2007). Innumeracy and incentives: A ratio bias experiment. *Judgment and Decision Making, 2*, 243–250.

Denes-Raj, V. & Epstein, S. (1994), Conflict between intuitive and rational processing: When people behave against their better judgment. *Journal of Personality and Social Psychology, 66*, 819–829.

Denes-Raj, V., Epstein, S., & Cole, J. (1995). The generality of ratio bias phenomenon. *Personality and Social Psychology Bulletin, 10*, 1083–1092.

Dulany, D. E., Hilton, D. J. (1991). Conversational implicature, conscious representation and the conjunction fallacy. *Social Cognition, 9*, 85–110.

Epstein, S. (1990). Cognitive-experiential self-theory. In L. Pervin (Ed.), *Handbook of personality theory and research*, pp. 165–192. New York: Guilford Press.

Epstein, (2008). Intuition from the perspective of cognitive-experiential self-theory. In Plessner, H., Betsch, C., & Betsch, T. (Ed). *Intuition in judgment and decision making*, pp. 23–37. New York, NY: Lawrence Erlbaum Associates.

Evans, J. St B. T. (2010). *Thinking twice: Two minds in*

https://doi.org/10.1017/S193029750000632X Published online by Cambridge University Press

one brain. Oxford: Oxford University Press.

Evans, J. St B. T. & Frankish, K. (2009). *In two minds: Dual processes and beyond*. Oxford, UK: Oxford University Press.

Evans, J. St B. T. & Over, D. E. (1996). *Rationality and reasoning*. Hove, UK: Psychology Press.

Hilton, D. J. (1995). The social context of reasoning: Conversational inference and rational judgment. *Psychological Bulletin, 118*, 248–271.

Kahneman, D. & Miller D. T., (1986). Norm theory: Comparing reality to its alternatives. *Psychological Review, 9*, 136- 153.

Kirkpatrick, L., & Epstein, S. (1992). Cognitive-experiential self-theory and subjective probability: Further evidence for two conceptual systems. *Journal of Personality and Social Psychology,* 63, 534- 544.

Macchi, L. (1995). Pragmatic aspects of the base rate fallacy. *The Quarterly Journal of Experimental Psychology, 48A*, 188–207.

Macchi, L. (2000). Partitive formulation of information in probabilistic problems: beyond heuristics and frequency format explanations. *Organizational Behavior and Human Decision Processes, 82*, 217–236.

Macchi, L. & Bagassi, M. (2012). Intuitive and analytical processes in insight problem solving: A psychorhetorical approach to the study of reasoning. *Mind and Society, 11*, 53–67.

Miller, D., Turnbull, W. & McFarland, C. (1989). When a coincidence is suspicious: The role of mental simulation. *Journal of Personality and Social Psychology, 57*, 581- 589.

Pacini, R., & Epstein, S. (1999a). The relation of rational and experiencial information processing styles to personality, basic beliefs, and the ratio-bias phenomenon. *Journal of Personality and Social Psychology, 76*, 972–987.

Pacini, R., & Epstein, S. (1999b). The interaction of three facets of concrete thinking in a game of chance. *Thinking and Reasoning, 5*, 303–325.

Pacini, R., Muir, F., & Epstein, S. (1998). Depressive realism from the perspective of cognitive-experiential self-theory. *Journal of Personality and Social Psychology, 74*, 1056–1068.

Peters, E.. Vastfjal, D., Slovic, P., Mertz, C. K., Mazzocco, K. & Dickert, S. (2006). Numeracy and decision Making. *Psychological Science, 17*, 407- 413.

Piaget, J. & Inhelder, B. (1975). *The origin of the idea of chance in children*. Oxford, England: W. W. Norton.

Pinto-Prades, J. L., Martinez-Perez, J. E. & Abellán-Perpiñán, J. M. (2006). The influence of the ratio bias phenomenon on the elicitation ofhealth states utilities. *Judgment and Decision Making, 1*, 118–13

Politzer, G. & Macchi, L. (2000), Reasoning and Pragmatics. *Mind & Society, 1*, 73- 93.

Price, P. C., & Matthews, T. V. (2009). From group diffusion to ratio bias: Effects of numerator and denominator salience on intuitive risk and likelihood judgments. *Judgment and Decision Making, 4*, 436–446.

Reyna, V. F. (2008), A theory of medical decision making and health: Fuzzy trace theory. *Medical Decision Making, 28*, 850–865.

Reyna, V. F. & Brainerd, C. J. (1995), Fuzzy-trace theory: An interim synthesis. *Learning and Individual Differences, 7*, 1–75

Reyna, V. F. & Brainerd, C. J. (2008), Numeracy, ratio bias, and denominator neglect in judgments of risk and probability. *Learning and Individual Differences, 18*, 89–107.

Reyna, V. F. & Brainerd, C. J. (2011), Dual processes in decision making and developmental neuroscience: A fuzzy-trace model, *Developmental Review*, 31, 180–206.

Royzman, E. B., Cassidy, K. W., & Baron, J. (2003). "I know, you know": Epistemic egocentrism in children and adults. *Review of General Psychology, 7*, 38–65.

Rudsky, J. M. & Volksdorf, J. (2002). Pictorial versus textual information and the ratio-bias effect. *Perceptual and Motor Skills, 95*, 547–554.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin, 119*, 3–22.

Sperber, D., Cara, F., & Girotto, F. (1995). Relevance Theory Explains the Selection Task. *Cognition 57*, 31–95.

Sperber, D. & Mercier, H. (2011). Why do humans reason? Arguments for an argumentative theory. *Behavioral and Brain Sciences, 34*, 57–111

Sperber, D. & Wilson, D. (1986). *Relevance: Communication and cognition*. Oxford: Blackwell.

Windschitl, P. D. & Wells, G. L. (1998). The alternative-outcomes effect. *Journal of Personality and Social Psychology* 75, 1411–1423.

Yamagishi, K. (1997). When a 12.86% mortality is more dangerous than 24.14%: implications for risk communications. *Applied Cognitive Psychology, 11*, 495–506.

Appendix 1: Lottery problem—postoutcome version

Imagine two scenarios involving lotteries. In both cases, a winning number pays ten thousand dollars. Now imagine that Ralph Jones, a friend of yours, thinks of all the things he could buy with the money, like a new car, and all he can do with the money, such as take his dream vacation. These thoughts and images make Ralph desperately want to win the lottery. In one of the lotteries, a single winning number is selected from 1,000 numbers. In the

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other, 10 winning numbers are selected from 10,000 numbers. Although you know the proportions are identical, you may have the feeling that it is less likely that Ralph will get a winning number in one lottery than in the other.

Ralph wins the lottery. In which lottery would you be more suspicious that the lottery had not been completely honest? (If you cannot make a choice, skip this item, and check "not at all" in the next item).

-- In the first lottery (1 winning number in 1.000)

-- In the second lottery (10 winning numbers in 10.000)

To what extent would you be more suspicious that the lottery had not been completely honest?

(Not at all) 0----1----2----3----4 (a great deal)

In which lottery would most people be more suspicious that the lottery had not been completely honest? (If you cannot make a choice, skip this item, and check "not at all" in the next item).

-- In the first lottery (1 winning number in 1.000)

-- In the second lottery (10 winning numbers in 10.000)

To what extent would most people be suspicious that the lottery had not been completely honest?

(Not at all) 0----1----2----3----4 (a great deal)

Appendix 2: Machine problem

Imagine two scenarios, which we shall call X and Y, in which there are colored balls in a round wire basket. A machine rotates the basket and randomly draws a single ball. In one scenario, there is one red ball among a total of a thousand balls (including the red ball). In the other, there are ten red balls among a total of ten thousand balls (including the ten red balls). Although the proportions are identical, you may feel that the chance of a red ball being selected is less in one scenario than in the other.

Preoutcome version

In which scenario would you feel there is less of a chance of the red ball being selected? (If you cannot make a choice, skip this item, and check "not at all" in the next item).

-- In situation X (1 red ball in 1,000)

-- In situation Y (10 red balls in 10,000)

To what extent would you feel that the chance of a red ball being selected is less in one than in the other? (Not at all) 0----1----2----3----4 (a great deal)

In which scenario do you think that most people feel there is less of a chance of the red ball being selected? *(If you cannot make a choice, skip this item, and check "not at all" in the next item).*

-- In situation X (1 red ball in 1,000)

-- In situation Y (10 red balls in 10,000)

To what extent would most people believe that this is true?

(Not at all) 0----1----2----3----4 (a great deal)

Postoutcome version

The machine had already selected a red ball.

In which scenario, if either, would you feel there is less of a chance of the red ball being selected? (If you cannot make a choice, skip this item, and check "not at all" in the next item).

-- in situation X (1 red ball in 1,000)

-- in situation Y (10 red balls in 10,000)

To what extent would you feel that the chance of a red ball selected is less in one than in the other?

(Not at all) 0----1----2----3----4 (a great deal)

In which scenario would most people feel there is less of a chance of the red ball being selected? (If you cannot make a choice, skip this item, and check "not at all" in the next item).

-- in situation X (1 red ball in 1,000)

-- in situation Y (10 red balls in 10,000)

To what extent would most people feel that the chance of a red ball selected is less in one than in the other?

(Not at all) 0----1----2----3----4 (a great deal)

Appendix 3: Transfusion problem

Imagine a situation in which you are watching TV late one night when you are startled by the telephone ringing. The caller says he is a policeman with unfortunate news to report. You learn that the person you love most in your life has been in an automobile accident and is in critical in a hospital. In desperation, you rush to the hospital. When you arrive there, the physician in charge of the case informs you that your loved one is in a coma and needs an immediate blood transfusion.

Preoutcome version

You are asked to choose between samples from two blood banks, both of which have a rate of HIV transmission that is barely accep, but they are the only samples available at the moment. One has a record of one HIV positive case out of a thousand transfusions, and the other has a record of ten HIV positive cases out of ten thousand transfusions. You know that the proportions are identical, but somehow you may feel that the chance of transmission is greater in one sample than in the other.

In which sample, if either, do you think there was a greater likelihood of HIV contamination?

-- The first sample (1 in 1,000)

-- The second sample (10 in 10,000)

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To what extent would you feel that the chance of transmission is greater in one than in the other? (Not at all) 0----1----2----3----4 (a great deal)

In which scenario do you think most people would feel that there was a greater likelihood of HIV contamination? (If you cannot make a choice, skip this item, and check "not at all" in the next item).

-- The first sample (1 in 1,000)

-- The second sample (10 in 10,000)

To what extent would most people believe that this is true?

(Not at all) 0----1----2----3----4 (a great deal)

Postoutcome version

Now imagine two different scenarios. In one, your loved one is given a transfusion from a blood bank with a record of one HIV positive case out of one thousand administrations. In the other, the blood comes from a blood bank that has a record of ten HIV positive case out of ten thousand administrations. A year later, your loved one test HIV positive. You are, of course, suspicious that the HIV positive was caused by the transfusion. You now that the proportion are identical, but somehow you may feel more suspicious in one case than in other.

Subjects indicated in which situation, if either, they would be more suspicious and the degree to which that would be the case. they then rated how most people would rate the situation.

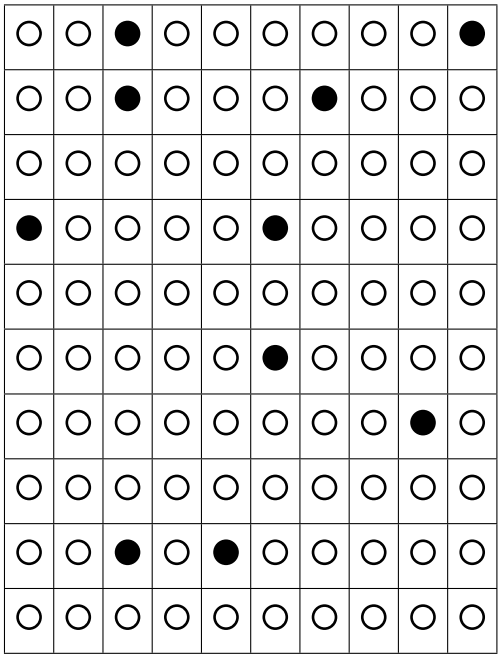
Appendix 4: Jelly Beans pictorial problem

Suppose you are faced with two trays of jellybeans, one of which contained 10 beans and one with 100.In each , you must draw one jellybean without peeking, of course, from either tray. Should you pick a black jelly bean, you will win 5$, Should you pick a white jellybean, you will win nothing.

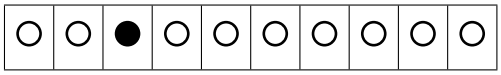
Now, what makes your choice interesting is that for each time you choose, both trays will offer identical odds of selecting a black jellybean. Still, many (but not all) people have a preference for picking one of the trays. Your job is to indicate whether you would prefer to pick from the large tray (100 beans), the small tray (10 beans) or if you have no preference.

From which tray would you select your jellybean?

1. Big tray



2. Little tray



3. No preference

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