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Irrational decisions: attending to numbers rather than ratios

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Abstract

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. 1:10) than of large numbers (e.g. 10:100). This is known as the ratio-bias (RB) phenomenon. Besides confirming the phenomenon, in this experiment participants made irrational decisions selecting probabilities of 10% in preference to 20 and 30%, in spite of the great discrepancy of probabilities between options (greater than in previous studies). These results support an interpretation in terms of the principles of cognitive-experiential self-theory (CEST). Relation between tendency to present the RB phenomenon and degree of rationality (as measured by the Need for Cognition Scale) was also examined. Scores in rationality obtained by participants who chose the nonoptimal response were lower than scores of participants who chose the optimal response.

Keywords: Ratio-bias phenomenom; Cognitive-experiential self-theory; Need for cognition; Experiential system; Rational system; Irrational decisions; Reasoning; Probabilistic judgement

1. Introduction

There are different ways of expressing the probability of an event. One of them consists of the use of ratios. Thus, one can say for example, that the probability of X happening is "1 in 20". This can give rise to a ratio being expressed by means of different numbers: "1 in 10", "10 in 100", etc. In spite of the mathematical equivalence of the two previous ratios, a surprising phenomenon has been observed when judging the probability of a low probability event: many people judge it as less probable when it is expressed as a ratio of small numbers (e.g. 1:20) than of

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large numbers (e.g. 10:200). This phenomenon is known as the ratio-bias (RB) phenomenon and it is of special interest because it shows that many people, still knowing that both ratios are equivalent, follow their intuitions when choosing between one of them. To illustrate the RB phenomenon, imagine two bags (A and B) with red and white balls. The bag A contains 10 balls, 1 of which is red, and the bag B contains 100 balls, 10 of which are red. Obviously, the ratio of red balls is the same in both bags. Suppose that you are provided with this information and are offered a certain reward if when extracting at random a ball from one of the bags, it turns out to be red. The key question is the following: From which bag would you prefer to extract the ball? Most of the participants usually choose bag B (Kirkpatrick & Epstein, 1992) because, as they affirm, "it contains more red balls". This RB is even presented in situations where bag B offers a smaller probability of winning than bag A (e.g. 8:100 vs. 1:10; Denes-Raj & Epstein, 1994). In this study of Denes-Raj and Epstein, almost half of the participants preferred the option "8 in 100" to the option "1 in 10". Still knowing that their decision went against the law of probabilities, they claimed that they felt that, somehow, it was more probable to obtain a red ball in the bag that contained more red balls.

Why do many people have the subjective belief that the occurrence of an event of low probability is more probable when the ratio is presented making use of large numbers rather than of small numbers, although they know that the objective probabilities are identical? One account for this that has greater empirical support is the one proposed by the cognitive-experiential self-theory (CEST, Epstein, 1991, 1994). This theory assumes the existence of two systems of information processing: rational and experiential, that act in a parallel and interactive way. The experiential system is a learning system that operates preconsciously according to heuristic rules. It is concrete, associative, rapid, automatic, holistic, primarily nonverbal and closely related with emotions. It also learns directly from experience and has a long evolutionary history. The rational system is inferential, operating according to the understanding that a person has of the culturally transmitted reasoning rules; it is conscious, relatively slow, analytic, primarily verbal, relatively free of emotions and it has a very brief evolutionary history. It is assumed that the behaviour is a function of the joint operation of the two systems. In a given condition, situational factors and individual differences determine the relative influence of each system. From the perspective of CEST, when people experience differences between what they think and feel, what they are experiencing are the outcomes of these two information-processing systems. In most situations, the two systems operate synchronously, people being only aware of what seems to be a single process, and in other circumstances their differences come to light, as happens in the RB paradigm.

According to CEST, the RB effect would be attributed to two facets of the concrete processing that carries out the experiential system (Pacini & Epstein, 1999b): the numerosity effect and the small-numbers effect. In accordance with the first facet, the experiential system codes and understands better whole numbers that are ratios, because numbers are more concrete than relations between numbers, which is coherent with other findings showing that the sensibility to frequencies—numbers—is one of the more important cognitive operations (Gallistel, 1990; Geary, 1995; Staddon, 1988). People code automatically the information about frequencies, prevailing over other more rational considerations, such as ratios, which can constitute an important source of errors in probabilistic judgements (Pelham, Sumarta, & Myakovsky, 1994). This way, the different number of red balls in the two bags can explain the bias in favour of the one containing the largest number of red balls, in the situation where there is a low ratio of successes in both bags (for example, 10%), which is consistent with the reports of the participants preferring the bag containing more red balls. By virtue of the numerosity-heuristic, it could be objected that people could also pay attention to the number of white balls. According to Pacini and Epstein (1999b), there are three reasons that would explain why people attend to the red balls and they ignore the white ones: (1) the instructions are stated in terms of the consequences of extracting a red ball, (2) the relationships figure–ground makes the few red balls stand out as a figure against a background of many more white balls, and (3) the authors assume the affirmative representation principle, according to which the experiential system can code the positive representations (in this case, "to extract a red ball") more easily than the negative representations (that is to say, "not to extract a white ball"), because the affirmation is more concrete than the negation.

The second facet, the small-numbers effect, consists in that, at the experiential level, small numbers are easier to understand than large numbers because they are more concrete (easier to visualize; Paivio, 1986). Then, when two equivalent low probability ratios are presented, one expressed with small numbers and the other with large numbers, people will understand better (at the experiential level) that the event has a very low probability of happening when the ratio is expressed with smaller numbers (Gallistel, 1990; Pacini & Epstein, 1999a; Siegler, 1981; Surber & Haines, 1987). That is to say, for example, the ratio 1:20 is more understandable and therefore more convincing that it represents an event of very low probability than the ratio 10:200, which will cause the subjective probability in the first case to seem smaller than in the second one.

According to the explanation provided by CEST, these two facets of concrete thinking, the numerosity heuristic and the small-numbers effect, operate simultaneously influencing the answer emitted by the individual. In the low probability condition (e.g. 10% of red balls), preference for the big bag would happen because both effects work in the same direction. On the other hand, in the high probability condition (e.g. 90% of red balls) the RB effect disappears, which is explained by the fact that the two facets work in opposed directions: while the numerosity heuristic would incline us towards the ratio 90:100, the small-numbers effect would induce us to choose 9:10 since these small numbers would express more clearly (from the experiential system) the idea of a high probability for their occurrence (Pacini & Epstein, 1999b).

Kirkpatrick and Epstein (1992) proposed that the experiential-learning principle could contribute to the RB effect. According to this principle, schemas in the experiential system are derived from emotionally significant past experiences. Frequently, people face situations where an unusual event is represented as 1 among many rather than 2 or 3 among many. Therefore, individuals are likely to learn that an event with the probability of 1 in some large number (e.g. 1:10) is a very low probability event and they can feel that its probability is smaller than when expressed with a larger number in the numerator.

The perspective from which the individual makes the decision is a variable whose influence in RB effect has been demonstrated consistently. Several studies have found a considerably stronger RB effect in people's estimates of other's behaviour (others-perspective) than when they estimate their own behaviour (self-perspective) (Denes-Raj, Epstein, & Cole, 1995; Kirkpatrick & Epstein, 1992). According to Denes-Raj et al. (1995), to judge the behaviour of other people can be more informative of our irrational tendencies, since it liberates us of the desire of presenting ourselves as rational people. Therefore, the difference in the answer given by the subject in function of the perspective that he or she adopts (self-perspective vs. others-perspective) can inform us about the coexistence of the two information-processing systems (rational vs. experiential).

1.1. Need for cognition

As previously mentioned, a basic assumption of CEST supported by the results obtained with the RB paradigm, is that many people make decisions influenced by compromises produced by the simultaneous operation of the rational and experiential systems. Individual differences play an important role in determining the relative contribution of each system and the direction of compromises (toward rational or experiential dominance). Previous research, using the Rational-Experiential Inventory (REI; Epstein, Pacini, Denes-Raj, & Heier, 1996; Pacini & Epstein, 1999a) showed that a rational thinking style was inversely related and an experiential thinking style was unrelated to nonoptimal responses in the RB paradigm.

Although it is not our main purpose, in this article we try to verify the relationship between rational thinking style and the RB phenomenon using the Need For Cognition Scale. The term *need for cognition* was defined by Cohen, Stotland, and Wolfe (1955) as "a need to understand and make reasonable the experiential world" (p. 291). Cacioppo and Petty (1982) adopted this term and proposed that need for cognition was a stable (although not invariant) individual difference in people's tendency to engage in and enjoy effortful cognitive activity. The Need for Cognition Scale (NCS) was developed by Cacioppo and Petty (1982) to assess this tendency. Later, a shorter modified version of the NCS (with the same name, NCS, and with 18 items) was developed by Cacioppo, Petty, and Kao (1984), and it has been considered as an appropriate measure of the rational thinking style (Pacini & Epstein, 1999a).

2. The present experiment

In the present study, we examined the RB effect in the typical version (e.g. where the two options have equal low probabilities: 1:10 vs. 10:100), and under conditions with unequal probabilities. As mentioned before, Denes-Raj and Epstein (1994) reported irrational decisions made by participants selecting probabilities of 9, 8, 7, 6, and even 5% (presented as 9:100, 8:100, 7:100, 6:100, and 5:100, respectively), in preference to 10% (presented as 1:10). Our experiment aims to verify and extend these previous findings, introducing the following modifications with respect to Denes-Raj and Epstein (1994): (a) our participants had to choose between 10% (10:100) and 20% (2:10) or between 10% (10:100) and 30% (3:10); therefore, the discrepancy of probabilities between options was greater than in the Denes-Raj and Epstein study, (b) the probabilities assigned to the optimal options (i.e. 20 and 30%) are higher than the one in the Denes-Raj and Epstein study (i.e. 10%), and (c) the optimal options are not expressed with a 1 in the numerator. It should be noted that this last modification excludes the supplementary contribution of the experiential-learning principle (Kirkpatrick & Epstein, 1992) to the RB effect. Paralleling the strategy used by Epstein and Pacini (2000–2001), in addition to their own responses (self-perspective), we asked participants to estimate how most people would respond (others-perspective) and how a completely logical person would respond (logical-perspective) if they had to make the decision. This way we can see that, as a consequence of the different weight of the experiential and rational system, people can vary their responses depending on the perspective they adopt. Nevertheless, our main interest is to observe the estimates from the others-perspective because of the stronger RB effect found from this perspective in previous research.

We also examined the relationship between rational thinking style, as measured by the NCS, and the tendency to present the RB phenomenon.

3. Summary of predictions

Based on previous findings, we made the following predictions for the condition in which participants had a choice between 1:10 and 10:100:

(1) As in previous research (Denes-Raj et al., 1995; Pacini & Epstein, 1999b), for others-perspective response, we anticipated a strong RB effect (i.e. preference for the 10:100 option), a weaker or no effect for the self-perspective response, and no effect at all for the logical-perspective response.
(2) Keeping in mind that NCS measures the rational processing, not the experiential one, and that the decisions made from an others-perspective reflect mainly the influence of the experiential system, one would not expect the differences between the NCS scores obtained by participants in different options from the others-perspective to be significant. Similarly, the decisions made from the self-perspective and, in particular, the logical-perspective are more related with the rational system, therefore it is expected that people who select the no-preference option will have higher NCS scores than those who select one of the other options.
We made the following predictions for the conditions in which participants had a choice between 10:100 and 2:10 or between 10:100 and 3:10:
(3) The magnitude of the RB effect, as measured by the percentage of preference for the 10:100 option, will decrease as the probability of the optimal option increases (from 20 to 30%) and this will occur to the greatest extent when responses are made from a logical-perspective and to the least extent when they are made from an others-perspective.
(4) Participants with the nonoptimal response (selecting 10:100 or the "no preference" option) will obtain the lowest scores in rationality.

4. Method

4.1. Participants

A total of 105 students enrolled in various secondary schools (55 men and 50 women), ranging in age from 16 to 17, who agreed to participate in this study.

4.2. Procedure and measures

Participants were assigned randomly to one of three experimental conditions (from now on which we will refer to as Condition 10, 20, and 30%). In Condition 10%, they were requested to choose between two equally probable options (1:10 vs. 10:100). In Condition 20%, the election was made between the ratios 2:10 and 10:100, and in Condition 30% between 3:10 and 10:100. Each participant received one of three descriptions (in the Spanish language) of a hypothetical situation that implied the election of one of two alternatives. The three descriptions began this way:

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.

Next the ratio vacant/candidates in each one of the job types was described to them. The three descriptions were different as was the experimental condition assigned to the participant, varying in the ratio assigned to the job Type P: 10, 20, or 30%. The three ratios had as denominator 10, only varying in the numerator (1, 2, or 3, respectively). The ratio vacant/candidates of the Type Q job was equal to 10% in the three descriptions, expressed with larger numbers, that is to say, 10:100. In turn, inside each version, in half of the cases the ratio represented by larger numbers was presented in the first place; in the other half it was presented in reverse order. This way, the description corresponding to the Condition 20% was as follows:

> They also tell you that: - For the Type P job, 2 people are 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).

Next, for all the participants, the text explicitly stated the percentages of the two options and it finished requesting from them: (a) the choice that they would make, (b) the choice that they believed that most people would make, and (c) what they believed that a logical person would decide. For example, for Condition 20% the vignette was as follows:

> As you can observe, the ratio between number of vacancies and candidates' number is 20% 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

On another sheet, the short form of the Need for Cognition Scale (Cacioppo et al., 1984) was presented. We used a Spanish adaptation ($\alpha = 0.71$). Respondents rated all NCS items on a five-point scale that ranged from 1 (definitely not true of myself) to 5 (definitely true of myself).

Therefore, participants were given one of three booklets, each presenting a Condition of the RB problem (Condition 10, or 20, or 30%) and the NCS.

5. Results

5.1. The RB effect

Responses where the two options had equal low probabilities (i.e. Condition 10%) and unequal probabilities (i.e. Condition 20% and Condition 30%) were analysed separately.

5.1.1. Equal-probabilities condition

Table 1 presents the percentages of participants responding to the various choices from a self-perspective, others-perspective, and logical-perspective. The RB phenomenon was indicated by the preference for the Type Q option. It can be seen that 34.3% of participants exhibited the RB effect in their self-ratings, 82.9% in their ratings of others, and 25.7% in their ratings of a logical person. The RB effect is present in all perspectives and is greatest in ratings of others, replicating the previous results with respect to the overall incidence of this phenomenon (Denes-Raj et al., 1995; Pacini & Epstein, 1999b). In addition, we compared the number of Type P relative to Type Q choices with an expectancy of an equal division by chi-square analysis. As predicted (Prediction 1), the RB effect was significant in others-perspective, $\chi^2(1)=16.94$, $P<0.001$. There was no significant differences in self-perspective, $\chi^2\ (1)<1$, and a logical-perspective, $\chi^2\ (1)<1$.

However, only 37% of the participants recognized that it is logical not to have a preference when choosing between equal probabilities.

Table 1
Option chosen by perspective and condition

	Option chosen			χ^2
	Type P (%)	Type Q (%)	No preference (%)	
Condition 10%				
Self-perspective	45.7	34.3	20	0.571
Others-perspective	14.3	82.9	2.9	16.941***
Logical-perspective	37.1	25.7	37.1	0.727
Condition 20%				
Self-perspective	68.6	17.1	14.3	10.8***
Others-perspective	42.9	51.4	5.7	0.27
Logical-perspective	71.4	17.1	11.4	11.645***
Condition 30%				
Self-perspective	68.6	31.4	0	4.829*
Others-perspective	48.6	45.7	5.7	0.03
Logical-perspective	62.9	25.7	11.4	5.452*

$N=35$ in each condition. Chi-square tests (1 d.f.) compared the frequency of Type P and Type Q choices to the expectancy of an equal division.

* $P<0.05$.

*** $P<0.001$.

5.2.2. Unequal-probabilities conditions

Selection of the Type Q option constituted a response in the direction of the RB phenomenon. Table 1 presents the percentages of participants responding to the various choices from self-perspective, others-perspective, and logical-perspective. It can be seen that the selection of the Type Q option, in spite of being a nonoptimal response, was chosen by 51.4 and 45.7% of participants in Condition 20% and Condition 30% respectively, both in others-perspective (Prediction 3). Comparing the number of Type P relative to Type Q choices by chi-square analysis, as much in Condition 20 as in Condition 30%, we obtained an inverse pattern of results to the one obtained in the Condition 10%. It is worthwhile to highlight that, in both conditions, there were no significant differences in others-perspective, $\chi^2(1) < 1$, which indicated to us that, although the correct option was the Type P, the RB effect was strong enough to allow the Type Q option to reach a similar level to that of the Type P option. In fact, in Condition 20%, the percentage of Type Q choices was even higher than Type P choices (51.4 vs. 42.9%).

5.3. Relation between the RB phenomenon and rationality as measured by NCS

To test Predictions 2 and 4, we computed a total score of optimal responses across the three probability conditions to correlate it with NCS scores. The total score of optimal responses consisted of the sum of the selection of the no-preference option in the condition 10% and the two Type P selections in the conditions 20 and 30% with a range of 0–3. There was no significant correlation between total score of optimal responses and NCS ($r(105) = 0.11$, $P =$ ns).

Finally, we conducted a series of separated one-way ANOVAs on NCS scores, with the option chosen (Type P, Type Q, no-preference) as between-subjects variable.

Condition 10% (when both options offered an equal 10% probability). There was a significant effect of option chosen from self-perspective, F (2, 34) = 4.32, $P < 0.05$. Post hoc comparisons using the HSD Tukey's post hoc test revealed that the NCS scores in Type Q group was significantly smaller than those in Type P (see Table 2). From a logical-perspective, there was a significant effect of option chosen, F (2, 34) = 7.57, $P < 0.005$. Post hoc comparisons using the HSD Tukey's post hoc test revealed that the NCS scores in Type Q group were significantly smaller than those in Type P and no-preference options. There were no other significant effects.

Conditions 20% and 30% (when Type P option offered 20 or 30% and Type Q option 10% probability). Scores in rationality obtained by participants who chose the nonoptimal response (selecting 10:100 or the "no preference" option) were lower than scores of participants who chose the optimal response, whatever perspective they adopted (self, others, or logical), although this tendency was not significant in any of the conditions. Therefore, our prediction (Prediction 4) was not confirmed.

6. Discussion

This study is a conceptual replication that extends the generality of the RB phenomenon in a number of ways. (1) It investigates Spanish high school students. Previously, the phenomenon has been investigated only with American college students and with young children. (2) It increases the discrepancy between the options beyond those previous investigated. (3) It examines the

Table 2
Average NCS scores in different options chosen by perspective and condition

	NCS scores in option chosen					
	Type P		Type Q		No preference	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Condition 10%						
Self-perspective	0.66	0.36	0.17	0.38	0.24	0.75
Others-perspective	0.47	0.42	0.37	0.51	10.22	0
Logical-perspective	0.58	0.39	−0.08	0.35	0.56	0.52
Condition 20%						
Self-perspective	0.35	0.45	0.15	0.58	0.46	0.37
Others-perspective	0.37	0.53	0.36	0.40	−0.22	0.08
Logical-perspective	0.30	0.43	0.40	0.64	0.43	0.50
Condition 30%						
Self-perspective	0.54	0.11	0.77	0.23	0.62	0.11
Others-perspective	0.51	0.58	0.40	0.68	0.58	0.82
Logical-perspective	0.57	0.56	0.39	0.72	0.03	0.61

$N=35$ in each condition.

phenomenon with ratios in which a number greater than one appears in the numerators of both ratios. (4) It presents the ratios in the larger numbers as the probability-advantaged rather than the probability-disadvantaged option, which is opposite to previous research. (5) It examines the relation between RB phenomenon and NCS.

6.1. The RB effect

The findings provided strong evidence for the RB effect and the existence of two independent information processing systems as proposed by CEST. When options have an equal probability, our results are consistent with the previous ones obtained by Denes-Raj et al. (1995), and confirm the statement that the RB phenomenon is a highly general phenomenon. In addition, as reported in previous research (Denes-Raj et al., 1995; Kirkpatrick & Epstein, 1992), the important influence of self vs. others rating is shown: the RB phenomenon was considerably stronger when individuals responded from others-perspective, which is consistent with the postulate in CEST that we have two systems for processing information. According to Denes-Raj et al. (1995), people tend to see themselves as rational people and therefore their responses are in accord with the principles of the rational system. However, at the same time, they detect in themselves the appealing tendency to RB responses, which lead them to think that others, not as rational as themselves, will respond in the RB direction.

As in the previous research (Epstein & Pacini, 2000–2001), when participants responded from a logical perspective, there was an absence of a RB effect. Nevertheless, 63% of participants reported that a logical person would have a preference. This data compares to 28% in the

American college sample in the Epstein and Pacini (2000–2001) study, and 12% in the Spanish college sample in Fernández-Berrocal, Segura, and Ramos (1998) study, suggesting a greater influence of the experiential system on the rational system in the Spanish high school students than in the college students.

In conditions where individuals made a decision between two unequal probability options, many participants made clearly irrational decisions by selecting an option that offered a less favourable objective probability than an alternative option. Denes-Raj and Epstein (1994) obtained evidence of this irrational behavior observing that a substantial number of individuals (23%) selected a 5% over a 10% probability. Our results parallel the Denes-Raj and Epstein ones, and have shown that, from others-perspective, about half of the participants made more extreme nonoptimal responses, such as selecting 10% over 20% probability, and even selecting the nonoptimal choice in spite of having only a third of the chance (10% vs. 30%) of winning. Again, when participants responded from their self-perspective or a logical perspective there was an absence of a RB effect. Nevertheless, 28% of participants in the condition 20%, and 37% in the condition 30% reported that a logical person would have a nonoptimal response. Therefore, our study went beyond previous research providing a new and extreme evidence of the extent to which people, influenced by their experiential system, behave against the prescriptions of their rational system.

6.2. The RB phenomenon and rationality

In Condition 10%, our prediction is fulfilled totally, revealing the existent relationship between nonoptimal response and a low degree of rationality. This same tendency appears in Condition 20% and Condition 30%, although it does not reach enough strength to be statistically significant.

It can be accounted for because of age and educational level of the participants in our study. CEST assume that the relative influence of the rational and experiential systems in the response of the individuals changes with age and/or education: more maturity, and more formation, more dominance of the rational system (Pacini, Muir, & Epstein, 1998). This way, keeping in mind the low age of the participants (high school students), it is possible that their judgements had been more heavily weighted in the experiential than in the rational direction. In consequence, it would be expected that the degree of experiential processing, not the rational processing degree, was related to the RB phenomenon at these maturity and instructional levels. Relationship between nonoptimal response and low rationality scores obtained in our study, although not statistically significant, could be explained by this insufficient influence of rational processing.

Surprisingly, some participants with higher NCS scores chose Type P option in condition 10%. This counter-intuitive choice is interesting evidence of over-compensation for the usual predominant intuitive tendency (Type Q option). Further studies should explore this influence of the experiential system on the rational system.

It may be concluded that the above findings provide new data supporting an interpretation in terms of the principles suggested by CEST about intuitive reasoning. These principles can help us to understand human thinking in everyday life and, specially, the ways in which adolescents make rational and irrational decisions.

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