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What are my chances? An imagery versus discursive processing approach to understanding ratio-bias effects

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ABSTRACT

Ratios are often used to communicate risk. Thus, it is important to understand when and why certain ratios communicate greater risk. Prior research on the ratio-bias effect suggests that people often assume greater risk when ratios use larger than smaller numbers. Yet, support for this effect has been mixed. The present research contributes to this literature by applying a dual-process theory that distinguishes between discursive and imagery-based processing of ratios, thereby offering new insights into the ratio-bias effect and when it occurs. Specifically, when processing discursively (as numbers), the ratio-bias effect should emerge. However, because imagery processing is more holistic, the ratio-bias effect should reverse when imagery processing is encouraged (via graphics or instructions to imagine). The results of six studies support these predictions. In addition to shedding light on how different ways of processing numerical information influences risk judgments and willingness to act, this research has important implications for crafting messages designed to communicate risk.

1. Introduction

Using ratios to convey the risk of low probability events is common. For example, a key finding highlighted in a report on dangerous driving is that three in ten admit to driving after consuming a few alcoholic drinks when driving a short distance (Harris Poll, 2014). Likewise, Mothers Against Drunk Driving (MADD) reports on their website that one in three people will be involved in an alcohol-related crash in their lifetime (National Highway Traffic Safety Administration, 2001). There is theoretical reason to use ratios rather than percentages: ratios often have greater influence, perhaps because they are more likely to elicit affect-laden images compared to percentages (Slovic, Finucane, Peters, & MacGregor, 2004; Slovic, Monahan, & MacGregor, 2000). Yet, there are also theoretical reasons to use more numerous than less numerous ratios: they can convey greater risk (Denes-Raj & Epstein, 1994; Kirkpatrick & Epstein, 1992; Pacini, Muir, & Epstein, 1998; Passerini, Macchi, & Bagassi, 2012; Pinto-Prades, Martinez-Perez, & Abellán-Perpiñán, 2006; Yamagishi, 1997)—a finding called the ratio-bias effect. Applied to the earlier examples, these findings would suggest that the ratios would convey greater risk if the less numerous ratios (3-in-10 and 1-in-3) were replaced with more numerous ratios (30-in-100 and 33-in-100).

Yet, the ratio-bias effect is not always observed (Denes-Raj & Epstein, 1994; Halpern, Blackman, & Salzman, 1989; Kirkpatrick & Epstein, 1992; Pacini & Epstein, 1999a; Price & Matthews, 2009). I propose that whether a ratio-bias effect is observed depends on how people process ratios. Specifically, the focus of this paper is to apply a dual-process model that distinguishes between discursive and imagery-based processing of ratios. I argue that the ratio-bias effect will be observed with discursive processing, because the numbers in a ratio will be processed sequentially from left to right. However, I argue that the ratio-bias effect will reverse with imagery processing, because the numbers in a ratio will be visualized in a holistic and simultaneous manner rather than independently and sequentially, thereby increasing consideration of the denominator. Thus, this research contributes to the literature by providing new insights into when the ratio-bias effect will occur and why. In addition, I test predictions that are unique to this approach and do not follow from prior explanations of the ratio-bias effect.

2. Psychology of ratios

One common method for examining how ratios affect judgments and decision-making is the ratio-bias paradigm. With this paradigm, participants are typically given a choice between two low-probability lotteries with different ratios, such as choosing between options that have a 1-in-10 versus a 10-in-100 chance of winning or losing. Among studies examining losses, the trend has generally been that people choose the option with the less numerous ratio, such as the option that has a 1-in-10 rather than a 10-in-100 chance of losing (Denes-Raj & Epstein, 1994; Kirkpatrick & Epstein, 1992; Pacini & Epstein, 1999a, 1999b; Pacini et al., 1998; Passerini et al., 2012), presumably because

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people feel there is less risk in choosing the option with the less numerous ratio (i.e., there is only 1 chance rather than 10 chances of losing).

This ratio-bias effect has been observed using other paradigms as well. For example, in the medical decision-making literature, risk perceptions increase when mortality rates are represented with more numerous ratios (e.g., out of 10,000 or 1000 vs. 100 people; Pinto-Prades et al., 2006; Yamagishi, 1997). Similarly, people assume there to be greater risk when mortality rates are presented annually (36,500 deaths per year) than daily (100 deaths per day; Bonner & Newell, 2008).

There is a general consensus that the ratio-bias effect occurs because people focus more on the numerator than the denominator of a ratio (e.g., Epstein & Pacini, 1999; Pacini & Epstein, 1999a, 1999b; Price & Matthews, 2009; Reyna & Brainerd, 2008; Stone et al., 2003). However, there are different explanations for why people focus more on the numerator than denominator of numerically presented information. One explanation is that individuals focus mainly on the numerator (the number affected) rather than the denominator (the number at risk) because of confusion due to denominators capturing both those affected and unaffected (Passerini et al., 2012; Reyna & Brainerd, 2008). As a result, people focus on the easier to comprehend numerator (i.e., those affected) at the expense of the denominator.

A second explanation is similar to the first, except that it focuses on visualization—that is, the ease and ability to clearly visualize the numerator versus the denominator. This explanation is based on cognitive-experiential self-theory (CEST), which is a dual-process framework that distinguishes between two processing modes: the rational system and the experiential system. The rational system involves carefully encoding information abstractly as words and numbers, whereas the experiential system involves automatically encoding information in images based on intuition (Epstein, 1991). It is argued that the ratio-bias effect is due to a reliance on the experiential system, which favors numerators over denominators because numerators are (1) easier to visualize because they are smaller in number (Epstein & Pacini, 1999; Pacini & Epstein, 1999a, 1999b; Paivio, 1971), and (2) more concrete because they involve a single number rather than relations between numbers (Epstein & Pacini, 1999). As a result, people focus more on the easier to visualize and more concrete numerator than denominator.

Although the general finding is that more numerous ratios convey greater risk, this finding is not always observed (Denes-Raj & Epstein, 1994; Halpern et al., 1989; Kirkpatrick & Epstein, 1992; Pacini & Epstein, 1999a; Price & Matthews, 2009), leading to speculation that individual differences are operating that cause individuals to focus more on the numerator and/or the denominator (Denes-Raj, Epstein, & Epstein, 1995; Pacini & Epstein, 1999a, 1999b). Consequently, there is a need to better understand when people focus on the numerator and/or the denominator in order to better predict when the ratio bias effect will emerge (Price & Matthews, 2009). I propose that whether the ratio-bias effect emerges depends on how individuals process the ratio: whether they engage in discursive processing or imagery processing of the ratio. Specifically, because imagery processing involves visualizing those affected and unaffected, it should cause individuals to focus more on both the numerator and denominator compared to those not using imagery. These predictions are based on a dual-process model of information processing that distinguishes between discursive and imagery processing (MacInnis & Price, 1987). I theoretically develop these predictions next.

3. Discursive versus imagery processing

Discursive processing is defined as "passing from premises to conclusions; proceeding by reasoning or argument," whereas imagery processing is defined as a process by which "sensory information is represented in working memory" (MacInnis & Price, 1987, p. 473), and is "very like picturing" (Fodor, 1981, p. 76) or forming pictures of a stimulus in the mind's eye (Aylwin, 1990). According to this model, abstract concepts and symbols (such as numbers) should prompt discursive processing. In contrast, imagery processing can be triggered in different ways, such as through the use of pictures, concrete words, as well as instructions to imagine (MacInnis & Price, 1987). Thus, whereas discursive processing involves symbols and abstract language, imagery processing involves mental images. For example, when asked to imagine a ratio, individuals likely form a mental picture of those affected among the unaffected. Furthermore, as with other dual-process models (for a review, see Chaiken & Trope, 1999; Reyna & Brainerd, 2008; Reyna, Nelson, Han, & Dieckmann, 2009), even though both types of processing can occur simultaneously, one is likely to dominate.

Importantly, unlike other dual-process models, such as cognitive-experiential self-theory (CEST; Epstein, 2003; Kirkpatrick & Epstein, 1992), System 1 versus System 2 thinking (e.g., Kahneman, 2003), and fuzzy-trace theory (Reyna & Brainerd, 2008; Reyna et al., 2009), both discursive and imagery processing can involve higher or lower levels of cognitive elaboration (MacInnis & Price, 1987). Specifically, at lower levels of elaboration, messages are processed automatically and heuristically, whereas at higher levels of elaboration, messages are processed carefully and systematically (e.g., Cacioppo & Petty, 1984; Eagly & Chaiken, 1993; MacInnis & Price, 1987; Petty & Wegener, 1999). Although imagery processing has often been considered automatic (i.e., involving little elaboration), it can involve greater elaboration as well (such as with visual problem solving; MacInnis & Price, 1987). I argue that providing information numerically versus encouraging the use of imagery will differentially affect how individuals process ratios (discursively or via imagery) rather than how carefully they process the information (i.e., at higher or lower levels of elaboration). Under typical conditions where there are no constraints on carefully processing ratios, both imagery and discursive processing should involve high elaboration.

Even when processing information carefully, people appear to focus on one number more than the other (Pelham, Sumarta, & Myaskovsky, 1994; Price & Matthews, 2009; Reyna & Brainerd, 2008). For example, as mentioned earlier, people often focus more on the numerator than the denominator. However, if the numerator is made to be more difficult to understand than the denominator (e.g., the denominator is presented numerically, such as 1000 people are exposed to a threat, whereas the numerator is given as a proportion, such as 10% are affected), people focus more on the relatively easier-to-understand denominator (Price & Matthews, 2009).

I propose that whether individuals focus more on the numerator than denominator in a ratio presented numerically as X-in-Y depends on how the information is processed. This is because discursive processing involves processing information in a piecemeal, independent and sequential fashion, whereas imagery processing involves processing information in a more gestalt-like, holistic and simultaneous fashion (Holbrook & Moore, 1981; MacInnis & Price, 1987). Applied to ratios, I predict that when ratios are represented numerically, individuals process the numbers discursively, thereby considering the numbers independently and sequentially. As a result, they focus more on the first number presented in the ratio (often the numerator). This prediction is based on the findings that individuals (1) process numbers from left to right (Hinrichs, Berie, & Mosell, 1982; Poltrock & Schwartz, 1984; Schindler & Kirby, 1997), and (2) often overweight the first number over the second number presented (Epley & Gilovich, 2010; Tversky & Kahneman, 1974). Thus, individuals will likely focus more on the first number presented in the ratio (the numerator) than the second (the denominator), causing them to perceive greater risk (and be more willing to act) when a ratio is presented in larger than smaller numbers. For instance, when the probability is 30%, individuals likely perceive there to be greater risk when the number of people afflicted are thirty than only three (i.e., a 30-in-100 vs. 3-in-10 ratio is given). Thus, if individuals focus more on the first number, then even when the proportion is held constant, ratios should be more effective—that is, increase perceived risk and willingness to act to reduce such risk—when