
7 Heuristics in numerical cognition: implications for pricing

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Abstract

In this chapter we review two distinct streams of literature, the numerical cognition literature and the judgment and decision-making literature, to understand the psychological mechanisms that underlie consumers' responses to prices. The judgment and decision-making literature identifies three heuristics that manifest in many everyday judgments and decisions – anchoring, representativeness and availability. We suggest that these heuristics also influence judgments consumers make concerning the magnitude of prices. We discuss three specific instances of these heuristics: the left-digit anchoring effect, the precision effect, and the ease of computation effect respectively. The left-digit anchoring effect refers to the observation that people tend to incorrectly judge the difference between \$4.00 and \$2.99 to be larger than that between \$4.01 and \$3.00. The precision effect reflects the influence of the representativeness of digit patterns on magnitude judgments. Larger magnitudes are usually rounded and therefore have many zeros, whereas smaller magnitudes are usually expressed as precise numbers; so relying on the representativeness of digit patterns can make people incorrectly judge a price of \$391 534 to be lower than a price of \$390 000. The ease of computation effect shows that magnitude judgments are based not only on the output of a mental computation, but also on its experienced ease or difficulty. Usually it is easier to compare two dissimilar magnitudes than two similar magnitudes; overuse of this heuristic can make people incorrectly judge the difference to be larger for pairs with easier computations (e.g. \$5.00–\$4.00) than for pairs with difficult computations (e.g. \$4.97–\$3.96). These, and the other reviewed results, reveal that price magnitude judgments entail not only deliberative rule-based processes but also instinctive associative processes.

Introduction

The seminal work by Tversky and Kahneman (1974) and Kahneman and Tversky (2000) has identified a set of reasoning heuristics that appear to characterize much of people's everyday judgments and decision-making. Three heuristics, presumably because of their ubiquity, have particularly attracted the attention of researchers – anchoring, availability and representativeness. In this chapter, we review these three heuristics in the context of price cognition. We use the term price cognition as a generic term to refer to the cognitive processes that underlie consumers' judgments concerning the magnitude of a price and their judgments of the magnitude of the difference between two prices. Price magnitude judgment refers to a buyer's subjective assessment of the extent to which an offered price is low or high. Judgments of the magnitude of the difference between two prices are required in many purchase situations; for example, when buyers compare two products, or when they assess the difference between a regular price and sale price of a product on sale.

Price cognition plays a pivotal role in models of consumer behavior postulated in the economics as well as the psychology literature (Monroe, 2003; Winer, 2006). Both streams of literature concur on the following assumption: a buyer's subjective judgment of the magnitude of a price is an important determinant in purchase decisions. However, economists and psychologists differ in the way they characterize the manner in which buyers process the price information. The following two assumptions play a

fundamental, though often implicit, role in traditional models of buyer behavior posited by economists: (i) people are aware of the factors that influence their price cognition; and (ii) biases in judgments are caused by volitional inattention or cognitive miserliness and therefore can be prevented at will. In this chapter, we challenge these assumptions about awareness and intentionality (of biases) in price cognition. We begin by reviewing the numerical cognition literature to characterize the price cognition process. We then review evidence to suggest that price magnitude judgments entail not only deliberative rule-based processes, but also instinctive associative processes often referred to as heuristics. Specifically, in this chapter we discuss how anchoring, availability and representativeness heuristics affect the price cognition process.

Our choice of the ‘heuristics in numerical cognition’ approach to understanding price cognition has been guided by two major considerations. First, we believe an informed characterization of the price cognition process calls for an integration of the numerical cognition literature and the judgment and decision-making literature. Second, the heuristics in the numerical cognition approach could offer a unifying framework to discuss the many seemingly unrelated effects reported in the pricing literature. We explicate each of these considerations in some detail.

First, in order to critically examine the issues of awareness and intentionality in price cognition, we need to examine the two issues in the terms of the underlying representations as well as the processes that operate on these representations.¹ The questions about representations are: what are the different forms in which a multi-digit price is represented in consumers’ minds? Are price magnitude judgments based on analog representations or on symbolic representations? The questions about process are: what processes operate on the different types of representations? Are these processes deliberative and rule-based or instinctive and associative? To answer these questions, we review the numerical cognition literature, and then the judgment and decision-making (JDM) literature. The numerical cognition literature elucidates how numbers are represented in people’s minds, and some of the basic, lower-level processes that operate on these representations. Research on numerical cognition tends to draw inferences from meticulous analyses of response latency patterns measured down to the milliseconds and error rates in sterile² numerical tasks such as binary magnitude judgments and parity judgments. For example, in a typical magnitude judgment task, several numbers are flashed on a computer screen in a random order, and participants have to quickly indicate whether the stimuli are higher or lower than another number, the comparison standard. In a parity judgment task, instead of making magnitude judgments, participants have to indicate whether the stimuli are odd or even. Using such tasks, numerical cognition researchers study how various factors such as magnitude, distance from a comparison standard, and response codes affect participants’ response time and error rates. Several robust and reliable effects have emerged from this stream of research: the distance effect (Moyer and Landauer, 1967), the problem size effect (Ashcraft, 1995), the size congruity effect (Henik and Tzelgov,

¹ See Markman (1999) for a discussion on the distinction between symbolic and analog representations of knowledge, and the implications of this distinction for the processes that operate on these representations.

² We describe them as sterile because it could be argued that many of these tasks are not presented in a practical context and are not representative of everyday judgments.

1982), and the spatial–numerical association effect (also referred to as SNARC; Dehaene et al., 1993), etc. Offering a parsimonious and coherent account for all these effects using the same framework has proved to be a challenge. Competing theoretical models of representations and processing of numerical information continue to strive towards this goal (Dehaene, 1992; McCloskey and Macaruso, 1995).

In contrast, the JDM research tends to be concerned with methods for discerning the nature of everyday judgments and deviations from normative behavior. The JDM literature offers a richer characterization of the cognitive rules that people use in everyday judgments. Research of this nature draws on economics in addition to social and cognitive psychology. Thus the integration of the numerical cognition and the JDM streams of literature, we believe, is not only useful but also necessary for the understanding of the price cognition process.

Second, the heuristics in the numerical cognition approach could serve as a unifying framework for the behavioral pricing literature. To illustrate with an example, research has shown that people's judgments of the magnitude of price differences are anchored on the left-most digits of the prices (Thomas and Morwitz, 2005). People incorrectly judge the difference between 6.00 and 4.95 to be larger than that between 6.05 and 5.00 due to the left-digit anchoring effect. In seemingly unrelated research, it has been shown that incidental prices can affect buyers' valuation of goods and their willingness to pay. Specifically, Nunes and Boatwright (2004) found that the price of a sweatshirt on display at an adjacent seller can influence a shopper's willingness to pay for a music CD. Conceptualizing both these effects as manifestations of a common anchoring heuristic could facilitate the development of some generalizable principles of price cognition.

A caveat is due here. As some readers might have discerned by now, this chapter does not purport to be a comprehensive review of the behavioral pricing literature. Our primary objective is to explore whether focusing on the heuristics used in numerical cognition will bring forth some generalizable principles of price cognition. Further, we hope that this endeavor will contribute to the debate on awareness and intentionality (of biases) in price cognition. In the course of doing this, a review of the numerical cognition literature is necessitated because it provides us with the language (i.e. a typology of processes and representations) to delineate the mechanisms underlying these heuristics. Given this objective, this review will discuss only a few selected research studies in the behavioral pricing area that illustrate the use of anchoring, availability and representativeness in price magnitude judgments and judgments of the magnitude of a price difference. Readers interested in a more comprehensive review of the behavioral pricing literature are referred to Monroe and Lee (1999) for a numerical cognition perspective, Monroe (2003) and Raghubir (2006) for information-processing perspectives, and Winer (2006) for a managerial perspective on behavioral pricing.

Numerical cognition and pricing

An important question that has emerged as a dominant theme in the JDM literature, and of particular relevance to the issue of awareness and intentionality of biases, is whether heuristics are based on quick and associative processes (i.e. system 1) or slow and rule-based processes (i.e. system 2). As discussed by Kahneman and Frederick (2002), the influence of system 1 on judgments is believed to be less deliberate and more automatic than that of system 2. Characterizing the numerical cognition process as an interaction

of slow and rule-based, and fast and associative processes will be helpful in delineating the volitional and unintended elements of the heuristics used in numerical cognition. However, the meaning of ‘quick and associative’ in the context of numerical cognition is not clear. How can some numerical computations be faster and easier than others? Why are people unable to verbalize some aspects of numerical cognition processes? To understand more about associative processes in numerical cognition, we focus on two important findings in the numerical cognition literature in this review: (i) cognitive arithmetic is not always based on online computations; instead it involves associative knowledge structures stored in memory; and (ii) numbers can also be represented as analog magnitudes and processed non-verbally, in much the same manner as other analog stimuli such as light and sound are represented and processed.

Evidence for associative processes in cognitive arithmetic

The area of cognitive psychology that examines the mental representation and the cognitive processes that underlie responses to a math task is referred to as cognitive arithmetic. Although researchers in this area have traditionally focused on the study of addition and multiplication, we believe that in the context of price cognition, since consumers often consider differences in prices of comparable products, subtraction is perhaps the most ubiquitous arithmetic operation. Some of the findings reviewed below were initially studied in the context of addition and multiplication; however, subsequent research has revealed that they are relevant to subtraction (Zbrodoff and Logan, 2005).

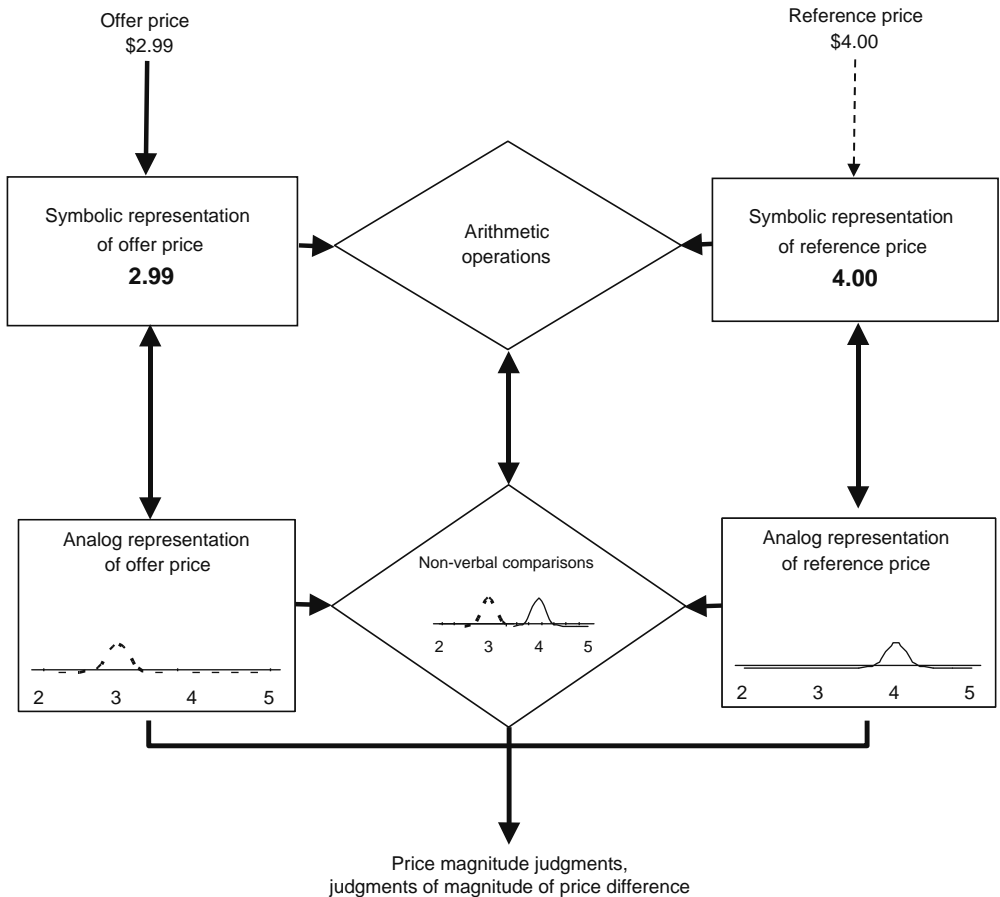
Ashcraft (1995) describes several pieces of evidence to suggest that responses to arithmetic problems are based not only on online computations but also on retrieval from associative knowledge structures. First, it has been shown that some problems can be solved faster than others. Problems that entail smaller numbers (e.g. $2 + 3$) are solved faster than problems that entail larger numbers (e.g. $7 + 9$); problems that include the number 5 are solved faster than problems that do not; and problems with identical operands (e.g. 8×8) are solved faster than other problems (e.g. 8×7). These patterns of response times for mental computations are comparable to the word frequency effects in language; they reflect the frequency with which arithmetic facts are acquired and practiced. Second, as in word recognition, repetition affects arithmetic fact retrieval: it is easier to respond to $7 + 9 = 16$ when it is presented the second time. Third, there is evidence for unintended interference in mental calculations by automatic activation of irrelevant arithmetic facts. For example, in a verification task, participants are less likely to respond ‘false’ to problems such as $3 + 4 = 12$ and $3 \times 4 = 7$ because the incorrect solutions to these problems are correct solutions to similar problems stored in the memory. This and other evidence reviewed by Ashcraft (1995) lead to an important conclusion about mental arithmetic: solutions to arithmetic problems are not always computed online; instead, mental arithmetic is based on associative knowledge structures in the memory.

The representation of arithmetic facts as associative knowledge structures has implications for price cognition processes. The spontaneous activation of arithmetic facts could influence consumers’ judgments. For example, while computing the difference between \$4.00 and \$2.99, the left-digit difference ($4 - 2 = 2$) might spontaneously ‘pop up’ in the consumer’s mind and might serve as an unintended anchor in numerical judgments. Such left-digit anchoring could cause consumers to incorrectly judge the difference between \$4.00 and \$2.99 to be larger than that between \$4.01 and \$3.00. Further, the spontaneous

activation of arithmetic facts makes some mental problems easier than others. For example, consumers will be able to assess the price difference between \$500 and \$400 much faster than that between \$497 and \$394. As we discuss later in this chapter, this ease by itself could influence consumers' price magnitude judgments.

Evidence for non-verbal processing of numbers

The arithmetic tasks discussed in the preceding section assume symbolic representations of numbers; the strings of digits in a multi-digit number are assumed to be represented in the working/long-term memory, preserving the syntactic structure of tens and units. However, magnitude judgments might not always entail such symbolic representations; instead they are assumed to entail analog representations. Analog representations refer to non-symbolic magnitude representations of the numbers on a subjective 'small-large'



Note: Price cognition is postulated to entail symbolic and analog representations. The arithmetic processes that operate on symbolic representations could be deliberative and rule-based or instinctive and associative. The non-verbal processes that operate on analog representations are likely to be instinctive and associative.

Figure 7.1 Putative processes in price cognition

mental number line (see Figure 7.1). In this section, we discuss the relevance of analog representations for price cognition.

When asked why she did not buy her usual brand of laundry detergent this week, a consumer might respond that her decision was based on the size of the difference between this week's price and the previous week's price. Such a response might mislead an observer to conclude that the numerical cognition process that led to this response might have entailed a symbolic comparison of two weekly prices: this week's price \$4.49 minus the previous week's price \$3.99 = 50 cents. While such a response could indeed be based on mental subtraction of symbolic representations, it is also possible that the response might have been based on the analog representations, in much the same way as she would judge the difference in hues of a light and a dark color, or the difference in the luminosity of a 30 watt bulb and a 60 watt bulb. Analog representations refer to semantic magnitude representations of the numbers on a subjective mental scale. Such analog representations are assumed to be similar to the representations of psychophysical stimuli such as light, sound, size etc. Dehaene (1992, p. 20) suggests that many of our daily numerical cognition tasks are based on analog judgments: 'tasks such as measurement, comparison of prices, or approximate calculations, solicit an approximate mode in which we access and manipulate a mental model of approximate quantities similar to a mental number line'.

Several pieces of evidence support the notion that numerical cognition entails analog representations. The most frequently cited evidence for the use of analog representations is the distance effect. In a typical distance effect experiment (e.g. Moyer and Landauer, 1967), pairs of digits such as 7 and 9 are flashed on the screen, and participants are asked to identify the higher digit by pressing one of two keys. The main finding from this experiment is that when the two digits stand for very different analog quantities such as 2 and 9, subjects respond quickly and accurately. But their response time slows down by more than 100 milliseconds when the two digits are numerically closer, such as 7 and 9. The distance effect has been interpreted by many cognitive psychologists as evidence for the proposition that magnitude judgments entail an internal analog scale. Dehaene suggests (p. 74):

the brain does not stop at recognizing digit shapes. It rapidly recognizes that at the level of their quantitative meaning, digit 4 is indeed closer to 5 than 1 is. An analogical representation of the quantitative properties of Arabic numerals, which preserve the proximity relations between them, is hidden somewhere in the cerebral sulci and gyri. Whenever we see a digit, its quantitative representation is immediately retrieved and leads to greater confusion over nearby numbers.

The distance effect manifests even when the comparison standard is not shown on the screen. For example, Dehaene et al. (1990) flashed randomly selected numbers between 31 and 99 on the screen, one at a time, and asked participants to judge whether the shown number was lower or higher than 65. That the distance effect has been shown to occur with all sorts of psychophysical stimuli such as light, sound, size etc. suggests that numbers also can be processed as psychophysical stimuli.

Additional support for the existence of analog representations of numbers comes from the fact that numerical cognition is non-verbal: it does not require linguistic capabilities. Infants and animals can also comprehend magnitude information. Based on the differences in the time that infants take to look at displays with different numbers of dots, Starkey and Cooper (1980) suggest that four- to seven-month-old infants can discriminate

between quantities of two and three. Similar results were presented by Lipton and Spelke (2003). Gallistel and Gelman (2005) found that the distance effect manifests in animals. This observation, once again, implies that linguistic ability is not necessary for representing the magnitude information. Based on such findings, Gallistel and Gelman (2005, p. 559) suggest that the human ability to think mathematically might draw on a primitive, non-verbal system: 'the verbal expression of number and of arithmetic thinking is based on a non-verbal system for estimating and reasoning about discrete and continuous quantity, which we share with many non-verbal animals'.

Researchers have also found evidence for the association of spatial orientation and numerical information. Several studies have shown that people's spatial orientation affects their ability to make magnitude judgments, a result known as the SNARC (spatial-numerical association of response codes) effect. Dehaene et al. (1993) showed participants in their experiment numbers between 0 and 9, one at a time, on a computer screen and asked them to judge whether the shown number is odd or even (i.e. parity). The assignment of the 'odd' and 'even' responses to response keys was varied within subjects such that for each number, participants responded using the left key in one half of the experiment and the right key in the other half. Results showed that, regardless of the parity, larger numbers yielded faster responses with the right hand than with the left, and the reverse was true for smaller numbers. The large-right and small-left associations are consistent with the notion that numbers are represented non-verbally. These spatial magnitude associations suggest that numbers activate semantic magnitude representations on a horizontal number line that extends from left to right, with smaller numbers on its left and larger numbers on its right.

The representation of numbers as analog representations raises new challenges as well as opportunities for theories of price cognition. An inevitable question that surfaces from this discussion is: when are prices likely to be represented and processed as analog representations or as symbolic representations? There is some evidence to suggest that price magnitude judgments are influenced by both analog and symbolic representations. Left-digit anchoring could be considered a signature of symbolic processing. If consumers were to ignore the numerical symbols and focus only on the underlying magnitudes, then they should perceive the difference between \$4.00 and \$2.99 to be the same as that between \$4.01 and \$3.00. The abundant evidence for left-digit anchoring (Schindler and Kirby, 1997; Stiving and Winer, 1997; Thomas and Morwitz, 2005) suggests that price cognition does entail symbolic processing. However, some studies have also found evidence for the distance effect in price magnitude judgments (Thomas and Morwitz, 2005, experiment 3; but see Viswanathan and Narayan, 1994), which is a signature of analog processing. Further, Thomas and Menon (2007) found that phenomenological experiences can affect consumers' price magnitude judgments even when the articulated price expectation remains unchanged. They interpreted this evidence as suggesting that while price magnitude judgments entail analog representations of reference prices, articulated price expectations draw on symbolic representations of prices in memory. Such a distinction between analog and symbolic representations of prices offers a promising framework to address a long-standing conundrum in the pricing literature: consumers are not very good at recalling the past prices of products (Dickson and Sawyer, 1990; Gabor, 1988; Urbany and Dickson, 1991), yet their brand choices are very sensitive to small changes in prices relative to past prices (Kalyanaram and Winer, 1995; Winer, 1988; also see Monroe and Lee, 1999). Exploring the dissociation between analog and symbolic representations

of price knowledge, understanding when one representation is likely to be more influential than the other, and examining how these two distinct types of price knowledge interact with each other could be promising avenues for future research.

A putative model of price cognition

The literature reviewed in the preceding paragraphs suggests that price magnitude judgments might be based on symbolic representations, analog representations, or on a combination of the two (see Figure 7.1). The processes that operate on these representations can be grouped into two distinct families: they can either be deliberative and rule-based or instinctive and associative. The non-verbal processes that operate on analog representations are likely to be instinctive and associative. For example, although we can easily identify the more luminous bulb when presented with two lighted bulbs of differing luminosities, it is difficult to explain how we made the judgment. In a similar vein, when people judge the magnitudes of two numbers using analog representations, they are likely to be aware of the final judgment without knowing how they arrived at it. However, the arithmetic processes that operate on symbolic representations could either be deliberative and rule-based or instinctive and associative. Specifically, they are likely to be deliberative and rule-based when people have to do online computations to respond to an arithmetic problem, but they are likely to be instinctive and associative when the response can be retrieved from associative knowledge structures in the long-term memory. People might have introspective access to the deliberative and rule-based cognitive processes, and therefore might be able to report the cognitive strategies used in such processes.

Figure 7.1 adapts Dehaene's (1992; also discussed in McCloskey and Macaruso, 1995) framework of numerical comparison to represent the putative processes in price magnitude judgments. These processes are best illustrated by an example. Consider a consumer who is evaluating a stimulus price, \$2.99. Numerical judgments usually involve comparisons with a reference point (Thomas and Menon, 2007; Winer, 1988). The broken line connecting the reference price to its internal representation indicates that it could either be retrieved from memory (an internal reference price), or it could be the most relevant comparison standard at the point of sale (an external reference price). During the encoding stage, the numerical symbols are transcoded to an analog representation in consumers' working memory. As discussed in the preceding paragraphs, the three digits in the numerical stimulus (2, 9 and 9) could be represented holistically as a discriminial dispersion on the psychological continuum used to represent magnitudes (see Figure 7.1). Also activated on the mental number line is the analog representation of the comparison standard associated with the stimulus product. The final response toward the stimulus price could be based on arithmetic operations on the symbolic representations, non-verbal comparisons of analog representations, or on a combination of these processes.

Heuristics in price cognition

Having characterized the representations and processes that underlie the price cognition process, we now review some of the heuristics used in price magnitude judgments and judgments of the magnitudes of price differences. Specifically, we focus on three heuristics: anchoring, representativeness and availability.

Anchoring in price cognition

The anchoring effect, which was first demonstrated in the context of numeric estimates, refers to the influence of uninformative or irrelevant numbers in numerical cognition. In their classic study, Tversky and Kahneman (1974) asked participants to estimate the percentage of African nations in the UN. Before they indicated their response, participants were first asked to indicate whether their estimate was higher or lower than a random number between 0 percent and 100 percent generated by spinning a wheel of fortune. These arbitrary numbers had a significant effect on participants' estimates. For example, participants who were first asked 'Was it more or less than 45 percent?' guessed lower values than those who had been asked if it was more or less than 65 percent. Since the publication of these results, several studies have documented the effect of anchoring in the context of price cognition (Adaval and Monroe, 2002; Bolton et al., 2003; Morwitz et al., 1998; Chapman and Johnson, 1999; Mussweiler and Englich, 2003; Northcraft and Neale, 1987; Raghurir and Srivastava, 2002; Schkade and Johnson, 1989; Thomas and Morwitz, 2005).

Mussweiler and Englich (2003) found that anchoring effects are more likely when people use an unfamiliar currency than a familiar currency. The introduction of the euro as a new currency in Germany offered them a natural setting to test the moderating role of currency familiarity in anchoring effects. Participants in their experiment were asked to estimate the price of a mid-sized car, immediately before and about half a year after the introduction of the euro. The researchers found that immediately before the introduction of the euro, the anchoring bias was more likely to manifest when German participants made price estimates in euros than in German marks. However, six months after the introduction of the euro, this pattern was completely reversed: euro estimates were less biased than mark estimates. Similar results were reported by Raghurir and Srivastava (2002). In a series of experimental studies, they found that people's valuation of a product in an unfamiliar foreign currency is anchored on its face value, with inadequate adjustment for the exchange rate. As a consequence, an American consumer is likely to underspend in Malaysia (because 1 US dollar = 4 Malaysian ringgits) and overspend in Bahrain (because 1 US dollar = 0.4 Bahraini dinar). As in Mussweiler and Englich's research, familiarity with the foreign currency was found to be a moderator of the face value anchoring effect. Morwitz et al. (1998) demonstrated anchoring effects in the context of partitioned prices. They found that charging the shipping and handling fee as a separate component from the catalog price reduced recall of total cost because of the propensity to anchor on the base price. In another experiment, Morwitz et al. (1998) found that auction bidders agreed to pay more in total cost in an auction when a 15 percent buyer's premium was charged separately than in one in which there was no buyer's premium. The anchoring effect observed in partitioned pricing has subsequently been replicated and extended in several studies (e.g. Bertini and Wathieu, 2008; Chakravarti et al., 2002).

Although these studies demonstrate the pervasiveness of the anchoring heuristic in price cognition, it is not clear whether the observed anchoring effects are the results of volitional cognitive strategies, or a consequence of the associative and non-verbal processes in price cognition. Some studies have explicitly addressed the issue of awareness and intentionality in anchoring.

Unaware anchoring Northcraft and Neale (1987) examined the effect of the anchoring heuristic in price estimates in an information-rich, real-world setting. They asked

students and real-estate agents to tour a house and appraise it. Their results revealed that not only the students' but also the real-estate agents' price estimates were anchored on the list price of the house. It could be argued that the use of an anchoring strategy in this example is not completely unwarranted. Since list prices are usually correlated with the real-estate value, participants in this experiment might have considered list price as relevant information. However, analysis of the decision processes based on participants' verbal protocols revealed that the real-estate agents seemed to be unaware of the anchoring effect of the list price: a majority of them flatly denied that they considered the list price while appraising the property.

Unintentional anchoring The proposition that anchoring might be occurring unintentionally is supported by the finding that completely irrelevant anchors can also affect people's price estimates and magnitude judgments. Nunes and Boatwright (2004) suggest that incidental prices (i.e. prices advertised, offered or paid for unrelated goods that neither sellers nor buyers regard as relevant to the price of an item that they are engaged in buying) can affect buyers' valuation of goods and their willingness to pay. They find that the price of a sweatshirt on display at an adjacent seller can influence a shopper's willingness to pay for a music CD. Adaval and Monroe (2002) show that even subliminally primed numbers can affect consumers' price magnitude judgments. The researchers demonstrate that exposing subjects to high numbers below the consumer's threshold of perception can make the price of a product seen later seem less expensive. This effect manifests even when the subliminal information is completely irrelevant (e.g. weight in grams) to the price judgment task. Their results suggest that numerical information is translated into a magnitude representation regardless of the associated attribute dimension (e.g. grams or dollars).

Another example of unintentional anchoring in price cognition is the left-digit effect in judgments of the magnitude of price differences. Research has revealed that the propensity to read from left to right leads to anchoring in judgments of the magnitude of the numerical difference. Thomas and Morwitz (2005) demonstrated that using a 9-ending price can affect judgments of the magnitude of the difference between two prices when the use of such an ending leads to a change in the left-most digit (e.g. \$3.00 versus \$2.99), but has no effect on the perceived magnitude when the left-most digit remains unchanged (e.g. \$3.50 versus \$3.49). More recently, these researchers found that participants in an experiment judged the numerical difference to be larger when the left-digit difference is larger (e.g. 6.00 minus 4.95) than when the left-digit difference is smaller (e.g. 6.05 minus 5.00), even though the holistic differences are identical across the pairs. Evidence for the left-digit effect has also come from analyses of scanner panel data (Stiving and Winer, 1997) and a survey of retailers' pricing practices (Schindler and Kirby, 1997).

Cognitive miserliness or numeric priming? Economists and like-minded marketing researchers have suggested that such left-digit anchoring in judgments is on account of volitional cognitive miserliness. This stream of literature suggests that the left-digit effect occurs because consumers volitionally ignore the right digits. Characterizing a model of rational consumer behavior, Basu (2006, p. 125) suggested that consumers do not ignore the right digits 'reflexively or out of irrationality, but only when they expect the time cost of acquiring full cognizance of the exact price to exceed the expected loss caused by the

slightly erroneous amount that is likely to be purchased or the slightly higher price that may be paid by virtue of ignoring the information concerning the last digits of prices'. In a similar vein, Stiving and Winer (1997, p. 65) suggest that consumers ignore the pennies digits in a price because they might be 'trading off the low likelihood of making a mistake against the cost of mentally processing the pennies digits'.

However, the price cognition model described earlier in this review suggests that the left-digit effect can manifest even when consumers diligently compute holistic numerical differences. Mental subtraction of multi-digit numbers proceeds from left to right, and entails several intermediate steps. One such step is the retrieval/computation of the difference between left-most digits as an initial anchor. For example, when a consumer tries to compute the holistic difference between \$6.00 and \$4.95, the difference between the left-most digits 6 and 4 might 'pop up' in her mind. Thus the left-digit difference is activated in the consumer's working memory as an intermediate step. Even when the consumer corrects this intermediate output for the right digits, the activation of this left-digit difference in working memory can unobtrusively prime the consumer's judgments. Thus the subjective numerical judgment is affected not only by the final corrected output (i.e. 1.05) but is also contaminated by the initial anchor (i.e. 2) generated during the mental subtraction process. This example illustrates the divergence in the predictions from the traditional economic models based on assumptions of deliberative and controlled thinking, and the price cognition model characterized by associative and non-verbal processes.

In conclusion, the evidence reviewed in this section supports the proposition that consumers' responses to prices are often influenced by irrelevant anchors. Further, in many instances, this influence seems to be occurring unintentionally and without consumers' awareness.

Representativeness heuristic in price cognition

According to Gilovich and Savitsky (2002, p. 618), the representativeness heuristic refers to the 'reflexive tendency to assess the fit or similarity of objects and events along salient dimensions and to organize them on the basis of one overarching rule: Like goes with like.' The classic engineer-lawyer study, discussed by Tversky and Kahneman (1974), offers an excellent illustration of the use of representativeness heuristic in everyday judgments. Participants in their experiment were provided with the non-diagnostic descriptions of several individuals, such as:

Dick is a 30 year old man. He is married with no children. A man of high ability and high motivation, he promises to be quite successful in his field. He is well liked by his colleagues.

Further, the participants were informed that the described individuals were sampled at random from a group of 100 professionals – engineers and lawyers. Half the participants were told that this group consisted of 70 engineers and 30 lawyers, while the other half were told that the group comprised 30 engineers and 70 lawyers. Tversky and Kahneman (1974) found, as they predicted, that the base rate manipulation had little effect on participants' judgment of the probability of Dick being an engineer. The results suggest that participants in the experiment might have judged the probability based on the degree to which the description was representative of the two stereotypes, without considering the base rates for the two categories.

Although in this experiment participants relied only on the representativeness heuristic and ignored rule-based reasoning, as Kahneman and Frederick (2002) suggest, this may not always be the case. In many instances, rule-based reasoning and heuristic thinking can co-occur.³ In our view, it is almost impossible to ignore rule-based thinking while evaluating numeric information such as price. The effects of representativeness-based thinking are likely to surreptitiously influence judgments as consumers engage in systematic rule-based evaluation of prices, so their final magnitude judgments are likely to be jointly influenced by rule-based and representativeness-based thinking.

Representativeness of font size Although the use of the representativeness heuristic has not been specifically implicated in price cognition, some published results could be reinterpreted as evidence for the use of representativeness. In our view, the size congruity effect reported by Coulter and Coulter (2005) is a good example of the influence of the representativeness heuristic in price cognition. Coulter and Coulter's (2005) results indicate that price magnitude judgments are not only influenced by the magnitude of the price but also by the physical size of the symbolic representation. The researchers predicted that consumers are likely to perceive an offered price to be lower when the price is represented in smaller than in larger font. To test this hypothesis, they presented participants with an advertisement for a fictitious brand of an in-line skate sold on sale; in addition to the usual product details, the advertisement also displayed the regular (\$239.99) and the sale prices (\$199.99) for the product. For half the participants, the font used for the sale price was smaller than that used for the regular price (\$239.99 versus \$199.99). For the other half, the font used for the sale price was larger (\$239.99 versus \$199.99). The results revealed that participants' evaluations of the sale price magnitude and their purchase intentions were influenced by this font manipulation. Participants judged the sale price magnitude to be lower when the font size for the sale price was smaller. Interestingly, participants' self-reports of their decision-making processes revealed that the effect occurred nonconsciously: they could not recall details of the font size manipulation, and a majority reported that font size did not influence their judgments at all. These results suggest that participants might have nonconsciously inferred smaller font size to be representative of lower price magnitudes.

Representativeness of digit patterns Consumers might also rely on representativeness of digit patterns to make magnitude judgments. Thomas et al. (2007) examine whether precision or roundedness of prices affects consumers' magnitude judgments. They found that consumers incorrectly perceive precise prices (\$395 425) to be lower than round prices (e.g. \$395 000) of similar magnitude. Previous research on the distribution of numbers has shown that all numbers do not occur with uniform frequency in printed or spoken communication. Dehaene and Mehler (1992) analyzed the frequency of number words in word frequency tables for English, Catalan, Dutch, French, Japanese, Kannada and Spanish languages. They found an overrepresentation of small, precise numbers (e.g. 1, 2, 3, . . . , 8 and 9) and large numbers rounded to the nearest multiple of 10 (e.g. 10, 20, . . . , 100, 110). Stated differently, precise large numbers (e.g. 101, 102, 103, . . . , 1011, 1121)

³ See Gilbert (1999) for a discussion on consolidative and competitive models of dual process systems.

are used relatively infrequently in our daily communication. This finding was replicated in studies on the patterns of number usage in the World Wide Web and in newspapers. Given this evidence of greater prevalence of precision in smaller numbers and roundedness in larger numbers, Thomas et al. (2007) hypothesized that the representativeness of digit patterns might influence judgments of magnitude. Specifically, drawing on previous research on the distribution of numbers and on the role of representativeness in everyday judgments, they suggest that people nonconsciously learn to associate precise prices with smaller magnitudes. They tested this hypothesized precision heuristic in a laboratory experiment. Participants in their experiment were asked to evaluate 12 different list prices of a house listed for sale in a neighboring city. Six of these prices were precise and the other six round. Participants were randomly assigned to two groups and each group evaluated six of the 12 prices, one at a time, in a random order on computer screens. Specifically, one of the groups evaluated the prices \$390 000, \$395 000, \$400 000, \$501 298, \$505 425 and \$511 534, while the other group evaluated \$391 534, \$395 425, \$401 298, \$500 000, \$505 000 and \$510 000. Consistent with their prediction, the researchers found that participants, systematically but incorrectly, judged the magnitudes of the precise prices to be significantly smaller than the round prices. This result suggests that magnitude judgments are influenced by the representativeness of digit patterns: precise digit patterns are considered to be representative of smaller magnitudes.

In conclusion, the evidence reviewed in this section suggests that price magnitude judgments can be influenced by representativeness-based thinking. The research we reviewed suggests a reflexive tendency in consumers to assess the magnitude of a price based on irrelevant factors such as font size and digit patterns. Given the obvious irrelevance of these factors, it is unlikely that consumers might be relying on these factors intentionally. It seems reasonable to assume that representativeness-based thinking might be influencing price magnitude judgments unintentionally and without consumers' awareness.

Availability heuristic in price cognition

People rely on the ease or the fluency with which information is processed to make judgments, a decision rule referred to as the availability heuristic. To demonstrate the role of the availability heuristic in judgments, Tversky and Kahneman (1974) asked participants whether it is more likely that a word begins with *r* or that *r* is the third letter in a word. Because words that begin with *r* come to mind faster than words with *r* as the third letter, participants overestimated the number of words that begin with *r*, and underestimated the words that have *r* as the third letter. Note that this effect in judgments could have occurred through two distinct mechanisms: (i) participants might have experienced a feeling of ease while retrieving words that begins with *r*, and might have made inferences based on this experiential information; or (ii) they might have been able to recall more words that start with *r*. In the former case, the judgment would be based on experiential information, while in the latter case it would be based on declarative information. Subsequent research (see Schwarz et al., 1991) revealed that experiential information by itself can influence judgments: the perceived ease or difficulty of information-processing influences judgments even when the declarative information is inconsistent with the experiential information.

Meanwhile, independent of this stream of research in judgment and decision-making, social and cognitive psychologists have discovered that fluency or ease of processing has

remarkable effects on preferences (Zajonc, 1980) and implicit memory (Jacoby et al., 1989). More recent research has identified that different types of fluency – conceptual and perceptual – have distinct effects on judgments (Whittlesea, 1993). These findings have had a substantive impact on research on consumer behavior: researchers have demonstrated that information processing fluency can influence judgments on a range of evaluative dimensions. However, although researchers examining consumer behavior have found that processing fluency can affect evaluations of products (e.g. Janiszewski, 1993; Lee and Labroo, 2004; Menon and Raghurir, 2003), it could be argued that not much work has been done to explore the consequences of processing fluency in the domain of pricing. In this review, we discuss some fluency effects that could be relevant to the understanding of price cognition process. Specifically, we discuss the effects of fluency on willingness to pay (Alter and Oppenheimer, 2006; Mishra et al., 2006) and on judgments of the magnitude of numerical differences (Thomas and Morwitz, forthcoming).

Fluency and willingness to pay Alter and Oppenheimer (2006) suggest that information-processing fluency can affect the price that investors and traders are willing to pay for shares listed on the stock market. They found empirical support for their suggestion in laboratory studies as well in real-world stock market data. In a laboratory experiment, they asked one group of participants to rate a list of fabricated stocks on the ease of pronunciation, as a proxy for fluency. A second group of participants estimated the future performance of the fabricated stocks. As predicted, participants expected more fluently named stocks to outperform the less fluently named stocks. For example, participants predicted that shares of the firm named Yoalumnix (a less fluent name) will depreciate by 11 percent while the shares of Barnings (a fluent name) will appreciate by 12 percent. In a subsequent study, the researchers found similar effects in real-world stock market data: actual performance of shares with easily pronounceable ticker codes were better than those of shares with unpronounceable ticker codes in the short run.

Mishra et al. (2006) suggest that fluency can also influence people's preference for certain denominations of money. Their findings suggest that consumers find processing money in smaller denominations (e.g. five \$20 bills) less fluent than processing money in larger denominations (e.g. one \$100 bill). The hedonic marking created by such fluency experiences results in a lower inclination to spend money when it is in larger denominations. Together, these studies suggest that fluency experiences can, in a variety of ways, affect buyers' valuations and willingness to pay for goods.

The ease of computation effect Thomas and Morwitz (forthcoming) suggest that the feelings of ease or difficulty induced by the complexity of arithmetic computations systematically affect people's judgments of numerical differences. Usually, the closer the representations of two stimuli on the internal analog scale, the greater the processing difficulty. It is easier to discriminate between two bulbs of 30 and 120 watts of power than to discriminate between bulbs of 70 and 80 watts of power. Likewise, it is more difficult to discriminate between two weights or two sound pitches that are similar to each other than two that are relatively far apart. However, overuse of this ease of processing heuristic can lead to biases in judgments of numerical differences. When presented with two pairs of prices with similar magnitudes of arithmetic difference, participants in Thomas and Morwitz's experiments incorrectly judged the difference to be smaller for pairs with

difficult computations (e.g. 4.97–3.96; arithmetic difference 1.01) than for pairs with easy computations (e.g. 5.00–4.00; arithmetic difference 1.00). They show that this ease of computation effect can influence judgments of price differences in several contexts. Ease of computation can influence the perceived price difference between competing products, and can also affect the perceived magnitude of a discount (i.e. the difference between regular and sale prices). Interestingly, they observed that the ease of computation effect is mitigated when participants are made aware that their experiences of ease or difficulty are caused by computational complexity. This finding suggests that the ease of computation effect is unlikely to be due to hedonic marking, and might be due to the nonconscious misattribution of metacognitive experiences.

In conclusion, the evidence we have reviewed suggests that consumers' willingness to pay and judgments of price differences could be influenced by the ease of information-processing. Ease of information-processing can be influenced by several incidental factors such as how easy or difficult it is to pronounce the name of the product, or whether money is held in small or large denominations. The ease of computation effect in judgments of numerical differences reveals that the fluency of information-processing not only influenced affective responses to stimuli, but also influenced cognitive judgments. The empirical regularities we have reviewed are quite counterintuitive. Clearly, no buyer will knowingly invest in a company on the basis of the fluency of its name, or be less willing to spend because of the denominations of wealth. Similarly, people will not knowingly judge that the difference between 4.97 and 3.96 is smaller than that between 5.00 and 4.00. The glaring normative inappropriateness of these judgments suggests that people might be unaware of these fluency effects in their price cognition, and therefore these effects might be occurring unintentionally.

Conclusion

Our objective in this chapter was to examine the psychological mechanisms that underlie the price cognition process. We chose to organize this review around the issues of awareness and intentionality in price cognition. The choice of these issues as the focal theme should not be interpreted as suggesting that all of price cognition occurs without awareness or intention. Demonstrating that the price cognition process is susceptible to unaware and unintended influences is one way to persuade a circumspect reader that price evaluations are not always based on economically valid rule-based reasoning, as portrayed in several models of consumer behavior.

We reviewed two distinct sets of literature to marshal evidence for our proposition that price cognition might entail processes that are not available to introspective analyses. The numerical cognition literature suggests that mental arithmetic relies not only on online computations, but also on activation of patterns of associations stored in the memory. Further, this literature also offers evidence for the existence of a non-verbal numerical cognition system: we can make numerical judgments based on analog representations in much the same way that we judge psychophysical stimuli such as light and sound. Then, drawing on the judgment and decision-making literature, we characterized the heuristics that people use to make price estimates, price magnitude judgments, and judgments of the magnitude of price differences. We showed that people rely on anchoring, availability and representativeness in price cognition, much as they do for other everyday judgments. Relying on the anchoring heuristic makes people incorrectly judge the difference between

6.01 and 5.00 to be smaller than that between 6.00 and 4.99; relying on the representativeness heuristic makes people incorrectly judge \$391 534 to be lower than \$390 000; relying on the availability heuristic makes people incorrectly judge the difference between 4.97 and 3.96 to be smaller than that between 5.00 and 4.00.

A circumspect reader could argue that the behavioral pricing effects reviewed in this chapter are anomalous deviations that do not represent the usual price cognition processes. Indeed, as we suggested earlier, we do not consider rule-based reasoning and heuristic evaluations of prices as mutually exclusive processes; heuristic processes can co-occur, and sometimes interact, with rule-based thinking. Further, we also acknowledge that rule-based reasoning could account for much of the variance in consumers' responses to prices. However, we believe that delineating the representations and processes that underlie consumers' responses to prices will have substantive and theoretic implications. First, this stream of research can lead to a sound theoretical basis for formulating a price digit policy. The findings in this stream of research highlight that pricing decisions entail more than just deciding the magnitude of the optimal price; managers also have to decide what type of digits to use for the optimal price magnitude. For example, if consumer research and strategic analysis reveals that the optimal price magnitude for a product is \$4.50, then the manager is left with the task of deciding whether the final price should have a 9-ending (i.e. \$4.49) or whether it should have precise digits (e.g. \$4.53) or some other pattern of digits (e.g. \$4.44). There is empirical evidence that such decisions can have a significant impact on sales and profits (Anderson and Simester, 2003; Schindler and Kibarian, 1996; Stiving and Winer, 1997). Second, understanding how prices are represented and processed can address the conundrum of how consumers seem to 'know' the prices without being able to recall them (Dickson and Sawyer, 1990; Monroe and Lee, 1999). Finally, this stream of research also promises to augment the pricing literature by providing a unifying framework to discuss the many seemingly unrelated effects reported in the literature.

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