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The Price Precision Effect: Evidence from Laboratory and Market Data

Manoj Thomas
Johnson Graduate School of Management, Cornell University, Ithaca, New York 14853,
mkt27@cornell.edu

Daniel H. Simon
Applied Economics and Management, Cornell University, Ithaca, New York 14853,
dhs29@cornell.edu

Vrinda Kadiyali
Johnson Graduate School of Management, Cornell University, Ithaca, New York 14853,
kadiyali@cornell.edu

We examine two questions: Does the roundness or precision of prices bias magnitude judgments? If so, do these biased judgments affect buyer behavior? Results from five studies suggest that buyers underestimate the magnitudes of precise prices. We term this the precision effect. The first three studies are laboratory experiments designed to test the existence of the precision effect and examine the underlying psychological processes. In Study 1, we find that precise prices are judged to be smaller than round prices of similar magnitudes. For example, participants in this experiment incorrectly judged \$395,425 to be smaller than \$395,000. In Study 2, we show that precision is more likely to affect magnitude judgments under conditions of uncertainty. Study 3 demonstrates that manipulating prior experience with the pattern of roundness and precision in numbers can moderate the precision effect. Studies 4 and 5 examine whether the precision effect influences buyers' willingness to pay for negotiated purchases (e.g., houses). In Study 4, we conduct an experiment on a nationally representative sample of homeowners to demonstrate that participants are willing to pay more for houses when the sellers use precise (e.g., \$364,578) instead of comparable round (e.g., \$365,000) prices. In Study 5, we analyze data from residential real estate transactions in two separate markets and find that buyers pay higher sale prices when list prices are more precise. These empirical results enrich our understanding of the psychological processes that underlie price magnitude judgments and have substantive implications for buyer and seller behavior.

Key words: behavioral pricing; numerical cognition; roundness; precision; heuristics; biases
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1. Introduction

Streams of literature in consumer psychology and economics share a prevailing view that a buyer's judgment of the magnitude of the price is an important determinant of her purchase decision (Monroe 2003, Winer 2006). Research on how people judge the magnitudes of prices (e.g., Morwitz et al. 1998, Wathieu and Bertini 2007) and numbers (e.g., Krishna 2008) has not only enriched our knowledge of pricing but has also contributed to theories of buyer behavior. Given the centrality of perceived price magnitude in buyers' decision making, we examine a ubiquitous, yet hitherto unexplored, aspect of price magnitude judgments: Do consumers perceive round prices to be higher or lower than precise prices? If so, what impact does this have on consumer behavior?

Consider the following illustrative example. A seller of a house can list the house for a round price such as \$365,000 or \$364,000, or a more precise price such as \$364,578.[1] How does the precision of the price affect buyers' evaluation of the list price and their willingness to pay (WTP)? Understanding how precision affects buyers' evaluations of prices not only has substantive implications for buyer and seller behavior, but it also offers new insights into the psychological mechanisms that underlie buyers' responses to prices.

In this article we postulate two effects of precise prices: First, under conditions of uncertainty, buyers will judge the magnitude of a more precise price (e.g., \$364,578) to be lower than the magnitude of a comparable, but more round price (e.g., \$364,000). Second,

[1] Our definition of precision is based on the number of consecutive zeroes at the end of a price. Relative to a round price, a precise price will have fewer ending zeroes. In §7 we discuss several operationalizations of this definition.

this bias in magnitude judgment leads them to negotiate less and to accept a sale price that is closer to the list price. In the following sections, we first present a conceptual framework to describe how precision in prices affects buyers' cognitive processes. We then test this framework through five studies.

Studies 1–3 are laboratory experiments in which we test the precision effect and identify two important moderators of the effect: uncertainty and prior experience. These moderators suggest that consumers are unaccustomed to seeing large precise prices because prices are usually rounded to the nearest ten, hundred, or thousand. Consequently, when consumers encounter a precise price, they are less certain whether the magnitude is low or high. Under these conditions, based on their prior experience they infer that precise prices are usually lower than round prices, and this leads to a bias in their magnitude judgments. Studies 4 and 5 are done outside the laboratory setting to test the external validity of the precision effect. They examine how price precision affects buyers' responses in the context of real estate transactions. We conclude with a discussion on the limitations of this research and directions for future work. In particular, we discuss the implications of price precision in other settings—such as the automobile industry—where consumers might be uncertain whether the list price is low or high. Similarly, we discuss how the precision effect might influence magnitude judgments in nonpricing contexts such as product weights.

2. The Precision Effect

Several researchers have suggested that the ease or difficulty with which a person processes a stimulus affects her judgments about the stimulus (Schwarz 2004, Whittlesea 1993). For example. Alter and Oppenheimer (2006) studied short-term fluctuations in the stock market and found that stocks of companies with names that are difficult to pronounce perform worse than those that are easy to pronounce. Similarly, when a piece of prose is difficult to read, people judge that it is written by a less intelligent author (Oppenheimer 2006). We extend this stream of research to investigate whether cognitive difficulty in judging the magnitude of a large precise price can influence magnitude judgments and hence buyer behavior.

Our conceptualization of the price precision effect is based on two key postulates. First, we propose that large precise prices (e.g., \$364,578) are more difficult to process than comparable round prices (e.g., \$364,000). They consequently evoke a feeling of uncertainty in buyers. Second, this uncertainty induces them to consider the implication of precision for the magnitude of the price. As we discuss below, precise prices are more frequently used for smaller magnitudes. Therefore, the precision-induced uncertainty results in a downward bias in the perceived magnitude.

2.1. Large Precise Prices and Feeling of Uncertainty

The notion that precision in large prices can evoke a feeling of uncertainty about the relative magnitude of the price is supported by multiple streams of literature. More precise prices, those with more ending nonzero digits, require greater cognitive effort to process than round prices of similar magnitude. Gill et al. (1998) and Kelley and Lindsay (1993) have shown that cognitive difficulty can reduce confidence in judgments. If people find it more difficult to process precise prices than round prices, then they are likely to feel more uncertain about the magnitude of a precise price than a comparable round price. That is, they are likely to feel less certain whether a precise price is larger or smaller than a round price of similar magnitude.

Precision-induced uncertainty could also be caused by violations of expectations. People have expectations about the relationships between various attributes of frequently encountered stimuli, and these expectations guide how they identify and judge the stimuli. Violations of these expectations lead to a feeling of uncertainty (see Kahneman and Tversky 1982 for a detailed discussion of violations of expectations and the resultant uncertainty). In the context of prices, buyers expect large prices to be rounded to the nearest convenient unit. For example, a buyer might expect a price in the hundreds of thousands to be rounded to the nearest thousand and a price in millions to be rounded to the nearest million. These expectations are violated when the buyer encounters a large price that is not rounded.

Why do people expect larger prices to be more round? Research on the distribution of numbers has found that in spoken and written communication, when referring to large magnitudes, round numbers are more prevalent than exact or precise ones. For example, Dehaene and Mehler (1992) analyzed the frequency of number words in word frequency tables for the English, Catalan, Dutch, French, Japanese, Kannada, and Spanish languages. They found that although the small numbers used in daily communication are not round (e.g., $1, 2, 3, \ldots, 8$, and 9), and large numbers are often rounded to the nearest multiple of 10 (e.g., $10, 20, \ldots, 100, 200$). Stated differently, larger precise numbers (e.g., $101, 102, 103, \ldots, 1{,}011$, $1{,}012$, $1{,}013, \ldots$) are used relatively infrequently in daily communication (also see Dorogovtsev et al. 2005, Jansen and Pollmann 2001). Because of the relatively infrequent occurrence of large precise numbers, a large precise price such as \$364,578 is surprising and could evoke a greater feeling of uncertainty than more round prices of similar magnitude such as \$364,000 or \$365,000.

Although these accounts are based on different underlying psychological processes, they converge on the prediction that buyers will feel more uncertain about the magnitudes of large precise prices.

2.2. Magnitude Judgment Under Precision-Induced Uncertainty

The uncertainty induced by precision can influence the perceived magnitude of a large precise price. It has been shown that metacognitive experiences can direct peoples' attention to additional cues for the task at hand (Alter et al. 2007). The precision-induced feeling of uncertainty experienced during the magnitude judgment task draws the buyer's attention to the relationship between precision and magnitude. Because precise numbers are usually used for smaller magnitudes (Dehaene and Mehler 1992), precise prices are expected to have smaller magnitudes. Consequently, under conditions of precision-induced uncertainty, buyers might judge precise prices (e.g., \$364,578) to be smaller than round prices of similar magnitude, even if the round prices are actually smaller (e.g., \$364,000). We refer to this psychological phenomenon as the price precision effect.

It is possible that precision could also trigger deliberative inferences about the price. When a buyer observes a price that is precise, she might infer that the seller has set the price carefully, without rounding the price up, and therefore it must be a more fair or accurate price. Similarly, in a negotiated price setting, buyers might infer that a precise price is less negotiable because the seller has set the price after careful deliberation and has not rounded the price up in anticipation of it being negotiated down. Although precision could induce such deliberative inferences about a seller's price strategy, the present research focuses on the implicit processes to suggest that even in the absence of such deliberative inferences, price precision could affect magnitude judgments.

Consider the previously discussed illustrative example of a homeowner setting the list price for her house. She could list the house for a more round price (e.g., \$364,000) or a more precise price (e.g., \$364,578). Based on the above discussion of the precision effect, we would expect buyers to perceive the precise list price to be lower, even though it is, in fact, a little higher. Note that we are interested in judgments of a price's "stand-alone" magnitude (i.e., whether \$364,578 is high or low) rather than in comparison with another price (i.e., whether \$364,578 is higher or lower than \$364,000). Therefore, in the context of such price magnitude judgments, our hypothesis is as follows:

Hypothesis 1 (H1). *Under conditions of uncertainty, buyers are more likely to judge a precise price* (*e.g.*, \$364,578) *to be smaller than a round price* (*e.g.*, \$364,000) *of similar magnitude.*

In addition to the impact of precision on price judgments, we are also interested in the effect of precision on buyers' WTP. Past research has demonstrated that in negotiated price settings, buyers arrive at their valuation by anchoring it on the asking price and then adjusting it downwards by an appropriate amount (Northcraft and Neale 1987). Furthermore, related research on anchoring (Janiszewski and Uy 2008; also see Mussweiler and Strack 2000) suggests that the amount of adjustment from the anchor will depend on the perceived magnitude of the asking price: if a buyer perceives the asking price to be low, then she is more likely to accept the asking price or a price close to it. Building on H1, when a buyer sees a precise asking price, she will perceive it to be lower than a round price of comparable magnitude. Therefore, the buyer will be more willing to accept an amount closer to the asking price.[2] Thus, we predict

Hypothesis 2 (H2). *Buyers will pay a higher amount when the seller sets a precise asking price than when the seller sets a round asking price of similar magnitude.*

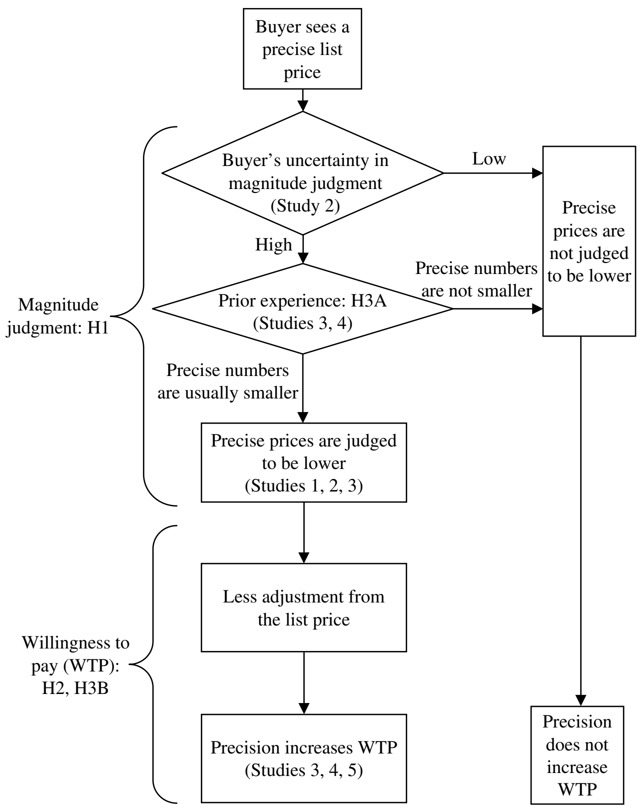
2.3. Testing the Model: Uncertainty and Prior Experience

We use residential real estate transactions to test the price precision effect because we can observe two different prices. The first is the price at which the seller lists the house (the list or asking price). This list price can be precise or rounded. The second is the sale price, which reflects the buyer's WTP after accounting for the list price precision. As depicted in Figure 1, two key constructs underlie our hypotheses: uncertainty about the magnitude of a precise list price, and beliefs about the relationship between magnitude and precision. We posit that if the precision effect is caused by a feeling of uncertainty about the magnitude of a precise price, then it should be moderated by buyers' confidence in their judgments.[3] Buyers should be less influenced by the mild uncertainty evoked by precision when they are confident about their judgments.

[2] This hypothesis is based on the premise that in most negotiated transactions, the final sale price is less than the asking price. However, when there are multiple bidders competing with each other, the final sale price could be higher than the asking price. In such situations, it is not clear whether the precision of the asking price will affect WTP because the final list price will be influenced more by the competitive bids than by the asking price.

[3] We assume that cognitive difficulty enhances uncertainty and reduces confidence. Therefore, we use the terms "low confidence" and "high uncertainty" interchangeably.

Figure 1 **Schematic Representation of How Price Precision Affects Willingness to Pay**



Previous research has found that confidence can moderate the effect of metacognitive feelings on judgments. For example, Lee (2001) found that participants' evaluations of stimuli were less likely to be affected by repetition-induced fluency when they were more confident about their responses. We expect a similar result in the context of the precision effect: buyers' judgments about a price's magnitude are less likely to be influenced by precision-induced uncertainty when they are more confident about their ability to evaluate the price. To illustrate the role of confidence, suppose that a buyer sees two prices side by side (e.g. $364,578 versus $364,000). In such a situation, buyers have no difficulty in identifying the higher of the two prices, regardless of the precision, or lack thereof, in these prices. Buyers are so confident about the correct answer in this task that the mild uncertainty induced by precision is irrelevant and is therefore ignored.

As depicted in Figure 1, lay beliefs about the relationship between magnitude and precision also play an important role in the precision effect. People are more likely to judge precise prices to be smaller if their prior experience creates the belief that precise numbers are usually smaller than round numbers. They are less likely to judge precise prices to be smaller if they believe that precise numbers are usually larger than round numbers. For this reason, we posit that manipulating prior experience with numbers should moderate the precision effect.

In the following sections, we describe five empirical studies designed to test the two hypotheses and the proposed model. In Figure 1, we summarize the purpose of each study, explaining how it tests the proposed model.

3. Study 1: The Price Precision Effect

Our first experiment tests H1, which states that under conditions of uncertainty, buyers are likely to judge the magnitude of a precise price (e.g., $364,578) to be lower than the magnitude of a comparable round price (e.g., $364,000).

3.1. Method

3.1.1. Participants and Design. Ninety undergraduate students at a large northeastern U.S. university participated in this experiment. They received a small amount of money for participating in this and other related experiments. The experiment was administered on personal computers, and had a 2 (price precision: Precise versus Round) × 6 (price magnitude: $390,000, $395,000, $400,000, $500,000, $505,000, and $510,000) mixed factorial design. The details of the design are described below.

3.1.2. Stimuli and Procedure. We used six different levels of prices in this experiment ($390K, $395K, $400K, $500K, $505K, and $510K), and for each level of price we created a precise and a round version of the price. This resulted in 12 different list prices that were used as stimuli: $390,000, $391,534; $395,000, $395,425; $400,000, $401,298; $500,000, $501,298; $505,000, $505,425; and $510,000, $511,534.[4] Note that in each of these six pairs of prices, the latter price is more precise, and it is higher than the comparable round price. As predicted by H1, we expect participants to judge the magnitudes of the precise prices to be lower than the magnitudes of the round prices.

The experiment was titled "Real Estate Price Evaluations." Participants were told that their task is to evaluate six different list prices for a house listed for sale in a neighboring city. As discussed above, we are interested in stand-alone judgments of a price's magnitude (e.g., is $391,534 high or low?) rather than side-by-side comparisons (e.g. is $391,534 higher or lower

[4] In the market data on residential real estate transactions (discussed in Study 5), the mean number of ending zeroes is about 2.75, and more than 60% of all observations have three ending zeroes. Therefore, in our experiments we use three ending zeroes for round prices.

than \$390,000?). For this reason, participants did not see precise and round prices of similar magnitude. Instead, participants were randomly assigned one of two groups: one of the groups evaluated the prices \$390,000, \$395,000, \$400,000, \$501,298, \$505,425, and \$511,534, whereas the other group evaluated \$391,534, \$395,425, \$401,298, \$500,000, \$505,000, and \$510,000. The prices were presented one at a time, in a random order, on computer screens.

To give them some idea of the house's market value, participants were informed that similar houses in the neighborhood are valued between \$400,000 and \$500,000. Participants submitted their responses to each of the six prices on an 11-point scale anchored at 1 = Low and 11 = High. On each screen they saw the stimulus price and the question: "For the house shown earlier, would you consider this price as high or low?" Participants' responses were self-paced. After submitting their response to a price, they clicked on a button labeled "Continue" to proceed to the next screen.

3.2. Results

Participants' judgments were submitted to a mixed factorial analysis of variance (ANOVA) using PROC MIXED in SAS, with price precision (Precise versus Round) as a between-subjects factor and price magnitude (390K, 395K, 400K, 500K, 505K, and 510K) as a within-subjects factor. This analysis revealed a main effect of price precision. As predicted by H1, participants judged precise prices ($M_{\text{precise}} = 5.74$) to be lower than round prices ($M_{\text{round}} = 6.05$; $F(1, 89) = 5.40$, $p = 0.022$), even though the precise prices were actually higher than the round prices. Not surprisingly, there was also a main effect of price magnitude ($F(5, 439) = 223.18$, $p < 0.01$); higher prices were judged to be higher than lower prices. However, the price precision by magnitude interaction was not significant ($F < 1$).

Consistent with H1, participants in this experiment incorrectly perceived the (higher) precise prices to be lower than the comparable round prices. Our conceptualization suggests that this precision effect is caused by uncertainty experienced while encoding the magnitude of large precise prices. We posit that this uncertainty induced them to consider the relationship between precision and magnitude. However, the present study did not directly test this proposed mechanism. We directly test the mechanism in the following study.

4. Study 2: Role of Uncertainty

As discussed in §2.3, buyers are less likely to be influenced by feelings of uncertainty if they are very confident (i.e., less uncertain) about their response to the price. To test this, in this study we manipulate participants' confidence in their responses to prices. Half the participants were made to feel very confident about their responses to various prices, and the other half were made to feel less confident about their responses. If the precision effect is caused by mild feelings of uncertainty evoked by large precise numbers, then it should not manifest when participants are very confident about their responses.

4.1. Method

4.1.1. Participants and Design. One hundred and nine students at a large northeastern U.S. university participated in this experiment. They received a small amount of money for participation. The experiment was administered on personal computers and used a 2 (confidence: Low versus High) × 2 (price precision: Precise versus Round) × 6 (price magnitude: \$390,000, \$395,000, \$400,000, \$500,000, \$505,000, and \$510,000) mixed factorial design. The details are described below.

4.1.2. Procedure. The procedure used in this study was identical to that used in the previous study with one exception. Participants were randomly assigned to one of two between-subjects manipulations of confidence. Following Maki (1998), we used a very simple method to manipulate participants' confidence in their responses. Before they judged the price magnitudes, the participants assigned to the "high-confidence" condition read the following information: "You do not need any real estate experience to do well in this task. It has been observed that most undergraduate students are able to accurately evaluate real estate prices even when they do not have any experience in real estate transactions." In contrast, participants assigned to the "low-confidence" condition read: "If you have some experience in real estate transactions, then you are likely to do well in this task. It has been observed that undergraduate students who have no experience in real estate transactions are usually unable to accurately evaluate real estate prices."

Following this manipulation, all participants evaluated one of the two sets of six prices described in the previous study. At the end of the study, as a manipulation check, all participants were asked to report how confident they felt while evaluating the prices on a -5 = "Not Confident" to $+5$ = "Very Confident" scale.

4.2. Results

4.2.1. Manipulation Check. An ANOVA confirmed that participants were less confident ($M = -0.44$) in the low-confidence condition than in the high-confidence condition ($M = 0.56$; $F(1, 105) = 4.22$, $p = 0.043$), and this effect did not change across the two sets of prices ($p > 0.27$).

4.2.2. Magnitude Judgments. Participants' judgments were submitted to a mixed factorial ANOVA with price precision (Precise versus Round) and confidence (Low versus High) as between-subjects factors, and price magnitude ($390K, $395K, $400K, $500K, $505K, and $510K) as a within-subjects factor. As in the previous experiment, there was a main effect of precision; participants incorrectly judged precise prices ($M_{\text{precise}} = 5.98$) to be lower than round prices ($M_{\text{round}} = 6.28$; $F(1, 107) = 6.31$, $p = 0.013$), even though the precise prices were actually higher than the round prices.

More importantly, this main effect of precision was moderated by a precision by confidence interaction ($F(1, 107) = 4.50$, $p = 0.036$). Consistent with our conceptualization, the precision effect manifested only in the low-confidence condition. Contrasts of means revealed that participants judged precise prices ($M_{\text{precise}} = 5.90$) to be lower than round prices ($M_{\text{round}} = 6.47$; $F(1, 107) = 10.02$, $p < 0.01$) only when they were less confident about their responses. When participants were more confident about their responses, the precision manipulation did not have a significant effect on magnitude judgments ($M_{\text{precise}} = 6.05$ versus $M_{\text{round}} = 6.10$; $F < 1$).

Not surprisingly, there was also a main effect of price magnitude ($F(5, 523) = 284.20$, $p < 0.01$); higher prices were judged to be higher than lower prices. No other effects were significant (Fs < 1).

4.3. Discussion

The results from this experiment demonstrate that the effect of precision on price magnitude judgments manifests only when the participants were uncertain about their ability to judge whether the price is low or high. When the feeling of uncertainty evoked by large precise prices was not alleviated, participants tended to judge precise prices to be lower. However, when participants were more confident about their responses, their judgments were not biased by the precision effect. Thus, these results suggest that the feeling of uncertainty about the magnitude of the price (i.e., whether the price is low or high) might be playing a role in the price precision effect.[5]

Importantly, it is difficult to reconcile these results with the notion that the precision effect is due solely to deliberative inferences about why the seller set such a price. If the bias in judgments was only due to inferences about seller motives, then the bias should have been unaffected by the confidence manipulation used in this study. Thus, these results suggest that under conditions of uncertainty buyers implicitly use price precision as a cue for magnitude, even when they do not make any explicit inferences about the sellers' motive in setting a precise or a round price.

Our conceptualization posits that a feeling of uncertainty is not the only factor that causes the precision effect. Participants' beliefs about the relationship between precision and magnitude also play an important role. The following study was designed to test this postulate.

[5] We will offer additional support for the role of precision-induced uncertainty in Study 4 by demonstrating that magnitude judgments of precise prices evoke greater uncertainty than those of round prices.

5. Study 3: Prior Experience with Numbers

This experiment serves two purposes. The first purpose is to test whether participants' prior experience with generic numbers (rather than prices) moderates the precision effect in prices. All participants in this study were first put through a numerical judgment task to prime their expectations about the relationship between precision and magnitude. Half the participants were primed to expect smaller magnitudes for precise numbers, and the other half were primed to expect larger magnitudes for precise numbers. We then examined whether this priming affects participants' judgments of prices in a subsequent task. Our conceptualization predicts that when participants are primed to expect larger magnitudes for precise numbers they should not judge precise prices to be smaller.

The second purpose of this study is to do a preliminary test of the link between participants' magnitude judgments of prices and their WTP. Participants in this study first judged the magnitudes of several asking prices for a house and then indicated the amount that they were willing to pay for the house. We expected the priming task to bias participants' judgments of precise list prices and the biased magnitude judgments to influence their WTP. We predicted that when participants are primed to expect smaller magnitudes for precise numbers, they would be willing to pay more when the asking price is precise than when it is round. Formally, we hypothesize the following:

Hypothesis 3 (H3A). *Participants' prior experience with precise numbers will moderate the effect of list price precision on their WTP. Participants will pay more for a precise list price than for a comparable round list price when their prior experience suggests that precise numbers are associated with smaller magnitudes.*

Hypothesis 3 (H3B). *This interactive effect of list price precision and prior experience on WTP will be mediated by participants' judgments of the magnitude of the precise list price.*

5.1. Method

5.1.1. Participants and Design. One hundred and thirty four students at a large northeastern U.S. university participated in this experiment. They received a small amount of money for participation. The experiment was administered on personal computers. Participants were randomly assigned to one of the four conditions created by crossing the two between-subjects factors: precision (Precise versus Round) and prior experience (Precise numbers are smaller versus Precise numbers are larger). Furthermore, during the test phase each participant saw nine test prices. This resulted in a $2 \times 2 \times 9$ mixed factorial design.

5.1.2. Manipulating Prior Experience. Participants were informed that they would be participating in two unrelated experiments. The first experiment was titled "Number Study," and the ostensible purpose of the experiment was to study the effect of response speed on accuracy. The actual purpose of this experiment was to prime the relationship between precision and numerical magnitude. Thirty two numbers between 1,000 and 10,000 were presented on the computer screen, one at a time, in a random order, and participants had to quickly judge whether each number was higher or lower than 5,000. Half of the numbers were higher and the other half were lower than 5,000. Participants indicated their responses by clicking on one of the two buttons—"Higher" or "Lower"—displayed on the screen. For participants assigned to the "precise numbers are larger" condition, the numbers that were higher than 5,000 were more precise (e.g., 5,563, 6,142, etc.) and the lower numbers were more round (e.g., 4,000, 3,000, etc.). This manipulation was intended to create an expectation of larger magnitudes for precise prices. In contrast, for participants assigned to the "precise numbers are smaller" condition, the numbers that were lower than 5,000 were more precise (e.g., 4,523, 3,526, etc.) and the higher numbers were more round (e.g., 6,000, 7,000, etc.).

5.1.3. Real Estate Evaluation. After completing the first experiment, all participants responded to another experiment, titled "Real Estate Price Evaluations." The procedure used in this task was similar to that in the previous studies. Participants were shown a picture and a brief description of a house listed for sale in a neighboring city. Then 15 list prices (9 test prices and 6 filler prices) were presented, one at a time in a random order. Participants judged the magnitudes of the presented prices on an 11-point scale anchored at 1 = Low and 11 = High. The nine test prices changed across the two precision conditions.

Participants assigned to the round condition saw test prices that were rounded to the nearest five or ten thousand: \$330,000, \$335,000, \$340,000, \$345,000, \$350,000, \$355,000, \$360,000, \$365,000, and \$370,000. Participants assigned to the precise condition saw test prices that were not rounded: \$332,126, \$337,851, \$341,162, \$346,178, \$351,342, \$356,193, \$361,584, \$366,793, and \$371,157. As in the previous studies, to create a more stringent test of whether price precision leads to biased magnitude judgments (H1), the precise prices were higher than the closest round price (e.g., \$332,126 and \$330,000). However, unlike in the previous two studies, participants in the round condition did not see any precise prices, because we wanted to test whether the manipulation of prior experience would influence their judgments (and hence their WTPs) in the conditions when only round prices are presented. The six filler prices did not change across the two conditions.[6]

Finally, as a preliminary test of H2, participants were asked to indicate the amount they were willing to pay for the house (in dollars) in response to the question: "Imagine that you are a real estate agent representing a prospective buyer. What do you think would be a fair price for this house?"[7] Our interest is in testing how magnitude judgments of the precise versus round list prices would influence participants' valuation of the house.[8] To control for individual differences, the participants also submitted information on possible covariates of WTP: age, their estimate of the average value of a property in the neighborhood, and prior experience in real estate transactions.

5.2. Results

5.2.1. Judgments. The judgments of the nine test prices were submitted to a $2 \times 2 \times 9$ mixed factorial ANOVA with precision (Precise versus Round) and prior experience (Precise numbers are smaller versus Precise numbers are larger) as between-subjects factors and price magnitude (nine levels) as a within-subjects factor. The summary of the means is presented in Table 1.

Consistent with our conceptualization, participants' prior experience with precise and round numbers moderated the precision effect; the precision by prior

[6] Three of these filler prices were higher (\$385,000, \$390,000, \$395,000) and three were lower (\$305,000, \$310,000, \$315,000) than the test prices.

[7] We asked participants to imagine themselves as being real estate agents to encourage them to offer a careful and well-considered valuation of the house. In the following study (Study 4), we word this question differently (asking directly for their willingness to pay) to test the generalizability of the result.

[8] As discussed in §2, a more stringent test of this hypothesis is to use precise prices that are lower (instead of higher) than round prices. Importantly, as we explain in our discussion of results, anchoring on higher precise prices does not appear to be the cause of higher willingness to pay. In addition, in Study 4, we use lower precise prices.

Table 1 **Summary of Results from Study 3**

	Judgment of list price (on 11-point scale)		Fair price estimate ($)	
Prior experience	Round list price	Precise list price	Round list price	Precise list price
Precise prices are smaller	6.65	5.92	329,582	346,015
	(0.26)	(0.24)	(6,344)	(5,842)
Precise prices are larger	6.54	7.31	339,429	321,619
	(0.24)	(0.28)	(6,195)	(7,055)

Note. Standard errors are in parentheses.

experience interaction was significant ($F(1, 130) = 8.46$, $p < 0.01$). When participants' prior experience induced them to expect smaller magnitudes for precise numbers, they incorrectly judged precise prices to be smaller than round prices ($M_{\text{precise}} = 5.92$ versus $M_{\text{round}} = 6.65$; $F(1, 130) = 4.224$, $p = 0.042$), which is consistent with the results of Studies 1 and 2, where we did not prime them to expect any relationship between precision and magnitude. As in the previous studies, this effect is particularly notable because the precise prices used in this study were slightly larger than the round ones. However, when participants' prior experience induced them to expect larger magnitudes for precise numbers, they judged precise prices to be larger than round prices ($M_{\text{precise}} = 7.31$ versus $M_{\text{round}} = 6.54$; $F(1, 130) = 4.25$, $p = 0.041$). Further comparisons revealed that the manipulation of prior experience affected only the judgments of the precise prices, $F(1, 130) = 13.84$, $p < 0.01$; it did not affect the judgments of round prices, $F < 1$. This result shows that only precise prices are susceptible to the manipulation of the relationship between magnitude and roundness; judgments of round prices are unaffected by this manipulation.

The main effect of prior experience, $F(1, 130) = 6.05$, $p = 0.015$, and the main effect of price magnitude, $F(8, 1,040) = 48.39$, $p < 0.01$, were also significant. Higher prices were indeed judged to be higher than lower prices, but the effect of price magnitude did not interact with any of the between subject factors ($F < 1$). No other effects were significant ($F\text{s} < 1$).

5.2.2. House Valuation. Participants' house valuations in dollars were collected in an open-ended format. To minimize the effects of outliers, we removed responses that were more than three standard deviations from the mean in either direction. Responses from the remaining 132 participants were submitted to a 2×2 ANOVA with the same between-subjects factors as in the previous analysis and the covariates mentioned in the procedure section.

Consistent with our conceptualization, once again the precision by prior experience interaction was statistically significant ($F(1, 126) = 9.24$, $p < 0.01$). When participants' prior experience induced them to judge precise list prices to be relatively low, precise list prices made them willing to accept a higher price as the fair price for the house ($M_{\text{precise}} = \$346{,}015$ versus $M_{\text{round}} = \$329{,}582$; $F(1, 126) = 4.62$, $p = 0.034$). In contrast, in the condition where their prior experience induced them to judge precise prices to be relatively high, precise prices reduced the amount that participants were willing to accept as a fair price ($M_{\text{precise}} = \$321{,}619$ versus $M_{\text{round}} = \$339{,}429$; $F(1, 126) = 4.63$, $p = 0.033$). Moreover, consistent with our results from the judgment task, the manipulation of prior experience affected only participants' valuations of precise prices, $F(1, 126) = 9.17$, $p < 0.01$; it did not affect their valuations of round prices, $p = 0.211$. No other effect was significant ($p\text{s} > 0.20$).

5.2.3. Mediated Moderation Analysis. To examine the link between price magnitude judgments and WTP postulated in H3, we conducted a three-step mediated moderation analysis (Muller et al. 2005). Specifically, we tested whether the interaction effect of prior experience and precision on WTP is mediated by magnitude judgments. First, we computed each participant's average magnitude judgment for the nine test list prices and regressed house valuations on these averaged judgments. Participants' judgments of list prices predicted their house valuations ($\beta = -14{,}082$, $p < 0.01$). The negative coefficient suggests that those participants who judged the list prices to be lower were willing to pay more for the house, consistent with the mechanism underlying H2. In a second model, we regressed the house valuations on the dummy variables for the two between-subjects factors, precision (with 1 indicating the precise price condition and 0 indicating the round price condition) and prior experience (with 1 indicating that precise numbers are smaller and 0 indicating that precise numbers are larger), and on the interaction of the two factors. The interaction of these two factors was a significant predictor of house valuations ($\beta = 33{,}823$, $p = 0.014$) in this model. However, this interaction effect was not significant ($\beta = 11{,}928$, $p = 0.302$) when judgments of list prices were included as an additional predictor in the third model. Furthermore, judgments of list prices remained a significant predictor of house valuations ($\beta = -13{,}823$, $p < 0.01$) in the third regression model. These results support our hypotheses that list price precision affects participants' WTP (H2) and that this effect is mediated by their magnitude judgments (H3).[9]

[9] Further details of the mediated moderation analyses are available in the electronic companion to this paper as part of the online version that can be found at http://mktsci.pubs.informs.org.

5.3. Discussion

Two important conclusions emerge from the results of this study. First, these results provide evidence that the propensity to use precision as a cue for smaller magnitudes is due to lay beliefs about the relationship between magnitude and precision, formed through prior experiences. When prior experience led participants to expect precise prices to be smaller, they (incorrectly) judged precise prices to be smaller (as they did in Studies 1 and 2 when prior experience was not manipulated). When their prior experience suggested that precise prices are usually larger, participants correctly judged precise prices to be larger. Second, these results also provide preliminary evidence of the link between magnitude judgments and WTP.

A possible concern with our experimental design and results is whether the effect of prior experience can be attributed to a simple demand artifact. The fact that the effect of prior experience varied across round and precise prices casts doubt on this possibility. If participants' responses were a demand artifact, then the effect of the prior experience manipulation should have manifested for both precise and round prices. Our results reveal that the manipulation of prior experience only influenced participants' magnitude judgments and valuations in the precise price condition; it had no effect in the round price condition. We posit that this differential effect of prior experience reflects the uncertainty evoked by precise prices (an assumption that we directly test in the following study).

A second concern is whether the higher valuations for the precise list prices are due to simple anchoring effects (Northcraft and Neale 1987).[10] In other words, did the larger WTPs for the precise prices simply reflect the fact that these prices were nominally larger than the round prices? Once again, the prior experience by precision interaction casts doubt on this possibility, because this anchoring would lead to higher WTPs in both prior experience conditions. Nonetheless, we directly address this concern in the following study by using precise prices that are nominally smaller than round prices.

Finally, it is germane to ask whether the effects observed with student participants in Studies 1–3 generalize to a more representative population. In the following study we administered an online experiment to a nationally representative sample of homeowners. In that study, we also seek direct evidence for our assumption that precise prices evoke a greater feeling of uncertainty than round prices.

[10] Recall that because our intention was to test whether participants will incorrectly judge nominally larger precise prices to be smaller than the round prices, we used precise prices that were nominally larger than the round prices.

6. Study 4: An Online Experiment

The design of this study was guided by three considerations. First, to test the external validity of the results from our three lab studies, we administered an experiment to a nationally representative sample of homeowners across the United States.

Second, this study was designed to more stringently test the effect of precision on WTP (H2). In the previous three studies, our primary focus was on magnitude judgments (H1). Therefore, we chose precise prices that are nominally larger than the round prices, and we found that participants incorrectly judged precise prices to be smaller than nominally smaller round prices. In this study, our interest is in participants' house valuations or WTP (i.e., H2). As noted above, anchoring is a concern because it induces a positive correlation between list price and WTP (Northcraft and Neale 1987). Therefore, we can more stringently test H2 by examining whether precise prices that are nominally *lower* than round prices elicit a higher WTP.

Third, we collected data on some direct process measures to further test whether the uncertainty induced by large precise prices is a necessary condition for precision to bias magnitude judgments.

6.1. Method

6.1.1. Participants and Design. Participants were recruited through an online market research agency (http://www.Zoomerang.com) and were randomly assigned to one of the following two conditions: round price or precise price. Participants in the precise condition saw more precise list prices (e.g., \$364,578); in the round condition the prices were rounded up to the nearest thousand (e.g., \$365,000). To minimize the idiosyncratic effects of the stimuli, each participant was asked to respond to three different houses. Thus, this experiment used a 2 (precision: Round versus Precise) × 3 (replicates) mixed factorial design.

We received 218 completed responses. Because participants' house valuations were collected in open-ended format, to minimize the effects of outliers we removed responses that were more than three standard deviations away from the mean response in either direction (as we did in Study 3). We analyzed the resulting data from 209 participants to test our hypothesis regarding the influence of precision on WTP (H2). The average age for the participants across the three conditions was 39.7 years. Ninety-four percent of the participants had an annual household income greater than \$40,000, and 92% currently owned a house.

6.1.2. Procedure. Two versions of the questionnaire were created using Zoomerang.com's online survey tool, with one version emailed to the participants in the round price condition and the other sent to subjects in the precise price condition. The questionnaires were administered by Zoomerang.com to respondents who were enrolled in its panel. Participants were informed that their task was to evaluate three different houses that had been listed for sale in Sacramento, California. They were given a wide price range ($250,000 to $400,000) for houses in a particular residential neighborhood. Participants then saw pictures, brief descriptions, and list prices of three houses, one at a time, on their computer screens. At the bottom of each screen they saw the question: "What price are you willing to pay for this house?" They had to submit the dollar amount that they were willing to pay in an open-ended box and then click on a button labeled "Submit" to proceed to the next screen.

The questionnaires used in the two between-subjects conditions were identical in all respects except for the list prices of the three houses. In the precise price condition, the three houses were priced $324,467, $364,578, and $374,576. In the round condition, the three prices were $325,000, $365,000, and $375,000. In both conditions, participants saw the three houses in increasing order of prices.[11] To control for individual differences, participants were also asked to report demographic information including age, market value of their current residence, the average value of a property in Sacramento, and their income.

6.1.3. Process Measures. After submitting their WTPs for the three houses, participants responded to two questions about large precise numbers. The first question was designed to test whether participants had expectations about the relative magnitudes of round and precise numbers: "Consider two six-digit numbers, X and Y. The number X is rounded to the nearest thousand. The number Y is not rounded. Which number is likely to be smaller: X or Y?" The second question was designed to directly test the hypothesis that large precise numbers evoke a feeling of uncertainty: "When asked to judge whether a number is low or high, some numbers are likely to evoke a feeling of uncertainty. Here are two sets of numbers: Set A: 380,000, 375,000, 370,000, 365,000 and Set B: 379,829, 375,169, 369,834, 365,164. For which set of numbers are you more likely to feel uncertain about the magnitudes of the numbers?"

[11] The software used for creating the online questionnaire did not allow randomization of the order of the stimuli.

6.2. Results

6.2.1. Mean WTP. Participants' WTPs were submitted to a 2×3 mixed factorial ANOVA with precision (Round versus Precise) as the between-subjects factor, price magnitude ($325K, $365K, and $375K) as the within-subjects factor, and the demographic variables described in the procedure section as covariates. Because the mixed factorial analysis revealed that the precision by price magnitude interaction was not significant ($p > 0.35$), we report the results collapsed across the three levels of price magnitudes.

The main effect of precision was significant, $F(1, 200) = 4.62$, $p = 0.033$. Across the three houses, participants were willing to pay more when the list price was precise ($M_{\text{precise}} = \$315{,}049$) than when the list price was rounded up ($M_{\text{round}} = \$305{,}200$). These results provide strong support for H2, indicating that precision increases buyers' willingness to pay a price closer to the list price. Moreover, because the precise prices are smaller than the comparable round prices, these results cannot be explained by anchoring. Not surprisingly, the main effect of list price was also significant, $F(2, 414) = 215.93$, $p < 0.01$, with the pattern of means suggesting that higher list prices elicited higher WTPs. As in the previous studies, the effect of precision did not vary across the magnitudes of the list price ($p > 0.35$).

6.2.2. Process Measures. In response to the question whether a number that is not rounded is likely to be larger or smaller than a rounded number, more than two-thirds of the participants (69%) said that the number that is not rounded (Y) is likely to be smaller, and this response rate was significantly different from chance ($t(208) = 6.06$; $p < 0.01$). Importantly, this question asked about generic numbers rather than prices. Therefore, this result also provides direct evidence that precision can bias magnitude judgments in the absence of any deliberative inference about seller pricing motives.

Our conceptualization suggests that this belief about the relationship between precision and magnitude is an important mechanism that underlies the effect of precision on WTPs. If this is the case, precision should not affect the WTP of people who do not expect precise numbers to be smaller in magnitude. To test this prediction, we separated participants into two groups. The first group comprises participants who reported that they believe that precise numbers have smaller magnitudes ("precise-is-small" group); the second group comprised the remaining participants ("precise-is-not-small" group). Consistent with our conceptualization, the effect of price precision only manifested in the precise-is-small group ($M_{\text{precise}} = \$319{,}553$ versus $M_{\text{round}} = \$304{,}046$; $F(1, 198) = 7.86$, $p < 0.01$). It did not manifest in the precise-is-not-small group ($M_{\text{precise}} = \$306{,}522$ versus $M_{\text{round}} = \$309{,}798$; $F < 1$). Moreover, as in the previous study, the presence or absence of the precise-is-small expectation only affected the responses to the precise prices, $F(1, 198) = 2.88$, $p = 0.092$, it did not affect the responses to the round prices, $F < 1$. This result is consistent with the observation in the previous study that participants' magnitude judgments of round numbers are less susceptible to bias.

In response to the question about uncertainty, a majority of the participants (72%) said that magnitude judgments for Set B (precise numbers) would evoke greater uncertainty, and this response rate was significantly different from chance ($t(208) = 7.17$; $p < 0.01$). This result offers direct support for our claim that magnitude judgments of precise prices evoke greater uncertainty than those of round prices.

6.3. Discussion

The results of this experiment corroborate our findings in Studies 1–3 and demonstrate the generalizability of those findings. In this study, we find that the precision effect influences WTPs in a nationally representative sample of participants, nearly all of whom had prior experience buying a house. Moreover, our process measures provide evidence that a majority of people expect precise numbers to have smaller magnitudes, in the absence of any kind of priming or cuing. They also provide direct evidence for the role of uncertainty in the precision effect. Thus, these results help to explain why the effects of the priming manipulation in Study 3 manifested only for precise prices and not for round prices; the latter prices do not evoke as much uncertainty.

Taken together, Studies 1–4 provide strong evidence for the precision effect and its influence on WTP. However, in none of these studies did the participants actually buy a house. Therefore, the decision rules and cognitive processes participants used in the experiments might not be representative of the rules and processes that buyers use in actual transactions. One might argue that buyers are likely to be more analytical and careful in actual real estate transactions, as a result of the large amounts of money at stake. As a result, the precision effect might not manifest in such situations. To examine this possibility, in the following study we analyze data from residential real estate transactions in two separate markets.

7. Study 5: Evidence from Residential Real Estate Transactions

In this study we examine whether the effect of precision on WTP observed in experimental data manifests in actual real estate transactions. Specifically, we collected data from actual real estate transactions and tested whether the precision or roundness of list prices influence the magnitude of the sale prices. Our conceptualization suggests that more precise list prices should be associated with higher sale prices.

7.1. Data

The completed residential real estate transactions data are from two locations, South Florida and Long Island, New York. The data for both locations come from the local Multiple Listing Service (MLS), which is a clearinghouse where realtors list properties for sale. The MLS data sets provide detailed information on each transaction. In addition to including both the list and sale price for each transaction, they contain a wealth of information on house location and characteristics (bedrooms, bathrooms, etc.), as well as the name of the seller agent, how much commission she earned, and the number of days the house was on the market.

To measure price precision, we considered three different approaches. In the first two approaches, following Dehaene and Mehler (1992), we defined precision based on whether the number was a multiple of 10, 100, 1,000, etc. In the third approach, we conducted a survey to measure price precision. The three operationalizations of precision are described below.

Three Zeroes. Across both markets (South Florida and Long Island), nearly 62% of all houses have three ending zeroes in the list price. This suggests that in the context of residential real estate, where prices are generally higher than $100,000, rounding is frequently done to the nearest thousand dollars. Therefore, we created a context-specific measure of precision, Precise000, which, consistent with our approach in the laboratory studies, indicates list prices with fewer than three ending zeroes (i.e., prices that are not multiples of 1,000). In this specification, $456,000 would be considered round, whereas $456,100 (and $456,120 and $456,121) would be considered precise.

Number of Ending Zeroes. We created a second measure precision, Ending Zeroes, which is a count of the number of ending zeroes in the list price; more ending zeroes indicates less precision. For example, $450,000 has four ending zeroes, whereas $450,500 has only two ending zeroes. This definition allows for gradations in perceived roundedness of numbers; some round numbers could be perceived as more round than others.

Survey. Both of these measures of precision rely on the definition of precise numbers based on ending zeroes, as suggested in prior research (Dehaene and Mehler 1992). To assess the validity of this approach, we considered a third empirically derived measure of precision.

We conducted a survey among 27 staff members at a large northeastern U.S. university and asked

Table 2 Summary Statistics

	South Florida	Long Island, NY
Sale price ($)	325,664	590,726
List price ($)	347,342	629,074
Precise000 (fewer than three ending zeroes)	0.334	0.196
Ending zeroes	2.781	2.702
Precise (survey-based measure)	0.285	
N	7,342	9,026

them to categorize each of the 766 unique prices in our South Florida sample as either precise or round. We considered South Florida prices for this survey because there are fewer unique prices in South Florida (766) than in Long Island (1,173). The survey was titled "Round and Precise Numbers." Participants in this survey were presented with the 766 numbers in a random order determined by the computer. The numbers were presented one at a time on the computer screen along with the question: "Is this number round or precise?" Participants responded by clicking on one of the two buttons—"Round" or "Precise"—presented below each number. Using these data, we then calculated the fraction of participants that defined a price as precise and used this fraction as our measure of precision. For example, 6 of the 27 participants responded that the price $467,000 is precise. Therefore, the value of the precision measure is 0.22 for this price.

Table 2 reports descriptive statistics for the key variables. The fraction of list prices with fewer than three ending zeroes is 33% in South Florida and 20% in Long Island. Overall, in South Florida the average list price has 2.78 ending zeroes, and in Long Island the comparable figure is 2.70 ending zeroes. Our survey data indicated that participants defined almost 29% of the list prices in our South Florida sample to be precise.

Table 3 reports the distribution of ending zeroes for each data set. In both data sets, three ending zeroes is the modal level of precision, with South Florida including a substantial proportion of prices with two and four ending zeroes, respectively, as well. Moreover, for the prices from the South Florida data set, Table 3 also reports the proportion of respondents who defined prices as precise, for each value of ending zeroes. Generally, the fraction of respondents that perceived a price to be precise decreases steadily with the number of ending zeroes, with a slight increase for the very few observations with four or five ending zeroes.

Table 3 Distribution of Precision Measures

Ending zeroes	Proportion of prices in Long Island	Proportion of prices in South Florida	Proportion of survey respondents defining price as precise
0	0.067	0.030	0.855
1	0.061	0.014	0.667
2	0.068	0.291	0.465
3	0.726	0.486	0.170
4	0.066	0.171	0.250
5	0.012	0.008	0.250
6	0.001		

Table 4 Correlation Matrix for Precision Measures in South Florida

Variable	1	2
1. Precise000 (fewer than three ending zeroes)		
2. Ending zeroes	−0.81*	
3. Precise (survey-based measure)	0.88*	−0.89*

*$p < 0.01$.

To summarize these results, Table 4 reports a correlation matrix for our three measures of precision in South Florida.[12] All three measures are highly correlated. Consistent with Table 3, Ending Zeroes is negatively correlated with the survey-based measure of precision (as well as with the dichotomous measure of precision). The high correlation between the survey-based measure and the other two measures of precision is noteworthy, suggesting that people do use ending zeroes as a proxy for precision or roundness.

7.2. Empirical Analysis

To assess the effect of price precision on buyer behavior, we regressed the sale price on each of our three measures of price precision. However, we had to account for the correlation between the list price and list price precision, for two reasons. First, as discussed above, there is evidence that buyers anchor their bids on list prices (Northcraft and Neale 1987). Second, consistent with the research discussed in §2.1, showing that large precise numbers occur infrequently, we find that sellers are more likely to round off higher prices.[13] For these reasons, we controlled for the list price in all of our models. In this way, we assessed the impact of list price precision on the sale price after accounting for the magnitude of the list price.

We also controlled for other factors that may be correlated with both the precision of the list price and the amount of the sale price. These other factors can be broadly grouped into four categories: property-specific, agent-specific, time-specific, and

[12] We report the correlation matrix only for South Florida, because we do not have the survey-based measure of precision for Long Island. However, the two other measures of precision, Precise000 and Ending Zeroes, are also highly correlated in Long Island (−0.86).

[13] In both data sets we find a negative correlation between precision and list price magnitude.

market-specific. Consider first property-specific variables. In all of our models, we included an extensive list of house characteristics such as square footage, number of bedrooms, number of bathrooms, age of the house, as well as dummies for house style, type of heating system, etc. These house characteristics will influence WTP if they are not fully reflected in the list price (e.g., if the list price is too low given the house characteristics). Agent characteristics might also be correlated with both list price precision and sale price. For example, agents might differ in their reputation, ability to negotiate, expertise, discount factors, etc. Some agents might be savvy enough to persuade sellers to set precise prices. To control for the influence of these agent-specific factors, we included seller agent-specific fixed effects in our models. In addition, we also controlled for the agent's commission to control for the possibility that agent compensation is correlated with both the sale price and list price precision. Finally, market-specific variables including school districts, local tax rates, current and expected future interest rates, inventory of unsold houses and new home construction, and concentration of real estate agents can influence sale price. We included zip code and year fixed effects to account for these variations.

We tested our hypothesis that precision increases buyers' WTP using data from transactions where the sale price is less than the list price. In deals where the sale price is greater than the list price, it is likely that there are multiple bidders. In such cases, buyers' WTP will be less influenced by the precision of the list price, because buyers are likely to focus on rival buyers' bids.[14]

7.3. Results

We report the results of our analyses in Table 5. These results provide broad support for the hypothesis that precision increases buyers' WTP (H2); buyers pay more for houses with more precise list prices, holding constant the magnitude of the list price.[15]

All three definitions of precision in South Florida, and both definitions of precision in Long Island (recall that we did not create a survey-based measure of precision for Long Island) show that more precise list prices are associated with higher sale prices. In Florida, the results for the context-specific definition of precision (Precise000) show that list prices with fewer than three ending zeroes increase the sale price by about 0.2%. Similarly, we see that each additional ending zero (which reduces precision) reduces the final sale price by about 0.09%. Finally, when we use the survey-based measure of precision, we find an even stronger effect: precise list prices increase the sale price by almost 0.6%. In Long Island, we obtain similar results, although the coefficient estimates for the two definitions of precision are larger than in South Florida. Taken together, these results provide strong evidence that price precision increases buyers' WTP.

Table 5 Effect of List Price Precision on Final Sale Price: Controlling for Other Factors

Dependent variable: ln(sale price)	South Florida	South Florida	South Florida	Long Island	Long Island
Precise000 (fewer than three ending zeroes)	0.0023** (0.0005)			0.0028+ (0.0015)	
Number of ending zeroes		−0.0009** (0.0002)			−0.0017* (0.0007)
Precise (survey-based measure)			0.0058** (0.0010)		
ln(list price)	0.96** (0.00)	0.96** (0.00)	0.96** (0.00)	0.95** (0.01)	0.95** (0.01)
Within R-squared	0.99	0.99	0.99	0.98	0.98
N	7,342	7,342	7,341	9,026	9,026

Notes. All models include control variables described in §7.2 (house characteristics, selling agent commission, agent, zip code, and year fixed effects, etc.). Standard errors, clustered by agent (i.e., we allow for arbitrary correlations in error structure for each agent), are reported in parentheses.
+Significant at $p < 0.10$; *significant at $p < 0.05$; **significant at $p < 0.01$.

The magnitudes of these effects might seem small. However, because we control for the list price and a detailed set of house characteristics, our results indicate that if there are two houses of the same size, have the same list price and the same number of bedrooms and bathrooms, are located in the same zip code, built in the same construction style and in the same time period, and are being sold by the same agent, then the house with the more precise list price will sell at a higher price. To see what this means, consider two houses in Long Island with the same zip code and with the same number of rooms and other features; one has a list price of \$485,000 and the other has a more precise list price of \$484,880. Our results suggest that the house with the more precise list price will sell for about \$1,200–\$1,450 more.[16] This example shows that the effect is nontrivial.

[14] To confirm our intuition, we also conducted the analysis on the full sample, including transactions where the list price was smaller than the sale price. For both data sets, the precision of the list price continues to have the predicted, although smaller, effect on the final sale price.

[15] We also controlled for nine-endings by creating a dummy variable for list prices that end in 9, 90, 900, 9,000, 90,000, and 900,000. Doing so leaves our results unchanged.

[16] To obtain this figure, we calculate the expected sale price using the average values for all variables except for the list price and the measure of precision. Note that there are three ending zeroes for the list price of \$485,000 and only one for the list price of \$484,880. Therefore, we compare the expected sale price when we plug in the list price value of \$485,000 and three ending zeroes (Precise000 = 0)

8. Conclusion

We examine whether consumers judge precise prices to be smaller than round prices and whether this biased judgment influences their WTP. Our laboratory experiments provide strong evidence for the existence of the precision effect; people judge precise prices to be smaller than round prices, even when the round prices are actually smaller than the precise prices. They also provide some evidence that price precision increases WTP. Moreover, results from Studies 2 and 3 identify two important moderators of the precision effect: the feeling of uncertainty induced by cognitive difficulty, and the belief about the relationship between magnitude and precision. The online survey (Study 4) and the analysis of market transactions (Study 5) provide evidence for the external validity of our conceptualization and results.

Although we conducted our empirical analysis in the context of the residential real estate industry, the proposed model is applicable to any purchase situation in which the buyer has to evaluate large precise prices under conditions of uncertainty. One prominent example is automobiles. It seems reasonable that price precision would have a similar effect on auto buyers, particularly in the used car market where prospective buyers might be uncertain whether the list price is low or high. These results, therefore, have important substantive implications for buyers and sellers. Buyers should be more cautious in their price magnitude judgments in light of our results. Sellers can strategically set precise prices and thus influence buyers' judgments and resulting WTPs.

This research contributes not only to the behavioral pricing literature, but to other streams of literature as well. There is a growing body of literature showing that biases in buyer behavior could be caused by implicit processes (e.g., Fitzsimons et al. 2002, Mishra et al. 2007). However, other researchers have suggested that biases in price cognition are due to volitional cognitive miserliness (Basu 2006, Stiving and Winer 1997) and that such biases will not manifest in high involvement categories. The result that precision in prices affects buyer behavior in real estate transactions suggests that some of the implicit biases in judgments will manifest under conditions of high involvement.

This research also contributes to the burgeoning literature on the effects of cognitive ease and difficulty on judgments (Schwarz 2004, Whittlesea 1993). Recent research in this domain (Alter et al. 2007) demonstrates that cognitive difficulty induces people to consider more cues to make judgments and that such processing reduces bias in judgments. Our results are consistent with the hypothesis that cognitive difficulty induces people to consider more cues: participants in our studies considered the relationship between precision and magnitude under conditions of precision-induced cognitive difficulty.

Our results on the precision effect bring forth several issues that merit further research. First, an important question is how a seller can optimize the trade-off between list price precision and list price magnitude. Consider the following example where the buyer forms her WTP for a house by adjusting the list price downwards. Our results suggest that the buyer's WTP will be about \$1,200–\$1,450 higher if a seller lists a house for a precise list price, such as \$484,880 or \$485,120, instead of rounding the list price to \$485,000. This is despite the fact that the actual difference between the precise and round list prices is only \$120. Because of the price precision effect, the buyer perceives the precise list price to be lower than the comparable round price, and consequently, the amount of downward adjustment from the list price to get to WTP is smaller for the precise list price. How far away should the precise list price be from the comparable round price to maximize the sale price? Will the price precision effect result in a higher sale price if the difference between the precise price and the round price is much larger, say, \$4,250 (i.e., if the precise list price is \$480,750 or \$489,250)? Furthermore, will the seller gain more by "precising" the list price upwards (e.g., \$485,120) or by precising it downwards (\$484,880)? Developing an analytical model to address these price optimization issues will be of theoretical as well as substantive importance. Therefore, this is a fruitful avenue for future research. However, the tractability of and the recommendations from such a model are contingent on the definition of precision and the nature of the relationship between precision and list price magnitude (see the appendix for the outline of such a model and how these issues influence the tractability of the model).

Second, although we find that the precision effect cannot be explained by cognitive miserliness, we do not systematically test how explicit (System 2) and implicit (System 1) processes interactively contribute to the price precision effect (Kahneman and Frederick 2002; also see Mishra et al. 2007). This could be another fruitful avenue for future research. Third, more analysis is needed on the definition of roundness or precision. Consistent with Dehaene and Mehler (1992; also see Sigurd 1988), we defined roundness based on whether the number was a multiple of 10, 100, 1,000, etc. However, it is not clear

versus the expected sale price when we plug in the list price value of \$484,880 and one ending zero (Precise000 = 1) into our regression model. The difference in the expected sale price is about \$1,450 when we use the continuous measure of precision (Ending Zeroes) and about \$1,200 when we use the dummy variable (Precise000).

whether roundness is defined based only on the factorial content of numbers. Jansen and Pollmann (2001) suggest that roundness could also be based on linguistic properties of numbers. For example, they say that any number that is preceded by the word "about" might be considered round. Therefore, 25 might be considered a round number although it is not a multiple of 10, because people might use it to round off 23 or 26 and instead say "about 25." Furthermore, some numbers might be considered more round in one context and less round in another context. Although 25 might be considered a round number in the context of numbers less than hundred, 364,525 is unlikely to be considered round even though it ends in 25. These examples suggest that roundness of a number might be based on the prototypicality of the number in the considered context (Rosch 1975). The factors that affect perceptions of precision and roundedness, and how the effect of precision could change with the degree of precision, are questions that deserve attention in future research.

Another worthwhile avenue of investigation is whether and how the precision effect influences numerical cognition outside the context of prices. For example, are consumers likely to judge a 5.43-ounce pack of cookies to contain fewer cookies than a 5-ounce pack? Should sellers of houses say their house is about 2,500 square feet rather than saying it is 2,584 square feet? These questions exemplify the richness of the phenomena that may be uncovered by exploring the implications of the precision effect in numerical cognition.

9. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mktsci.pubs.informs.org/.

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Appendix. Choosing Optimal Precision in List Price

When a seller uses a precise list price (e.g., \$485,120 or \$484,880) instead of a round one (e.g., \$485,000), it has two effects on the transaction: (1) it changes the level of the list price (the level effect), and (2) it biases buyer's subjective judgment of whether the list price is low or high (the underestimation effect). In this section, we sketch a model to show how these two effects influence the sale price. Although a seller can make a round price precise by changing it by just a dollar (e.g., listing the price as \$485,001 instead of \$485,000), such a precise list price might not be the profit maximizing list price. The purpose of this model is to examine the cumulative effects of list price magnitude and list price precision on the buyer's willingness to pay. Specifically, if the seller wants to use a precise list price instead of using a round list price (e.g., \$485,000), what level of the list price will maximize her profits (e.g., \$483,120, or \$484,120, or \$485,120, or \$486,120)?

Consider a seller trying to maximize the sale price from her home. She must choose a list price that anticipates the prospective buyer's adjustment process. We use an anchor-and-adjust model for the buyer's willingness to pay (WTP). A buyer i arrives at her WTP for house j by adjusting the list price LP by an amount *Adjust*. That is,

$$\mathrm{WTP}_{ij} = \mathrm{LP}_j(\mathit{Precision}_j, \cdot) - \mathit{Adjust}_{ij}(\mathit{Precision}_j, \cdot). \quad (1)$$

Note that in Equation (1) a change in the *Precision* of the list price can either increase or decrease the list price. If the list price is "precised up" (e.g., the list price changes from \$485,000 to \$485,120), then the level of the list price increases. In contrast if the list price is "precised down" (e.g., the list price is changed from \$485,000 to \$484,880), then the level of the list price decreases.

We model the amount of adjustment as a function of three factors: the level of the list price LP, the *Precision* of the list price, and a vector X that includes house characteristics, selling agent commissions, zip code and year fixed effects, and buyer characteristics as follows:

$$\mathit{Adjust}_{ij} = \beta_1 \mathrm{LP}_j(\mathit{Precision}_j) - \beta_2 \mathit{Precision}_j - X_j\beta_3. \quad (2)$$

That is, a change in LP (resulting from a change in precision) should affect the amount of adjustment in the buyer's offer price in two ways. First, the higher the level of the list price, the greater is the downward adjustment. This effect is captured by β_1. Second, the more precise the list price, the smaller is the amount of adjustment. As discussed in this paper, when a seller uses a precise list price (e.g., \$485,120 or \$484,880) instead of a round list price (e.g., \$485,000), precision-induced uncertainty will cause the buyer to underestimate the list price and therefore make a smaller (downward) adjustment to reach her WTP. This effect is captured by β_2. Furthermore, independent of the list price, the amount of adjustment is also influenced by the features of the house; the amount of adjustment is lower if the house has more attractive features, X_j. This effect is captured by the vector of coefficients β_3. Combining (1) and (2) we get

$$\mathrm{WTP}_{ij} = (1-\beta_1)\mathrm{LP}_j(\mathit{Precision}_j) + \beta_2 \mathit{Precision}_j + X_j\beta_3. \quad (3)$$

We refer to the term $(1-\beta_1)$ as the *level effect of precision* because it captures the effect of the level of the list price on WTP. We call β_2 the *underestimation effect of precision* because this effect of precision is caused by biased magnitude judgment.

The resulting sale price SP for house j will be a function of the WTP of the highest bidder. Therefore, we obtain

$$\begin{aligned}\mathrm{SP}_j &= \gamma_0 + \gamma_1 \mathrm{WTP}_{ij}\\ &= \gamma_0 + \gamma_1\big[(1-\beta_1)\mathrm{LP}_j(\mathit{Precision}_j)\\ &\qquad + \beta_2 \mathit{Precision}_j + X_j\beta_3\big]. \end{aligned} \quad (4)$$

To see how a change in precision of the list price will affect the SP, we differentiate Equation (4) to obtain

$$\frac{\partial \mathrm{SP}_j}{\partial Precision_j} = \left[\gamma_1(1-\beta_1)\frac{\partial \mathrm{LP}_j}{\partial Precision_j}\right] + \gamma_1\beta_2. \qquad (5)$$

Recall that $(1-\beta_1)$ captures the level effect of precision and β_2 captures the underestimation effect of precision. The level effect has two parts—a direct effect on the anchor and an indirect effect on the adjustment. $\partial LP/\partial Precision$ indicates how precision changes the level of the anchor (i.e., list price). This effect could be either positive (e.g., precising up from \$485,000 to \$485,120) or negative (e.g., precising down from \$485,000 to \$484,880). The term $-\beta_1\partial \mathrm{LP}/\partial Precision$ indicates how the change in the level of the anchor affects the amount of adjustment. Finally, β_2 indicates how the underestimation of the list price magnitude caused by precision affects the amount of adjustment. Therefore, assuming positive γ_1, an increase in precision will lead to a higher sale price if the sum of the direct- and-indirect-level effects and the underestimation effect is positive.

The model described above has limitations that deserve attention in future research. First, this model assumes that price precision is a continuous variable, corresponding to our survey-based measure of precision that measures precision on a continuous scale. It would be useful to have a model that considers price precision as a discrete variable (e.g., a number of zeroes in a six-digit price that could vary from 0 to 5), corresponding to the discrete measures of precisions that we use in the paper. Second, the relationship between list price and precision is likely to be nonlinear and discontinuous, making Equation (5) harder to interpret. For example, increasing the list price by a dollar can make it more precise (e.g., \$485,000 versus \$485,001); however, increasing it by a \$1,000 may not make it more precise (e.g., \$485,000 versus \$486,000).

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