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Do Consumers Perceive Precise Prices to be Lower Than Round Prices? Evidence from Laboratory and Market Data

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Abstract

We examine two questions: Does precision or roundedness of prices bias magnitude judgments? If so, do these biased judgments affect buyer behavior? In a laboratory pre-test, we find that people incorrectly judge precise prices (e.g., $325,425) to be lower than round prices of similar magnitudes (e.g., $325,000). Building on evidence of greater prevalence of precision in smaller numbers and roundedness in larger numbers (Dehaene and Mehler 1992), we suggest that representativeness of digit patterns might influence magnitude judgments. We term this the "precision heuristic" in price magnitude judgments. We examine the effect of this precision heuristic on buyer's willingness to pay (WTP) in two distinct but complementary ways. First, we conduct a laboratory study to understand the psychological mechanism behind the precision heuristic. We find that people do learn to associate precision with smaller magnitudes, and that this association biases their price magnitude judgments. Additionally, we rule out alternative explanations which posit that a precise price signals a seller's low-price strategy or her unwillingness to negotiate. Based on these findings, we suggest that although the precision heuristic can lead to biased judgments, it is an ecologically valid judgment criterion. Next, using data from more than 27,000 residential real estate transactions in two separate markets, we find that buyers pay higher sale prices when list prices are more precise. This finding is consistent with the precision heuristic, suggesting that buyers perceive precise list prices to be lower, and therefore accept sale prices that are closer to the list price. These results have substantive implications for buyer and seller behaviors, and theoretical implications for the understanding of price cognition process.

Key words: Price magnitude judgments, representativeness, precision heuristic.

"Don't interrupt," Bruno said as we came in "I'm counting the Pigs in the field!"

"How many are there?", I enquired.

"About a thousand and four", said Bruno.

"You mean 'about a thousand'", Sylvie corrected him. "There's no good saying 'and four': you can't be sure about the four!"

"And you're as wrong as ever!" Bruno exclaimed triumphantly. "It's just the four I can be sure about; 'cause they're here, grubbing under the window! It is the thousand I isn't pruffickly sure about!"

<div align="right">

- Lewis Carroll, in *Sylvie and Bruno Concluded*

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1. Introduction

Literature in consumer psychology and economics both share a prevailing view that a buyer's judgment of the magnitude of the price is an important determinant of her purchase decisions (Monroe 2003; Winer 2006). Research on factors that affect consumers' magnitude judgments in general (see Krishna 2006 for a review) and price magnitude judgments in particular (Greenleaf 1995; Morwitz, Greenleaf and Johnson 1998; Wathieu and Bertini 2007) has not only unveiled several new behavioral phenomena, but also has enhanced our understanding of the consumers' cognition processes. 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 precise prices to be higher or lower than round prices? Consider the following illustrative example: A seller of a house can list the house for a more precise price such as $395,425 or the more round price $395,000. Is the buyer's evaluation of the precise price likely to be any different than that of the round price?

Two important clarifications about our approach are due right at the outset. First, following Sigurd (1988), we consider multiples of 10 as round numbers and other numbers as precise numbers.[1] Second, we note that our discussion of precision is distinct from the well-established literature on nine-endings in pricing (e.g., Stiving and Winer 1997). A precise price

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[1] However, we also recognize that there could be differences in the degree of precision or roundedness of numbers and that the degree of precision depends on the judgment context. We return to this issue later in the paper.

can have a nine-ending (e.g., 299,999) or not (e.g., 301,465). Comparing consumers' evaluations of a nine-ending precise price with that of the corresponding round price (e.g., 299,999 vs. 300,000) is problematic, because the effect of precision will be confounded with the nine-ending effect. Therefore, in our experiments we do not use prices that end in nine, and in the analyses of the market data we find that our results are robust to controlling for the nine-endings effect.

To explore whether precision influences magnitude judgments, and if it does, in which direction, we first ran a simple laboratory pretest. The results show that participants judged precise prices to be smaller than similar, *but larger*, round prices. Ninety undergraduate students at a large Northeastern university were asked to evaluate twelve different list prices of a house listed for sale in a neighboring city. Six of the prices were precise and the other six round. Participants were randomly assigned to two groups and each group evaluated six of the twelve prices, one at a time, presented 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. This experiment was designed to ensure that participants do not see precise and round prices of similar magnitude. This is because our interest is in examining the heuristics at play in situations where there is uncertainty; specifically, in judging a number's "stand-alone" magnitude (e.g. is $391,534 large or small) rather than in comparison with another number (e.g. is $391,534 larger or smaller than $390,000). It is important to note that the six precise prices used as stimuli were higher than the six round prices of similar magnitudes (e.g., $391,534 vs. $390,000). Yet, as figure 1 reveals, participants systematically judged the magnitudes of the precise prices to be significantly *smaller* than the round prices.[2] This result suggests that people

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[2] An ANCOVA revealed a main effect of precision ($F(1, 537) = 4.98$, $p = .026$; $M_{Precise} = 5.71$ vs. $M_{Round} = 6.07$) and a significant effect of price ($F(1, 537) = 783.62$, $p < .001$) that served as a covariate in the model.

might be using precision as a cue for smaller magnitudes. We refer to this decision rule as the "precision heuristic" in price magnitude judgments. Based on this initial evidence, in the coming sections we proceed to examine the psychological basis of the precision heuristic in price evaluations and to assess its influence on buyers' WTP

Figure 1
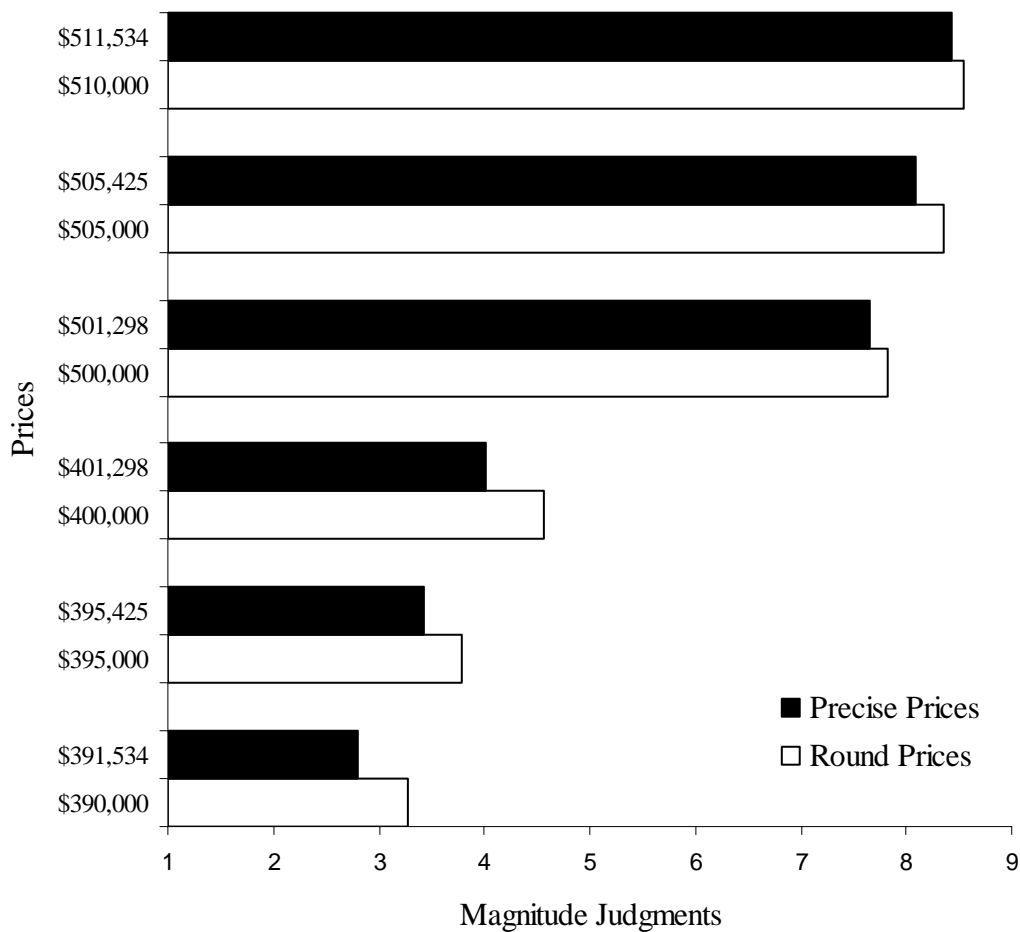
In the following section we discuss the germane literature. Then, we conduct a laboratory experiment to examine the psychological mechanisms that underlie the precision heuristic and its effect on buyer behavior. We find that people learn to associate precision with smaller

magnitudes, and we are able to reverse this association in the laboratory. Importantly, we show that this learned precision-magnitude association biases price magnitude judgments. Additionally, we rule out alternative explanations which posit that a precise price may signal a seller's low-price strategy or her unwillingness to negotiate.

Next, we examine the effects of precision on buyer behavior in residential real estate transactions. We analyze data from more than 27,000 completed residential real estate transactions in two different US markets and examine whether the sale price is influenced by the precision or roundedness of the list price. We find that more precise list prices are correlated with higher sale prices. These results are consistent with the hypothesis that buyers rely on the precision heuristic, as they suggest that buyers perceive precise list prices to be lower, and therefore accept higher sale prices.

We believe that this research has important practical and theoretical implications. It can make buyers and sellers aware of factors that influence their magnitude judgments. Moreover, this research contributes to our understanding of the price cognition process, in particular, and of numerical cognition processes, in general.

2. A Hypothesis for Price Magnitude Judgments

2.1: The Precision Heuristic

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 numbers (e.g., 1, 2, 3,… 8, and 9) and numbers rounded to the nearest multiple of 10 (e.g., 10,

20, …, 100, 110). Stated differently, large, precise numbers (e.g., 11, 21,… 101, 121,…1011, 1121) are used relatively infrequently in daily communication. This finding was replicated by Dorogovtsev, Mendes and Oliveira (2005) who studied patterns of number usage on the World Wide Web, and by Jansen and Pollmann (2001) who studied patterns of number usage in newspapers.

The infrequent use of large, precise numbers in printed and spoken communication is surprising because the majority of numbers are precise, not round (i.e., most numbers are not multiples of 10). Although it is difficult to conclusively determine the cause of this phenomenon, Dehaene (1997) suggests that it could be due to the logarithmic nature of the mental representation of numerical magnitudes.[3] That is, large numbers are compressed on the internal scale used for magnitude representations such that the distance between 99 and 100 is perceived to be smaller than that between 1 and 2. Consequently, while smaller magnitudes are expressed precisely, larger magnitudes are rounded to the nearest multiple of 10, leading to an infrequent use of large, precise numbers. "The larger a quantity is, the fuzzier our mental presentation of it, and the less often we feel the need to express that precise quantity" (Dehaene 1997, p.114).

We posit that the infrequent use of large, precise numbers will affect people's numerical cognition process. Because people encounter large, precise numbers infrequently, they are likely to be less certain about the underlying magnitude of such number. How are buyers likely to react to this uncertainty in the case of prices? Previous research on judgment under uncertainty suggests that the representativeness of digit patterns might influence judgments of magnitude (Kahneman and Tversky 1973). Gilovich and Savitsky (2002) describe numerous erroneous judgments and beliefs resulting from the overuse of the representativeness heuristic. However,

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[3] Benford (1938; also see Raimi 1969) offers a mathematical explanation for why numbers are more likely to start with 1 than with 9. However, their account does not explain why round numbers are overrepresented.

the existing literature on the representativeness heuristic has neither researched numerical magnitude judgments in general, nor price magnitude judgments in particular. Therefore, we extend the notion of representativeness to the realm of numerical magnitude judgments and posit that because people encounter large, precise numbers infrequently, they will associate precision with smaller magnitudes. Such an association between precision and small magnitudes suggests the activation of a precision heuristic in magnitude judgments: *Precise numbers are usually smaller than round numbers*.

We are interested in examining precision heuristic in the context of prices. The above association suggests that, based on their prior experience, buyers might judge a large, precise price (e.g., 391,234) to be smaller than a round price of similar magnitude (e.g., 391,000). Therefore, in the domain of pricing, the precision heuristic can be restated as: *Precise prices are usually smaller than round prices.*

A necessary condition for buyers to invoke the precision heuristic is the presence of uncertainty about prices. There may be purchase situations where price magnitude judgments might not entail any uncertainty; for example, when a buyer is comparing prices of two identical apartments in the same building or two identical products placed on the same shelf in a store. However, many, if not most, purchase situations involve products that are not perfectly identical, or involve identical products where a buyer might not be able to confidently recall the comparison price, either because she is comparing prices at different stores or at different points in time.

2.2: Linking Price Precision with Buyers' WTP: Three Possible Psychological Mechanisms

The evidence from our pretest was consistent with the precision heuristic; participants systematically judged the magnitudes of the precise prices to be significantly *smaller* than the round prices. In this section we link the precision heuristic with buyer behavior. We hypothesize that the precision of a price will have a positive effect on buyers' WTP, because buyers will perceive precise prices to be lower. For example, consider the case in which the same car model is being offered at dealerships in two different cities. In City A the price is $30,000, and in City B the price is $30,113. Based on the above discussion of the precision heuristic, we would expect buyers at the dealership in City A to be willing to pay less, relative to the original list price, than would the buyers in City B, because the buyers in City A would perceive that the list price is higher, even though it is in fact a little lower. Since this hypothesis is based on the assumption that people learn to associate precise numbers with smaller magnitudes, we refer to this as the *learned precision-magnitude association* (LPMA) hypothesis.

However, there are at least two other plausible alternative explanations for the effect of price precision on WTP: the *low-price signal* and the *expected negotiability* hypotheses. The low-price signal hypothesis posits that the precision heuristic might be based on deliberative economic thinking. It suggests that buyers might perceive precision to signal the seller's attempt to set the price as low as possible. Stated differently, a precise price might reflect the pricing strategy used by a cost-conscious seller who is offering a good deal. Importantly, the low-price signal hypothesis is similar to the LPMA hypothesis in that both posit that price magnitude judgments mediate the relationship between price precision and buyers' WTP.

Unlike the LPMA hypothesis and the low-price signal hypothesis, the expected negotiability hypothesis does not posit that precision will affect buyers' price magnitude

judgments. Rather, this account suggests that buyers might consider precision as a signal of sellers' unwillingness to negotiate (Rogers 2007).[4] For example, when presented with a list price of $325,573, a buyer might reason: "If the seller's expectation is so meticulously defined, then there is little scope for negotiation." As a result, buyers are more likely to accept a higher sale price.

Although they yield predictions similar to the LPMA hypothesis, these two alternative hypotheses are based on distinct psychological mechanisms. Both the low-price signal hypothesis and the expected negotiability hypothesis are based on deliberative, context-specific reasoning: precise prices indicate that the seller has very carefully calculated the price, or that the seller is unwilling to negotiate. In contrast, the LPMA hypothesis assumes the spontaneous activation of a domain-invariant, associative knowledge structure in memory: round numbers are associated with larger magnitudes, and precise numbers are associated with smaller magnitudes. Therefore, the LPMA hypothesis predicts that prior learning about number patterns, with numbers that are *not* prices, can affect associative knowledge structures. Specifically, the precision heuristic can be reversed if people learn that precise numbers are usually higher than round numbers. The low-price signal and the expected negotiability hypotheses, in contrast, predict that prior learning with numbers that are not prices will not moderate the effect of precision on magnitude judgments because the effect is based on inferences about seller's pricing strategies.

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[4] Rogers (2007) quotes realtors discussing the non-negotiability hypothesis. "I've seen prices like $433,779," said James Lake, a vice president of Bellmarc Realty. "It indicates its going to be a difficult transaction from beginning to end." Ms. Sacks agreed. "That would be a real turnoff," she said. "Then, you're talking about someone who's going to be arguing about leaving a curtain rod".

3. Evidence from Laboratory Study

In this study, we further test the precision heuristic, and examine its effect on buyers' WTP. To do so, we first test whether precision in prices will affect participants' magnitude judgments. Next, we test the effect of such biased price magnitude judgments on buyers' WTP. We predict that price precision will have a positive effect on buyers' WTP, because buyers will judge precise numbers to be smaller than round numbers of similar magnitude.

In addition, we try to discriminate between the LPMA hypothesis and the two alternative explanations for why price precision might have a positive effect on buyers' WTP: the expected negotiability and low-price signal hypotheses. In other words, we try to demonstrate that the LPMA is the psychological mechanism underlying a positive effect of price precision on buyers' WTP.

3.1: Method

3.1.1: Participants. One hundred and thirty four students from a large Northeastern university participated in this experiment. They received a small amount of money for participation. The experiment was administered on personal computers. The computer was programmed to randomly assign the participants to one of the four conditions created by crossing the two between-subjects factors: Precision (Precise vs. Round) and Prior Experience (Precision is associated with smaller magnitudes vs. Precision is associated with larger magnitudes).[5]

3.1.2: Procedure. 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 mental associations between precision and numerical magnitudes.

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[5] Note that in the pretest there was no manipulation of prior experience. Therefore, the results from the pretest reflect the natural associations between precision and magnitude in consumers' minds.

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 the shown number is higher or lower than 5,000. Half of the numbers was higher and the other half was 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 "precision is associated with larger magnitudes" condition, the numbers that were higher than 5,000 were precise (e.g., 5,563, 6,142) and the lower numbers were round (e.g., 4,000, 3,000). This manipulation was intended to create an association between precision and larger magnitudes. In contrast, for participants assigned to the "precision is associated with smaller magnitudes" condition, the numbers that were lower than 5000 were precise (e.g., 4,523, 3,526) and the higher numbers were round (e.g., 6000, 7000).

After completing the first experiment, all participants responded to another experiment titled Real Estate Price Evaluations. Participants were shown a picture and a brief description of a house listed for sale in a neighboring city. To reduce the random noise in their responses, they were informed that similar houses in that city are valued between $270,000 and $430,000. Then fifteen list prices (nine test prices and six filler prices) were presented, one at a time in a random order. Participants judged the magnitudes of the presented prices on an eleven-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 (in dollars) 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.[6] Participants assigned to the precise condition saw test prices (in dollars) that were precise: 332,126, 337,851, 341,162, 346,178, 351,342, 356,193,

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[6] In our real estate data, the mean number of zeros is about 2.75, and more than 60% of all observations have three ending zeros. Therefore, in the experiment we use three or more ending zeros as an indicator of roundedness in prices.

361,584, 366,793, and 371,157. To test whether the precision heuristic can lead to incorrect magnitude judgments, the chosen precise prices were larger than the closest round number (e.g. 332,126 and 330,000). The six filler prices did not change across the two conditions.[7] Finally, participants indicated 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?" Our primary interest was in testing how magnitude judgments of the precise versus round list prices would influence WTP.

Two aspects of this experiment are particularly noteworthy. First, we use generic numbers rather than prices in the learning phase to create such associations between precision and magnitude. This reflects our belief that the precision heuristic is an abstract and context-invariant association that is not restricted to the domain of prices. That is, if people learn an association between precise numbers and smaller magnitudes, it will influence their judgments of prices even if the learning was in a context completely unrelated to prices. Second, the prices used in the test phase of the experiment were different from the numbers used in the preceding number study. The numbers used in the number study were less than 10,000 while the prices used in the real estate price evaluation study were higher than $300,000. This design reflects another important aspect of the abstractness and context-invariance of the precision heuristic. Learning the association between precision and magnitude of numbers in smaller numbers influences participants' magnitude judgments, even when they see much larger numbers.

Furthermore, the learning phase in this experiment has been designed to exclude the low-price signal and expected negotiability hypotheses as alternative explanations for the effect of precision on WTP. If the effect of precision on price judgments and WTP is due to inferences

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[7] 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.

about the seller's pricing strategy, then the results should be invariant to the manipulation of the learning of associations of precise-small versus precise-high. However, if the effect of precision is caused by the LPMA, then our manipulation of participants' experiences with small, precise versus large, precise numbers should reverse the effect of the precision heuristic.

3.2: Results

3.2.1: Judgments. The judgments of the test prices were submitted to a 2 x 2 x 9 mixed factorial ANOVA with Precision (Precise vs. Round) and Prior Experience (Precision is associated with smaller magnitudes vs. Precision is associated with larger magnitudes) as between-subjects factors and Price Magnitude (nine levels) as a within-subjects factor. The summary of the means is presented in table 1.

TABLE 1

Summary of Experiment Results

Prior Experience	Judgment of List Price (on a eleven-point scale)		Fair Price Estimate (in $)	
	Round List Price	Precise List Price	Round List Price	Precise List Price
Precision is associated with smaller magnitudes	6.65 (0.26)	5.92 (0.24)	332,343 (6460)	348,342 (5928)
Precision is associated with larger magnitudes	6.54 (0.24)	7.31 (0.28)	352,108 (6008)	323,888 (7033)

Standard errors are in parentheses

Consistent with our prediction, the precision by prior experience interaction was statistically significant ($F(1, 130) = 8.46$, $p < .01$). Simple contrasts revealed that when participants' prior experience indicated that greater precision is associated with smaller

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magnitudes, they incorrectly judged precise prices to be smaller than round prices ($M_{precise}$ = 5.92 vs. M_{round} = 6.65; $F(1, 130)$ = 4.22, p = .04). This effect is particularly interesting because the precise prices used in this study were slightly higher than the round ones. However, when participants' prior experience indicated that greater precision is associated with larger magnitudes, they judged precise prices to be larger than round prices ($M_{precise}$ = 7.31 vs. M_{round} = 6.54; $F(1, 130)$ = 4.25, p = .04). Further comparisons suggest that this effect may be due to uncertainty about the magnitudes of precise prices. The manipulation of prior experience only affected the judgments of the precise prices, $F(1, 130)$ = 13.84, p < .01, it did not affect the judgments of round prices, $F < 1$.

 3.2.2: House Valuation. Participants' house valuations were submitted to a 2 x 2 ANOVA with the same between-subjects factors as in the previous analysis. Again, the precision by prior experience interaction was statistically significant ($F(1, 130)$ = 12.03, p < .01). The pattern of means suggests that participants' valuations were influenced by their judgments of list prices. When their prior experience induced them to judge precise list prices to be relatively low, they incorrectly judged the precise prices to be lower than the round prices. As a result, their valuation of the house was around $16,000 more when shown precise list prices ($M_{precise}$ = $348,342 vs. M_{round} = $332,343; $F(1, 130)$ = 3.33, p = .07). In contrast, when their prior experience induced them to judge precise prices to be relatively high, they indeed judged these prices to be higher. Consequently, their valuation of the house was around $28,000 lower when shown precise list prices ($M_{precise}$ = $323,888 vs. M_{round} = $352,108; $F(1, 130)$ = 9.31, p < .01).

 3.2.3: Mediation Analysis. The LPMA suggests that the effect of precision on house valuation will be mediated by participants' judgments of list price magnitudes. That is, when participants judge list prices to be low, they will be more willing to pay that list price, and

consequently, their valuation of a fair price is higher. Conversely, when participants' judge list prices to be high, they will be less willing to pay that list price, and consequently, their valuation of a fair price will be lower. To examine this hypothesis, we tested a mediated moderation model (Kenny, Kashy, and Bolger 1998). 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 valuation ($\beta = -14918$, $p < .01$). The negative coefficient suggests that those participants who judged the list prices to be lower were willing to pay more for the house. In a second model, we regressed the house valuations on the dummy variables for the two between-subjects factors, Precision (with the precise list prices condition coded as 1 and the round list prices condition coded as -1) and Prior Experience (with -1 indicating that precision is associated with smaller magnitudes, and 1 indicating that precision is associated with larger magnitudes), and the interaction of the two factors. This analysis confirmed that the interaction of these two factors was also a significant predictor of house valuations ($\beta = -10858$, $p < .01$). However, this interaction effect was weakened ($\beta = -4854$, $p = .15$) when judgments of list prices was included as an additional regressor in the third regression model. Further, judgments of list prices remained a significant predictor of house valuations ($\beta = -14688$, $p < .01$) in the third regression model. In addition to these diagnostics, the Sobel test for mediated moderation was also significant ($t = 2.59$, $p < .01$). Thus, the effect of price precision on participants' WTP, induced by their prior experience, is weakened when we control for their magnitude judgments.

3.4: Discussion

Several important conclusions emerge from the results of this experiment. First, these results show that the propensity to associate precise prices with smaller magnitudes is due to

learning from prior experiences. Precision in prices was considered to be representative of smaller magnitudes only when participants' prior experience with numbers was consistent with such an association. When participants' prior experience suggested that precise numbers are usually associated with larger magnitudes, precision in prices was considered to be representative of larger magnitudes. Therefore, the precision heuristic seems to be an ecologically valid decision rule, because it reflects the reality that the precise numbers we encounter in our daily lives are more likely to be small than large (Dehaene and Mehler 1992).

Second, these results also highlight the human mind's ability to make abstract and context-invariant inferences from prior experiences with numbers. Recall that in the first part of this experiment, the only instruction given to the participants was to judge whether the shown number, which was between 1000 and 10,000, is higher or lower than 5000. They were not instructed to identify or learn any patterns of associations. Nevertheless, participants seemed to have spontaneously discerned the association between precision and magnitude. More importantly, the learning from this experience influenced their judgments in an unrelated context. Specifically, judging that 4523 is lower than 6000, made them more likely to judge $351,342 to be lower than $350,000 even though the judgment context (numbers vs. dollars), the absolute numerical magnitudes (<10,000 vs. >300,000) and the response formats (binary judgments vs. analog judgments) were completely distinct.

Finally, by demonstrating that price precision affects magnitude judgments, and by showing that participants judge precise prices to be higher when they are primed to believe this, these results rule out the low-price signal and the expected negotiability hypotheses as drivers of price judgments in the experiment. In addition, we demonstrate that the learned association between precision and magnitude influences buyers' WTP, even when there is no possibility of

negotiation. This result is of substantive importance because it suggests that the precision heuristic can affect buyer behavior even in retail stores and other such situations that do not entail negotiations.

4. Evidence From Residential Real Estate Transactions

The analysis in section 3 provides evidence for the existence of the precision heuristic, and its influence on buyers' WTP, and shows that these results were driven by the LPMA. We now turn to real-world data to examine the external validity of our laboratory results. Specifically, we examine data on single-family residential real estate transactions from two separate locations: South Florida and Long Island, New York.

Residential real estate data are ideal for testing the effect of price precision on buyer behavior for two reasons. First, they include two sets of prices for each transaction: a list price and final sale price. Our conceptualization of the precision heuristic suggests that the degree of precision in the list price might have a systematic impact on the sale price. If buyers perceive precise list prices to be low, then they are likely to accept higher sale prices. Equivalently, if buyers view round list prices as relatively high, then we would expect buyers' WTP to be lower, leading to lower sale prices. Second, no two houses are identical. Therefore, buyers never face a situation where the same house is available at two different prices. This is important because, as we discuss above, the precision heuristic should only apply in cases of uncertainty, where consumers must judge the stand-alone magnitude of a price. If the identical house is available at two different prices, there is no uncertainty; clearly the consumer will choose the lower-price option. Finally and importantly, since a real estate purchase is the largest purchase most people

ever make, these data offer a test of the precision heuristic in a high involvement setting, allowing us to assess the robustness of the effect.

4.1: Data:

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 datasets provide detailed information on each housing transaction. In addition to including both the list and sale price for each transaction, they contain a wealth of information on house location and house characteristics (bedrooms, bathrooms, etc.), as well as the name of the seller and buyer agent, how much commission they earned, and the number of days the house was on the market.

Our goal in this section is to empirically assess how the precision of the list price influences the final sale price. To measure price precision, we consider three alternative specifications of price precision: Round, Round000, and Ending Zeros. We first create an indicator variable, Round, which takes a value of one for list prices that end in a zero, and zero otherwise. For example, $450,120 would be considered round, while $450,127 would be considered precise. This measure is consistent with the definition of precision offered by Sigurd (1988). However, as we discussed above, roundedness is likely to be context-specific. Some numbers might be considered more round in one context and less round in another context. As an illustrative example, 50 might be considered round while thinking of numbers that are smaller than 100. However, 395,550 might not be considered round while thinking about numbers that are larger than 100,000. Consistent with this view, we note that across both datasets (South Florida and Long Island), more than 63% of all transactions have three ending zeros in the list price. This suggests that in the context of real estate pricing, where prices are generally higher than $100,000, rounding is frequently done to the nearest thousand dollars. Therefore, we

consider a second context-specific measure of precision, Round000, which, consistent with our approach in the laboratory study, indicates list prices with three or more ending zeros. In this specification, $450,000 would be considered round, while $450,100 would be considered precise. Finally, we consider a third measure of precision, Ending Zeros, which is a count of the number of ending zeros on the list price. For example, a house that is priced at $450,000 has four ending zeros, while a house priced at $450,500 has only two ending zeros. This definition recognizes that there could be gradations in perceived roundedness of numbers; some round numbers could be perceived to be more round than others.

TABLE 2

Summary Statistics

	South Florida	Long Island, NY
Sale Price	$325,664	$590,726
List Price	$347,342	$629,074
Round (At least one ending zero)	0.973	0.936
Round000 (At least three ending zeros)	0.667	0.819
Ending Zeros	2.76	2.74
N	12218	15442

Table 2 reports descriptive statistics for these three measures of precision, along with sale prices, list prices, and other house characteristics. Interestingly, we see that the fraction of transactions in which list prices have at least one ending zero is about 97% (94%) in South Florida (Long Island). When we define roundedness with three ending zeros, we see that the proportion of transactions with round list prices falls considerably; 67% of all transactions in

South Florida include list prices with three or more ending zeros. Interestingly, we see that in South Florida, the average list price has 2.74 ending zeros, and in Long Island the comparable figure is 2.76 ending zeros.

4.2: Empirical Analysis

We regress final sale price on the three measures of price precision. However, first we must account for the correlation between the list price and list price precision. Consistent with the research discussed above, showing that large precise numbers occur infrequently, we find that sellers are more likely to round off high prices.[8] For this reason, we control for the list price in all of our models. In this way, we assess the impact of list price precision on the sale price, holding constant the level of the list price.

We test our hypothesis on data where the sale price is less than the list price. In deals where sale price is greater than list price, it is likely that there are multiple bidders. In these cases, buyers' WTP will be less influenced by the precision or roundedness of the list price, because buyers likely focus on rival buyers' bids.[9] We report the results of our analysis in table 3.

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[8] In both datasets we find a positive correlation between roundedness and list price magnitude.

[9] 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 datasets, the precision of the list price continues to have a negative, though smaller, effect on the final sale price. Rogers (2007) speculates on why round list prices might even lead to *higher* sale prices when there are competing bids "Even if round numbers invite negotiation, proponents say, they are more effective than fractional ones because soliciting bids of any amount is exactly the point, leading to snowballing and competing interest". While testing this is outside the scope of our paper, it is an interesting hypothesis to test, e.g. in internet auctions where bidding behavior can be observed.

TABLE 3

Effect of List Price Precision on Final Sale Price

Dependent Variable: Ln(Sale Price)	South Florida	South Florida	South Florida	Long Island	Long Island	Long Island
Round (At least one ending zero)	-0.0072* (0.0030)			-0.0027[+] (0.0014)		
Round000 (At least three ending zeros)		-0.0073** (0.0010)			-0.0044** (0.0009)	
Number of Ending Zeros			-0.0039** (0.0006)			-0.0036** (0.0004)
Ln(List Price)	0.99** (0.00)	0.99** (0.00)	0.99** (0.00)	0.97** (0.00)	0.97** (0.00)	0.97 ** (0.00)
R-squared	0.99	0.99	0.99	0.99	0.99	0.99
N	12218	12218	12218	15442	15442	15442

[+] Significant at $p < .10$; * Significant at $p < 0.05$; ** Significant at $p < 0.01$. Standard errors are reported in parentheses.

In both markets, we see that, as expected, the list price is very strongly correlated with the final sale price. More importantly, across all three definitions of precision, the results in both markets reveal that more round list prices are associated with lower sale prices. In Florida, the results for the first definition of round prices (Round) show that round list prices reduce the sale price by about 0.72 percent. When we use the context-specific definition of precision (Round000), we see that list prices with three or more ending zeros, reduce the sale price by about 0.73 percent. Finally, we see that each additional ending zero reduces the final sale price by about 0.39 percent. In Long Island, we obtain similar results, although the coefficient

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estimates are smaller. These results are consistent with the notion that the precision heuristic influences buyers' magnitude judgments; buyers judge more round prices to be higher, and this judgment reduces their WTP for the house.

The magnitudes of these effects might seem small. However, because we control for the list price, our results indicate that for the same list price, if one price is more round than the other, than the house with the more round list price will sell at a lower price. To see what this means consider two houses - one with a list price of $485,000 and the other with a more precise list price of $484,700. Our results suggest that the house with the more precise list price will sell for about $1380 more.

4.2.1: Robustness Tests: Controlling for Other Factors. While the above analyses provide evidence that precision affects buyers' WTP, one might think that these results reflect spurious correlations caused by 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 as: property-specific, agent-specific, time-specific, and market-specific. Consider first property-specific variables. These house characteristics control for WTP drivers not captured by the list price (e.g. if list price is inaccurately set too low given the house characteristics). Additionally, it is possible (though unlikely) that sellers set round prices for houses with particular characteristics. To control for these effects, in all of our models we include various hedonic descriptors of the property including square-footage, number of bedrooms, number of bathrooms, dummies for house style, dummies for type of heating system, age of the house, etc.

Agents might differ systematically in their propensity to set round prices and in their negotiating styles. For example, agents might differ in reputation, ability to negotiate, attitude toward negotiations, expertise, discount factors, etc. Some agents might be savvy enough to

persuade sellers to set precise (and high) prices. To control for the influence of these factors, we include agent-specific fixed effects in our model, which control for all time-invariant, agent-specific factors that are correlated with the selling price.

Finally, time varying and time-invariant market-specific variables may also influence our key variables. Some of these market-specific variables include school districts, local tax rates, current and expected future interest rates, local employment rates, inventory of unsold houses and new home construction, trends in the industry (e.g., internet penetration, which gives buyers information beyond that provided by agents),and concentration of real estate agents. We include zip code and year fixed effects to account for these variations.

We report the results of our analyses including this set of controls in Table 4.[10] In both markets, we see that the results are largely consistent with those in Table 3, though smaller in magnitude. The lone exception is that the effect of the first definition of roundedness (Round) is no longer statistically significant in Long Island. These results provide further evidence that the precision heuristic influences buyers' magnitude judgments; buyers judge more round prices to be higher, and this judgment reduces their WTP for houses.[11]

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[10] Including these controls results in a smaller sample sizes seen in table 4 compared to those in table 3. The results in table 3 remain largely unchanged when we use the smaller sample used in table 4.

[11] We also controlled for the nine-endings by creating a dummy for list prices that end in 9, 90, 900, 9000, 90,000 and 900,000. Doing so leaves our results unchanged.

TABLE 4

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	Long Island
Round (At least one ending zero)	-0.0021* (0.0009)			-0.0006 (0.0025)		
Round000 (At least three ending zeros)		-0.0023** (0.0005)			-0.0028^{+} (0.0015)	
Number of Ending Zeros			-0.0009** (0.0002)			-0.0017* (0.0007)
Ln(List Price)	0.96** (0.00)	0.96** (0.00)	0.96** (0.00)	0.95** (0.01)	0.95** (0.01)	0.95** (0.01)
Within R-squared	0.99	0.99	0.99	0.98	0.98	0.98
N	7342	7342	7342	9026	9026	9026

All models include control variables described in section 4.2.1 (house characteristics, selling agent commission, agent, zip-code, and year fixed effects, etc.).
$^{+}$ Significant at $p < .10$; * Significant at $p < .05$; ** Significant at $p < .01$. Standard errors, clustered by agent, are reported in parentheses.

Once again, the magnitudes of these effects may seem small. However, because we control for the detailed set of house characteristics, our results indicate that if there are two houses of the same size, with the same number of bedrooms and bathrooms, built in the same construction style, in the same time period, then the house that is priced with more ending zeros will sell at a lower price.

These results provide strong evidence that greater precision in the list price results in a higher final sale price, and this effect is large, and cannot be explained by other factors. Importantly, these results are consistent with the precision heuristic, suggesting that buyers judge precise prices to be lower, and that this heuristic increases their WTP for the house. However, these data do not allow us to rule out the low-price signal hypothesis or the expected negotiability hypothesis. Nonetheless, the laboratory data demonstrate that neither of these alternative hypotheses is a necessary condition for the precision effect to manifest.

5. Conclusion

5.1: Summary

We examine whether consumers systematically judge precise prices to be higher than round prices and whether this biased judgment influences their buying behavior. Our hypotheses reflect the confluence of two research streams. Research demonstrating the (empirical) prevalence of precise, low numbers and round, high numbers (Dehaene and Mehler 1992) provides the phenomenological impetus for the study; the research on representativeness (Kahneman and Tversky 1973) provides the mechanism for how this empirical fact can bias judgments of price magnitudes.

Our laboratory experiments provide evidence consistent with the precision heuristic and its effect on buyer behavior. The results show that participants who were exposed to a set of numbers where precise numbers are smaller than round numbers, judged precise prices to be smaller than round prices, even though the round prices were, in fact, greater. Similarly, those participants who were exposed to a set of numbers where precise numbers are smaller than round numbers expressed higher WTP for a house when they were shown precise list prices rather than

round list prices (even though the precise list prices were higher). The former set of results provides support for the precision heuristic and its basis in a learned association between precision and magnitude. The latter set of results provides evidence that this learned association influences buyers' WTP. At the same time we find the opposite results for those participants exposed to a set of numbers in which the precise numbers are bigger than round numbers. These participants judged precise prices to be bigger than round prices, and expressed a lower WTP for a house when shown precise list prices rather than round list prices.

Our ability to reverse the findings helps us to demonstrate that the learned association between precision and magnitude provides the causal mechanism underlying the precision heuristic and its influence on WTP. Moreover, these results help us to exclude the low-price signal and the expected negotiability hypotheses as an alternative explanation, as this effect should not be influenced by exposure to numbers where large, precise numbers are more prevalent. Finally, our ability to reverse the findings in the laboratory also points to the ecological validity of the precision heuristic in making magnitude judgments in the real world.

Results from more than 27,000 residential real estate transactions provide evidence that the precision heuristic influences buyers' behavior, even in what is likely the largest purchase that most buyers will make in their lives. We cannot rule out either the low-price signal hypothesis or the expected negotiability hypothesis in the market data. Therefore, one must interpret the results carefully. However, the results from the laboratory experiment strongly suggest that it is likely that some of the effect that we observe in the real estate data is driven by the learned association between precision and magnitude.

5.2: Implications for Practice and Research

These results have important substantive implications for buyers and sellers (and their agents). Buyers (and their agents) should be more cautious in their price magnitude judgments in light of our results. Sellers (and their agents) can strategically "precise up" their prices, i.e. choose a higher precise price rather than a lower round price.

These results also have implications for psychologists' and economists' conceptualization of decision making. It is now widely accepted that judgment and decision making is characterized by expedient rules of thumb, or heuristics. However, debates on the rationality, efficacy, and ecological validity of heuristics persist (Gigerenzer 1996). One view is that heuristics are invoked to save the time and effort required for thinking, and that they will not be invoked when the gains from thinking exceed the cost of thinking (Shugan 1980). Proponents of such a viewpoint also tend to assume that buyers and sellers are aware of the judgmental errors caused by the use of heuristics and volitionally incur the cost because of its perceived net benefit. The opposing perspective posits that many judgmental biases are consequences of unwanted mental processes (Fitzsimons et al. 2002). Whether the buyer behavior documented in this research is better characterized by the cost of thinking models (Shugan 1980), other models of quasi-rational behavior (Stiving and Winer 1997), or by models of nonconscious behavior (Fitzsimons et al. 2002) could be a fruitful avenue for future research.

In classic signaling models in economics, sellers are all aware of buyer behavior and then strategically make the choice whether or not to signal their "type". For example, a seller can signal her high quality product by offering warranties; this is not worthwhile for a lower-quality seller to do because her product will fail and the cost of servicing warranties is too high. If it is possible to fool buyers with high precise prices, we should expect all sellers to do this, especially

as there does not appear to be any cost to setting these precise prices. If some sellers are smart enough to figure this out, it should be a matter of time before others do, too. Why then, in our data, do we see only some sellers setting precise prices? Is this because only some sellers and their agents are aware of buyer behavioral biases, a possibility that is inconsistent with the assumptions in traditional signaling models in economics? Answering this question could be another fruitful avenue for future research.

Another possible avenue for further investigation is the definition of precision and roundedness. It is not clear whether roundness is defined based only on the factorial content of numbers (Jansen and Pollmann 2001). As five decades of research on categorization has revealed (e.g., Rosch 1975, Murphy 2002), mental categories are not well-defined, mutually exclusive constructs. Instead, categories are formed based on the prototypicality of the elements being considered. As discussed above, there could be gradations in perceived roundedness of numbers; that is, some round numbers could be perceived to be more round than others. We also discussed how some numbers might be considered more round in one context and less round in another context. The factors that affect perceptions of precision and roundedness, and how the effect of precision heuristic could change with the degree of roundedness, are questions that deserve attention in future research.

Another worthwhile avenue of investigation is whether representativeness influences numerical cognition outside the context of prices. For example, are consumers likely to judge a 10.43-ounce pack to contain less than a 10-ounce pack? Should sellers of houses always say their house is about 2,500 square feet rather than saying it is 2,589 square feet? These questions exemplify the richness of the phenomena that may be uncovered by exploring the implications of representativeness in numerical cognition.

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