ANCHORING EFFECTS IN INVENTORY CONTROL DECISIONS

by

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ABSTRACT

When supply chain managers are responsible for making forecasting decisions, those decisions may be influenced by a number of decision-making biases, one of which is anchoring. Anchoring is defined as "the disproportionate influence on decision makers to make judgments biased toward an initially present value." The impact of anchoring has been tested in a number of different fields, ranging from valuation of products to legal judgments. However, it has not been researched extensively in the area of supply chain management. This research aims to fill this gap by presenting an anchor to subjects who are making decisions in the field of inventory management to see what, if any, impact anchoring has in this context. The results from this research will inform managers whether they need to be careful about the presence of anchors in the information they provide to decision makers. Limiting the potential impact of the anchoring bias will lead to better inventory management. Effective inventory management has the power to greatly reduce costs by eliminating the risk of stockouts and holding excess inventory, both of which create additional expenses for companies.

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INTRODUCTION

Decision making regarding inventory management is crucial to the efficiency and success of an organization's operations and supply chain. Making such decisions poorly or without the proper knowledge, training, and research can have negative consequences. Poor decisions may lead to excess inventory, which increases operating costs. They could also lead to stock outs, which can result in lost sales and impact customer service. For instance, Gruen and Corsten (2002) estimate that on average retailers lose approximately 4% of sales due to stockouts. Such suboptimal inventory levels can have a significant financial impact on businesses. Because of the gravity of these implications, there is a great deal of literature concerning inventory management. While many businesses utilize software that produces sales forecasts and replenishment quantities automatically, it is common in practice for managers to make adjustments to these figures.

Inventory control decisions are often subject to human adjustments for a number of reasons. First, managers often have insights that forecasting software is unable to capture and incorporate into the models it employs. In addition, forecasting software takes into account a number of factors, the most prevalent being historical sales data. When new products are introduced into the market, the forecasting software has no past sales data from which to generate forecasts. This hinders the ability of automated systems to generate inventory replenishment plans, creating a need for manager intervention. Lastly, as incentives are common for employees who control inventory successfully, it is not uncommon for managers to adjust inventory control processes in their own self-interest. For instance, some employees are given bonuses for exceeding a certain number of sales, which would cause a downward bias in forecasts. Other managers may be rewarded for attaining certain customer service levels or fill rates, which would cause an upward bias in forecasts to decrease the likelihood of a stock out. With these factors in mind, understanding managerial judgment and decision making is critical to ensuring informed inventory control decisions.

With the prevalence of human intervention in inventory control decisions, managers need to be aware of ways that human biases play a role in these decisions. Literature from psychology and behavioral economics has documented many ways in which human decision makers deviate from rationality and make suboptimal decisions. In the inventory control context, multiple decision biases have been recognized as threats to efficiency. These biases include framing effects (Schultz et al), supply line underweighting (Croson and Donohue 2002), and coordination risk (Croson et al.; Schweiter and Cachon 2000).

While many of these biases have been explored in the context of inventory replenishment decisions, one that has not been extensively researched is the anchoring and adjustment heuristic. The purpose of this paper is to explore the anchoring bias in an inventory control context. Anchoring has been studied in a number of other contexts, but only to a very limited extent in inventory control. If it is shown that anchors do affect decision makers in the context of inventory control decisions, managers can be aware of the potential of biased decisions and can work to mitigate the effects. Overall, knowledge of this bias can allow supply chain managers to make more informed decisions when restocking inventory, thus minimizing costs and maximizing customer service levels.

To this end, the paper is organized as follows. In the following section, we present a review of relevant literature and develop hypotheses regarding the anchoring bias in an inventory control context. We then describe the methodology used to gather data and the analysis performed to test our hypotheses. Following these sections, we present a discussion of our findings, along with limitations of this study and opportunities for future research.

LITERATURE REVIEW

Anchoring Bias

The anchoring effect has been defined as "the disproportionate influence on decision makers to make judgments biased toward an initially present value" (Tversky, Kahneman 1974). In other words, when a decision maker is presented a number, regardless of its accuracy or relevance, that number can often profoundly influence the decision maker. That number serves as an anchor and becomes the starting point for the decision maker's analysis. While the decision maker typically adjusts away from the anchor based on what they know, or think they know, about the decision context, the adjustment is rarely sufficient.

The initial study on the anchoring effect was conducted by Tversky and Kahneman (1974). They asked subjects to estimate the percentage of African countries that are a part of the United Nations. Before making this estimate, subjects were presented with a number between 0 and 100 that was found as a result of spinning a wheel of fortune in front of the subjects. First, the participant stated whether their estimate was above or below the value that appeared on the wheel, then they provided their actual numerical estimate. For subjects who watched the wheel land on 10, the average estimate was 25%. Subjects who watched the wheel land on 65 estimated, on average, that 45% of the countries were a part of the United Nations. The offering of payoffs for accurate estimates did not decrease the effect of anchoring in this study.

The anchoring effect has been documented in a number of different decision scenarios in various contexts. In their extensive review of anchoring literature, Furnham and Boo (2008) noted that most anchoring studies pertain to general knowledge (Blankenship et al. 2008; Wegener et al. 2001; Epley and Gilovich 2001; McElroy and Dowd 2007; Mussweiler and Strack 1999; Tversky and Kahneman 1974). These studies ask participants to provide the age of George Washington at his death, the average starting annual salary of college graduates in the United States, the boiling point of water on Mount Everest, and other facts with which most participants are not familiar. This methodology leads some to call into question the validity of the subjects' answers.

Other studies have looked at more relevant subject matter and have brought in experts as participants. These studies have looked at areas ranging from legal judgments (Englich and Mussweiler 2001; Englich, Mussweiler, and Strack 2006) to forecasting (Critcher and Gilovich 2008), valuation and purchasing decisions (Ariely et al. 2003), and negotiation (Galinsky and Mussweiler 2001). In one of the studies regarding legal judgments, judges with 10 or more years of experience were affected by the rolling of a dice when determining the length of a defendant's sentence (Englich, Mussweiler, and Strack 2006). In forecasting studies, participants predicted higher sales for products with higher model numbers. In another study, subjects' estimates of an athlete's performance were affected by the number on the athlete's jersey (Critcher, Gilovich 2008).

While a number of researchers have looked at the anchoring bias under various contexts, anchoring has been given limited attention in the literature on operations, supply chain management, and logistics. Anchoring has been studied to a limited extent in the context of forecasting, (Eroglu and Croxton 2010, Critcher, Gilovich 2008), and has been proposed as an explanation for observed behavior in a Newsvendor decision task (Schweitzer and Cachon 2000), but has not been explicitly studied in an inventory control situation. This paper seeks to determine whether or not anchoring can be observed in a simple replenishment task. Given the overall robustness of the bias to context, we hypothesize that inventory control tasks are no exception and that anchoring will hold in these decisions.

Hypothesis 1: Decision makers in an inventory control task are subject to the anchoring bias

Ariely (2008) discusses the theory of arbitrary coherence, which proposes an explanation for why people cling to completely illogical anchors. "Arbitrary" refers to the fact that irrelevant anchors do impact decisions. "Coherence" refers to a person's need to maintain internal consistency. In short, once a decision is made based on an anchor, the impact of that anchor will continue to affect decision making into the future. Ariely conducted an experiment where he subjected participants to an annoying noise. He asked half of the group whether they would be willing to endure the sound for a payment of 90 cents, thus establishing a 90 cent anchor. He asked the other half whether they would be willing to endure the sound for a payment of 10 cents, establishing a 10 cent anchor. When asked the lowest amount each participant would require to listen to the noise, there was a clear anchoring effect. The 90 cent group required an average of 73 cents, while the 10 cent group requested an average payment of 33 cents. He subsequently switched the anchors. The 90 cent group was given a different annoying sound of equal unpleasantness, and asked whether they would listen to the sound for a payment of 10 cents. The original 10 cent group was presented with the same sound and asked whether they would be willing to listen for a payment of 90 cents. Each group remained locked in to their original anchors when asked for the minimum payment they would require. This demonstrates an individual's need to be internally consistent, or "coherent," with their prior decisions.

As illustration, Ariely, Lowenstein, and Prelec (2003) conduct an experiment with a group of MBA students at MIT. Subjects were asked to write down the last two digits of their social security numbers, convert that number to dollars, then determine whether they would be willing to spend that amount on various items for which people do not usually have detailed knowledge about the absolute value. Items included bottles of wine and wireless computer accessories. His results showed that the students with the social security numbers in the highest 20% bid significantly larger amounts of money than students with the lowest social security numbers.

In short, human decision makers seek to make relative decisions whenever possible. This desire for relative decision making is so strong that when a benchmark is not immediately available from which to make a comparison, we are prone to selecting an arbitrary one that can lead to irrational and inefficient decisions. However, when appropriate information exists, humans tend to make excellent decisions. Thus, we hypothesize that in an inventory control context, the provision of relevant and useful information to decision makers will mitigate the anchoring bias.

> *Hypothesis 2*: Providing information immediately relevant to an inventory control decision will mitigate the anchoring bias

EXPERIMENT 1

Method and procedure

Hypothesis 1 was tested using a simple inventory management task. Participants in the experiment, Experiment 1, were presented with the following replenishment task:

> Imagine you are a retailer who buys and sells a generic product for which demand is uniformly distributed and ranges from 0 to 100.

Subjects were then presented with one or two questions, depending on the condition to which they were assigned. Those in the Low (High) Anchor condition were asked,

> Would you order more or less than 20 (80) units? (circle) More / Less

Subjects were then asked,

> How much would you order? _____ units.

Subjects in the control condition were not presented an anchor and were only asked to provide an order amount. Thus, Experiment 1 manipulated a single factor, (Anchor), made up of 3 levels, (Control, Low, and High).

Subjects in the experiment were 76 undergraduate students, (34 females), from two supply chain management courses at a small, private school in the southern US. The experiments were conducted in separate sessions and lasted approximately 5 minutes each.

To begin each session, subjects were instructed not to talk during the event. They were told a short scenario would be presented to them and that they were to read it carefully and provide their response. The experiment was then administered to each subject on a single sheet of paper, passed out face down. The three treatment conditions were shuffled within the stack of papers so as to randomize the assignment of subjects. Verbal instruction was given not to turn over the sheet until instructed by the facilitator. Once all subjects had received the experiment, they were told to read the scenario, provide answers, and then flip their paper back over. After about 3 minutes, the papers were collected.

After collecting and examining subjects' responses, 2 were deemed problematic as they placed an order larger than the maximum possible realization of demand. These responses were removed from the data set and subsequent analysis. All other responses were found to be valid, leaving a total sample of 74 responses.

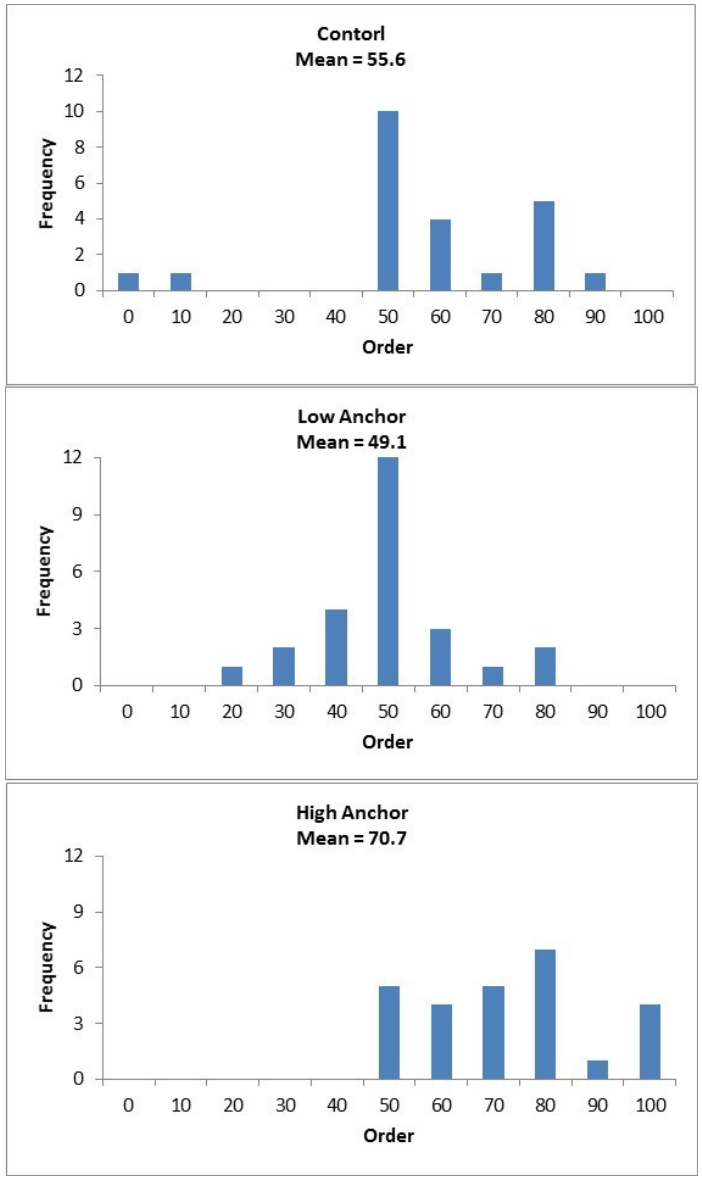
Analysis and results

We test for differences in order size between conditions using an Analysis of Covariance. The test was performed using a general liner model in SPSS version 21. Treatment condition served as the fixed factor in the model, while the number of supply chain management courses each subject had taken served as the covariate. The purpose of the covariate was to control for any potential differences between subjects resulting from differing levels of supply chain education.

Preliminary analysis was undertaken to evaluate the model assumption of homogeneity of slopes. Results indicate that the relationship between the number of supply chain courses taken and order size did not differ significantly across treatment levels, $F(2,66) = 0.46$, $MSE = 109.2$, $p = 0.64$, partial $\eta^2 = 0.014$. Thus, the assumption was found to hold.

ANCOVA results reveal a significant impact of anchoring condition on order size, $F(2, 68) = 12.40$, $MSE = 234.97$. $p < 0.001$, partial $\eta^2 = 0.267$, after controlling for the number of supply chain courses each subject had taken, which was not statistically significant, ($F(1, 68) = 0.463$, $MSE = 234.97$, $p = 0.499$, partial $\eta^2 = 0.007$. Figure 1 shows histograms of order size and estimated marginal means for each treatment condition.

Figure 1. Frequency of order quantity by condition in Experiment 1



Pairwise comparisons reveal that those in the high anchor condition ordered significantly more than those in the low anchor condition, ($p < 0.001$), thus presenting clear evidence of an anchoring bias and support for Hypothesis 1. To further understand the impact of the bias, the two anchoring conditions are compared to the control condition. Those in the high anchor condition ordered significantly more than those not presented with an anchor, ($p < 0.01$), but the difference between the low anchor condition and the control condition was not statistically significant, ($p = 0.19$), though the mean of the low anchor condition was lower than the control.

EXPERIMENT 2

Method and Procedure

Hypothesis 2, that the increased provision of relevant information will mitigate the anchoring bias, was tested with a second experiment. Experiment 2 was similar to Experiment 1, though subjects were provided with information about the costs associated with inventory. Based on the range and distribution of demand in Experiment 1, an unbiased decision maker would have ordered 50 units. In Experiment 2, we also provide cost data pointing to an optimal order of 50 units. Specifically, we present subjects with the following scenario:

> Imagine you are a retailer who buys and sells a generic product for which demand is uniformly distributed and ranges from 0 to 100. At the end of the sales period, any inventory that is left over costs your company $1. Conversely, any sales that you were not able to make because you did not have enough inventory cost your firm $1

As in the previous experiment, subjects were then asked:

> Would you order more or less than 20 (80) units? (circle) More / Less

And finally:

> How much would you order? _____ units.

A control condition was also included in which subjects were not presented an anchor. Thus, Experiment 2 manipulated a single factor, (Anchor), made up of 3 levels, (Control, Low, and High).

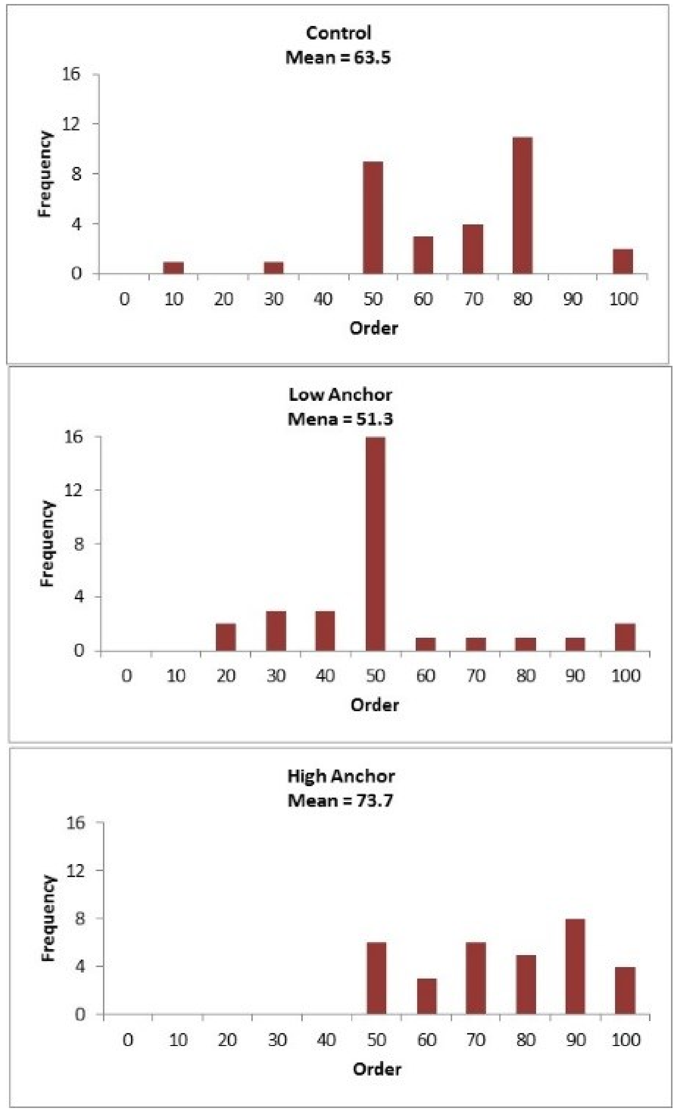
Subjects in the experiment were 94 undergraduate students, (32 females), from three supply chain management courses at a small, private school in the southern US. The experiments were conducted in separate sessions and lasted approximately 5 minutes each. The procedure for administering the task in each session was identical to that outlined in Experiment 1. After collecting and examining subjects' responses, 1 was discarded for placing an order larger than the maximum possible realization of demand. All other responses were included in subsequent analysis, leaving a total sample of 93 responses.

Analysis and results

A general linear model (GLM) was used to test for differences in order size between treatment conditions. Treatment condition served as the fixed factor in the model. Unlike Experiment 1, the number of supply chain courses taken was not included as a covariate in this model. There were two reasons for this change. First, there was no variance among the participants, so the model could not return an estimate. Second, results from Experiment 1 suggest this variable does not have a significant impact on decision making.

Results reveal a significant impact of anchoring condition on order size, $F(2, 90) = 12.44$, MSE= 3,872.60. $p < 0.001$, partial $\eta^2 = 0.203$. Figure 2 shows histograms of order size and estimated marginal means for each treatment condition.

Figure 2. Frequency of order quantity by condition in Experiment 2



Pairwise comparisons reveal that just as in Experiment 1, those in the high anchor condition ordered significantly more than those in the low anchor condition, ($p < 0.001$). In addition, both anchoring conditions are significantly different from the control condition, ($p < 0.05$ in both cases). Thus, it appears that the provision of additional relevant information did not eliminate the anchoring bias in this context. In fact, when anchoring conditions are compared between experiments, (e.g.

Experiment 1 Control (Low anchor, High anchor) vs. Experiment 2 Control (Low anchor, High anchor)), independent samples t-tests return no significant differences.

Immediately, these results raise questions as to why decision making within conditions remained essentially unchanged between Experiments 1 and 2. Specifically, did participants in Experiment 2 consider the cost data they were provided but still chose to order consistent with participants in Experiment 1, or did they simply not notice or fail to comprehend the cost data? To address this uncertainty and thereby clarify the findings from the first two experiments, a third, exploratory experiment is conducted.

EXPERIMENT 3

Experiment 3 serves as a manipulation check in that it clarifies whether lack of significant findings in Experiment 2 was due to subjects ignoring the provided cost data or considering it yet it having no debiasing effect.

Method and procedure

Experiment 3 was conducted using the same decision task as Experiment 2, however the cost parameters were changed so that the optimal order was no longer 50 units. Specifically, subjects were presented to following scenario:

> Imagine you are a retailer who buys and sells a generic product for which demand is uniformly distributed and ranges from 0 to 100. At the end of the sales period, any inventory that is left over costs your company $2. Conversely, any sales that you were not able to make because you did not have enough inventory cost your firm $1

Would you order more or less than 20 (80) units? (circle) More / Less

How much would you order? _____ units.

As in previous the experiments, subjects in the control condition were not presented an anchor and were only asked to provide an order amount.

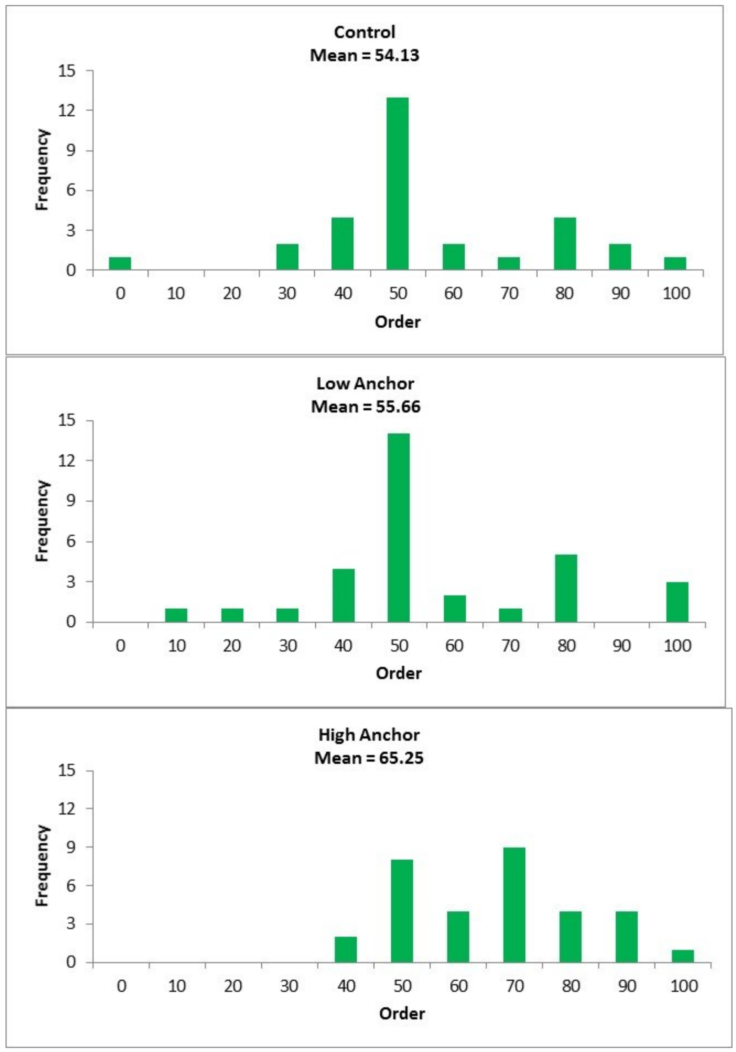
Notice that in this experiment, inventory holding cost is now $2 while stock-out cost remains unchanged at $1. Thus, unlike Experiments 1 and 2, it is no longer optimal to order 50 units. Instead, participants should order 33 units if they are following an optimal, unbiased order policy. While we do not necessarily expect subjects to order optimally, we should see average orders decrease in each condition, (as compared to the first two experiments), if they are considering the provided cost data. If orders remain consistent with Experiments 1 and 2, it suggests that the cost data is being ignored or is not salient to participants.

Subjects in Experiment 3 were 94 undergraduate students, (37 females), from three supply chain management courses at a small, private school in the southern US. The experiments were conducted in separate sessions and lasted approximately 5 minutes each. The task administration procedure was identical to that outlined in Experiment 1. After the responses were collected, they were examined for validity and no orders were found to be larger than the maximum possible realization of demand. Thus, all 94 responses were included in the analysis.

Analysis and results

As a preliminary test, a GLM was used to examine differences in order size between treatment conditions. Results reveal a marginally significant impact of anchoring condition on order size, $F(2, 91) = 3.00$, $MSE = 381.08$, $p = 0.055$, partial $\eta^2 = 0.062$. Figure 3 shows histograms of order size and estimated marginal means for each treatment condition.

Figure 3. Frequency of order quantity by condition in Experiment 3



Pairwise comparisons reveal that those in the High Anchor condition placed larger orders than those in the Low anchor, ($p = 0.052$), and Control ($p = 0.027$) conditions, but that there was not a significant difference between the Low Anchor and Control conditions, ($p = 0.76$). In short, we continue to see evidence of an anchoring bias. However, in order to address the issue of whether or not the cost information had any impact on decision making, we conduct a series of t-tests within conditions but between Experiments 2 and 3.

Table 1. Within-condition differences between experiments

Condition	Experiment		Difference (2-tailed)
	2	3	
Control	63.48	54.13	*
Low Anchor	51.33	55.66	n/s
High Anchor	73.69	65.25	**

*$p < 0.10$; **$p < 0.05$

Results are mixed, but overall they suggest that participants were indeed considering the cost data that was provided to them. In support, for both the Control and High Anchor conditions, mean orders were significantly different between experiments and the differences were in the expected direction, (lower in Experiment 3). Curiously though, the mean order was slightly higher between experiments in the Low Anchor condition, though the difference was not statistically significant.

DISCUSSION AND CONCLUSION

When beginning this research, we set out with the intent of discovering whether or not anchoring exists in the context of inventory control. After performing three experiments, we concluded that it does exist and has an effect on decision makers. In Experiment 1, there was a 21.6 percent spread between the high and low anchors. In Experiment 2, there was a 22.4 percent spread between the high and low anchors. And Experiment 3 revealed a 9.6 percent spread between the high and low anchors.

The effect of the high anchor was more pronounced than the effect of the low anchor in each of the three experiments. In Experiment 1, the high anchor group's ordering quantity averaged slightly over 15 units more than the control group. The low anchor group's ordering quantity average was a little less than six units lower than the control group.

In Experiments 2 and 3, the introduction of information that should logically steer the participants toward the optimal ordering quantity (50 units in Experiment 2 and 33 units in Experiment 3) did not produce the expected results.

There was no supplemental information offered in Experiment 1. One would expect the participants to assume the cost of over ordering to be the same as the cost of under ordering, absent any reason to assume otherwise. Nevertheless, the average order across all three groups was 58.5. When information was offered to confirm that the cost of over ordering was the same as the cost of under ordering (Experiment 2), one would expect the overall result to be closer to the optimal result of 50 than the results from Experiment 1. However, the average quantity ordered rose to 62.8. One might suspect that this anomaly is not statistically significant. The discrepancy between the optimal ordering amounts and the amounts selected by the participants was more pronounced in Experiment 3. Information was provided suggesting that the optimal ordering quantity was 33, but the average ordering quantity across all three groups was 58.3, a full 25 units higher than the optimal amount. In fact, the average ordering quantity did not vary much between the three experiments (58.5, 62.8, and 58.3, respectively). This suggests that effects of the anchoring bias are fairly immune to the introduction of additional relevant information.

Additionally, all three experiments had an overall bias on the high side. The first two experiments had an optimum ordering quantity of 50 units. The overall average of the first experiment across all three groups was 58.5. The overall average of the second experiment was 62.8. The third experiment had an optimum ordering quantity of 33. Strangely, the overall average of the third experiment across all three groups was 58.3.

It would be useful to test the possible reasons for the overall high side bias through further experimentation. One hypothesis is that participants are more sensitive to declines in customer satisfaction through stock outs than they are to higher inventory costs.

Managerial Implications

Anchoring is a psychological phenomenon. It represents a blind spot that affects decision-making. As such, supply chain managers should be educated about anchoring and shown the potential impact of anchoring on their decisions.

When the anchoring bias is present, the impact of relevant information may be surprisingly low. In short, managers should not assume that decision makers will make logical decisions when presented with relevant data.

Further, the experiments unexpectedly revealed another possible bias. The results of each experiment suggest that there may be a general tendency to order high and avoid stock outs rather than to order low and reduce excess inventory costs. Evidence of this potential bias existed in all three experiments. Managers should consider the correct tradeoffs between the risks of under ordering versus the expense of over ordering for their particular organization. Once that judgment is made, inventory decision makers should be carefully educated about how to evaluate decisions consistent with that judgment.

Lastly, managers should avoid exposing their decision makers to potential anchors. They should not offer any numerical information, even by way of example, that could become an irrelevant anchor for decision makers to cling to.

Limitations and Future Research Opportunities

While the results from our experiments do show the effects that anchoring can have on a decision maker's ability to think critically and logically, there are other criteria that may need to be considered. First, our experiments all involved students studying supply chain principles instead of practicing supply chain professionals. In addition, each of the experiments took place at a single university. Lastly, Experiment 2 and Experiment 3, which produced surprising results, were conducted with college freshmen and sophomore with limited training in supply chain management. At the time of the experiments, they were enrolled in their first supply chain management class. While students samples have been shown to be representative of managers in inventory control decisions, (Bolton et al. 2012), and this research setting is one in which student samples are widely seen as appropriate, (Thomas 2011), it is nonetheless worth noting. Future research could report on the decision making of experienced industry professionals.

These studies could focus on whether an anchoring bias exists, as well as the impact of relevant information to counter the impact of the bias. Perhaps professionals with a broader understanding of the implications of both stock outs and increased inventory costs would be able to make more logical inventory ordering decisions.

Similar experiments might also be performed with the addition of gathering basic demographic information from each of the participants. It is possible that age, gender, educational background, or other individual differences might affect the degree to which the anchoring bias influences participants.

Lastly, each of our experiments required the participants to make one single ordering decision. It might be worth noting whether or not the anchoring bias would persist if decision makers were prompted to make a series of multiple decisions over a number of periods.

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