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Thinking orientation and overconfidence: a newsvendor study

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This study uses the newsvendor problem to investigate the correlations between thinking orientation, overconfidence, and economic outcome. We aim to shed light on possible interconnections between these variables and extend the existing conceptual models of thinking orientation and overconfidence. To test the conceptual model and the corresponding hypotheses empirically, we employed a laboratory experiment with 50 hypothetical decision periods in which 142 participants ordered a highly profitable product. We found compelling evidence that suggests overprecision as the mediating variable between thinking orientation and the economic outcome. Furthermore, this research offers some practical implications.

KEYWORDS

overconfidence, overprecision, analytic thinking, intuitive thinking, decision-making, newsvendor problem

1 Introduction

The seminal heuristics-and-biases research program proposed by Kahneman and Tversky in the early 1970s (Kahneman and Tversky, 1972; Tversky and Kahneman, 1974) has established the accepted opinion that individuals deviate from the expected axioms of rationality when making decisions (Frederick, 2005; Moore and Healy, 2008; Kahneman, 2011). These deviations vary from one to another, creating a unique characteristic set that enduringly affects an individual's behavior (Williamson, 2018). One important element of this set is overconfidence, understood as an excessive belief in one's own abilities (Moore and Healy, 2008). This bias is conceptualized into three different varieties: (a) overestimation (overconfidence in one's own abilities in absolute terms), (b) overplacement (overconfidence in one's own abilities relative to others), and (c) overprecision (overconfidence in one's own accuracy of subjective estimations; Moore and Healy, 2008). Bazerman and Moore (2013, p. 14) call overconfidence "the mother of all biases," while Plous (1993, p. 217) claims that it is the most "prevalent and potentially catastrophic" of all biases. Overconfidence can have a broad range of real-life consequences—from positive competition effects (Li et al., 2017) to suboptimal ordering decisions (Ren and Croson, 2013), poor supply chain performance (Jain et al., 2018; Song et al., 2021; Wang et al., 2021), and negative platform effects and market amplification (Yan et al., 2024). For example, Renerte et al. (2023) investigated the effect of overconfidence on group investment decisions, showing significantly more above-optimum investment levels (overinvestment) for groups with more overconfident members.

A parallel stream of research examines differences in cognitive characteristics, more precisely individuals' thinking orientation (Frederick, 2005; Hoppe and Kusterer, 2011; Moritz et al., 2013; Białek and Domurat, 2018). Scholars have emphasized separating thinking orientation into two types of

cognitive processes: those that are executed fast and intuitively and those that are slower and more analytic (Kahneman and Frederick, 2002; Frederick, 2005; Kahneman, 2011). Stanovich and West (2000) labeled intuitive thinking as "System 1" and analytic thinking as "System 2." We use the terms *analytic thinking* and *intuitive thinking* (collectively referred to as *thinking orientation*) but emphasize their interchangeable character in System 1 and System 2.

In this article, we combine these two streams of literature in a laboratory decision experiment to investigate how thinking orientation and overconfidence affect economic outcomes. Our setting represents a canonical problem of planning under uncertainty in operations management: the newsvendor problem (Schweitzer and Cachon, 2000). Typically framed in the context of inventory management, the problem has direct equivalents to economic situations such as supply chain contracting (Su, 2008), staffing (He et al., 2012), and revenue management (Kocabiyikoglu et al., 2015). Previous research investigating individual differences has repeatedly utilized the newsvendor problem, analyzing the effects of national differences (Cui et al., 2013; Li et al., 2019), gender differences (de Véricourt et al., 2013), experience (Bolton and Katok, 2008; Bolton et al., 2012), and decision style (Han et al., 2020). Ren and Croson (2013) show extensive explanatory power by associating overprecision, the most robust variety of overconfidence (Moore and Healy, 2008), with the economic outcome in the newsvendor setting. Furthermore, the economic outcome is analyzed in relation to newsvendors' analytic and intuitive thinking, with analytic thinkers outperforming their intuitive counterparts (Moritz et al., 2013).

Although previous research suggests that, among others, the economic outcome is influenced by overconfidence and thinking orientation, no study has converged the two literature streams to explain deviations from rationality in the newsvendor setting so far. As contemporary decision environments are frequently characterized by rapid environmental changes and the need for quick decisions, rather than exhaustive analytic optimization (Shepherd et al., 2015; Laker et al., 2018), our study addresses this literature gap by investigating the correlations between thinking orientation, overconfidence bias, and economic outcomes. Furthermore, we conduct a mediation analysis leveraging overprecision as a mediating variable on the "thinking orientation–economic outcome" relationship (Moore and Healy, 2008; Ren and Croson, 2013). Our assumption follows Evans (2020), who states that individuals' thinking orientation captures the cognitive mechanisms by which biased behavior is channeled, mostly driven by intuition. We aim to empirically enhance the conceptual model of the thinking orientation–economic outcome relationship by Moritz et al. (2013), assuming an individual's thinking orientation correlates with the level of overconfidence and, thus, the level of biased behavior applied. The choice of thinking orientation as an individual difference variable was motivated by the literature (Frederick, 2005; Moritz et al., 2013; Weinhardt et al., 2015; Białek and Domurat, 2018). Consequently, we formulate our research questions as follows:

RQ: How does thinking orientation influence decision outcomes in economic environments?

SRQ1: How is thinking orientation correlated with (1.1) the economic outcome and (1.2) overconfidence?

SRQ2: How is overconfidence correlated with the economic outcome?

SRQ3: What is the mediating effect of overprecision on the "thinking orientation–economic outcome" relationship?

The results show that analytic thinkers present lower overconfidence levels and perform better in our newsvendor setting. Lower overconfidence also results in higher economic outcomes. Finally, we emphasize a complementary mediation effect of overprecision on the "thinking orientation–economic outcome" relationship. Based on our results, the conceptual model establishes a holistic understanding of correlations between these variables. Furthermore, the proposed model serves as a foundation for practitioners to manage employees' preferences for analytic and intuitive thinking, and to develop a sufficient level of confidence.

The article is structured as follows. In Section 2, related literature is discussed. Section 3 describes our hypotheses and the methodology. Then, results are presented and discussed in Sections 4 and 5. Section 6 addresses limitations and future research directions.

2 Related literature

Our work closely relates to Moritz et al. (2013) and Ren and Croson (2013). Moritz et al. (2013) analyze the effects of analytic and intuitive thinking on individuals' newsvendor behavior. They investigate the mediating effect of demand chasing on the thinking orientation–economic outcome relationship. Bostian et al. (2008) describe demand chasing as an individual's tendency to anchor decisions on the previous order and adjust toward the most recently realized demand. Chasing is an appropriate strategy if the demand distribution has an underlying trend. However, when drawn from a stationary random distribution, chasing previous demands is a suboptimal decision shortcut (Moritz et al., 2013). A parallel stream of research is presented by Ren and Croson (2013) and Ren et al. (2017), who analyze the effects of overprecision on newsvendors' economic outcomes.

Our work, nevertheless, differs from Moritz et al. (2013) and Ren and Croson (2013). We converge both literature streams into a holistic conceptual model. Furthermore, we include overestimation as a second overconfidence variety in the correlation analysis on the economic outcome, enhancing the insights of Ren and Croson (2013). Moreover, our work differs from Moritz et al. (2013) and Ren and Croson (2013) because it focuses on how overprecision mediates the thinking orientation–economic outcome relationship. Finally, we *ex post* include demand chasing as a simplifying heuristic resulting from intuitive thinking (Moritz et al., 2013) and expectedly contributing to individuals' overconfidence.

2.1. Analytic and intuitive thinking

The cognitive characteristics of individuals are a fundamental pillar in the decision literature (Kozhevnikov, 2007). Even small

differences can significantly influence reference judgments, uncertainty assessments, and course-of-action decisions (Payne et al., 1993). One of these characteristics is the orientation toward analytic and intuitive thinking. Captured by the dual-process theory (Kahneman, 2011), scholars distinguish between two process types: those that are executed quickly and intuitively, labeled System 1, and those that are slower and reflective, labeled System 2 (Stanovich and West, 2000; Kahneman and Frederick, 2002). While intuitive processes occur unconsciously, spontaneously, and impulsively, analytic processes feature conscious reflection, mental effort, and computational expense (Stanovich and West, 2000).

To quantify an individual's thinking orientation, Frederick (2005) proposed the Cognitive Reflection Test (CRT). It consists of three quantitative questions, each triggering an intuitive but wrong answer. Initially, these questions appear similar to the well-established insight problems in the problem-solving literature. However, the CRT shows a unique difference because classic insight problems do not intend to prime an intuitive response (Gilhooly and Murphy, 2005; Gilhooly and Fioratou, 2009). Research has shown that CRT scores correlate with general IQ scores. Nevertheless, CRT appears to better predict analytic thinking than measures of intelligence, thinking dispositions, and executive functioning do (Oechssler et al., 2009; Toplak et al., 2011; Mata et al., 2013; Fernbach et al., 2013).

Given its explanatory power, the CRT has been used in a broad variety of studies. Thus, using the original version raises the risk of subjects being familiar with the correct answers in advance (Haigh, 2016). Addressing this method bias, scholars have proposed test expansions (Toplak et al., 2014; Primi et al., 2016), alternative quantitative forms (Thomson and Oppenheimer, 2016), and qualitative forms (Sirota et al., 2021). Assessing their predictive power revealed a strong correlation with the original. The analysis showed that a modified CRT is a unique predictor of analytic thinking (Toplak et al., 2014; Primi et al., 2016). Regarding its application, Brañas-Garza et al. (2019) emphasized the performance effects of (1) test implementation timing with positive performance effects of pre-experiment compared to post-experiment tests, (2) test implementation procedures with positive performance effects of computerized compared to hand-run tests, and (3) population differences with a strong and robust (male) gender bias. The latter was also recognized by Frederick (2005). Furthermore, monetary incentives do not influence test performance (see Brañas-Garza et al., 2019, for further discussion).

2.2. Biased behavior in the newsvendor problem

The newsvendor problem is a classic operations management setting and serves as an apt framework for studying decision-making under uncertainty. Ordering decisions Q ($Q \geq 0$) are made to satisfy a stochastic demand D ($D \geq 0$) during a single sales period. Unsold goods perish in the following period. For each unit purchased, decision-makers face constant cost c ($0 < c < p$) and earn a fixed price p ($p > 0$) if sold. Unsatisfied demand causes a loss of customer goodwill g ($g > 0$) per unit, while unsold units lead to a salvage value s ($0 < s < c < p$). This results in underage costs (profit lost due to insufficient inventory) of $c_u = p - c + g$ and overage costs (profit lost due to too much inventory) of $c_o = c - s$. Realized demands are drawn from a demand distribution D, defined by the mean μ and variance σ^2 (Ren et al., 2017). The problem is solved by placing orders that maximize expected profits:

$$\Pi(Q) = \int_{D=0}^{\infty} \Pi(D, Q) f(D)\, dD.$$

The optimal order quantity Q^* can be calculated using the inverse of the cumulative demand distribution function ${F_D}^{-1}$ and $c_u/(c_u + c_o)$ as the critical ratio:

$$Q^* = {F_D}^{-1}\left(\frac{c_u}{c_u + c_o}\right).$$

Although the optimal solution can be calculated, Schweitzer and Cachon (2000) found that decision-makers tend to order quantities between the profit-maximizing optimum and the mean demand, a phenomenon called the "pull-to-center effect." The effect has been replicated by multiple follow-up studies (Bolton and Katok, 2008; Moritz et al., 2013; Han et al., 2020). When the driving mechanisms of the pull-to-center effect were investigated, newsvendor decisions were associated with a broad variety of contributing variables (e.g., Benzion et al., 2008, 2010; Bolton et al., 2012; de Véricourt et al., 2013; Cui et al., 2013). Two approaches to explain the pull-to-center effect dominate: thinking orientation (Moritz et al., 2013) and overprecision (Ren and Croson, 2013; Ren et al., 2017). In the newsvendor context, Ren et al. (2017, p. 499) understand overprecision as "a biased belief that the distribution of demand has less variance than its true variance." Ren and Croson (2013) experimentally assess the proposition of overprecision causing the pull-to-center effect. Subsequently, Ren et al. (2017) present a mathematical model of an overprecise newsvendor i who mixes the true demand distribution $F_D(\mu, \sigma^2)$ with a zero-variance version $F_{D_0}(\mu, 0)$ (see Alpert and Raiffa, 1982). The resulting demand D_0 is "a mean-preserving but variance-reducing transformation of the true consumer demand $D(\mu, \sigma^2)$" (Ren et al., 2017, p. 500):

$$D_0 = \gamma_i D + (1 - \gamma_i) F_{D_0}(\mu, 0),\ 0 \leq \gamma_i \leq 1.$$

The γ parameter represents the strength of the overprecision impact on variance estimation, with $\gamma = 0$ implying a fully overprecise individual and $\gamma = 1$ implying perfect accuracy. For further insights on model validation, see Ren et al. (2017).

3 Hypotheses and research method

In this study, we extend previous work on thinking orientation (analytic and intuitive) and overconfidence by empirically assessing the underlying cognitive mechanisms utilizing a newsvendor problem setting. We relate intuitive thinking as a mechanism by which biased behavior is channeled to analyze the mediated direct effect on the economic outcome (Evans, 2020). We investigate

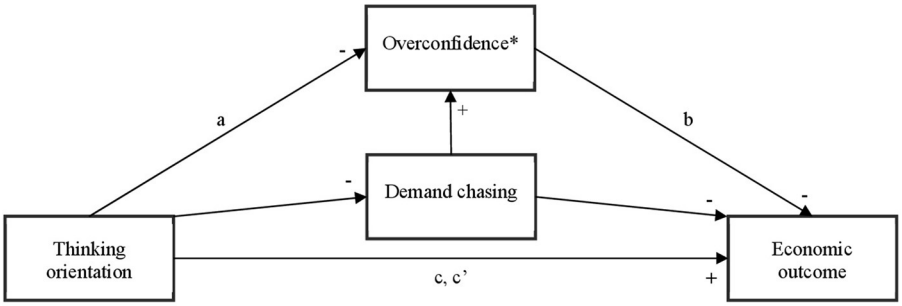

FIGURE 1
Conceptual and mediation model of the study. * For our mediation model, we used task-related overprecision due to its prevalence and robustness in previous newsvendor studies.

this second-order effect using a simple mediation model involving overprecision as a mediating variable. We chose overprecision based on its robustness and prevalence in earlier studies (Ren and Croson, 2013; Ren et al., 2017).

The correlations and polarities assumed between the variables are depicted in Figure 1. The direct (a, b, c) and indirect (c′) mediation paths are depicted in brackets in our mediation model. Addressing the endogeneity of the conceptual framework, neither the economic outcome nor overconfidence was expected to impact thinking orientation. We treat thinking orientation as a fundamental human characteristic that is stable over time and only changes in the long term, while overconfidence can vary in the short term, for example, due to feedback (Bolton and Katok, 2008). To our knowledge, no previous research has assessed the correlations between thinking orientation and overconfidence to explain economic outcome variations. We note that some of our expected links have been assessed individually. For instance, Hoppe and Kusterer (2011) and Noori (2016) provide insights that analytic thinkers overestimate performance to a lesser extent in general knowledge questionnaires than their intuitive thinker counterparts.

We formulate our hypotheses according to the links in our conceptual model. Hypotheses 1.1 and 1.2 correspond to SRQ1. Based on the literature (Frederick, 2005; Hoppe and Kusterer, 2011; Moritz et al., 2013; Noori, 2016; Białek and Domurat, 2018), we assume individuals with an analytic thinking orientation to resist impulsive responses provided by intuitive thinking. Therefore, we hypothesize that analytic thinking is positively correlated with the economic outcome and negatively correlated with overconfidence:

- **Hypothesis 1.1—Thinking orientation and economic outcome:** Analytic thinking increases the economic outcome.
- **Hypothesis 1.2—Thinking orientation and overconfidence:** Analytic thinking decreases overprecision, overestimation, and overplacement.

Hypothesis 2 corresponds to SRQ2. We assume overprecision and overestimation to correlate with newsvendors' economic outcomes. We expect higher overprecision to create higher misjudgments of demand distribution variance (Ren and Croson, 2013; Ren et al., 2017), while higher overestimation increases peoples' proneness to responses like ordering the mean demand. *Ex post*, we excluded overplacement since established measurements are directly related to the economic outcome and, thus, a relation is trivial (see, e.g., Moore and Healy, 2008).

- **Hypothesis 2—Overconfidence and economic outcome:** Stronger overprecision and overestimation decrease the economic outcome.

Finally, Hypothesis 3 corresponds to SRQ3. We build on insights regarding the mediating role of different varieties of overconfidence, for example, for emotional intelligence and financial effectiveness (Riaz and Shah, 2022), self-attribution and market efficiency perception (Jalal and Leonelli, 2021), and personality traits and investment intention (Jain et al., 2022). Our mediation model assumes that thinking orientation correlates with economic outcomes even when overprecision is included. Following Duttle (2016) and Białek and Domurat (2018), we use thinking orientation, rather than cognitive abilities, as a suitable input variable to examine the correlation between overconfidence and the economic outcome. Indicating one's susceptibility toward cognitive biases, thinking orientation relates to one's willingness to avoid overconfidence by engaging in System 2 (analytic) thinking (Toplak et al., 2011; Białek and Domurat, 2018). We assess this second-order effect in Section 4.1.

Note that we emphasize recent insights on the importance of accounting for an omitted variable bias in mediation analyses (Cinelli and Hazlett, 2020; Wilms et al., 2021; Busenbark et al., 2022). Mediation analysis typically assumes that the input variable (X) leads the mediator (M) and the outcome variable (Y) to be correlated. However, the analysis is valid only if no omitted variables independent of X cause M and Y to be correlated outside the experiment. While mediation analysis aims to capture the causal effects within the tested model, it can also inadvertently capture confounded effects from any omitted variables correlated with M outside the experiment. This can potentially invalidate the mediation results found in the analysis due to a systematic overprediction of the indirect effect of M on Y (Simonsohn, 2022). In our model, individuals' math ability could be such a confounding variable. We address this by selecting a sample of students and practitioners (see Section 3.3) with backgrounds requiring uniformly high math skills, thereby mitigating potential

bias. This approach enhances the validity of our mediation model, although other confounds may still cause M and Y to be correlated outside our experiment. For a more concise discussion of the issue, we refer to the Data Colada Blog [103], available at https://datacolada.org/103.

- **Hypothesis 3—Overprecision as a mediator:** Individuals with analytic thinking are less affected by overprecision and increase their economic outcome.

To test our hypotheses, an online correlational study design including one experimental treatment was chosen over other data collection approaches due to the COVID-19 pandemic and restrictions regarding in-person meetings. Our instruments, supplementary materials, data, and analyses are available at https://osf.io/38KCD/ (doi: 10.17605/OSF.IO/38KCD). We used Forio Epicenter® to design an interactive online application interface for remote experiment access. Our computerized newsvendor setting contained 50 hypothetical decision periods, following Ren and Croson (2013). A high critical ratio setting of $CR = 0.83$, defined by $p = 4$, $c = 2$, $g = 8$, and $s = 0$ was chosen. This setting resulted in an optimum order quantity $Q^* = 119.4$ (see Moritz et al., 2013). Study parameters are known to the participants and are stable throughout the experiment, as differences in behavior were the focus rather than the context-specific parameter estimation. That also supports our one-treatment-only design to ensure sufficient power of results. Thus, all subjects faced the same high critical ratio setting and demand pattern. Stochastic demand D was drawn from a normal distribution ($\mu_D = 100 \mid \sigma_D = 20$), as Su (2008) proposes investigating decision biases under non-uniform distributions. Moritz et al. (2013) argue that demand is rarely uniformly distributed in practice. We do not expect result distortions due to the chosen demand pattern. Research done by Benzion et al. (2008) showed that pull-to-center effects occur equally for uniform and normal distributions. Naddor (1978) states that optimal order sizes exclusively depend on distribution mean and variance, not on its specific shape.

While our study design was based on previous newsvendor experiments, we incorporated a significant modification. Due to COVID-19 pandemic restrictions, direct interaction between the subjects and the experimenters was not feasible, nor could subjects ask for clarification without significantly delaying the procedure. To address this, we added a 10-period demand manipulation at the outset unbeknownst to the participants. During this phase, an algorithm closely matched the realized demand with subjects' order quantity previously set. A normal distribution ($\mu_D = 0/\sigma_D = 3$) added slight deviations between customer demand and the order quantity, with a maximum deviation of three units in Period 9. This manipulation aimed to familiarize subjects with the online experimental interface rather than provide pre-task learning about the actual demand process. Subjects were debriefed individually via email about the manipulation after finishing the experiment.

We contend that our demand algorithm did not influence participants' decision behavior in the remaining experimental periods, particularly regarding demand chasing. The algorithm's design did not alter the overall environmental scenario; instead, it merely reduced the deviation between participants' order quantities and the actual demands without introducing any underlying trend in the demand pattern. So, while order adjustments between periods are smaller, chasing behavior itself would not be based on any effects of the manipulation. Therefore, as in the other 40 decision periods, chasing previous demands remained a suboptimal decision strategy during these 10 periods (Moritz et al., 2013). If a participant fully engaged in demand chasing, they would essentially be "chasing" their previous decisions rather than a consistent demand pattern. To support our claim, the algorithm was specifically designed so that participants who fully engaged in demand chasing would end up ordering the same quantity in Period 10 based on the realized demand as they started with in Period 1. Consequently, we believe that our manipulation does not introduce any issues affecting the validity of the results.

3.1 Study measurements

To quantify our variables, we applied three different measurements. We refer to Table 1 for an exemplary overview of our instrumentation. First, **overconfidence** was quantified using (1) overprecision, (2) overestimation, and (3) overplacement measures from the literature (Moore and Healy, 2008). We distinguish between (1) pre-task overconfidence (Noori, 2016; Ren and Croson, 2013; Hoppe and Kusterer, 2011) and (2) in-task overconfidence (Ren and Croson, 2013). By collecting pre-task data before the experiment, we aimed to reveal a task-unrelated presence of the bias. This allowed partial control for endogeneity issues, for example, the reverse correlation of the overconfidence–economic outcome relationship.

Pre-task and in-task overprecision data were collected by asking subjects to provide 90% confidence intervals. These intervals were expected to capture "correct" answers with a 90% probability. **Pre-task overprecision**, captured by 10 general knowledge questions (Ren and Croson, 2013), was calculated by subtracting correct intervals x from 9. We expect accurate subjects to score zero, while higher/lower scores indicate overprecision/underprecision:

$$PreOpr = 90\%^{*}10 - x.$$

In-task overprecision, captured by estimates for the demand of the following newsvendor period, was calculated based on the 5th and the 95th percentile of the demand distribution (Ren and Croson, 2013). Hereafter denoted as $x(0.05)$ and $x(0.95)$, we used the following equation:

$$InOpr = \frac{x\,(0.95) \; - \; x(0.05)}{3.2}.$$

The measure, stating that more overprecise subjects show lower $InOpr$ values, replicates the "Imputed Volatility" measure proposed by Ren and Croson (2013) and represents the individual estimation of the demand standard deviation. The denominator of 3.2 is based on Moder and Rodgers (1968), who analyzed variance estimation problems of different distribution types regarding their percentiles and modes. Subjects' mean demand hit rates were quantified to

TABLE 1 Exemplary overview of instrumentation.

Overprecision		
Pre-task	*"How many countries are members of NATO? Lower Limit: __ Upper Limit: __"*	See Ren and Croson, 2013
In-task	*"Tell us what you think demand will be in the next round: 1. My best guess is that demand will be: __newspapers 2. There is a 1-in-20 chance that demand will be less than: __ 3. There is a 1-in-20 chance that demand will be more than: __"*	See Ren and Croson, 2013
Overestimation		
Pre-task	*"What is the longest river in the world? (a) Nile (b) Mississippi (c) Amazon (d) Ob"*	See Noori, 2016
In-task	*"Let us assume that the maximum possible profit in this game is set at €25,000. With 90% probability, how much do you think you can earn in the 50 periods?"*	–
Overplacement		
In-task	*"Considering all the study participants: How many will have earned more money than you by the end of this simulation? (in %)"*	See Ren and Croson, 2013
Thinking orientation		
Post-task	*"A bat and a ball cost $1.10 in total. The bat costs $1 more than the ball. How much does the ball cost? __Cents"*	Frederick, 2005
	"If it takes 5 machines 5 min to make 5 widgets, how long would it take 100 machines to make 100 widgets? __Minutes"	Frederick, 2005
	"In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half the lake? __Days"	Frederick, 2005
	"A man buys a pig for $60, sells it for $70, buys it back for $80, and sells it finally for $90. How much has he made? __Dollars"	Toplak et al., 2014
	"Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class? __Students"	Toplak et al., 2014 Primi et al., 2016

support our arguments on in-task overprecision. If subjects were accurate, realized demand should fall inside the demand confidence intervals 90% of the time.

Pre-task overestimation was surveyed with five general knowledge questions (Noori, 2016), each with four possible answers. Subjects had to choose the correct one and, afterward, estimate their number of correct responses. Individual overestimation scores were calculated as follows:

$$PreOes = E_i\,[x_i] - x_i.$$

$E_i[x_i]$ represents the belief about one's number of correct responses, while x_i shows the actual number (Moore and Healy, 2008). Accurate subjects score zero, while those who estimated too high or too low overestimated or underestimated their performance.

In-task overestimation was measured by asking subjects to estimate their expected economic outcome. The ratio between the guessed performance $E_i[x_i]$ and the anchor was compared to the ratio of realized profit x_i and the possible maximum. We chose an anchor of €25,000 (€500 over 50 periods) as the subjects' reference point for their estimation. The actual maximum outcome possible amounted to €7,714. Expecting accurate subjects to score zero (both ratios would be equal in value), we used the following formula:

$$InOes = \left(\frac{E_i\,[x_i]}{25,000}\right) - \left(\frac{x_i}{7,714}\right).$$

In-task overplacement asked subjects to estimate how many other participants would be more profitable than themselves (Ren and Croson, 2013). Overplacement was calculated based on Moore and Healy (2008) by subtracting the actual percentage x_i from the estimated percentage $E_i[x_i]$ of better performances. Accurate subjects score zero. The measure's inverse character must be mentioned, as positive scores denote underplacement, while negative ones indicate overplacement:

$$InOpl = E_i\,[x_i] - x_i.$$

Second, the numerical version of the CRT was chosen to quantify subjects' **thinking orientation**. We understand the CRT as a predictor of analytic thinking rather than a measure of intelligence or executive functioning (Oechssler et al., 2009; Toplak et al., 2011; Mata et al., 2013; Fernbach et al., 2013; Białek and Domurat, 2018). The latter (1) focus on the computational power available to individuals, not the depth of processing applied to realize an error, and (2) do not assess the susceptibility to accept intuitive responses (Toplak et al., 2014). As proposed by Haigh (2016), we mitigate result distortion due to prior knowledge of

the CRT by combining the three original questions with two items developed by Toplak et al. (2014) and Primi et al. (2016). Further extension items and other CRT forms were discarded at the study design stage for the following reasons: (1) Closed-ended items allow picking the correct response by chance (Primi et al., 2016), (2) one item did not generate the heuristic or the correct response (Toplak et al., 2014), and (3) environments like the newsvendor setting are often quantitative rather than qualitative in nature; thus, qualitative CRT forms were discarded. Therefore, thinking orientation was measured by the number of correct responses in our five-item CRT, with subjects who scored five classified as "analytic." Subjects with zero and one correct response were classified as "intuitive." The remaining subjects were classified as "moderate." This grouping approach helps further mitigate result distortion due to existing prior knowledge of CRT questions (Haigh, 2016).

Finally, we understand the **subjects' economic outcome** as the realized profit quantified by measuring newsvendor order quantities (Schweitzer and Cachon, 2000; Moritz et al., 2013). We further used subjects' order quantities to quantify (1) the pull-to-center effect in our newsvendor setting and (2) the strength of subjects' demand-chasing behavior for our *ex post* exploratory analyses.

3.2 Data analysis plan

All parts of the data analysis were performed using a significance level of $\alpha = 0.05$. We followed the *ex ante* analysis plan detailed at the design stage of the study. In the first step, data obtained in the manipulation phase was excluded from the set, as customer demand was not randomly generated. So, the results of Periods 11–50 were used for all analyses.

Corresponding to our hypotheses, we performed a single-factor analysis of variance (ANOVA) to analyze the effect of thinking orientation on (1) the economic outcome and (2) pre-task and in-task measures of overprecision, overestimation, and overplacement. For the overestimation and overplacement measures, we used absolute score values for our analysis, as positive (e.g., overestimation) and negative (e.g., underestimation) scores would equalize each other, indicating high group accuracy in the mean. As group means for both our overestimation measures were expected to be close to zero, a multiplying factor of 100 was included for both measures to visualize group differences. Furthermore, we performed linear regression analyses, calculating Cohen's multiple correlation coefficient R and the effect size R^2 (Cohen, 1988), to analyze the effect of in-task overprecision and pre-task overestimation on the economic outcome. The coefficient r captures both the strength and the direction of the relationship being tested. The effect size r^2 indicates the prediction accuracy of the relationship by showing the proportion of variance in the dependent variable that is explained by the independent variable. Note that the measures of **overplacement** as well as in-task **overestimation** were excluded from the analysis *ex post* since the data collection was based directly on task performance. Thus, a relation seems trivial.

For the **mediation analysis**, we used in-task overprecision to test the relationship between thinking orientation and the economic outcome. We analyzed how thinking orientation correlates with the economic outcome (1) indirectly through overprecision (paths a and b), (2) directly without mediation (path c), and (3) directly mediated by overprecision (path c′). Our notation follows Preacher and Hayes (2008), path significance was tested using linear regression analyses. Following Baron and Kenny (1986), a mediation relationship operates when four conditions are met: (1) a significant relationship between thinking orientation and overprecision (path a), (2) a significant relationship between overprecision and the economic outcome (path b), (3) a significant relationship between thinking orientation and the economic outcome (path c), and (4) with thinking orientation and overconfidence as independent variables and the economic outcome as dependent variable, the correlation of path c must be strongly reduced. Thus, the coefficient becomes non-significant or, at least, less significant (path c′).

To account for within-subject interdependence, we analyzed the variability in participants' ordering decisions under our high critical ratio treatment. Additionally, we compared the overall decision variability with data from Periods 11–30 and Periods 31–50 of our experiment. We quantified decision variability using the standard deviation of subjects' orders as the unit of analysis (see Kocabiyikoglu et al., 2024, for a similar approach). Finally, we assessed the robustness of our results by considering the influence of subjects' demographics. We applied three control variables: subject's gender (male, female, other), experience (student, practitioner), and nationality (international, German). The latter addressed the required German-specific (Willy Brandt, Bundestag), regional (the river Neckar), and "Western" civilized knowledge (New Testament) of some pre-task overconfidence questions.

Additionally, a *post hoc* power analysis with the software G*Power (Faul et al., 2007) was conducted to show the achieved and adequate power to detect effects in the analyses central to our hypotheses stated in Section 3. As measures of the effect size, we used Cohen's R^2 for our linear regression analyses and Cohen's η^2 for our ANOVA analyses (Cohen, 1988). Both indicate the prediction accuracy of the relationship by showing the proportion of variance in the dependent variable that is explained by the independent variable. For more detail and potential replication, we refer readers to our analyses available at https://osf.io/38KCD/ (doi: 10.17605/OSF.IO/38KCD).

Aside from our primary analysis, we conducted some *ex post* exploratory analyses to support existing literature and our findings. First, we examined the pull-to-center effect in our newsvendor setting. We compared the overall average order quantity $\bar{\bar{Q}}$ with the mean of the demand distribution and the optimum Q^*. We quantified the effect strength by using the formula:

$$PTC = \frac{Q^* - \bar{\bar{Q}}}{Q^* - \mu_D}.$$

The ratio indicates stronger pull-to-center effects as the average order quantities approach the distribution mean. We applied a one-sided t-test to empirically test the deviation between subjects' average order quantities and the optimum order quantity.

Second, we employed a single-factor ANOVA to empirically assess the correlation between thinking orientation and demand

chasing β. The demand chasing variable β was calculated from subjects' order quantities. Following the studies of Bostian et al. (2008) and Moritz et al. (2013), we utilized the linear partial-adjustment model to investigate demand chasing:

$$x_{it} = x_{i,t-1} + \beta_i \left(d_{t-1} - x_{i,t-1}\right) + \varepsilon_{it}.$$

According to the model, a newsvendor i adjusts a previous order quantity $x_{i,t-1}$ toward the most recent realized demand d_{t-1}, where $\beta = 1$ indicates full demand chasing (Kirshner and Moritz, 2021).

Last, we explored whether demand chasing correlates with subjects' in-task overconfidence and the economic outcome. Moritz et al. (2013) highlight the explanatory power of demand chasing in newsvendor settings. We assume higher levels of demand chasing to increase overconfidence due to a perceived sense of situational control. In our conceptual model, we propose a unidirectional link between demand chasing and overconfidence, viewing demand chasing as a simplifying heuristic frequently observed in newsvendor settings, arising from intuitive thinking (Bostian et al., 2008; Moritz et al., 2013; Kirshner and Moritz, 2021).

3.3 Participants and procedure

Data were collected in September 2020 and October 2021. Our convenience sample was drawn from the University of Stuttgart and other organizations. Target subjects were bachelor's and master's students and practitioners with a degree in business administration or equivalent newsvendor-related work experience, for example, in inventory or supply chain management. Two hundred participants were contacted personally or via e-mail and invited to participate in the study. In total, 142 subjects participated; the demographics are provided in Table 2. The sample size is consistent with other behavioral studies on the newsvendor problem that analyze main and interaction effects, for instance, Study 1 in de Véricourt et al. (2013), Study 2 and mediation analysis in Moritz et al. (2013), and Han et al. (2020).

Despite its heterogeneity, we argue that the sample is representative. Bolton et al. (2012) compared newsvendor performances of students and experienced procurement managers. Pull-to-center effects appeared similarly, while task experience and training improved the economic outcome equally. Analyzing the CRT performance, Brañas-Garza et al. (2019) found student subjects to outperform non-student subjects. Therefore, our sample is externally valid for investigating expected correlations since all subjects had university backgrounds. We propose using managers only to investigate effect magnitudes due to their experience in actual newsvendor settings.

Figure 2 presents the procedural implementation of our experimental design: if willing to participate, subjects were given individual access to Forio Epicenter. The total time of study participation was 45–50 min. Before the experiment, subjects provided answers to the pre-task questionnaire. When finished, subjects entered the newsvendor experiment. Task instructions included information on costs, demand distribution, and sample demand data of 10 periods, mitigating information asymmetry.

TABLE 2 Subjects' demographics.

Demographics	Subjects, *n* (%)
Total no. of subjects	142
Age range (years)	18–62
Sex	
Male	92 (64.79)
Female	50 (35.21)
Nationality	
German	132 (92.96)
Others	10 (7.04)
Profession	
Student	106 (74.65)
Practitioner	36 (25.35)

This reduces result distortions due to participants' inability to understand normal distributions. Feedback regarding order quantity, demand, and cumulative profit was provided in each experimental period. Every fifth period, subjects estimated the demand of the following period (in-task overprecision). After 50 periods, subjects processed the post-task questionnaire containing the five-item CRT and demographic questions. As we understand thinking orientation to be anchored in the characteristic set and stable in the short term, we assume the correlations of our conceptual model to hold, although administering CRT after the experiment. A caveat is that Brañas-Garza et al. (2019) show that subsequent CRT results are lower on average due to subjects' increased cognitive load during an experiment. Note that this effect would not influence correlations in our setting as all subjects performed the same sequence of tasks. After completing the experiment, subjects were debriefed individually on the study's purpose and the manipulation phase via email.

In our experiment, individual performance was not financially compensated, as compensation schemes would be perceived differently by participants with varying experience levels and income (students vs. practitioners). Therefore, the decisions made in our experiment were purely hypothetical. Moritz et al. (2013) assessed result robustness in the absence of performance-based financial incentives, indicating minimal loss of experimental control in newsvendor settings. Katok (2018, p. 24) states that there are decision types, for example, in newsvendor-like scenarios, "for which there is no evidence that real vs. hypothetical payments make a difference." As compensation for participating in the study, subjects could win one of 10 Amazon gift cards worth €20 each to secure participants' motivation.

4 Main results

Following Frederick (2005), subjects' thinking orientation was measured by the number of correct responses in our five-item CRT. Subjects were classified as analytic (51), moderate (65), and intuitive (26).

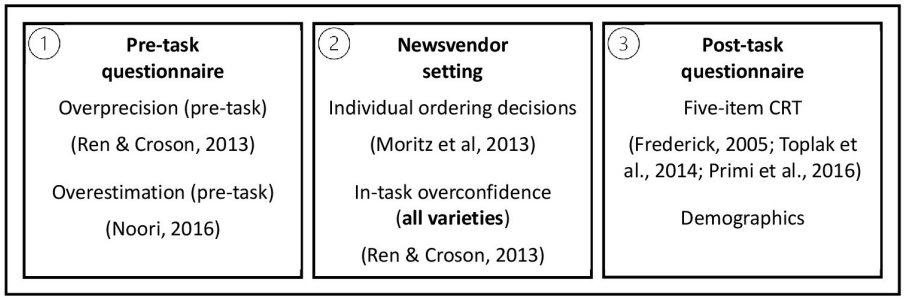

FIGURE 2
Summary of the study design in three stages.

Results indicate that thinking orientation correlates with newsvendors' economic outcomes. Analytic thinking significantly increases realized profits toward the optimum of €140.23 per period. We found an economic outcome score of €124.10 (SD = 13.51) for the analytic group, €110.82 (SD = 18.63) for the moderate group, and €76.38 (SD = 46.08) for the intuitive group. The ANOVA is significant between groups, $F = 32.52\ (2,\ 139), p \leq 0.001$, with an effect size of $\eta^2 = 0.32$. *Post hoc*, statistical power was calculated to be 1.0, suggesting that the study had a sufficient likelihood of detecting an effect.

Result 1. On average, thinking orientation correlates significantly with the economic outcome in newsvendor settings, thus supporting Hypothesis 1.1 and the results of Moritz et al. (2013).

As shown in Figures 3A, B, the results further indicate that thinking orientation significantly correlates with both pre-task and in-task **overprecision**. The former revealed an overall score of 4.15, indicating subjects' overprecision before the experiment. We found an overprecision score of 3.45 for the analytic group, 4.14 for the moderate group, and 5.58 for the intuitive group. The ANOVA is significant between groups, $F = 10.64\ (2,\ 139), p \leq 0.001$, with an effect size of $\eta^2 = 0.13$. *Post hoc*, statistical power was calculated to be 0.9896. By contrast, in-task overprecision revealed an overall score of 32.82, indicating newsvendor-specific overprecision. We found an *InOpr* score of 34.37 for the analytic group, 32.38 for the moderate group, and 30.89 for the intuitive group, representing the strongest overprecision (lowest score). The ANOVA is significant between groups, $F = 8.89\ (2,\ 139), p \leq 0.001$, with an effect size of $\eta^2 = 0.11$. *Post hoc*, statistical power was calculated to be 0.9728. Concerning participants' hit rates, demand interval borders captured realized demand in only 74% overall. Considering thinking orientation, we found a hit rate score of 84% for the analytic group, 73% for the moderate group, and 58% for the intuitive group. The ANOVA is significant between groups, $F = 14.75\ (2,\ 139), p \leq 0.001$, with an effect size of $\eta^2 = 0.18$. *Post hoc*, statistical power was calculated to be 0.9990.

As shown in Figures 3C, D, thinking orientation also significantly correlates with pre-task and in-task **overestimation**. Concerning participants' estimates in the pre-task, the guessed number matched the actual number of correct responses in only 33% overall, implying overestimation before the experiment. We found an overestimation score of 43.14 for the analytic group, 104.62 for the moderate group, and 173.10 for the intuitive group. The ANOVA is significant between groups, $F = 26.71\ (2,\ 139), p \leq 0.001$, with an effect size of $\eta^2 = 0.28$. *Post hoc*, statistical power was calculated to be 0.9999. By contrast, in-task overestimation revealed an overall score of 21.51, implying newsvendor-specific overestimation. We found an *InOes* score of 23.80 for the analytic group, 16.79 for the moderate group (lowest score), and 28.79 for the intuitive group. The ANOVA is significant between groups, $F = 3.96\ (2,\ 139), p \leq 0.03$, with an effect size of $\eta^2 = 0.05$. *Post hoc*, statistical power was calculated to be 0.7130. However, thinking orientation strongly correlates with preexisting, rather than task-related, levels of overestimation.

As shown in Figure 3E, thinking orientation correlates with in-task **overplacement**. The analysis revealed an overall overplacement score of 24%. Differences between individuals' estimated and actual number of better performing subjects were larger than 5% in 9 of 10 cases. We found an overplacement score of 21.57% for the analytic group, 23.10% for the moderate group, and 33.17% for the intuitive group. The ANOVA is significant between groups, $F = 4.45\ (2,\ 139),\ p \leq 0.02$, with an effect size of $\eta^2 = 0.06$. *Post hoc*, statistical power was calculated to be 0.7658.

Result 2. On average, thinking orientation correlates significantly with pre-task and in-task overconfidence in newsvendor settings, thus supporting Hypothesis 1.2.

Furthermore, our results show that in-task overprecision and pre-task overestimation significantly correlate with newsvendors' economic outcomes. We found that higher overprecision (thus, lower *InOpr* values) negatively correlates with the total economic outcome in our newsvendor setting ($t = 4.01, p < 0.001/a = 99.76$). Furthermore, we found that higher overestimation negatively correlates with the economic outcome ($t = -3.95, p < 0.001/a = -4.28$). Effect sizes result in $R = 0.32$ ($R^2 = 0.10$) for both varieties, indicating medium-sized effects. *Post hoc*, statistical power was calculated to be 0.9797 for overprecision and 0.9767 for overestimation.

Result 3. On average, overprecision and overestimation correlate significantly with the economic outcome in newsvendor settings, thus supporting Hypothesis 2 and enhancing the results of Ren and Croson (2013).

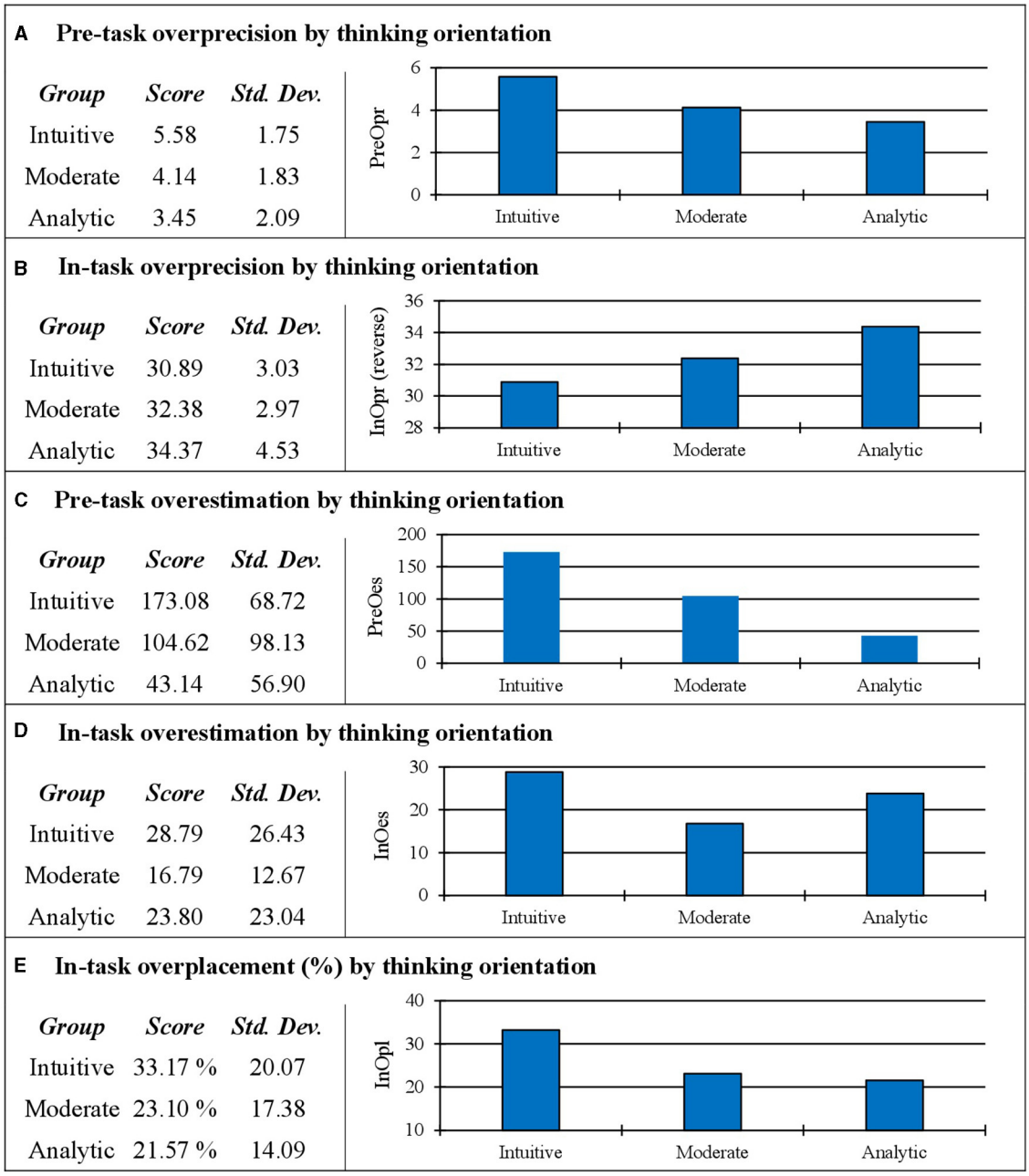

FIGURE 3
Comparison of overconfidence varieties by thinking orientation. Varieties include pre-task and in-task measures of overprecision, overestimation, and overplacement.

4.1 Overprecision as a mediator of thinking orientation and the economic outcome

The empirical results of our mediation model support partial mediation in our newsvendor setting, as presented in Table 3. To summarize, path a is significant, which indicates a negative relationship between thinking orientation and overprecision (remember the reverse character of *InOpr*). We also find a strong negative effect of *InOpr* on the economic outcome (path b). Path c is significant ($t = 7.109$, $p < 0.001/a = 446.331$), which supports results by Moritz et al. (2013) and is to be compared with the direct effect c' after including the mediator.

If overprecision mediates the thinking orientation–economic outcome relationship, (1) the coefficient of c' is smaller than the coefficient of c, and (2) path c' is not significant. The empirical results of path c' meet the first criterion since its coefficient of 399.278 is smaller than c. However, path c' is still significant ($t = 6.200, p < 0.001$). This still implies the *ex ante* relationship of thinking orientation and overprecision (path a) and the *ex post* relationship to the economic outcome but

TABLE 3 Overview of mediation analysis results.

	Path	*Coefficient *a*	Standard error	*t*	*p*
Model summary					
$R^2 = 0.297$	a	0.809	0.225	3.592	≤0.001
$R^2_{adj} = 0.287$	b	99.760	24.898	4.007	≤0.001
$F = 29.394\ (2, 139)$	c	446.331	62.785	7.109	≤0.001
$p \leq 0.001$	c′	399.278	64.399	6.200	≤0.001
Sobel test					
Significant complementary mediation	a_s	0.290	0.081	3.592	≤0.001
	b_s	0.321	0.080	4.007	≤0.001
	a_s * b_s	0.093	0.034	2.722	≤0.001

*Coefficients understood as in regression: the change in output per unit increase in the input.

indicates a complementary mediation only (Zhao et al., 2010). To strengthen our results, we processed a Sobel test using the standardized regression coefficients of our data. The combined path significance (path a_s * path b_s) resulted in $t = 2.722, p < 0.001$, supporting a complementary mediation of direct and indirect effects. We show consistency with our hypothesized but incomplete conceptual model as other (mediating) cognitive aspects impact this relationship.

Given that G*Power does not provide specific tools for mediation analysis, the *post hoc* power analysis was conducted using general linear regression parameters, resulting in a power estimate of 1.0. This suggests that the study had a reasonable likelihood of detecting the mediated effect, although this *post hoc* approach may not fully account for the complexities inherent in mediation models.

Result 4. In newsvendor settings, overprecision complementarily mediates the thinking orientation–economic outcome relationship, thus supporting Hypothesis 3 and enhancing the results of Moritz et al. (2013) and Ren and Croson (2013).

4.2 Decision variability and control variable analysis

Table 4 presents the descriptive statistics for the within-subject standard deviations observed in our study. Notably, the minimum observed value in the high critical ratio setting was zero, indicating that these participants did not alter their order decisions during the experiment. These participants consistently ordered 100, 105, 115, or 125 units across all 40 experimental rounds. Our results indicate that, although the standard deviation and the standard error decreased toward the end of the experiment, period-to-period adjustments in decisions remained relatively consistent within subjects throughout the experiment.

We also assessed differences in decision behavior based on subjects' *ex ante* demographics of gender, experience, and nationality. We investigated the differences in these control variables for all applied study measurements. First, our gender analysis shows no significant differences for any of the measures analyzed except overplacement ($t = 2.2, p < 0.05, n = 142$; critical value of 1.98). Results indicate that females, on average, tend to underplace their performance, while overplacement is dominant for their male counterparts. Second, we did not find significant effects for the measures analyzed in relation to results recorded by students and practitioners. This supports the results of Bolton et al. (2012). Finally, we compared the behavior of international and German subjects. We found no significant effects for the measures analyzed.

4.3 Ex post exploratory results

First, over all subjects, the pull-to-center effect was 71.23%. Results show that average order quantities $\bar{\bar{Q}} = 105.58$ ($SD = 8.05$), compared to the optimum of $Q^* = 119.4$, are "pulled" toward the mean demand of $\mu_D = 100$. Individual average orders $\bar{\bar{Q}}$ varied from 83 to 128 with an interquartile range of [100.32, 110.68] and a median of 104.49. Deviations of $\bar{\bar{Q}}$ from the optimum are significant ($t = -20.46$, $p < 0.001$, $n = 142$; critical value of 1.66).

Second, as shown in Figure 4, thinking orientation correlates with participants' demand chasing. On average, β resulted in 0.48 ($SD = 0.81$), implying that participants were chasing the demand of previous periods. We found a demand-chasing score of 0.235 for the analytic group, 0.541 for the moderate group, and 0.782 for the intuitive group. The ANOVA is significant between groups, $F = 4.59\ (2,\ 139)$, $p \leq 0.012$.

Third, we found that the chasing heuristic is correlated with in-task overprecision ($t = -2.61$; $p < 0.011/a = -1.02$). Effect size results in $R = 0.22$; ($R^2 = 0.05$), indicating a small-sized effect. We found no significant effects of demand chasing on overestimation ($t = 0.27, p > 0.05/a = 0.58$) and overplacement ($t = 1.81, p > 0.05/a = 3.24$). We explain these results by the specific nature of demand chasing as a kind of forecast decision, thus resembling a (confidence) interval estimation. So, exhibiting more demand chasing might only increase the overconfidence in one's accuracy of a subjective estimation (overprecision) but neither in one's own abilities in absolute nor in relative terms (Moore and Healy, 2008). Last, we found that demand chasing is correlated with the economic

TABLE 4 Descriptive statistics: within-subject standard deviations.

High critical ratio setting ($p = 4, c = 2$)						
Period	Mean *SD*	Median *SD*	Min. *SD*	Max. *SD*	Standard error of *SD*	Max. standard error
Overall	13.70	13.24	0.00	47.55	2.17	7.52
11–30	15.56	13.89	0.00	62.49	2.46	9.88
31–50	10.43	11.17	0.00	37.22	1.65	5.89

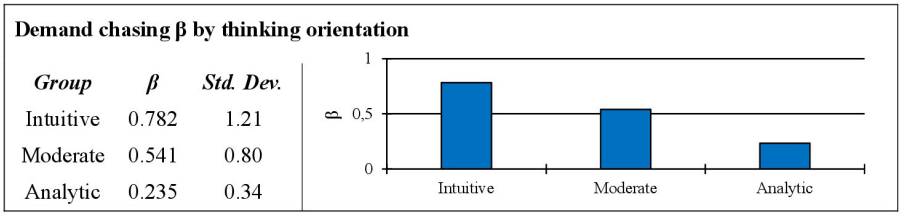

FIGURE 4
Comparison of demand chasing β by thinking orientation.

outcome ($t = -2.67$, $p < 0.009/a = -323.82$). The effect size results are $R = 0.22$ ($R^2 = 0.05$), indicating a small effect size.

5 Discussion of empirical results

We show that an individual's thinking orientation, as part of the characteristic set, correlates with pre-task and in-task overconfidence. Across our one-treatment-only newsvendor experiment, analytic thinkers consistently outperform their intuitive counterparts. Specifically, we emphasize the in-task overprecision measure's resulting values and hit rates. In our newsvendor setting, subjects overall had an *InOpr* value of 32.82. For comparison, Ren and Croson (2013) found an in-task overprecision score of 24.93; thus, our subjects were less overprecise than the sample of Ren and Croson (2013) (as higher *InOpr* indicates lower overprecision). Concerning hit rates, Moore and Healy (2008) reported an overall score of 73.1% in a non-newsvendor setting. In our case, the hit rates of the analytic group (84%) exceeded the undifferentiated results by Moore and Healy (2008), while the hit rates of the moderate group (73%) equaled them. These findings support Evans (2020), who states that individuals' thinking orientation captures the cognitive mechanisms by which humans channel biased, overconfident behavior independent of the newsvendor context (Payne et al., 1993).

Moreover, individuals' overprecision is negatively related to their economic outcome. We highlight the robust nature of overprecision present in our study. For comparison, Ren and Croson (2013) report constant overprecision values between 0.721 and 0.730 in their generalized least squares regression, even when incorporating the effects of other biases such as self-generated anchoring. This indicates a strong and robust effect of overprecision on the pull-to-center effect and, thus, on the economic outcome, as shown in our study. We enhance these insights by showing medium-sized correlation effects of overestimation on economic outcomes.

In our study, analytic thinkers better self-assess their abilities and, thus, show less overconfidence than intuitive thinkers. We highlight the significant differences found in our study between the analytic and intuitive groups for all overconfidence varieties. Specifically, we want to highlight the group differences for our measures of pre-task (analytic: 43.14; intuitive: 173.10) and in-task (analytic: 23.80; intuitive: 28.79) overestimation. For comparison, Hoppe and Kusterer (2011) report that analytic thinking significantly mitigates overestimation, increasing the share of subjects with correct self-assessment from 23.2% (intuitive) to 32.4% (analytic). Noori (2016) even reports an increase in correct self-assessment from 16.9% (intuitive) to 34.4% (analytic). We claim our results to support and enhance these insights for both pre-task and in-task overestimation, as we also found a significant reduction of overestimation for our analytic groups.

Analytic thinkers also engage in significantly less demand-chasing behavior. We emphasize the increased overall demand-chasing value in our study ($\beta = 0.48/48\%$), which represents a stronger engagement in demand-chasing compared to other studies. For instance, Kirshner and Moritz (2021) emphasize a moderate demand-chasing value of $\beta = 0.3$, while Moritz et al. (2013) report an average β of 0.34. According to their correlation, Bolton and Katok (2008) state demand-chasing values between 30% and 40%. When thinking orientation is included, we found a clear trend toward demand chasing for intuitive thinkers rather than for their analytic counterparts (intuitive: 0.782; analytic: 0.235). This is supported by the results of Moritz et al. (2013), who found a β of 0.458 for their all-intuitive group and 0.247 for their all-analytic group.

Our mediation analysis revealed a significant complementary mediation of overprecision on the cognitive reflection–economic outcome relationship. Due to the positive product of path coefficients ($a * b * c > 0$), direct and indirect effects of thinking

orientation seem to supplement each other in an equal direction. However, other mediating variables likely also influence the relationship of interest (Zhao et al., 2010). For comparison, Moritz et al. (2013) found similar insights for mediating the thinking orientation–economic outcome relationship with demand chasing as a mediator. This allows the proposition to investigate the effects of meditation on this relationship using multiple mediator models (Preacher and Hayes, 2008). Thus, the indirect impact of thinking orientation on the economic outcome could be simultaneously assessed and compared by multiple (mediating) variables.

Finally, the well-known pull-to-center effect also occurred in our newsvendor setting. Expected profits declined by 5% as $\bar{\bar{Q}}$ results in €134.04/day instead of an optimum of €140.23. The average order quantities are close to the mean of the demand distribution at the beginning of the experiment. Subjects learned from their experience and feedback as orders moved upward toward Q^* in the last 10 periods. Consistent with previous results, scholars observed pull-to-center effects to decrease over time, suggesting learning effects (Bostian et al., 2008; Benzion et al., 2008). To ensure that the observed order uptake is truly due to learning and not triggered by demand chasing, we compared chasing behavior to the magnitude of β in the last 10 periods. Overall, we observed $\beta = 0.48$ ($SD = 0.81$), while results show $\beta = 0.37$ ($SD = 0.73$) for periods 41–50. Thus, demand chasing in the last 10 periods is lower than the overall mean with a stable standard deviation, implying that the order uptake is not due to chasing behavior.

Our results are relevant for practitioners. A stronger orientation toward analytic thinking helps individuals show more accurate confidence in highly critical newsvendor-like settings. Thus, thinking orientation should be considered in the staffing process in these environments. Note that we do not emphasize neglecting other individual characteristics, as even intuitive thinking might be beneficial in certain situations, for example, under high pressure or high complexity (Burkhardt et al., 2023). Thus, we stress the importance of addressing contextual aspects, factor-related process standardization, and individuals' cognitive processes when developing appropriate policies, as no one-size-fits-all approach is applicable (e.g., compare Ren and Croson, 2013, and Li et al., 2017).

Because overconfidence occurs persistently in our study, managers need to be aware of employees' mental models and motivate individuals to reflect on them regularly. The awareness (and the measurement) of individuals' overconfidence is a first step for the company to (1) assess better how behavior is driven by overconfidence and (2) foster individuals' regular reflection on their own overconfidence tendencies. The willingness to reflect on one's tendencies toward overconfidence and its mediating role in the thinking orientation–economic outcome relationship should help modify tacit mental models and improve the fit to the decision context.

Regular reflection on decisions and evaluation of the accuracy of tacit mental models could help strengthen individuals' analytic thinking orientation. Nesbit (2012) argues that effective self-development depends on the individual's skill to self-reflect effectively on one's practices. As proposed, for example, by Jayatilleke and Mackie (2013), these reflections contribute to the continuous development of professionals' work practices. Helyer (2015) states that continuous reflection positively affects ongoing personal and professional work-based learning. While the potential of continuous reflection is demonstrated in the literature, the efficient incorporation into firms' daily operational routines is the object of future research. We refer to London and Smither (1999) and Grossmann et al. (2021) for self-reflection applications in contexts other than economics.

6 Conclusion, limitations, and future research

We investigate situations in which thinking orientation, as a fundamental pillar in the characteristic set, correlates with overconfidence and, thus, individuals' behavior in the classic newsvendor setting. Including 142 participants, we show that thinking orientation, more precisely analytic and intuitive thinking, correlates with individuals' overconfidence and economic outcomes (as outlined in Results 1 and 2). Furthermore, overprecision and overestimation are negatively correlated to the economic outcome in the newsvendor setting (as outlined in Result 3). We excluded the measure of overplacement as our measurement relates to task performance, and a relation seems trivial. Last, we find a complementary mediation relationship of overprecision on the thinking orientation–economic outcome relationship (as outlined in Result 4). So, we propose using multiple mediator models to compare the indirect effects of this relationship.

While our study contributes to a better understanding of individual decision behavior, it has limitations. First, our results are specific to the newsvendor setting context, and thus, caution should be employed when generalizing results to other contexts. Second, despite using the design of previous newsvendor studies, the loss of experimental control in an online experiment compared to a laboratory in-person study needs to be considered. Third, as our focus was on thinking orientation, the possible impact of other individual factors, which might be better predictors of overconfidence and economic outcomes, cannot be ruled out. Next, we emphasize the potential for omitted variable bias in our mediation model. While we expect that thinking orientation causes overprecision and economic outcomes to be correlated in our experiment, we must also consider that other confounding variables could cause this correlation outside our experiment. Although our sample allows us to argue against math ability as an omitted variable, other confounding variables and their effects on the tested correlations might still apply, which could limit the validity of our results. Finally, we acknowledge the potential for statistical power limitations due to multiple hypothesis testing. To address this, we propose implementing multiple hypothesis correction analyses in future studies building on our insights. Another caveat regarding the reported statistical power concerns the *post hoc* design of our analysis. Given the challenges of study replication in psychology and other disciplines, the importance of conducting *a priori* statistical power calculations has significantly increased. Nevertheless, we believe that our *post hoc* approach still offers valuable insights into the statistical power of our findings.

Our study provides insight into how thinking orientation and overconfidence correlate with the economic outcome in the

newsvendor setting, but there remain directions to add to this line of research. Our findings could serve as a pilot study, offering valuable input for future power calculations. Moving forward, future research should investigate the interplay of individual characteristics with the decision-specific combination of environmental features. The extant literature grounds the assumption that the individual' decision strategy selection, for example, analytic and intuitive thinking, and its advantageousness is driven by the contextual features of the decision (Kahneman, 2011). So, research should investigate whether cognitive processes are triggered by the context rather than the individual characteristic set, which might only influence process magnitude. Next, our approach could be replicated using multiple mediation analyses to generate empirical results on the parallel indirect effects of thinking orientation on the economic outcome. Moreover, the study design could be replicated, providing subjects with information technology systems supporting the decision process. For implications for software tool vendors, see Yamini (2021). Finally, Renerte et al. (2023) already emphasized the importance of overconfidence in group decision-making. Thus, our study could be replicated with a focus on overconfident group behavior in the newsvendor setting.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because at the time of the study, the University of Stuttgart had not yet established an ethics committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements because all participants provided oral consent to participate in the study. Given the online environment spanning various locations, participants were afforded the opportunity to withdraw from the simulation at any time without any repercussions.

Author contributions

JW: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. IĐ: Writing – review & editing, Validation, Supervision, Software. AG: Writing – review & editing, Validation, Supervision, Project administration.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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