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Journal of Information Systems Applied Research

Decisional Guidance to Promote Motivation in Supply Chain Decision Making

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Abstract

Supply chain decision making can cause exaggerated fluctuations in inventory levels in spite of small changes in customer demand. While previous research has recognized the positive impact of information sharing on supply chain decision making, little attention has been given to how information is presented, such as through dashboards or information displays. This study applies bounded rationality theory, intrinsic motivation, and the knowledge-based view to address this gap, exploring the effects of providing information to supply chain managers, emphasizing how the information is presented rather than merely its availability. Via an experiment using a version of the beer game supply chain simulation, we find that the display of information about inventory and upstream incoming orders significantly impacted overall performance. Psychometric modeling indicates that knowledge acquisition and shared meaning are crucial in decision-makers' perceived performance. Moreover, information distribution among supply chain participants will likely contribute to cognitive overload and reduce motivation to improve decision-making.

Keywords: Information display, supply chain performance, bounded rationality, intrinsic motivation

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Decisional Guidance to Promote Motivation in Supply Chain Decision Making

Russell Haines and Darin Hodges

1. INTRODUCTION

In 2022, amid a post-COVID boom in retail sales, large retailers such as Target, Walmart, and Kohl's reported poor financial performance and cut profit forecasts (Repko, 2022). They blamed the poor performance on an inventory build-up and subsequent discounting of prior-season apparel and home items (Waldow, 2022). Analysts noted that the inventory build-up occurred because of cascading problems throughout the supply chain: (1) late deliveries of items manufactured in China because of back-ups of container ships at ports along the west coast of the United States, (2) the back-up of container ships at ports was the result of a shortage of truck drivers, and (3) the shortage of truck drivers was due to Covid-19 shutdowns (Saraiva, 2021).

In examining these supply chain disruptions at the system-wide level, supply chain experts saw a clear case of the bullwhip effect – the supply chain members overreacted to small changes in customer demand at the beginning of the Covid-19 lockdowns (Tan, 2021). This, in turn, led to large increases in orders, which ironically, meant that subsequent large deliveries would cause supply chain problems and take even longer to arrive (Moin, 2022). Similar ordering inefficiencies during Covid-19 lockdowns that had wide-reaching effects were observed in integrated circuit ordering at automobile manufacturers (Wayland, 2021) and even with toilet paper (Shih, 2021).

When criticizing the decision-making of these supply chain members, it is easy to point to the various warning signs that were available in the news. The more rational thing for them to do would have been to take the predicted effects of those warning signs into account and increase safety stocks, anticipating the supply disruption and being able to capitalize on it. However, in most circumstances, human decision-making is less than rational (Kahneman et al.,1982) especially when making decisions in supply chains (Sterman, 1989). In this paper, we explore the effects of providing information to supply chain managers on supply chain performance, which has been proposed to mitigate supply chain inefficiencies such as the bullwhip effect (Croson & Donohue, 2003; Yang et al., 2021). We focus on *how* the information is presented rather than simply what information is available.

The greater information system and operations management literature have investigated supply chain inefficiencies and how to mitigate them quite extensively in the past and suggest increasing data sharing across the supply network, tightening supply chain slack, and decreasing overall risk in decision making (Chen et al., 2022; Hult et al., 2004; Kovach et al., 2015). Still others have suggested that information complexities in the supply chain decision matrix for organizations and individuals lead to strategic dilemmas. These dilemmas are where information ambiguity, information overload, and information asymmetry create failures within the decision-making process that bounds the decision makers' rational response mechanisms (Gunessee & Subramanian, 2020; Hodges & Salam, 2018; Patnayakuni et al., 2006; Vosooghidizaji et al., 2020).

Transaction cost economics (TCE) theory predicts that firms would wish to vertically integrate to alleviate any irrationality in the supply chain while at the same time attempting to reduce information ambiguity and asymmetries (Short et al., 2016), especially during times of environmental uncertainty. However, due to cost mitigations, merely monitoring the supply chain has become an acceptable form of supply chain governance, with data sharing being at the center, to help overcome transaction costs and reduce said information asymmetries and ambiguity.

While it is generally accepted that supply chain monitoring via upstream and downstream information sharing can lead to positive outcomes for supply chain operations and reduced bullwhip effect, little attention has been placed on how information is presented (or signaled) to supply chain participants. Few studies have focused in on information presentation strategies which can be used to design a bullwhip mitigation strategy, combating information overload via simplifying and expanding the rational boundaries for decision makers as opposed to the general sharing of information. We attempt to fill this gap. This study focuses on how supply chain data is presented during experimental supply chain simulations to examine differences in supply chain performance outcomes due to *how* data is presented, and follow with theoretical tests to tease out how decision-makers incorporated the displayed information during the simulations. We will attempt to answer the following question: How can we diminish the perception of overwhelming environmental uncertainty for supply chain decision-makers?

2. THEORETICAL FOUNDATION

Bounded Rationality and Upper Echelons Theory

Bounded rationality focuses on the organization's or individual's lack of full information about alternate decisions that may be available even though the consequences of inaction about those decisions are recognized (Simon, 1972). Complex problems, such as supply chain sourcing or purchasing, are thought to have limited outcomes based on all possible reasonable and rational choices due to an individual or organization’s ability to compute whether a choice is feasible or logical (Hodges & Salam, 2018). When considering time-sensitive decisions, Simon (1991) viewed linear models as too simplistic to anticipate and articulate optimized decisions for complex problems with large amounts of data. Upper echelons theory suggests that managers are constrained by their bounded rationality, which in turn influences how they process information regarding environmental uncertainties (Hambrick, 2007). Perceived environmental uncertainty is a subjective state experienced by individuals, such as managers, who perceive a lack of information about environmental factors that would affect their decision-making performance (Milliken, 1987), and hence would be limited by their bounded rationality.

Three main elements are considered for information processing to engage with an organization's main goal of lower costs and shortening the overall supply chain process (Hult et al., 2004), which are tied to individual and/or organizational rational boundaries. Grant (1996) stipulated that the ability to differentiate how organizations and individuals process information can lead to higher firm and organizational performance. In the age of big data, a large portion of this ability is placed on algorithmic calculations. Once derived, these algorithms require decision makers to understand what data is relevant, what decisions needs to be integrated into the supply chain decision matrix, and then leverage that information into an operational decision. In any given environment of the supply chain or operational environment, organizations and individuals attempt to find meaning in the information within the operational environment and go through a sensemaking exercise to build a strategy of plausible actions which create knowledge and a willingness to act (Weick et al., 2005).

Sensemaking is a form of rational boundary creation based on available knowledge and understanding. When managing product flows through a supply chain, information about those flows is critical for decision-makers – with correct and timely reactions to occurrences of over- and under-ordering mitigated by making sense of shared information (Haines et al., 2017). Information about underlying consumer demand for the end product is thought to be critical to this process, with underperforming supply chain decision-makers blaming a lack of knowledge about consumer demand for their performance (Sterman, 1989). Providing information from the point-of-sale to upstream decision-makers has been shown to mitigate the bullwhip effect specifically (Croson & Donohue, 2003). We therefore hypothesize:

H1: Sharing consumer demand information with members upstream in the supply chain will increase supply chain performance.

Intrinsic motivation and information display

Intrinsic motivation refers to the internal drive and self-regulation that leads individuals to engage in activities or tasks for their inherent enjoyment, personal fulfillment, or satisfaction rather than relying on external factors or rewards. When intrinsic motivation is present, it can contribute to individual empowerment, particularly when individuals are engaged in tasks that provide a sense of accomplishment and where performing the task serves as a reward. In such cases, external reinforcement for task completion becomes unnecessary (Deci and Ryan, 1980).

Research on intrinsic motivation within the Information Systems (IS) discipline has focused on exploring the various factors influencing an individual's perceived competence to perform a task. Directly relevant to the supply chain management context is that individuals' feelings of competence is related to their intrinsic motivation (Herath and Rao, 2009a); therefore, providing information in a way that reduces complexity and enhances decision-making performance could create a positive feedback loop where decision makers feel they are better able to make sense of the environment, perform better, and thereby feel that they can make sense of the changing decision environment.

However, it is important to recognize that the mere availability of information does not automatically enhance decision-making in supply chain management (Haines et al., 2017). Indeed, research has shown that sharing information may hurt performance when it leads to information overload and overwhelms the processing capacity of ordering managers (Tokar et al., 2012) by suppressing their ability to make sense of shared data. To improve decision-making and, therefore, intrinsic motivation, information needs to be effectively integrated into the decision-making process of supply chain managers. Therefore, it is essential to view supply chain management as a learning process that includes cognitive training (cf. Sterman, 1994; Wu & Katok, 2006). Within this framework, supply chain managers, as learners, can have varying learning outcomes based on their intrinsic or extrinsic motivation (Ghosh, 2016). Motivation also influences how individuals transfer their learning to different contexts (Ghosh, 2022).

While past research has proposed that additional information is the main way to improve decision-making, we focus instead on how display signaling encourages the use of the most relevant information, even in the presence of the overwhelming amount of information normally available to supply chain managers. We adopt a tangentially minimalist view in which the simplicity and elegance of the display are enhanced to provide the positive feedback loop, thereby helping make sense of the changing decision environment and ultimately increase intrinsically motivated abilities, competence in decision making, and relatedness to the task at hand. Prior research has also found that users rate information higher in usability when the characteristics of beauty, clarity, effectiveness, and simplicity are present and when those characteristics meets their expectations (Hill et al., 2018). We hypothesize:

H2: Providing information about inventory and the incoming supply line in an easy-to-process display will improve supply chain performance versus traditional ways of making the information available.

Intrinsic Motivation, Bounded Rationality, and the Knowledge-based View

The organizational learning literature provides another source of support for understanding the relationship between knowledge and supply chain dynamics. Huber (1991) identified key learning elements such as knowledge acquisition and information distribution. Knowledge acquisition refers to the process of acquiring new knowledge or information. It involves gathering data, conducting research, learning from external sources, or training programs to expand an organization's or supply chain's knowledge base. Information distribution involves disseminating relevant knowledge or information to individuals or departments within the organization. It ensures that the acquired knowledge is shared and accessible to those who need it.

While these learning elements have been studied in marketing and decision sciences, their application within the supply chain context is crucial. Understanding how knowledge acquisition, information distribution, information interpretation, and organizational memory operate within the supply chain can provide insights into how knowledge is generated, shared, and leveraged to improve supply chain performance and outcomes.

Intrinsic motivation and the knowledge-based view of the firm are interrelated and mutually reinforced. When intrinsically motivated, individuals have a natural curiosity and desire to learn, explore, and engage in tasks that provide personal fulfillment, this intrinsic motivation leads them to actively seek new knowledge, acquire expertise, and develop unique abilities (Deci and Ryan, 2010). As a result, the firm should benefit from its employees' increased knowledge, capital, and capabilities within the supply chain environment. Additionally, this cooperation between intrinsic motivations and increased knowledge should expand the bounds of rational decisions and increase the alternatives available to individuals to make sense of supplied information. As individuals gain knowledge, an expectation of improved efficiency in each participant’s role within the supply chain should increase chain performance (Grant, 1996a) and lead to positive feedback loops.

Knowledge is also acquired through simplifying cognitive loads through reductions in complexity and is a way to increase learning for novices (Fathi et al., 2023). Developing knowledge about the supply chain is important for decision-makers in a supply chain in order to increase its performance (Hult et al., 2004). Thus, we assert that decision-makers who indicate higher levels of knowledge acquisition about the supply chain will perceive that they perform better than those with lower levels. We hypothesize:

H3: Knowledge acquisition activities will positively affect satisfaction with supply chain performance.

Hult et al. (2002) also noted that information distribution is linked to efficient operations of supply networks as supply chain members become more educated about supply partners and the patterns they articulate over time. Information distribution has also been shown to be a part of the knowledge development process (Kamel & Syed Awais Ahmad, 2019). Therefore, we would expect:

H4: Information distribution activities will positively affect satisfaction with supply chain performance.

Shared meaning has been analyzed within information processing literature (Daft and Weick, 1984; Gioia and Thomas, 1996; Thomas et al., 1993). In a supply chain context, shared meaning enables supply chain members to have a common understanding of goals, strategies, and anticipation of disruptions and/or opportunities. The sharing of information has been shown to positively affect the sensemaking ability of why and/or for whom decisions are made within the supply chain environment. Hult et al. (2004) concluded that shared meaning between supply partners created positive effects on reductions of supply cycle times. We therefore hypothesize:

H5: Shared meaning of information between supply network partners will positively affect satisfaction with supply chain performance.

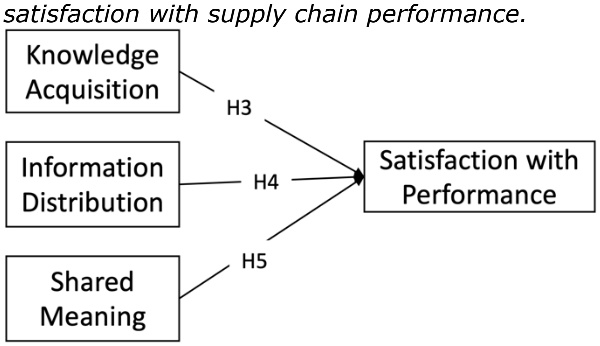


Figure 1: Research Model

The research model is shown in Figure 1.

3. RESEARCH METHODOLOGY

We used an experiment to examine how information display could influence supply chain performance. A version of the beer game (Sterman, 1989) called the "Distribution System Simulation" was used with bullets (•) representing cases of merchandise. Figure 2 shows the game screen in the control condition. Each supply chain made a total of 52 orders, lasting about 50 minutes total.

The simulation was set to have human players operate the wholesaler and distributor positions. Computerized players operated the retailer and factory positions to have a more predictable bullwhip pattern in response to incoming consumer orders.

Treatments

The demand information display was manipulated by randomly selecting supply chains to see a column on the record sheet with actual consumer demand listed (right hand side of Figure 3). Both human players in a supply chain saw the information display for consumer demand information. Showing consumer demand in this way was display manipulation because players could track this number by observing the retailer inventory level and amount shipped to consumer areas of the game screen.

The supply line information display was manipulated by randomly selecting supply chains to see "Your Inventory" and "Shipping to you" captions with their current inventory level and the number of cases that the player had in the supply line (lower left corner of Figure 4). Both human players in a supply chain saw the same supply line information - either with the inventory and supply line numbers in the order form or without (compare Figures 1 and 3). This was also a display manipulation because players without the information display could calculate both numbers via the game screen using their inventory, their upstream partners backlog, and the incoming shipments.

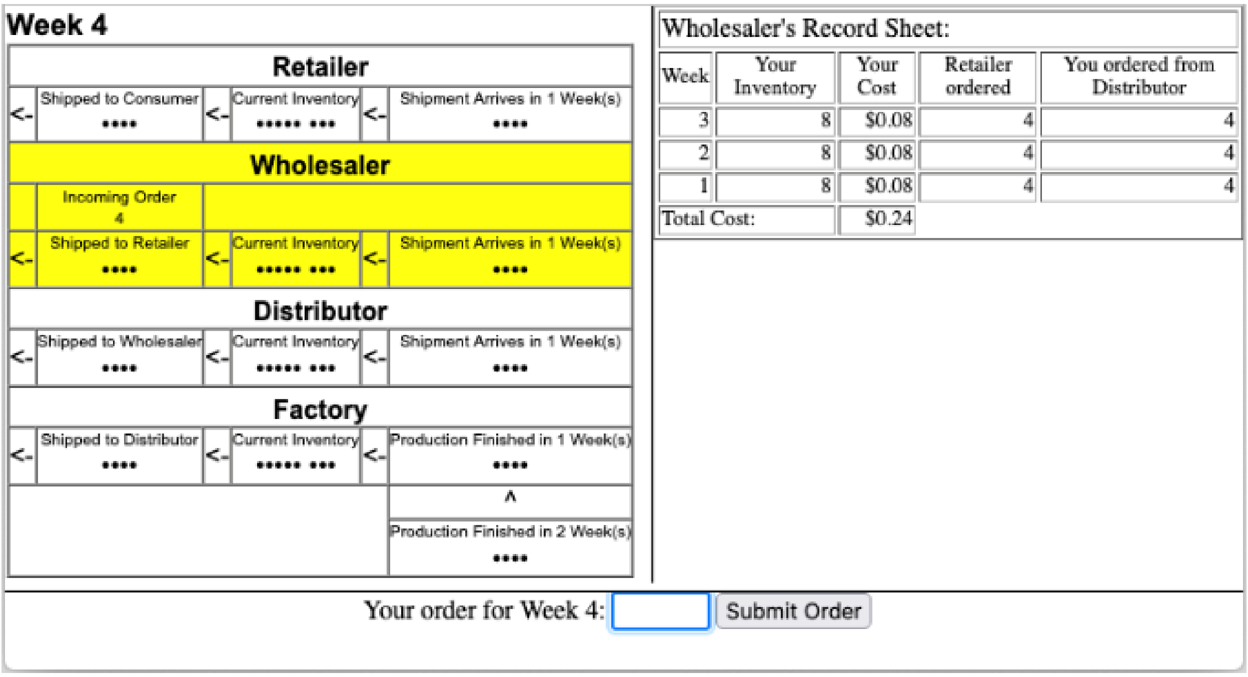


Figure 2: Game Screen in Control Condition

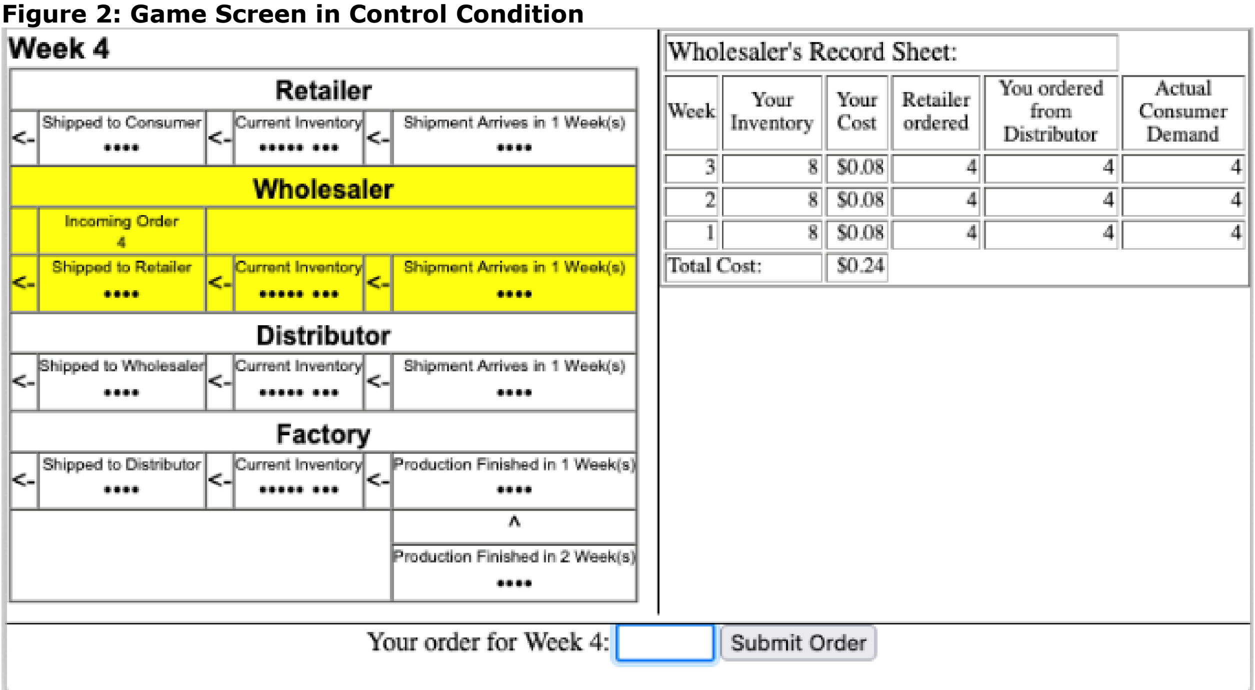


Figure 3: Demand Information Treatment

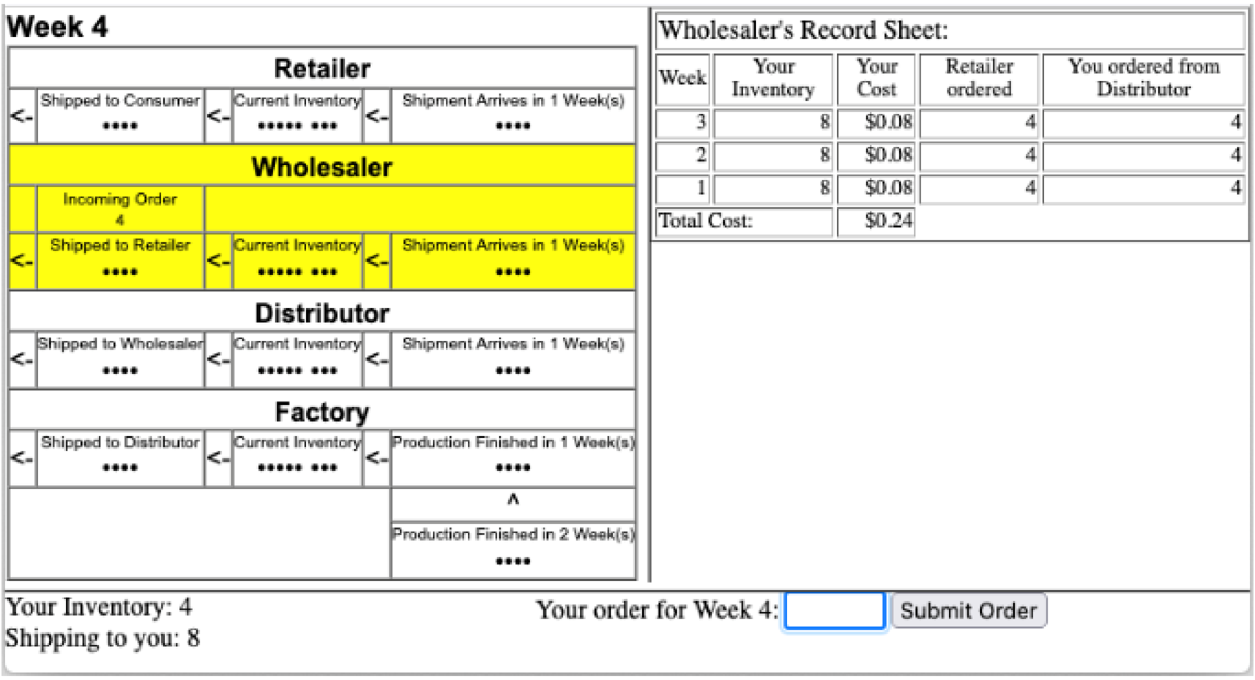


Figure 4: Supply Line Information Treatment

Overall, our contention is that information display can improve performance by enabling relevant information search and incorporating relevant information into the decision-making process. As shown in Figures 2, 3, and 4, the entire supply line was visible to all players in all positions in all conditions (cf. Croson & Donohue, 2003, 2006; Wu & Katok, 2006). Additionally, inventory backlogs were shown numerically in the "Current Inventory" cell when any supply chain member was backlogged (cf. Haines et al., 2017). Thus, information availability alone was not a factor in determining decision-making performance.

Dependent Variable

The dependent variable was the total cost for the supply chain, about which the players were explicitly instructed before the simulation began: "Your objective is to run the minimum total cost distribution system (retailer, wholesaler, distributor, and factory combined)". Costs were assessed for each position based on their current inventory level: $0.01 per case per week of inventory on hand, and $0.02 per case per week of unfilled orders. The supply chain with the lowest total cost won a prize of $20 less their total cost. During the simulation, each participant's weekly and total costs were shown on their game screen (see Figures 1, 2, and 3).

Experimental Procedures

All players in an experimental session were present in the same classroom, where each player was seated in front of their computer. Supply chains and positions were randomly assigned, and participants were explicitly instructed that they could not talk or communicate with any other participant and could not look at the screen of any other participant. Each session began with the players indicating their informed consent. Next, the players completed a demographic and personality survey. Then, the players completed a 12-week trial session where they could familiarize themselves with the ordering process and on-screen displays. Computer players managed all the other positions during the trial. During the first three ordering periods of the trial, the administrator verbally guided the ordering process and instructed them about the various screen elements and how the costs were calculated. After those weeks, the players completed the remaining trial weeks. When all participants in a session had completed the trial, all inventories and supply lines were reset to the starting quantities, and the actual experiment began. At the end of the session, participants completed the psychometric questionnaire.

Psychometric Variables

The independent variables for the psychometric analysis were based on the questionnaire created and validated by Hult et al. (2004). They measured knowledge acquisition, information distribution, and shared meaning (for the exact wording, see Appendix Table A1). The dependent variable was created specifically for this experiment and measured satisfaction with performance. We note here that satisfaction with performance had an expected significant, negative relationship with team total cost in a PLS model with all measures integrated (b=-0.242, t=1.983, p=0.047); however, the psychometric data was collected after the simulation was completed, and our intrinsic motivation approach recognizes that supply chain costs could have influenced the responses as much as costs were influenced by their decision-making perceptions.

4. RESULTS

A total of 124 students completed the simulation as a required class exercise in a junior-level operations management class required of all business majors at an Eastern U.S. university (62 total supply chains). Six supply chains were eliminated due to one or more members indicating that they misunderstood the ordering process via their ordering strategy, leaving 56 total supply chains included in the analysis. The average supply chain performance (total cost) and standard deviation for each treatment are summarized in Table 1.

Hypothesis Testing

The effect of showing information about consumer demand and/or a simplified presentation of supply line information (Hypotheses 1 and 2) was tested at the supply chain level using the general linear model in the R statistical package. The dependent variable was supply chain total cost, while three dummy variables representing the three different experimental conditions were the independent variables (consumer demand displayed, inventory and pipeline information displayed, and both displayed). Thus, the control condition is no additional information display, with the three dummy variables testing the extent to which each experimental condition was greater than the control condition. Table 2 summarizes the results.

The results showed no significant differences in supply chain performance when consumer demand information was displayed to all supply chain members (p=0.4619), providing no support for hypothesis one. There were significant differences in supply chain performance when inventory and the incoming supply line were presented in an easy-to-process display (p=.0205), which supports hypothesis two. The difference between supply chains that had both displays was marginally significant with respect to the no additional information (control) condition (p=.0817). Given this result, visual inspection of Tables 1 and 2 suggests that the additional consumer demand information may have hurt rather than helped decision-making versus an easy-to-process display of inventory and pipeline information alone.

	Pipeline Info Not Displayed	**Pipeline Info Displayed**	**Overall**
Consumer Demand Not Displayed	56.05 (29.04) n=13	33.55 (11.01) n=14	44.38 (24.10) n=27
Consumer Demand Displayed	49.19 (31.86) n=15	39.34 (19.90) n=14	44.43 (26.77) n=29
Overall	52.37 (30.22) n=28	36.44 (16.06) n=28	44.41 (25.29) n=56

Table 1: Mean (Standard Deviation) of Supply Chain Total Cost by Treatment Condition

	Estimate	**Std. Error**	**t-value**	**p-value**
Consumer Information Display	-6.864	9.260	-0.741	0.4619
Pipeline Information Display	-22.505	9.412	-2.391	0.0205
Consumer and Pipeline Information Display	-16.709	9.412	-1.775	0.0817

Table 2: Statistical Results of Treatments on Supply Chain Performance

	Knowledge Acquisition	Information Distribution	Shared Meaning	Satisfaction w/ Perf.
Knowledge Acquisition	**0.838**			
Information Distribution	0.679	**0.821**		
Shared Meaning	0.415	0.633	**0.96**	
Satisfaction w/ Performance	0.444	0.508	0.635	**0.775**

Table 3: Discriminant Validity Statistics. Correlation of Latent Variables, Square Root of AVE on Diagonals

	Chron. Alpha	Comp Rel.	AVE
Knowledge Acquisition	0.858	0.888	0.702
Information Distribution	0.837	0.851	0.674
Shared Meaning	0.914	0.915	0.921
Satisfaction Performance	0.663	0.777	0.601

Table 4: Reliabilities and Variance Extracted

The psychometric model and scale reliability and validity were tested at the individual level using SmartPLS (Ringle et al., 2022). The measurements all exhibited satisfactory reliability (Table 4), with Cronbach's alpha greater than the .6 cutoff for all constructs and composite reliability greater than the .7 cutoff for all constructs (Hair et al., 2011).

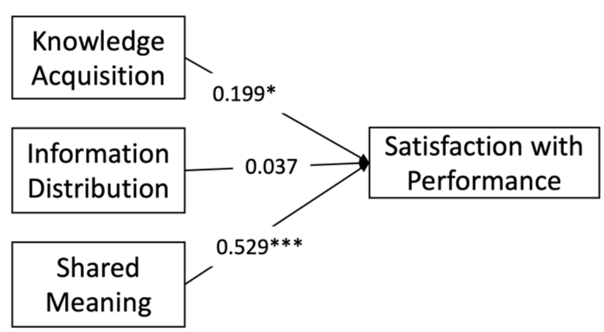
Discriminant validity was supported overall with correlations of latent variables all less than the square root of average variance extracted (Table 3) and item loadings on their own construct greater than cross-loadings on the other constructs for all items (Table A1 in the Appendix). Low levels of multicollinearity were shown with variance inflation factors (VIF) less than 2.569 (Table 5).

We note here that the loading for satisfaction with performance item three was 0.508 (see Table A1 in the Appendix), which, along with the relatively low alpha and AVE for that construct, indicates that rewording the item would increase the scale's reliability.

Hypoth.	Path Coef.	t-Value	p-value	VIF
KA-> SP (H3)	0.199	2.206	0.027	1.859
ID-> SP (H4)	0.037	0.315	0.753	2.569
SM-> SP (H5)	0.529	6.153	<0.001	1.671

Table 5: Path Statistics. t-value, p-value, Variance Inflation Factor

The measurement model is shown graphically in Figure 4, with path statistics summarized in Table 5. In the model, there are significant links from knowledge acquisition to satisfaction with performance (b=0.199, t=2.206, p=0.027) and shared meaning to satisfaction with performance (b=0.529, t=6.153, p<0.001), supporting hypotheses three and five. The link between information distribution and satisfaction with performance was not significant (b=0.037, t=0.315, p=0.753), providing no support for hypothesis four.



*** p<.05, ** p<.01, ***p<.001**

Figure 5: PLS Model Results

5. DISCUSSION AND CONCLUSIONS

This experimental task was completed by college students, which limits its generalizability versus contexts where supply chain professionals are making ordering decisions. However, the data can be analyzed for psychological insights into the behavior of people who participate in supply chain exercises. Additionally, the results offer a theoretical grounding for future research about supply chain decision making by professionals.

The experimental results offer insights into the behavioral causes of the bullwhip effect and the broader research stream of information seeking and overload. Most importantly, the display treatment for inventory and upstream incoming orders had a significant impact on the overall performance of the supply chains. Prior research has suggested that underweighting of the upstream supply has the most effect on performance (Croson & Donohue, 2006; Yang et al., 2021); however, no treatment condition has confirmed this cause-and-effect relationship until now.

The relative simplicity of gathering upstream incoming order information has significant implications for information systems that support supply chain decision-making. Broad-based supply chain information systems have been proposed that involve all supply chain members (Smith et al., 2021). Because of power asymmetries, implementing supply chain information systems normally is determined by the most powerful member (Vanajakumari et al., 2021); however, our results suggest that individual supply chain members can develop and implement systems that aid inventory management and improve supply chain performance without involving other supply chain members. Such internal systems evoke intrinsic motivations while expanding the rational decisions available and allowing more purposeful sensemaking about shared information between partners.

The psychometric results suggest that knowledge acquisition and shared meaning impact decision-makers' perceived performance. Prior research has suggested generically that communication and coordination are able to improve supply chain decision-making (Wu & Katok, 2006; Yang et al., 2021). Our results suggest that information systems should encourage supply chain members to seek out relevant information that can be used to create a common understanding of what events are critical and how to react to them.

The insignificant link from information distribution to satisfaction with performance further supports the notion that additional information from upstream and downstream partners is as likely to add to cognitive overload and reduce motivation as it is to improve decision-making (cf. Tokar et al., 2012). Tokar et al. (2012)'s findings, along with the insignificant impact of sharing consumer demand information, further support our contention that complicated supply chain management systems that integrate data from all levels of the supply chain are as likely to hurt as help supply chain decision-making.

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APPENDIX A:

	ID	KA	SM	SP
ID1: I was aware of trends as they moved through the supply chain	**0.869**	0.633	0.490	0.441
ID2: I could see what future needs in the supply chain would be.	**0.872**	0.568	0.606	0.469
ID3: I was aware of how satisfied the [other human player's position] was with me.	**0.794**	0.476	0.612	0.398
ID4: I could see when something important happened in the supply chain.	**0.741**	0.556	0.348	0.346
KA1: I tried to predict future needs in the supply chain.	0.623	**0.878**	0.348	0.401
KA2: I attempted to determine the effect that my orders had on the supply chain.	0.576	**0.901**	0.339	0.388
KA3: I made an effort to predict the effect of others' orders on the supply chain.	0.578	**0.871**	0.422	0.424
KA4: I tried to uncover faulty assumptions that I had about the supply chain.	0.502	**0.685**	0.262	0.241
SM1: The [other human player's position]and I developed a shared understanding of the available supply chain information.	0.610	0.387	**0.958**	0.600
SM2: The [other human player's position]and I developed a shared understanding of the implications of a supply chain activity.	0.605	0.409	**0.961**	0.619
SP1: I am satisfied with the performance of the supply chain.	0.497	0.402	0.629	**0.892**
SP2: Based on my knowledge of the supply chain, I think it was efficient and effective.	0.399	0.420	0.506	**0.866**
SP3: I feel that the performance of this supply chain could not be much better than it was.	0.235	0.138	0.263	**0.508**

Table A1: Loadings and Cross Loadings