Intelligence, Personality, and Interests – Determinants of Individual Inventory Management Performance?

Jürgen Strohhecker (j.strohhecker@fs.de)
Frankfurt School of Finance & Management

Andreas Größler (a.groessler@fm.ru.nl)
Institute for Management Research, Radboud University Nijmegen

Abstract
The purpose of this study is to investigate the influence of four personal traits (intelligence, knowledge, personality and interests) on performance in an inventory management task. We base our model on PPIK theory from cognitive psychology and ground the experiment we conduct on the tradition of dynamic decision making research. Findings are that intelligence and knowledge are good predictors of inventory management performance, while the analysis shows no relation or only partial relations between personality and interests, and performance. Implications for research comprise investigating the relationship between the four traits and accounting for different task complexities. The value of this paper lies in the adaptation and the application of psychological theory on inventory management.

Keywords: inventory management, personal traits, PPIK theory, stock control, experiment

Introduction – The Inventory Management Challenge and its Personal Foundation
Anecdotal evidence of poor inventory management (IM) performance is omnipresent in everyday life. Who has not yet gone to a supermarket in order to replenish the refrigerator at home only to find the shelf empty of their favorite drink or food? Such shortages can severely damage earnings and raise costs. Excess inventories are, however, just as bad as stock-outs. Large inventories increase the working capital and the inventory risk. In the worst-case-scenario of extreme excess inventory coinciding with decreasing demand, a company’s financial solvency is endangered and bankruptcy will be the consequence.

Mostly, research in operations management addresses the issue how inventory control performance can be improved. A wide variety of policies, models, and concepts have been developed to support decision making of inventory and purchasing managers (see, e.g., Williams and Tokar 2008 for a review). Nearly all formal analytical models that aim at supporting inventory management assume that the decision makers are either

1 Corresponding author: Jürgen Strohhecker, Frankfurt School of Finance & Management, Sonnemannstraße 9-11, 60314 Frankfurt am Main, Germany, Telephone: +49 69 154008-110, Telefax: +49 69 154008-4110, E-mail: j.strohhecker@fs.de
2 E-Mail: a.groessler@fm.ru.nl
fully rational or can be stimulated to behave rationally (Gino and Pisano 2008) or that human decision-makers can be replaced by automated decision systems.

Compared to the vast body of normative research, much less attention has been directed in the field of operations management to the investigation of behavioral aspects for poor stock management performance. Sterman’s (1989b) pioneering work in behavioral supply chain research is one of the few and early examples. It made use of the Beer Game as an experimental setting and shows that participants’ IM performance suffers systematically from the use of inappropriate anchoring heuristics and misperceptions of time lags. Croson and Donohue (2003, 2006) build on this research by confirming that low—albeit improved—supply chain performance still exists when participants are aware of the underlying demand distribution or point of sales data. Bloomfield et al. (2007) find lamentable results even in a single echelon supply chain experiment, where inter-echelon coordination problems are absent. However, these studies in behavioral operations management do rather not discuss the personal traits of the participants that took part in the experiments.

Psychological research (Dörner 1980; Brehmer 1992; Ackerman and Kanfer 1993; Dörner, Kreuzig et al. 1994; Dörner 1996; Wittmann and Hattrup 2004) on complex dynamic decision making has produced relevant findings regarding the linkages between personal characteristics and performance in complex situations. Focusing on dynamic systems, this research stream suggests that human beings have severe difficulties understanding and managing systems which are dynamically complex, that is, which are characterized by feedback, time delays, nonlinearities, and accumulation. For these dynamically complex tasks, elaborate and corroborated theories exist that relate intelligence, personality, interests and knowledge to decision making performance. Especially Ackerman’s (1996) PPIK theory has been bolstered by many empirical studies (see, e.g., Wittmann and Hattrup 2004). However, none of these psychological studies have addressed inventory management as such.

Figure 1 – Research design – the influence of PPIK on inventory management performance

In this research, we combine the two research lines mentioned above: behavioral operations management studies of poor inventory management behavior on the one hand and personal characteristics and their relationships to complex problem solving performance on the other hand. Therefore, we test if PPIK theory can explain inventory management performance. Thus, the purpose of this paper is to find out whether intelligence, personality, interests, and knowledge determine performance in an inventory management task, with the ultimate goal to give recommendations what personal traits successful inventory managers should have. In order to operationalize the four personal traits, we use different standard psychological tests from the literature; we
operationalize inventory management performance by the degree of control performance participants demonstrate in a simulated inventory task in a controlled experiment. Figure 1 summarizes our research design.

In Section 2 we present the experimental design and methods that are used; in particular, we describe the tests used to measure personal traits and which method is employed to derive inventory management performance. In the third section, the results of the experiment conducted are shown, addressing the relation between personal traits and inventory management performance. The paper concludes with a discussion of contributions and limitations of this research and outlines directions for further research.

**Research design and implementation: Inventory Task and PPIK Measures**

In the laboratory, inventory management performance is measured following the well-established experimental paradigm for investigating dynamic decision making (Brehmer 1992) by using a computer simulated microworld. According to the game's cover story, participants act as production controller in a pump body manufacturing company called Pugepo (Figure 2). They are responsible for one single product and have to decide on the weekly production start rate. Production throughput time is three weeks; in week four, the batch of end product is put into storage, from where the customers could be delivered according to their needs. As the company produces a range of different pump bodies, batch production is used. The maximum batch size is restricted to 600 units. Smaller batch sizes are possible, but do not reduce set-up costs. The objective is to minimize total costs, which include set-up cost, inventory holding cost, stock-out costs and lost contribution margins. Stock-out costs account for late deliveries of customer orders that could not be served immediately. These orders are not lost, but have to be delivered subsequently. However, if customers experience bad service levels, they place more orders with competing suppliers causing the incoming orders to decrease. An exceptionally good service quality may also lead to increased orders. To account for this, for each lost ordered unit the products contribution margin is added to total costs, while for each additional unit sold the contribution margin is subtracted from total costs.

<table>
<thead>
<tr>
<th>Inventory holding costs:</th>
<th>5 €/(unit • week)</th>
<th>Production lead time:</th>
<th>3 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set-up costs:</td>
<td>400 €/batch</td>
<td>Delivery lead time:</td>
<td>1 weeks</td>
</tr>
<tr>
<td>Stock-out costs:</td>
<td>5 €/unit</td>
<td>Maximum batch size:</td>
<td>600 units/batch</td>
</tr>
<tr>
<td>Contribution margin:</td>
<td>100 €/unit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The participants have information on all cost parameters and lead times (Error! Reference source not found.). They know that customer demand is initially 1,000 units per week, not influenced by any random effects and only sensitive to the service level. However, they do not know the exact functional relationship. The game is run over a time span of 26 simulated weeks, and therefore participants have to make 26 decisions. Once a decision is entered and the button “continue simulation” is pressed, the decision outcomes are calculated and the information displayed on the screen is updated (Figure 2). At the end of the simulation the participants are informed about their overall performance in the game.
The game is thoroughly introduced: Participants receive both a verbal briefing and on-screen instructions, which precisely describe the setting, the task, and the objective. The participants can go back to this information at any time throughout the game. To minimize the danger of “video-gaming” and exclude learning biases from multiple iterations, only one simulation run is allowed. To allow for thorough reasoning, time pressure is kept as low as possible. No explicit deadline for terminating the simulation is set. As the experiment was integrated in a standard 180 minutes lecture unit, an implicit end time exists though.

Following Sterman (1989a, b), Croson and Donohue (2006) and many others, this study uses the outcome performance measures total accumulated costs as a measure for decision quality in the inventory management task. Inherent in the game’s design is that increasing the production order rate also increases inventory costs and set-up costs (step-fixed), yet decreases stock-out costs and lost contribution margin. More frequent production orders increase set-up costs but decrease inventory costs. Consequently, total accumulated costs can be seen as a balanced measure for decision quality in the inventory game and is therefore used as measure for inventory management performance.

The simulation game is designed to be the last task in the laboratory. Before the game is started, the participants have to complete the interest and personality tests. The choice of tests is somewhat restricted due to the fact that German versions had to be available. For measuring interests we therefore use the AIST-R test (Bergmann and Eder 2005), which is well-established and widely used in Germany. Personality is assessed based upon the revised NEO FFI personality inventory (Costa and McCrae 1992), which is probably the most commonly used personality test worldwide. For both tests, the traditional paper and pencil version is used. Tests are conducted precisely as described in the manuals (Costa and McCrae 1992; Bergmann and Eder 2005). Each test takes about 15 minutes to complete.

Measuring intelligence-as-process by using standard tests such as the BIS test or alternatively the Wechsler Adult Intelligence Scale (WAIS–IV) is time consuming and costly. For example, administering the full BIS test takes more than two hours; for the shortened version still about 50 minutes have to be available. Instead of conducting such a lengthy test, we take advantage from the fact that our participants are students...
that have passed through an entrance assessment center which included completion of the BIS test short form. Admittedly, these data stem from archival sources and are two to three years older than the data gathered in the laboratory. However, psychological research shows that general cognitive ability is rather stable over long time periods (Larsen, Hartmann et al. 2008; Lyons, York et al. 2009), which seems to justify the use of these data.

For the inventory management domain to the best of our knowledge no established instruments for assessing intelligence-as-knowledge exists. Instead of developing a specific test on our own, we use the students’ grades in typical business administration and economic courses as a first proxy.

For testing the PPIK theory of IM performance, data were gathered from both a laboratory experiment conducted at a German business school and archival sources. Archival data were retrieved from the school’s databases. The experimental sessions were integrated in an elective course on “Operations Management” that is part of the Bachelor of Business Administration program. In September 2009 and September and November 2010 five experimental sessions were performed, involving in total 79 students in their seventh and final semester as participants.

The experimental design follows suggestions from experimental economics (e.g. Friedman, Cassar et al. 2004; Guala 2005) as well as experimental psychology (e.g., Kantowitz, Roediger et al. 2009). Applying Smith’s (1976, 1982) induced value theory participants are not only motivated by an informative individual analysis of the test results but also incentivized by a monetary reward. The financial incentive was linked to the participant’s performance in the inventory management game. The lower the cumulated total costs the more money was paid out up to the maximum of 9.50 €. On average, 4.55 € were achieved by the participants for an exercise of about 30 to 40 minutes.

**Presentation and Discussion of Results of Experimental Research**

Based on 72 completed and usable simulation runs, Error! Reference source not found. and Figure 3 show descriptive statistics and the distribution of the participants’ IM performance (IMP). When comparing these results to a benchmark, the conclusion is at hand, that the “logic of failure” of human decision makers is once more impressively demonstrated (Dörner 1996). This inference is supported by comparing the participants’ results to the outcome of one of the simplest decision rules that one can come up with: Just placing the incoming orders as production orders—seemingly a “no-brainer” policy—would result in accumulated total costs of 146,905 €. Only 39 out of 72 participants are able to outperform this simple policy; 33 participants do even worse—with the poorest result being more than five times higher than it. Another extremely simple and obviously inadequate decision rule would be to keep production orders constant at the initial value of 1000 units per week from week 1 to week 22. Even this “Do-nothing” decision rule would outperform 27 participants who “manage” to accumulate more than 180,110 € of total costs.

<table>
<thead>
<tr>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMP</td>
<td>72</td>
<td>1,360</td>
<td>783,460</td>
<td>197,359.10</td>
<td>182,412.11</td>
<td>1.420</td>
</tr>
</tbody>
</table>

Table 2 – Descriptive statistics for IM performance
Based on the theoretical discussion above and on the fact that there is no clear indication about the relationships of the four personal traits to inventory management performance in the literature, we estimate the following straight-forward regression:

$$IMP = \beta_0 + \beta_1 \text{INTELLIGENCE-AS-PROCESS} + \beta_2 \text{INTELLIGENCE-AS-KNOWLEDGE} + \beta_3 \text{INTERESTS}_i + \beta_4 \text{PERSONALITY}_j + \epsilon$$

In order to test if PPIK theory can be adapted to an inventory management setting, five hierarchical regressions were performed, with IMP as the dependent variable. Model A includes the intelligence-as-process-measure BIS-AI-S as independent variable only; model B focuses on WIWI as intelligence-as-knowledge measure. Model C includes both intelligence-as-process and intelligence-as-knowledge as predictors. Model D adds all six interest dimensions and five personality scales, while in model E only significant predictors have been included. Note that negative signs indicate a supporting influence of the independent variable on inventory management performance, since this performance was measured as costs and, thus, lower values indicate better performance.

Models A, B, and C show that both intelligence and knowledge are positively and significantly related to inventory management performance, tested in isolation as well as in combination. Higher intelligence and more knowledge result in lower total costs. For instance, based on Model C an increase of one standard deviation in BIS-AI-S implies a decrease of .311 in cost. Concerning intelligence, we see our results in accordance with Beckmann and Guthke (1995) that—when measured carefully—general intelligence has an influence on performance in dynamic decision making; they also report on the discussion about the relationship between intelligence and performance in such tasks in general. With regard to knowledge, the results corroborate findings by Wagner and Sternberg (1985) that knowledge positively affects managerial performance; they further postulate that the level of (tacit) knowledge differentiates experts and novices in a domain. Krems (1995) suggests that knowledge in a domain is particularly helpful in providing cognitive flexibility in problem solving in that domain and, thus, leads to higher performance in decision making tasks. Concerning both intelligence and knowledge, Wittmann and Hattrup (2004) report similar strong relations to dynamic decision making performance as we find in our analysis.

![Figure 3 - IM performance distribution](image-url)
### Table 3 - Regression results for IMP (standard deviations from the mean)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-.005</td>
<td>.028</td>
<td>.004</td>
<td>.001</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td>(.111)</td>
<td>(.117)</td>
<td>(.112)</td>
<td>(.108)</td>
<td>(.106)</td>
</tr>
<tr>
<td>BIS-AI-S</td>
<td>-.363***</td>
<td>-.326***</td>
<td>-.383***</td>
<td>-.335***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.111)</td>
<td>.109</td>
<td>(.118)</td>
<td>(.110)</td>
<td></td>
</tr>
<tr>
<td>WIWI</td>
<td>-.286***</td>
<td>-.234**</td>
<td>-.161</td>
<td>-.244**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.122)</td>
<td>(.118)</td>
<td>(.131)</td>
<td>(.115)</td>
<td></td>
</tr>
<tr>
<td>AIST-R practical and technical</td>
<td>-.084</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIST-R intellectual and investigative</td>
<td>-.170</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIST-R artistic and linguistic</td>
<td>.062</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIST-R social</td>
<td>-.052</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIST-R entrepreneurial</td>
<td>.313**</td>
<td>.219**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIST-R organizational and administrational</td>
<td>-.016</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEO-FFI neuroticism</td>
<td>-.105</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEO-FFI extraversion</td>
<td>-.167</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEO-FFI openness to experience</td>
<td>.159</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEO-FFI agreeableness</td>
<td>.200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEO-FFI conscientiousness</td>
<td>-.057</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>.132</td>
<td>.082</td>
<td>.186</td>
<td>.330</td>
<td>.233</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>.120</td>
<td>.069</td>
<td>.162</td>
<td>.180</td>
<td>.199</td>
</tr>
<tr>
<td>No. observations</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
</tbody>
</table>

Model D shows that when including all available independent measures the overall predictive power is better (adjusted R² increases slightly from .162 to .180); the model is still significant (F = 2.203, p = 0.022); however, all factors except intelligence and entrepreneurial interests remain insignificant. Note that entrepreneurial interests negatively influencing performance. Cautiously interpreting the other interest factors shows that investigative interests seem to have a small positive effect on inventory management performance, while artistic, social and organizational interests do not matter at all. Regarding the personality factors—again cautiously interpreted since factors are not significant—neuroticism and extraversion are positively related while openness and agreeableness have a negative effect. Conscientiousness seems to be irrelevant for good or bad inventory management performance.

Model E shows the result of a step-wise backward refinement of the regression until only significant predictors remain. With this model 23% of the variance in participants’
inventory management performance can be explained. Like in models A to C, intelligence and knowledge positively affect performance. None of the personality factors is retained in the model since they were not significant. From the set of interests, only entrepreneurial interests remain in the model and are negatively related.

Conclusions and Implications for Further Research
To our knowledge this is the first study that relates a comprehensive picture of the psychological state of participants to their performance in an inventory management task. Based on the set of personal traits offered by PPIK theory, we investigated what characteristics good decision-makers in the area of inventory management possess. Intelligence and knowledge stand out as predictors of performance: both are persistently positively related to outcomes of the experiment in the regression models. In that sense, our results contribute to the literature about the influence of intelligence and knowledge on the capability of humans to solve complex problems. While findings have been mixed so far, for inventory management we achieved a rather unequivocal result of the positive influence of intelligence and knowledge. From a practical point of view, this suggests that persons that deal with inventory management tasks will benefit from being intelligent and having acquired knowledge in the wider field of that domain. From the perspective of PPIK theory, testing in how far both can be substitutes of each other and whether intelligence must be invested in order to accumulate knowledge and how this relates to performance in inventory management tasks is an open question.

Our results are less clear regarding interests and personality. For both, no findings in the literature exist that can be related to inventory management tasks. Thus, the linkage of our findings to the literature is difficult. We found no significant factors as being effective for inventory management with regard to the personality of participants. Therefore, we assume no restrictions to exist regarding the personality of inventory managers to be successful in practice. The results concerning the participants’ interests seem to indicate that an entrepreneurial spirit is not advisable. Whether this means that individuals that favor entrepreneurial activities cannot achieve good inventory performance in principle is difficult to say at the moment. Probably, the exact nature of the task is important for their actual result, since entrepreneurial persons might not feel challenged by the task at hand with a repetitive set of decisions to be made.

This study is limited since the relatively small number of participants does not allow using more sophisticated statistical analysis instruments, like structural equation modeling. With such methods, a more comprehensive picture of the relationships between the four personal traits and inventory management performance would be possible, for instance permitting to investigate relationships between the four PPIK traits. There is, of course, a certain variety of real-life inventory management scenarios. Customer, supplier, and production characteristics can differ in many ways from the scenario implemented in the inventory management microworld Pugepo used in this research. Cost parameters, lead times, and capacity restrictions may vary. Therefore, another sensible way to extend this study would be to use inventory management tasks of (1) different complexity, since this might be a strong moderating factor, (2) different demand patterns, since uncertainty in demand might have a strong impact, and (3) different cost and revenue parameterization, since the economic valuation of stock-outs or excess inventory might be influencing as well.
References


