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STUDIES OF FRAMING, JUDGMENT AND CHOICE

Ann Hedborg

Dissertation for the Doctor's Degree in Philosophy
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1996
"THE UTILITY AND THE CURSE OF WINNING AN AUCTION: AN EXPERIMENTAL ANALYSIS"
Key words:
auction experiment
arousal
cognitive and motivational biases
strategic bidding

"WHO IS CURSED IN A TREASURY SECURITIES AUCTION?: AN EMPIRICAL ANALYSIS OF THE SWEDISH 6-MONTH TREASURY BILL AUCTIONS FROM 1991 TO 1994"
Key words:
auctions
information asymmetry
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learning and feedback

"IS CONFIDENCE IN ONE'S BELIEF A MATTER OF KNOWLEDGE OR OF COGNITIVE ILLUSION?"
Key words:
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cognitive biases

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Preface

This report, carried out at the Economic Research Institute, is submitted as a doctor’s thesis at the Stockholm School of Economics.

The author has been entirely free to conduct her research in her own ways as an expression of her own ideas.

The Institute is grateful for the financial support, which has made this research possible.

Stockholm in April 1996

Sven-Erik Sjöstrand
Director of the Institute

Lennart Sjöberg
Professor in Economic Psychology
Head of the Center for Risk Research
To
Johan and Niklas

“The heart has its reason
That the reason does not always perceive.”
La Rochefoucauld
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I take full responsibility for any errors in the reports.

Stockholm and Göteborg, April 1996

Ann Hedborg
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1. INTRODUCTION

This volume presents three papers within the research domain of economic psychology. The focus in these three studies was to investigate how people form their judgments and their choices in different contexts. In order to position these three papers in their research context an introduction to economic psychology as a research field is presented here. In the second section the experiment as a research technique and its advantages and disadvantages are discussed.

Economic behavior in for example financial markets and the evaluation of its consequences for economic society have often been compared with the rationality norms in neoclassical economic theory. Section three gives first a brief description of mainstream economic theory and its strength and weaknesses. Thereafter some alternative approaches to a rational behavior are presented.

In sections four to eight various aspects of the human as being an information processor are considered.

New descriptive decision models account for choice behavior in situations which involve both risk and uncertainty. When a choice is made under both risk and uncertainty more variables than the assessment of the probabilities for the various outcomes to occur will influence the judgment and choice. Section nine presents brief descriptions of three descriptive decision models. One of them considers decision making under risk while the other two models also include the aspects of uncertainty.

Finally, section ten presents a summary of the three studies that are presented here. The two auction studies analyzed how people make decisions in two different auction contexts, namely real-world Treasury securities auctions and auction experiments. The auction experiments were designed as emulations of a Treasury securities auction. Both auction studies were conducted in dynamic decision situations where the task environment may shift rapidly.

The third study on overconfidence, which was conducted as an experiment, involved less contingent decision making than the auction studies. Here the main purpose was to
investigate whether subjects revealed overconfidence in their confidence assessments after having selected answers to binary questions in a questionnaire and whether their perception of the questions as either difficult or easy could explain the overconfidence level.

1.1. Economic psychology as a field of research

The focus in economic psychology is to observe economic behavior as a psychological process in which expectations, attitudes, preferences and motivation are factors that influence the progress of the economic decision making process (Warneryd, 1988a).

Warneryd has given an excellent description of economic psychology and its approach to studying and describing economic behavior. The researchers in the field of economic psychology aim to better understand real life economic behavior and to test it against for example the norms in the neoclassical economics. In short, neoclassical economic theory states that people's preferences are precise and consistent over time. An alternative claim to this theory is that economic behavior is affected by (Warneryd, 1988a, p. 30):

1. motivational factors involving discrepancies between actual and desired states which give force and general direction to behavior;
2. value structures that have both stable and volatile components;
3. processing of information from the external and internal environment, combining new information with information from memory;
4. social comparison processes and social influence;
5. rules of weighing benefits and sacrifices against each other (choice heuristics)
6. attributions of success and failure to causes: learning.

Warneryd remarked that the six characteristics above are typical aspects of human behavior which are also studied in many other disciplines. An important demand in the field of economic psychology is however the requirement of 'empirical anchoring' for the concepts that are used (Warneryd, 1988a, p. 30).

2. EXPERIMENTS AS A RESEARCH TECHNIQUE

Two of the studies reported here were conducted as experiments. For instance, to test whether preferences are stable, as suggested in economic models, preferences can be observed under shifting conditions in the laboratory. However, studies involving experiments have been criticized by scientists for various reasons.

Berkowitz and Donnerstein (1982) presented the most common criticisms of experiments as a research form. A controversial topic is for instance whether it is possible to make generalizations about rationality in reasoning from the results in psychological experiments. In experiments the sample of participants is often limited for example with respect to age, occupation and education. This may mean that the sample is unrepresentative of a larger population.
Furthermore, critics argue that experimental researchers often neglect the social contexts within which people are embedded in their everyday lives. Besides, critics argue that the experimental researchers ask their subjects to react to some stimulus object on the basis of extremely limited information.

Experimental work with human subjects in dynamic market situations involves studying how people adapt to a certain task and task environment. Edwards (1990) emphasized that if the conditions of the experiment resemble the conditions of the nonexperimental context the generalizations from experiments to nonexperimental contexts are more forceful. It is however well known that external validity in an experiment is difficult to achieve since the environmental conditions can be altered infinitely.

Cohen (1993a) promoted the naturalistic paradigm by arguing that: "By focusing on the way people actually handle complex environments, the naturalistic paradigm illuminates the functions that cognitive processes serve. As a result, it stands a better chance of developing a successful and coherent set of explanatory models. One by-product is a decreases emphasis on relatively ad hoc cognitive procedures, like heuristics, and more focus on an integrated picture of how knowledge structures are created and adjusted in dynamic environments." (p. 49)

Berkowitz et al argued that experiments are not conducted to establish population estimates. External validity may facilitate the formulation of population estimates but is not necessary for causal hypothesis testing. Instead, “…the meaning the subjects assign to the laboratory setting and their actions, rather than the laboratory setting’s mundane realism, affects the generalizability of the laboratory result … whether laboratory results are generalizable to other situations is an empirical question” (p. 245).

Furthermore, Berkowitz et al claimed that experiments may even give a more authentic image of human complexity than do uncontrolled, naturalistic investigations. The latter can only hint at the richness of human nature, they argued. Furthermore, the logic of an experiment does not require that the settings and subjects represent real-world conditions since the external validity of a study (in the sense of the generalizability of its results) is not necessarily governed by physical representativeness.

Other defenders of experiments as a research technique (e.g., Plott, 1986) claim that the laboratory is important as a complement to real-world studies in that important variables can be observed under the controlled conditions which the laboratory context offers. However, a common request is that the experiments on decision making should strive to incorporate the complexity in the decision making process in order to for example improve the understanding of how people adapt their decision strategies to shifts in the task conditions (e.g., Orasanu et al, 1993). These authors claimed that “experimental laboratory research would still play an important role, but the tasks and subjects would be selected to reflect critical aspects of operational situations.” (p. 15)

The designs of the two experimental studies were selected in order to best fit the purpose and proposals in each study. Since auction experiments have proven to be a useful
method for studying market behavior (Plott, 1986) the first auction study was conducted as an experiment. In the auction experiments the subjects participated in a series of auction rounds and they were asked to make a series of real choices which would have real outcomes. However, there is a cost for using this type of design since the experimenter must give up some of the control over the process. Control over the process in the laboratory is an important requirement in psychological experiments on decision making.

However, there is always a trade-off between control and realism when designing an experiment. Even the most careful design does not ensure that people will act within the framework that is anticipated by the experimenter (e.g., Berkeley & Humphreys, 1982; Cohen 1993b; Frisch, 1993). Although the experimenter makes efforts to induce a specific perspective for the problem to be studied there is no guarantee that he/she succeeds in this task since people's framing is very complex and sensitive. The subjects may still use a different frame which leads them to different inferences than those that were anticipated by the experimenter. Framing effects refer to the findings in experimental studies that the subjects' preferences, choice and evaluation of an outcome are affected by the manner in which a problem situation is presented (Frisch, idem).

In many experiments on decision making and choice the subjects are asked to solve a problem by making a theoretical choice from a set of anticipated outcomes (e.g., Arkes & Blumer, 1985; Romanus, Hassing & Gärling, 1996; Tversky & Kahneman, 1981). The design of the overconfidence experiments was more in line with this type of conventional experiments on decision making and choice. Here the subjects were asked to make a series of theoretical choices between two answers in a questionnaire with binary questions and then report their confidence in the selected answer. This type of experiments has been criticized for only investigating one part of the decision making, referred to as a decision event (Orasanu et al, 1993) while the dynamics in the decision process has been largely ignored.

3. ASPECTS ON RATIONALITY
3.1. Neoclassical economic theory

Neoclassical economic theory is a normative theory and its focus is on interaction between agents in markets. This theory presents a set of rules and prescriptions for action toward the goal of achieving a rational economic decision on which economists can rely in their analyses. It states that individuals act rationally if their judgment and choices are based on a stable and well-organized value system and if they select, among those alternatives that are available, that alternative which provides them with the highest utility with respect to both present and future order of preference. To be rational in terms of neoclassical economic theory decision makers must fulfill the requirements of consistency and coherence in their choice. Thus this theory does not allow for time varying preferences and contexts to have any impact on choice.
The shortcoming in neoclassical economic theory is that it does not include assumptions concerning mechanisms for learning and adaptation as part of the decision process. Economic theory has been described as "... studying decision rules that are steady states of some adaptive process, decision rules that are found to work over a range of situations and hence are no longer revised appreciably as more experience accumulates" (Lucas, 1986, p. 402). Lucas argued that the question whether people are rational or adaptive will depend on the context in which behavior or outcome is to be predicted. Therefore, the approach to understanding economic behavior is to view rationality and adaptation as complementary.

According to Simon (1986) neoclassical economics differ from other social sciences in three main respects, namely (p. 210):

"(a) in its silence about the content of goals and values; (b) in its postulating global consistency of behavior; and (c) in its postulating 'one world' - that behavior is objectively rational in relation to its total environment, including both present and future environment as the actor moves through time."

He further claimed that other social sciences, in their search for understanding what is a rational economic behavior (p. 210):

"(a) seek to determine empirically the nature and origins of values and their changes with time and experience; (b) seek to determine the processes, individual and social, whereby selected aspects of reality are noticed and postulated as 'givens' (factual based) for reasoning about actions; (c) seek to determine the computational strategies that are used in reasoning, so that very limited information-processing capabilities can cope with complex realities; and (d) seek to describe and explain the ways in which nonrational processes (e.g. motivations, emotions, and sensory stimuli) influence the focus of attention and the definition of the situation that set the factual givens for the rational processes."

Already in 1955, Herbert Simon suggested a more operational version of rationality in decision making than that previously assumed in economic theory. This version of rationality was named bounded rationality. Simon's point was that although decision makers want to act rationally they do not make decisions in a vacuum. Therefore a decision can be both reasonable and 'intendedly rational' even when it is influenced by the decision context as well as by personal characteristics, education and personal experience.

3.2. Economic rationality ≠ human rationality?

In the last decades behavioral-oriented economists have presented evidence that people do not act in accordance with the proposals in economic theory. Critics, such as Scitovsky (1976), Simon, Dantzig, Hogarth, Plott, Raiffa, Schelling, Shepsle, Thaler, Tversky and Winter (1987) have claimed that reality is too complex to fit the framework of economic rationality. Although theories such as the theory of subjectively expected utility (e.g., Edwards, 1954) allow the decision maker to formulate subjectively estimated probability
of each of the available outcomes its usefulness when studying decision making in a real-world context is limited.

Many scientists have focused on how well economic theory can be applied to behavior in the financial markets. Evidence on economic anomalies has been presented by for example Shefrin, Statman and Constantinides (1985) and de Bondt and Thaler (1985). A review of findings on economic anomalies is presented in Thaler (1992).

Gradually the assumption of bounded rationality has been incorporated in many decision making models. Abelson and Levi (1985) presented two reasons for studying decision making as an information process in the tradition of Simon’s proposal of bounded rationality. First, process-oriented decision research allows the scientist to study the psychological process that leads to a decision whereas structural models do not provide that insight so easily. Secondly, new results in cognitive psychology can offer concepts and methods which facilitate new approaches to process modeling in decision making.

As mentioned above, Lucas (1986) claimed that economic decisions in real life are obtained through an adaptive process. He argued that a rational and adaptive decision maker is capable of trying and testing old decision rules against experience, i.e. learning. Decision rules that are obsolete will be exchanged for new and better ones while others that still serve their purposes will be kept. Although people have limited information-processing capacity they are adaptive, i.e. they are capable of adjusting to changes in their environment (e.g., Hogarth, 1987).

To determine whether a selected strategy has provided a rational outcome, rationality must be defined. Rationality has been given a variety of definitions by decision researchers. The word rationality derives from the Latin verb ratio which denotes a wise or reasonable estimation. Being rational is being reasonable and considerate. Elster (1990) suggested that rationality is “...a variety of intentionality. For something to be rational, it has to be within the scope of conscious, deliberate action or reflection” (p. 23).

Both ‘weakness of the will’ and ‘excess of the will’ can hinder a person from achieving a goal in a rational manner (Elster, 1990). Elster described rational behavior as a physical expression of desires and beliefs: “Rational actions, then, involve three optimizing operations: finding the best action, for given beliefs and desires; forming the best-grounded belief, for given evidence; and collecting the right amount of evidence, for given desires and prior beliefs” (p. 21). People can depart from rational behavior on all three levels described above for example because they lack information or evidence or just because there is no single optimal action or belief.

Rationality can be defined as strategic rationality (White, 1988) or rationality of means (Hogarth, 1987) when rationality concerns the ability to choose the best means towards a certain end. A person demonstrates strategic rationality if he/she selects means that efficiently lead to a chosen goal. This type of rationality is for example often considered today in the domain of economic decision making. A second definition of
rationality is the \textit{rationality of goal} (Hogarth, idem). Here the selection of a goal determines whether a choice is rational or not.

Alternatively, \textit{contextual rationality} concerns the ability to select an action in accordance with for example prevailing norms in a certain environment or social setting or the consensus among members of a specific society (White, 1988). As mentioned above, social norms can explain how individuals order their preferences and search for information and ultimately for their behavior. A \textit{social norm} refers to rules that are established in a certain environment and therefore may call for a certain behavior. The social norm is shared with other members of a specific community and is enforced in part by sanctions from other members of this society (Elster, 1990, p. 45).

Sometimes there is a need for a trade-off between social norms and the norms of economic rationality. In their study of risk taking propensities among executives in the US and in Canada MacCrimmon and Wehrung (1986) concluded that the executives' risk willingness was partly cultural biased. They found that the executives made a clear distinction between risk taking in their business environment and in their private life in that they were more willing to take risks in business investments. They also found that the corporate environment, the reward system within the firm as well as personal experience all had a strong influence on attitude and willingness to take risks. The executives claimed that risk taking in business was both necessary and exciting but they also expressed their respect for the impact of the social norms upon their willingness to take risks.

4. \textbf{DECISION MAKING UNDER RISK AND UNCERTAINTY}

The three studies that are presented here concern different types of decision making under risk and uncertainty. In an ideal risk situation the decision maker can define the probability of any one of a number choices occurring. The more unique and novel the situation is to a decision maker the higher is the degree of uncertainty regarding the outcome of a selected choice.

In a situation characterized by uncertainty there is an unknown set of obtainable solutions. Unlike the risk situation, in which probabilities can be estimated, an uncertain future outcome does not offer this possibility. When a decision must be made under risk and uncertainty the probability estimation for a possible outcome to occur cannot be based solely on historical information or learning from earlier outcomes of similar events. In many such instances the decision maker must instead rely on his/her expectations, preferences and imagination in the estimation of the likelihood of a partially uncertain outcome to occur (Hogarth, 1987; Hogarth & Einhorn, 1990).

However, it has been found that capacity to imagine what alternatives that are available and what their outcomes may be is limited (Hogarth, idem). Therefore it is often the ability to think with imagination and creativity that set the boundaries for the selection process.
The perceived complexity of a task and task environment tends to increase the sense of uncertainty (Huber & Daft, 1987). Furthermore, Edwards (1990) argued that the more complex, vague and dynamic the environment is, the higher is the risk that people become overloaded in their mental process and the higher is the risk for over- or underestimation of the probability of an outcome.

Perceived complexity also increases the disposition to use simple rules and heuristics in decision making. The perception of a situation as uncertain can furthermore decrease people's willingness to act (Weick, 1995).

4.1. **Humans as information processing systems**

Research in cognitive psychology has provided us with some characteristics of human information processing which seem to be quite stable. One of these characteristics is that people have a limited information-processing capacity. But they are adaptive in that they are capable of adjusting to changes in their environment. A second characteristic is that on a conscious level people tend to prefer to process information in a sequential manner (Hogarth, 1987).

However, people tend to overestimate the likelihood of an outcome based on causal reasoning (Bar-Hillel, 1990; Hogarth, 1987). The gambler's fallacy is an example of how people's preferences for causal structure, i.e. the belief that one can for example expect a specific order of heads and tails, can bias their probability estimations and choice and produce a *pseudocertainty* (Tversky & Kahneman, 1981).

In general there is more information available than we can process due to our limited information-processing capacity. A typical judgment strategy can be to obtain information in sequences and continuously make adjustments on the basis of new information. One piece of information is combined with other pieces of information and suddenly a pattern might take shape, what may or may not be an accurate interpretation of information.

In order to reduce the cost for selecting and processing information some people may use simple rules, such as accepting an outcome uncritically and abstain from further evaluation. It might appear less troublesome to accept an outcome and to search for confirming evidence that the choice was correct than to seek disconfirming evidence. It is still possible to blame chance for the negative consequences of a choice.

5. **THE CRITICAL STAGE OF FRAMING A PROBLEM**

When encountered with a new problem people first construct a mental 'framework' for their future actions in the decision making process. When people make decisions, they start the problem analysis by composing a reference point or an anchor. At this initial stage, called the framing and editing stage in prospect theory (Kahneman & Tversky, 1979) a decision maker makes a preliminary analysis of the problem situation. The aim of the editing process is to investigate whether the representation of the problem can be
simplified. If this is possible the task also might be easier to handle. For example the decision maker selects, from the information available, that information which is perceived as relevant for solving a problem. The anchor point then constitutes the foundation from which the information processing and evaluation is made. (A brief description of prospect theory is presented in section 9.1).

The work that is done in the editing stage is often referred to as framing. Framing can refer not only to the acts in the decision process but also to the outcome as well as the contingencies, i.e. the total situation (Tversky & Kahneman, 1981). Framing also involves the process of relating a problem to a 'wider reality' (Morgan, Frost & Pondy, 1983). These authors suggested that “... People realize their reality by ‘reading into’ their situation patterns of significant meaning” (p. 24).

Different frames may induce different sets of options how to solve a problem. For instance the problem framing is influenced by people's norms, habits, and expectations. The manner in which a decision problem has been framed may therefore later affect a person’s experience of an outcome (Frisch, 1993).

Bruner (1990) argued that the contingency aspect in the framing, i.e. an adaptation to the environment, is the most vital element for the inference process. Bruner referred to Shotter (1932/1990) when he claimed that the social adaptation and 'sharing of memory' in the framing process might be even more vital than 'ensuring individual storage' which is mainly considered in cognitive psychology (Bruner, idem; p. 56).

As mentioned above, Bruner argued that the contingency aspect in the framing, i.e. an adaptation to the environment is the most vital element in the framing process. Bruner suggested that: "Framing pursues experience into memory, where... it is systematically altered to conform to our canonical representations of the social world, or if it cannot be so altered, it is either forgotten or highlighted in its exceptionality" (1990; p. 56).

6. BIASES IN THE DECISION MAKING PROCESS

Biases refer to deviations from correct assessments or judgments. In terms of economic theory a choice that is influenced by biases may hinder a rational economic behavior. Camerer (1992) suggested that “...the only interesting judgment errors are those which create systematic bias ... if people err in the same direction for instance so that their error do not cancel out. Market errors may therefore be even more statistically reliable that individual errors” (p. 240).

Biases in reasoning can often be ascribed to the first phase of the inference process, namely the framing stage. For example, if irrelevant information has been selected as vital for a decision and/or if too little attention has been paid to information that is formally relevant there is a risk that the outcome of the subsequent analysis will also be biased.
6.1. Examples of biases in the decision making process

The critical point in the decision making process is when people select their original anchor. Behavioral scientists claim that the selection of the anchor, or reference point, should be as objective and unbiased as possible since future outcomes are then assessed from this reference point (e.g., Kahneman & Tversky, 1979). Once the anchor is selected the adjustments and reevaluations are made from the anchor point and with respect to anticipated changes in conditions. New information leads to adjustments in relation to the initial anchoring point. This strategy is called the anchoring-and-adjustment strategy (Tversky & Kahneman, 1974). A bias in decision making occurs when a selected anchor hinders appropriate adjustments in decision and choice after new information is presented or conditions are altered.

A decision process can be biased for many reasons. For instance, availability affects the decision making (Tversky & Kahneman, 1973). There is a high probability that an event easily recalled in memory, because it occurred recently or the experience had a strong impact, or that displays salient similarities to earlier events will influence the assessment of the expected outcome of a similar event more than statistics would allow. Bar-Hillel (1990) has demonstrated that people tend to neglect relevant background information in their judgments when they are presented with more salient information.

Prices are for instance highly salient stimuli. Andreassen (1988) found in his studies of securities market behavior that the persistence of price volatility, after new information had been released, depended strongly on how the traders and media were able to causally link the new information to the old information when explaining the price changes. To make the relation between price and volume appear causally linked this relation is sometimes reinforced by outside forces e.g. the media. If the traders then believed that they could make profits from the new causal structure, they may choose to match new information with old information in order to induce an overreaction in security prices. This reaction contradicts the principle of regression towards the historical mean. Andreassen concluded that "...it appears that whether or not investors predict that prices return to previous levels (i.e. make a regressive prediction) depends on whether the changes are made salient" (1988; p. 387).

However, a probability judgment that is based on similarities or recent events can very well be correct or at least be a meaningful indicator of the likelihood for the event to occur in the future.

Langer (1975) found that people believe that they can control the occurrence of an event to a larger extent than probability would justify. She named this version of bias an illusion of control. Weinstein (1980) found that many people seem to bear the misconception that they are invulnerable. They believe that the probability of an accident or a misfortune happening to them is smaller than it is to others. Weinstein named the systematic failure to judge one's own risk propensities unrealistic optimism. Weinstein showed that unrealistic optimism can be eliminated through training and information.
**Representativeness** is an other type of bias (Kahneman & Tversky, 1972). The possible cause for its occurrence is that “...the predicted value is selected so that the standing of the case in the distribution of outcomes matches its standing in the distribution of impressions” (p. 416).

It has been suggested that an alternative which is presented in negative terms is often perceived as more complex (Reyna & Brainerd, 1991) and might be less easily perceived than an alternative that is positively formulated. For instance, MacCrimmon and Wehrung (1986) found a bias in executives' choices of goals for their business performance. The executives preferably selected their goals in terms of ‘upside possibilities’, e.g. expected returns and chances of gains rather than in terms of variance and risks for losses (1986, p. 150).

People also have a tendency to seek information to confirm their ideas rather than to look for possible disconfirming evidence (the confirming bias) and they weight positive feedback more heavily in memory than negative (Einhorn & Hogarth, 1978).

Finally, Fischhoff (1975) suggested that people are often biased in their memory of the causes of an historical event by information that they received after the event had actually occurred (a hindsight effect). To avoid, or at least reduce, the effects from a hindsight bias it is important to identify how the situation in which the evaluation is made might differ from that in which the decision was made.

An example of hindsight effects was presented by Sevón (1984) who showed that managers perceived the causes for an economic event, such as unemployment and inflation, as less dramatic and more complex when looked at in retrospect in comparison with how they perceived the same event in a future perspective.

Some scientists have suggested that retrospection is a method to evaluate whether a previous decision was correct and makes sense. In other words, “...outcome comes before decision” (Weick, 1995, p. 10). Weick claimed that “... pasts are reconstructions which means that they never occurred precisely the way they are remembered” (p. 57). Since retrospection is a technique of evaluating what an action means, hindsight should not be viewed as a bias. If so, “... then everyone is biased all the time ” (p. 16).

### 7. Learning and Feedback and Their Impact on Decision Making

Appropriate feedback from the environment is essential for learning. Accurate feedback has in many instances been shown to increase the capability to select and evaluate new pieces of information (e.g., Arkes, Christensen, Lai & Blumer, 1987). When studying decision making processes it is therefore necessary to incorporate in the analysis the effects from learning in order to understand how human rationality is best achieved. Economic learning is part of social learning which can be acquired for instance as a direct consequence of rewards and punishments (Bandura, 1977). However, neither correct feedback nor rewards and punishments necessarily provide a specific behavior. Nor will
accurate feedback always provide an increased capability to make accurate predictions.

Besides, correct feedback is not always available. Possible options cannot be tested since they were rejected in the selection process. Not all alternatives can advance to actual outcomes, such as in an employment situation where only the outcome of those who were employed in the firm can be analyzed.

If feedback is delayed or if the outcome of an event is loosely coupled to the feedback the problem may be harder to solve than if the outcome is firmly coupled to the event (Orasanu et al., 1993). The assessment of causal relations between action and outcome may be misinterpreted.

Goldberg (1968) identified three important requirements for efficient learning. First, he claimed that feedback is necessary for efficient learning. Secondly, decision makers are supported in their decisions if they are given the opportunity to repeatedly reflect on the relations between their expectations that an outcome will occur and the actual outcome. Edwards (1990) argues that decision makers rarely get a chance to make a second decision in which he might apply whatever he may have learned as a consequence of the first. Furthermore, learning is facilitated if people are given the opportunity to keep a record of their predictions and the auction outcomes which is the third requirement for improved decision making.

The requirements above can seemingly be applied to the Swedish Treasury bill auctions. The bidders in these auctions received correct and instant feedback from their decisions. The auctions were repeated in very similar manner with a very similar group of bidders. Furthermore, it was possible for the bidders to keep records of their bids and the auction outcomes which was public information.

A distinction needs to be made between judgment and choice in stable environments and in unstable environments. The more variations in the structure and content of the information the more effort is needed for gathering, processing and interpreting the information that is perceived by the decision maker as crucial for judgment and choice. Then it is also more difficult to identify and evaluate the feedback and to learn from the outcome of a selected choice.

In stable environments and when people make repeated decisions the opportunities to learn are manifold. A relatively stable environment also facilitates for the decision maker to focus on those parts of the information process that are relevant for the decision, such as signals indicating that auction market prices are unexpectedly volatile or that the attraction for an auctioned security is altered. Thus, it is more probable that adjustments to new observations that are built on simple decision rules and heuristics will be accurate in stable environments than if they were made under less stable conditions.
Johnson and Plott (1989) examined the effect that different trading institutions have on sellers' price expectations and market behavior in experimental markets. Their results indicated that the complexity in the sellers' expectations was a reflection of the relatively complexity in the laboratory markets. The traders price expectations were relative complex and adaptive to available information when they were dealing in information-rich markets while their expectations were relative simple and extrapolative (i.e. the next price was contingent on the previous price) when they were dealing in more information-poor markets.

8. TRADE-OFF IN THE SELECTION OF A DECISION STRATEGY

Researchers in human decision making processes have found that decision making in real life is not a steady state as postulated in neoclassic economic theory. An economic decision strategy is often selected so as to enable actors to obtain a specific goal. Often this goal is assumed to be that of maximizing expected economic utility or of maximizing profit.

But individuals and organizations do not always primarily strive for the highest possible profit in their decisions. Decision strategies can be selected so as to satisfy goals beyond that of economic rationality because people are not merely self interested.

Theories such as the contingency theory (e.g., Beach & Mitchell, 1978; O'Connor, 1989) suggest that individuals possess a collection of strategies. The contingency theory assumes that the selection of decision strategies is contingent on the interaction between individuals, the characteristics of the task and the task environment. Furthermore, different strategies require different efforts due to for instance complexity, accountability, familiarity and time and money constraints. The theory assumes that the decision maker's strategy is selected in order to optimize the relation between the efforts required to use a certain strategy and the accuracy in the decision.

When decisions are made under time pressure decision makers have a tendency to use simpler decision strategies (e.g., Payne et al, 1990). Other factors that influence the decision makers' strategy selection are the size of payoff (Payne et al, 1990) and the decision makers' need to justify a decision (van Raaij, 1988).

Also Payne et al (1990, 1993) claimed that decision makers have the ability to adjust their strategy to the task and the conditions in the task environment, i.e. they conduct a contingent strategy selection. By a contingent strategy selection the authors denote that the decision maker, before deciding what strategy to use for a certain task in a certain environment, makes an assessment of the trade-off between the need for accuracy in the choice and the efforts needed for achieving this accuracy.

The choice of a decision strategy is thus assumed to be a function of the costs for the cognitive work and the benefits that decision makers are expected to gain from their efforts to select the best alternative (Mano, 1990; Payne et al, 1990). For instance, heuristics, simple decision rules or procedures and habitual thinking require less
thinking. An example of a rule that simplifies the decision process is the lexicographic rule. By this rule is referred that the decision maker chooses one alternative, $A_1$, over another, $A_2$, if the former alternative is best on the attribute that is considered to be most important by the decision maker. If it is not possible to separate the two alternatives on the most important attribute the same procedure is applied on the second best alternative. The procedure is repeated until only one alternative is left.

Payne et al (1993) suggested that some decision heuristics approximate the accuracy of normative decision rules fairly well. By using these simpler rules the decision maker can save cognitive efforts while keeping the accuracy in the decisions on an acceptable level (p. 99).

However, decision heuristics must be used with care and contingent of the environment in which the decision is to be made. Although simpler decision rules may increase efficiency in the decision making process the cost for using simpler decision rules may be that the number of biases in the future decision process is increased.

The Swedish Treasury bill auction market is a task environment where decision heuristics may be useful. In this market the tasks are fairly simple and the time period for making a decision is brief. Besides, the secondary market is open all day long. Therefore, if the bidders in the Swedish Treasury bill auctions learn that they have reacted incorrectly on new auction information, they can adjust their money market portfolios at any time during and after the auction procedure.

When tasks are more complex and the decisions have consequences over a longer period of time the mental effort of thinking about the problem and its consequences may be rewarded in that a decision maker gains better control over the decision process and the actions involved. Furthermore, when a decision maker regularly reflects over his/her problem goals and preferences may become more explicit. By thinking about a problem the decision maker may become aware of the actual degree of uncertainty in the problem and of the fact that the decision maker’s preferences and goals need to be defined and clarified so as to achieve a good solution to a problem (Hogarth, 1987). Thereby the process of thinking may become more efficient.

The consequence from thoroughly thinking about a problem may be that it highlights the necessity of making a choice, i.e. some alternatives must be rejected and may be regretted (see Bell, 1988; Festinger, 1957). Cognitive dissonance theory (Festinger, 1957) suggests that if people find out, in retrospect, that their decision might have negative outcomes they search for information that will enhance the positive aspects of the selected choice and also enhance the negative aspects of the alternatives that were not chosen. Besides, new and creative ideas and alternatives may not always be well received and appreciated in an economic society. Thus, the cost of withstanding social pressure must be added to the costs involved in the mental effort of thinking.
9. DESCRIPTIVE DECISION MODELS ON JUDGMENT AND CHOICE

9.1. Prospect theory - a descriptive model on decision under risk

In their prospect theory Kahneman and Tversky (1979) focused on evaluations of probabilities under risk. Prospect theory divides the decision making under risk into two stages:

1. Framing and editing and
2. Evaluation

As mentioned above, in the editing phase people examine, structure and simplify the task and the task situation in order to facilitate future evaluation and choice. In the evaluation phase the options, or prospects, that remained from the editing process, are evaluated in order to select the best prospect.

Prospect theory considered two components in the decision making. The first component is the \textit{value function} which refers to people’s evaluation of their utility of various prospects as either losses or profits. The second component is the \textit{weighting function} which refers to their subjective probability estimation.

Kahneman et al argued that people often lack in precision and consistency when we make decisions under risk because they allow other factors than the objective probability which is based on statistical background information influence their probability assessments. To better describe how people evaluate prospects the theory propose that people make their evaluations of the probability of an outcome to occur by adding a subjective value, a decision weight, to the objective probability. The decision weight measures the impact of the probability on, for instance, the \textit{desirability} (or lack of desirability) of an outcome (or a prospect). The desirability of a possible outcome can be derived from a person's preferences. In other words, the decision weight is a measure of a person’s disposition or willingness to (a) include a possible outcome in the analysis but also to (b) evaluate the likelihood of its occurrence.

Prospect theory suggests that a decision maker first establishes a mental utility function which then is the point of reference from which the probability of future profits and losses will be assessed. This utility function is \textit{concave} for profits as is the utility function in classical theory. Prospect theory predicts that the utility function is \textit{convex} for losses and the curve is also steeper for losses than for profits.

Prospect theory postulates that people often fail to evaluate risks objectively because they are biased in their sensitivity to deviations from their selected reference point. Besides, people are most sensitive to deviations close to their selected reference point. People take risks because they have an aversion to accepting and effectuating a loss. The disposition to seek risk is greater in potential loss situations than the tendency to avoid risks when there is a probability of a profit. People also tend to overestimate small probabilities and they tend to underestimate large probabilities in their process of weighting probabilities against their possible outcomes.
The proposal on loss aversion has been supported in many studies (e.g., Arkes & Blumer, 1985; Shefrin et al, 1985). For instance people tend to weigh future losses in a stock market portfolio higher than future profits or failures in a job situation higher than successes. Shefrin et al tested the proposal on loss aversion in a study on stock market behavior. They found that investors had a tendency to sell stocks with a profit too early and keep stocks with a loss for too long. Investors also seemed to have an aversion to realize a loss even if such a decision would increase the probability of making a larger profit later. They called this variant of loss aversion a disposition effect.

Tversky and Fox (1995) used the conceptual framework of prospect theory but extended the proposals in this theory to also include decision under uncertainty. They introduced the principle of bounded subadditivity and claimed that this principle is more pronounced for uncertainty than for risks. The principle of bounded subadditivity refers to the finding that people are more affected by an event A if it is added to the null event than if it is added to any other nonnull event B (lower subadditivity). Furthermore, this principle suggests that people are more affected by an event A if it is subtracted from a certain event S than when it is subtracted from any other uncertain event \( A \cup B \) (upper subadditivity).

As in prospect theory the psychological basis of bounded subadditivity includes both judgment of probabilities and estimation of decision weights. However, Tversky et al claimed that the effect of subadditivity is more pronounced when decisions are made under uncertainty. Then factors such as fear, hope and desire will influence a probability estimation for an outcome than when the decision is made under risk.

9.2. Venture theory - a descriptive decision model on judgment and choice under risk and uncertainty

Venture theory (Hogarth & Einhorn, 1990), accounts for choice behavior in situations which involve both risk and uncertainty. The venture theory is a decision model that is largely influenced by the proposals in prospect theory. According to venture theory more variables than the weighting of a probability will influence the selection of an outcome in an uncertain choice situation. Hogarth et al claimed that real-life probabilities differ from the laboratory probabilities in that the former incorporates not only the coin-tossing probabilities but also a psychological aspect of the probability, a meaning. In real life the outcome of a single gamble might be perceived as more uncertain than if the gamble was repeated many times in a laboratory although the outcome of the gambles objectively have the same probability.

Venture theory suggests that the initial reference point is based on a stated probability, the anchor probability. From this anchor the decision maker gradually adjusts the likelihood of an uncertain event to occur by mentally simulate what other possible probabilities there are for an uncertain outcome to occur.

The mental simulation process can be described in the formula below (Hogarth et al, 1990; p. 783):
\[ w(p_A) = p_A + k \]

where \( p_A \) is the anchor probability and \( k \) measures the adjustment with respect to the decision weight. \( k \) can be either a positive or a negative value. The sign of \( k \), i.e., the adjustments from the original anchor probability, is an effect of both individual factors, such as their imagination of probabilities below and above the anchor, and of contextual factors.

An example of a contextual effect is the finding that gambling situation induces less risk aversive behavior than an insurance situation. Yet both situations involve potential losses. Venture theory suggests that people view uncertainty in gambling differently than uncertainty in an insurance situation. They imagine the value of the decision weight in the insurance situation above the anchor probability (i.e., \( k \) is positive) while they imagine the value the decision weight in the gambling situation below the anchor probability (i.e., \( k \) is negative).

The effort that is put into the mental simulation is an effect of the size of the payoff involved and the vagueness of the probabilities, the outcome uncertainty. The mental simulation increases with increased expected payoff and perceived outcome uncertainty.

The individual factors that influence the mental simulation process and which will determine the decision weight can be both cognitive and motivational in character. Imagination is an example of cognitive factors while risk attitude and emotions are examples of motivational factors. The impact of the aspects which are measured in the decision weight are then added to the anchor probability. This means that the decision weight is assumed to be an attribute that is distinguished from probability estimation. The consequence of adding a decision weight to the probability estimation is that the shape of the value function need no longer be linear from zero to 1 as in ordinary probability functions. In fact the more uncertainty is involved the more the shape of the value function can be expected to deviate from a straight line.

Hogarth et al. suggested that "... the roles of cognition and motivation become particularly important as one moves from studying gambles in stylized laboratory settings to decisions taken in more realistic settings where, although people may have knowledge about payoffs, information about uncertainties or probabilities is typically incomplete." (p. 799)

Many studies of decision making under risk are conducted as 'stylized experimental gambles' and therefore findings are often interpreted as 'paradoxical'. Hogarth et al. therefore suggested that the venture theory could offer an improved understanding of decision making under risk and uncertainty since it "... provides a useful structure for studying the impact of uncertainty in a wide range of tasks both in and outside the psychological laboratory ... [and it] ... models how decision weights are affected by psychological constructs of emotion (e.g., caution) and cognition (e.g., imagination)." (p. 801)
10. A SUMMARY OF THE THREE STUDIES OF FRAMING, JUDGMENT AND CHOICE

The results in the three studies presented here support earlier findings that the manner in which a decision maker frames a problem is crucial for subsequent steps in the decision process and for the final outcome. The first two papers describe studies of bidding behavior in auctions. The third study reports the results of a calibration study in a laboratory context.

10.1. The auction studies

The two auction studies were conducted in order to investigate bidding behavior as dynamic decision making processes. In a dynamic, real time context "... decision making ... requires the decision maker to cope with processes rather than events" (Brehmer, 1990, p. 263)

The first paper reports the results from auction experiments which were conducted as emulations of a real-world Treasury bill auction. The second paper presents a study of bidding behavior in a field setting or a natural decision setting (Orasanu et al, 1993), namely the Swedish 6-month Treasury bill auctions. Characteristics of a natural decision setting is for example that the environment is uncertain and decision making is made under time pressure. Besides, feedback from selected actions does not always provide the decision maker improved basis for future decisions. As mentioned above, feedback will merely facilitate future decision making when the outcomes are closely connected with a selected choice.

Accurate and direct feedback is provided in the Swedish Treasury bill auctions. These auctions are part of a larger market, namely the secondary market. Those who submit bids in the Swedish Treasury bill auction are to a large extent the same people who continuously trade Treasury securities in the larger secondary market. The results from the Treasury bill auctions is published directly after the auctions and the outcome is evaluated by the post-auction secondary market immediately thereafter. The price reaction in the secondary market on auction news will rapidly show the winning bidders whether their bids were good or bad in terms of money.

The auction experiment was a novel situation to most participants while the bidders in the Swedish Treasury bill auctions are expected to be familiar both with the tasks and the task context as an effect of the authorization in the Swedish Treasury securities auctions. This authorization allows only a limited group of dealers to distribute bids from all other investors to the seller. The group of bidders is quite stable over time. Therefore the bidders had several opportunities to attain training in how to bid in this auction context. The regular and correct feedback in the Swedish 6-month Treasury bill auctions could be expected to be an important factor for making the bidders more efficient in their decision making.
Also the subjects in the auction experiments received instant feedback regarding the outcome in an auction round from the experimenter. To some extent these subjects were able to compare their performance with that of their fellow participants in the auctions.

In both auction studies the bidders had to make their decisions under time pressure and with uncertainty regarding other bidders' bidding preferences. As mentioned above, when time is limited the decision makers have been shown to be more prone to adopt simpler decision rules, such as non-compensatory rules (e.g., Payne et al, 1990). An example of a non-compensatory rule is the lexicographic rule described above.

In both studies it was investigated whether bidders were able to use available auction information and adjust their bidding strategies to the prevailing market conditions in order to avoid overbidding. In the study on Swedish Treasury bill auctions the analysis was mainly focused on investigating whether contextual factors, such as asymmetrically distributed information (e.g., Cammack, 1991), could explain the size of the bids. A general assumption in auction theory is that overbidding in auctions occurs because bidders do not adjust their bids to the information asymmetry that is assumed to be present in the auction market (Kagel & Levin, 1986).

Besides, in the auction experiments it was investigated whether subjective factors, such as attraction to winning an auction (Cox, Smith & Walker, 1988) could explain the magnitude of purchase prices in the auction rounds.

### 10.1.1. The auction experiments

The main purpose of this study was to investigate whether the bidders were able to optimize their bids so as to gain as much money as possible from the laboratory auctions or whether subjects overbid and thus lost money from their purchases of the auctioned items. Overbidding in the auction experiment might be due to personal preferences, such as desire to win an item in an auction. Overbidding could also occur because the subjects are unable to utilize available auction information or the auction rules correctly.

It was further proposed that subjects who expressed a higher need for stimulation would be willing to take more risks in the auction experiment than subjects who expressed a lower need for stimulation. It is suggested that the subjects who find pleasure in arousal-stimulating activities will presumably assign a higher value to winning an auctioned item than other bidders.

As mentioned above, the auction experiments were designed as emulations of a Treasury securities auction. A real-world Treasury securities auction market can be described as consisting of three parts, namely the pre-auction market, or the when-issued market, the auction and the post-auction market. In analogy of this description a bid cycle was created for the analysis in the current study. As in the Treasury securities auction market the bid cycle also included three segments. The midpoint of the bid cycle was the purchase round. The round immediately preceding the purchase round and the round
succeeding the purchase round completed the bid cycle. In the auction experiments bid cycles were assumed to be embedded in the dynamic decision process, namely the set of auction rounds that constituted the auction experiment. The creation of the bid cycles made it possible not only to study the outcome of the subjects' separate decisions but also to observe the dynamics in the entire decision process. It was then also possible to investigate whether the subjects maintained a strategy during the entire auction or whether they continuously adjusted their bidding with respect to the outcome of the bidding in the separate auction rounds, for instance after a winning experience.

Students in business administration and professional actors in the Swedish money market participated in the experiments.

The experimenter introduced the calculated expected value very carefully in order to induce an initial frame from which the subjects could decide what strategy to choose in the auction. The subjects were only allowed to buy one item in each auction round.

The subjects were both offered a reward for best performance and a warning for overbidding. By offering an award to the best end-of-auction performer(s) the subjects were encouraged to fulfill their task to the best of their ability. In one auction experiment, the BONUS auctions, the award was SEK 500.00. In the other auction experiment, the TICKET auctions, the award was two cinema tickets. In order to restrain the subjects from bidding too aggressively they were warned that if their cash balance, real or imaginary, went below zero they would no longer be allowed to bid.

In the BONUS auctions the subjects received a participant fee of SEK 50.00 which they could use as risk money in the auctions. In the TICKET auctions the subjects received no real money for participating in the auction experiment. They were told to bid with an imaginary starting balance of SEK 50.00.

Before each auction round the subjects were informed about the two alternative repurchase prices that were to be randomly drawn from an urn and the probabilities for their outcomes (p; 1-p). This information was presented in order to make the link between this price information, the items' calculated expected value and its post-auction value clear. All subjects were told that there was a risk free bid alternative in all auction rounds, namely the low repurchase price.

The results showed that it seems reasonable to believe that the items' calculated expected value was employed as the subjects' initial reference point, or anchor value. The bids were, on average, submitted close to the calculated expected value of the items.

Although the results from the comparisons between the two award types are less reliable due to lack of randomization between the two experiments, they indicate that the size of the award did not significantly affect the general bidding.
Two main strategies were distinguished in this study indicating that both internal factors, such as their relative desire to win an item, as well as external factors, such as prevailing auction rules and bidding aggressiveness affected the subjects differently. One group of subjects, the subjects who purchased no items, accommodated early to the strategy of consistently bidding close to the calculated expected value. They tended to bid in accordance with the suggestions in expected utility theory. This theory suggests that the probability of a gambling outcome occurring in a near future should be the same as the probability of that gambling outcome occurring if repeated infinitely. By choosing the strategy of consistently bidding close to the calculated expected value the bidders were able to optimize their financial outcome from the auctions.

The subjects who bought one or more items in the auction experiments, the buyers, used a strategy that allowed for some temporary 'controlled' gambling. This strategy tended to reflect more instant goals such as achieving a winning experience by obtaining one or more items in the auction. In this auction context where bidding was aggressive the bidders who intended to buy an item consistently submitted bids in excess of the calculated expected value in order to win an item. Otherwise their bidding was almost as moderate in this group of bidders as in the nonbuyers' group.

In terms of venture theory (see section 9.2 above) the difference between the subjects' actual probability estimation of the items' post-auction value and the judged probability estimation, i.e., the calculated expected value, could be viewed as being the decision weight derived from their preferences. In the first stage of a bid cycle the sign of the decision weight $k$, i.e. the adjustments from the anchor probability, was positive. However, the winning experience per se seemingly decreased the attraction of becoming a winner, at least temporarily. Both after a loss experience and after a winning experience the sign of the decision weight among the buyers was close to zero.

The potential buyers increased their bids in the same manner in rounds immediately after auction rounds in which the winners had lost money as in rounds immediately after rounds in which the winning bidders had gained money from their purchase.

The auction rules limited the subjects' financial responsibilities for the outcome in the auction experiments. This restriction may have stimulated some subjects to take higher risks than they would have if they had been bidding in a real-world Treasury securities auction where the bidders have wider personal responsibilities for the financial outcome (i.e. a contextual effect).

It was also investigated whether the bidders who selected the strategy of more aggressive bidding expressed a higher interest in financial risk taking and arousal-stimulating activities than other subjects. For instance Harlow and Brown (1990) reported that financial risk tolerance was significantly related to the subjects' sensation seeking attitude. The results showed a tendency among the buyers to express a higher interest in financial risk taking and arousal-stimulating activities than among the nonbuyers. This difference was however not significant.
In summary, although some buyers failed in terms of profit maximization, it seems reasonable to conclude that the subjects in the auction experiments were bidding in accordance with their perception of the auction context and their preferences. Overbidding tended to be an effect of bidders' selected strategies and adjustments to the auction conditions rather than misinterpretation of the auction rules.

In real-world business auctions, a bidding strategy that provides a bidder with a loss, or at least a lower profit, might have more serious consequences for the winning bidders than in an auction experiment. An important issue for future research is therefore to search for cues in the environment and in the mind of the decision maker that activate and deactivate a risk-prone behavior. Also, a more comprehensive scale to measure sensation-seeking among risk managers should be developed in order to identify potentials for excessive risk taking in the financial market.

10.1.2. The study on Swedish 6-month Treasury bill auctions

The second auction study investigated bidding behavior in a field setting or a natural decision setting (Orasanu et al., 1993), namely the Swedish 6-month Treasury bill auctions. The analysis was conducted on secondary data from the Swedish 6-month Treasury bill auction market from February 1, 1991, to June 30, 1994.

A critical aspect in field studies is that it is seldom possible to fully assess the market complexity due to lack of reliable secondary data. However, the design of the second auction study was aimed at incorporating the main part of the auction market procedure in the analysis. Thus the auction market was defined as consisting of the pre-auction secondary market (often referred to as the when-issued market in studies of US Treasury securities auctions), the auction and the post-auction secondary market.

Earlier studies of government securities auctions have mainly focused on the dynamics in the auctions and the post-auction secondary market (e.g., Cammack, 1991; Wachtel & Young, 1990). However, if the pre-auction secondary prices are excluded from the analysis of the information distribution in a Treasury securities auction, it is less feasible to distinguish at what time the auction information is spread in the auction market. It is not possible to investigate whether relevant auction information is in fact recognized by the public in the secondary market before they submit their bids in the auctions or if information is being kept secret by the better informed bidders until the auction has started. These limitations make some of the conclusions in these studies less reliable.

In studies of real-world auctions, researchers have often reported that business corporations have paid prices for the auctioned items that were above the auctioned items' true value as it was later established in the post-auction market (e.g., Roll, 1986; Thaler, 1992). If the winners overestimate the auctioned item and they stand the risk to lose money or at least decrease their profit, they are said to experience the winner's curse. A likewise interesting observation has been made in studies of a
specific type of auction, namely the government securities auctions. In these auctions bidders have succeeded in purchasing Treasury securities at prices below the price later established by the post-auction market (Bikhandani & Huang, 1993; Cammack, 1991; Simon, 1994; Umlauf, 1990).

The main purpose of this study was to investigate whether bidders were able to avoid overbidding in the Swedish 6-month Treasury bill auctions. Secondly it was investigated whether information was perfectly distributed or whether any private auction information systematically affected the price system and thereby the efficiency in the distribution of the issued securities in the auction market. It was furthermore investigated whether the prevailing auction rules generated strategic trading among the bidders.

Some of the dealers who trade daily in the money market are also appointed by the seller, the Debt Office, as distributors of bids from all other investors to the seller. As rational agents in the Treasury securities markets the authorized dealers can be expected to strive for the highest possible profit at the lowest possible risk. They know that they can purchase a Treasury security that is identical to the one issued in the secondary market before, during and after the auction on auction day. Thus they can be expected to search for compensation for any risks and information costs inherent in the auctions.

The results showed that the bidders as a group selected bidding strategies that were in line with economic rational goals. The professional bidders tended to adapt rationally to the auction rules and the prevailing market conditions so as to gain as much money as possible from the auctions.

As has been found in earlier studies of Treasury securities auctions the winning bidders succeeded in purchasing the Treasury bills in the auctions at prices that were, on average, lower than that of an identical bill in the secondary market. The systematically lower prices for an identical 6-month Treasury bill in the auctions present evidence that the bidders were able to adjust their bids so as to avoid overbidding and to compensate themselves for the additional risks that they incurred in the auction. The difference between the secondary market prices and the auction price was, however, quite small in terms of real money.

The underbidding may have been facilitated by the low competition in the Swedish 6-month Treasury-bill auctions and of the prevailing auction rules. In comparison with most business situations, the Treasury securities auctions are stable institutions where tasks are repeated in a regular manner and the auction rules are rarely altered. Besides, the secondary market was open during the auction procedure. Therefore the bidders in the Swedish Treasury bill auctions could adjust their trading portfolios in this market at any time during the auction procedure if they learned that new auction market information would render a different price for the auctioned securities than that represented in their submitted bids.
The results from the two auction studies indicated that the bidders' perception of the prevailing auction rules and task contexts affected their selection of bidding strategies. In the auction experiments the winners were seemingly affected by a subjective goal such as that of winning an auctioned item while the winners in the Treasury securities auctions adjusted their bidding in order to maximizing profits from the auctions.

Although the bidders in the Treasury securities auction seemingly were capable of underbidding the most common finding is that bidders in business auctions, like the subjects in the auction experiments presented here, pay excessive prices for the auctioned items. In order to better understand what individual factors as well as factors in the task and the task environment that may cause or hinder over bidding in real world auctions future research on bidding in auctions should integrate the findings in behavioral oriented decision research with proposals in auction theory. Thereby it might be possible to improve efficiency in decision making in auctions.

10.2. The overconfidence experiments

In many studies of judgment and choice it has been found that people have a tendency to be overconfident in their decisions. Overconfidence in experiments is defined as the general tendency to overestimate the likelihood of having selected the right alternative from a set of available answers. Some researchers have claimed that a positive illusion, such as overconfidence, may promote people's well-being (Taylor & Brown, 1994). Others, like Griffin & Tversky (1992) claimed that the benefit from attaining comfort by displaying overconfidence in a choice will be exceeded by its costs. Sjöberg (1982) noted that "...It seems that we become increasingly inconsistent as the amount of information increases. Thus, the subjective notion of confidence is of little help in establishing the quality of a decision or judgement. Confidence, in other words, cannot be trusted" (p.350).

The study on overconfidence was conducted as two experiments. The aims of the overconfidence study were (1) to investigate whether ecological validity matters for calibration and (2) to investigate whether subjective, or perceived, difficulty can provide additional explanation for the variance in confidence. Furthermore, (3) the aim was to compare the realism in judgments about the probability of one's separate answer being correct with the effects on realism in assessments of the frequency correct answers among a set of 10 questions. Finally, (4) it was investigated whether the realism of one's confidence judgment and frequency estimation was affected by information about the existence of the overconfidence phenomenon.

In the frequency experiment the tasks involved frequency estimations and in the confidence experiment the tasks involved confidence judgments. Gigerenzer (1993) made a distinction between frequency estimations (for example '4 out of 10') and probability assessments (for example '40 percent'). He argued that overconfidence occurs in experiments because people are asked to assess their probability estimations. From his point of view probability theory is not intended to be applied to unique events. Instead, frequency assessments are more appropriate when events are isolated (1993; p. 8).
Gigerenzer also suggested that a frequency statement contains more information than the probability judgment. The former statement gives additional information about the size of the sample from which the estimation is made. However, Allwood and Granhag (in press) found that the frequency proposal is somewhat unstable in experiments.

With the exception of the frequency-estimation and confidence-judgment instructions the same procedure was employed in the two experiments. Students in psychology and in business administration participated in the confidence experiments.

Ecological models, such as the lens model (Brunswik, 1955) and the Probabilistic Mental Model (Gigerenzer, Hoffrage & Kleinbölting, 1991), assume that in order to select one of a set of available alternatives people select reference class that is relevant for the current task. For instance, the Probabilistic Mental Model suggests that the decision frame from which decision and choice is made, is a product of the problem's *internal representation*, i.e. the decision maker's perception of the problem and of its *external representation* i.e. the context or environment in which the problem is presented to the decision maker.

According to Gigerenzer et al (1991) and Juslin (1993) there is no general overconfidence bias. Instead, the proper selection of items is the important requirement for achieving good calibration in experiments. A major cause of overconfidence in many experiments is that the only criterion for the selection of items in a questionnaire is that they are 'typical' general knowledge items. This technique of item selection is called the informal technique of item selection. The representatives for the ecological school claim that if a representative selection technique is used, i.e. if laboratory tasks are selected randomly from a relevant reference class on each occasion and if the assessors have a reasonable knowledge of the domain in which they are to make predictions, overconfidence will be eliminated.

Thus, in order to investigate whether the method of selecting items is the key to creating as well as eliminating overconfidence as has been suggested in ecological models two types of question items were used in the experiment, namely informally selected items and randomly selected items.

The results in this study showed increased realism when the subjects were asked to make frequency assessments compared with when they were asked to make confidence assessments. The subjects gave significantly lower frequency assessments than confidence assessments both for informally selected and for randomly selected questions.

It was furthermore found that in the representative selection condition, i.e. when items were randomly selection from a representative domain the subjects' overconfidence decreased in comparison when items were informally selected. The cost for the lower overconfidence was a very poor resolution. Resolution is defined as the ability to "... discriminate different degrees of subjective uncertainty by sorting the items into categories whose respective percentages correct are maximally different from the overall percentage correct." (Lichtenstein & Fischhoff, 1980, p. 162). A higher value for resolution tells us
that subjects are able to utilize the extreme response categories on a probability scale, ranging from 50% to 100% confidence rating, relative the percentage correct of all items.

All in all, the resolution score for the representative selection condition was lower and the number of items that registered on the response category, reporting 50% confidence in a selected answer of a binary question, was larger in the representative selection condition. These results indicate that calibration was not significantly different in the two selection conditions. However, the subjects in the representative selection condition did not utilize the entire probability scale as fully as was done in the informal selection condition. Furthermore, the subjects in the representative selection condition displayed extreme overconfidence in the higher confidence categories.

Furthermore, fifty percent of the subjects in each experiment received information about the overconfidence phenomenon at the beginning of the experiment in order to investigate whether providing this information would reduce overconfidence. As was found in earlier studies of overconfidence (e.g., Fischhoff, 1982; Gigerenzer et al, 1991) warnings had no effect on the overconfidence level. Neither the percentage correct items among the subjects, their confidence assessments nor their frequency assessments were influenced by the received information about the overconfidence phenomenon.

Earlier research on overconfidence has not attempted to distinguish the effects on the confidence level judgments of, on the one hand, actual or objective difficulty (measured as the actual proportion correct items), and on the other hand, perceived difficulty. Therefore, in order to better understand whether subjective factors, such as perceived difficulty and familiarity could explain the confidence this study made a distinction between these two measures of difficulty, namely on the one side objective difficulty and on the other side perceived difficulty. The subjects were asked to report whether they perceived an item as difficult or familiar. The results in this study showed that the confidence level could be explained to a significant degree by the subjects' perception of a question as either difficult or familiar.

One of the most important results in the present study is that the analyses show the importance of making a distinction between objective and perceived difficulty. The results in the confidence experiments presented evidence that the subjects' perception of a question as either difficult or familiar could explain their confidence level to a significant degree. Perceived difficulty and perceived familiarity contributed independently of objective difficulty to explain the subjects' confidence judgments and thus conceivably to the interpretation of the causes of the overconfidence phenomenon. The subjects were more sensitive to the perceived difficulty than to the objective difficulty in their confidence judgments. They tended to display decreased confidence when items were perceived as difficult or very unfamiliar and they tended to display increased confidence in the opposite situation.

A positive gap between perceived difficulty and objective difficulty is an indication of overconfidence and a negative gap between perceived difficulty is an indication of underconfidence. The gap could alternatively be explained in terms of venture theory (see
which states that the individual factors that will determine the decision weight can be both cognitive and motivational in character. In accordance with the proposals in venture theory the difference between the anchor probability, which would be reflected in the percentage correct items, and the subjects' confidence ratings, measured as percentage items that were perceived to be correct, could then be represented by a decision weight. The sign of the decision weight would reflect the subjects' imagination of the task and/or the task environment as either difficult or easy, as either familiar or unfamiliar.

It is therefore suggested that in order to improve our understanding of the overconfidence phenomenon future research should further explore the role of perceived difficulty of the task and the task context as well as item familiarity in confidence judgments.

11. FINAL REMARKS

Many studies have presented evidence that knowing the rules that provide an economically rational decision does not necessarily lead to improved decision making. Neither has training in decision making always provided people with better insight as to when they may use simple rules and heuristics and when they should avoid them in order to reduce the risks for biases in their decision process. Yet I hope that the three papers on framing, judgment and choice presented here will provide decision makers some understanding of what factors in the reasoning process that may support or hinder rational judgment and choice. The results reported here may motivate and inspire researchers and professional decision makers to further search for internal and external factors that can improve efficiency in decision making. An effort was made to interpret both overbidding and overconfidence in the laboratory in accordance with proposals in venture theory which accounts for choice behavior in situations which involve both risk and uncertainty. The concepts suggested in this model and in similar models may provide a useful framework for studying the impact of risk and uncertainty on decision making in real-world contexts such as business auctions and financial advisory services. Moreover, it is essential to search for research techniques on dynamic decision making in laboratory contexts which offer an adequate balance between control and realism in the representation of real-world decision making.
12. REFERENCES


THE UTILITY AND THE CURSE OF WINNING AN AUCTION:
AN EXPERIMENTAL ANALYSIS
ABSTRACT

A general assumption in auction theory is that overbidding in auctions occurs because bidders do not adjust their bids to the information asymmetry in the auction market. Two auction experiments were conducted in order to investigate whether other factors, such as the subjects' desire to win an item, or prevailing market conditions can explain overbidding. The experiments were designed as an emulation of a Treasury securities auction. Students in business administration and professional actors in the Swedish money market participated in the experiments. Furthermore, by offering an award to the best end-of auction performer(s) the subjects were also encouraged to fulfill their task to the best of their ability. In one experiment the bidders were offered a notably high award to the best performer. In another experiment bidders were offered a moderate award. The bids were on average submitted close to the calculated expected value of the items. The mean bids in the two auction types were not significantly different indicating no effect on the general bidding due to the size of the award. Two main strategies were distinguished in this study indicating that the auction institution attracted bidders differently. The bidders who purchased no items in the auctions accommodated early to the strategy of bidding close to the items' calculated expected values thus allowed them to optimize their financial outcome from the auctions. The bidders who purchased one or more items used a strategy that allowed for some temporary 'controlled' gambling. In the competitive auction context the bidders who intended to buy an item consistently had to submit bids in excess of the calculated expected value. Otherwise their bidding was moderate and in line with that of the nonbuyers. There was a tendency among the buyers to express a higher interest in financial risk taking and arousal-stimulating activities than among the nonbuyers in the auction experiments. In real-world auctions risk taking may be less controllable and manageable and the effects from excessive bidding may be less beneficial to the winning bidders. An important issue for future research is therefore to investigate more deeply the causes for and consequences from overbidding in commercial auctions. Another important issue for future research is to search for cues in the environment and in the mind of the decision maker that activate and deactivate a risk prone behavior.

KEYWORDS: auction experiment, arousal, cognitive and motivational biases, strategic bidding
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THE UTILITY AND THE CURSE OF WINNING AN AUCTION:
AN EXPERIMENTAL ANALYSIS

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1. INTRODUCTION

This paper reports a study on bidding behavior¹ in a laboratory auction setting. The auction experiment was designed to emulate a Treasury securities auction which is generally defined as a multiple-unit, sealed-bid, common-value auction (McAfee & McMillan, 1987).

The auction market is a huge market for trading commodities. In many studies on auctions, for instance oil lease, drilling rights and book publishing rights auctions, researchers have found that business corporations have paid excessive prices for the auctioned items (see Roll, 1986; Thaler, 1988). These studies have shown that bidders tend to be biased in their bidding not only by the asymmetrically distributed information which is assumed to be present on most auctions, but also by for example their expectations. Roll (1986) suggested that overbidding in real-world auctions occurs because bidders believe themselves to be better predictors of the future value of for instance a firm than the stock market. He called this phenomenon the ‘hubris hypothesis’.

2. THEORETICAL FRAMEWORK

2.1. Common-value and private-value auctions

The effects of overbidding are most clearly revealed in the type of auctions that are known as common-value auction. In common-value auctions the item for sale is assumed to have no personal value to the bidders as it would have in a private-value auction, such as an auction for works of art, antiques and wine, where the buyers are assumed to retain their purchase for private use. In common-value auctions it is assumed that the auctioned item will be resold after the auction at a market value. The post-auction market will then examine the auction price in the light of what price this market is willing to pay for the auctioned item.

An assumption in theoretical common-value auction models is that bidders have different sets of information about the auctioned item’s ‘true’ value, measured as its value in the post-auction market. Besides, the bidders are assumed to know that the information they have access to is not the complete set of relevant auction

¹ Since the subjects were expected to bid in accordance with their intentions a more appropriate terminology than bidding behavior would have been that of bidding action (Bruner, 1990).
information. Others have additional information that is relevant for the estimation of the item and therefore also relevant for the outcome of the auction. Each bidder must therefore lower his/her bid to adjust for the missing information. When bidders fail to include in their price estimation some kind of downward correction to compensate for the information asymmetry they might end up having submitted bids that are higher than the item's true value.

In this ideal situation it is assumed that no risk preference or risk aversion influences the price estimation, that there is no collusion among bidders, no signaling or communication, and no side payments.

According to auction theory a rational bidder is expected to make an evaluation so that the bid represents his/her estimation of the greatest chance for a profit. In other words, the submitted bid should be the price at which the bidder is on the 'margin of indifference' as to whether he/she acquires the item or not. To increase the probability of winning an item, the bid must be raised but then the probability that the price paid for the auctioned item will be higher than the price in the post-auction market also increases. On the other hand, to avoid the risk of paying too much for the item the bidder can lower the bid but then at the expense of a decreased probability of winning the item.

2.2. Overbidding and the winner's curse

As mentioned above, overbidding in common-value auctions is explained by many economists as a judgment error that occurs when bidders in making their bids fail to consider how their incomplete information will affect their price estimations (Kagel & Levin, 1986).

However, the distinction between common-value and private-value auctions is not always very clearly made in analyses of real-world auctions. For example, Treasury securities auctions are defined as common-value auctions (McAfee & McMillan, 1987) and most investors submit bids in the Treasury securities auctions with the aim of selling them in the post-auction secondary market at a profit. But others purchase the Treasury securities with the intention of keeping them until their maturity date. Therefore the post-auction market value of the auctioned securities will be less important to these bidders. Another example of the confusion in defining an auction as either a common-value or a private-value auction is that of an auction for works of art. Although many bidders in an auction for works of art aim at purchasing a painting for private use, the professional art dealers who participate in the same auction and bid for the same object can be expected to resell the object in a post-auction market.

A distinction must be made between overbidding in theoretical models of common-value auctions and overbidding in real-world auctions. In the latter the bidders must still consider that the item's future purchase price is an aggregation of its technical value and its anticipated strategic value to each individual bidder participating in the auction.
The more bidders' private values influence the item evaluation the more each bidder must focus on the strategic forces that are inherent in the auction procedure in order to avoid overbidding (Kagel & Levin, 1993). Some bidders might perceive an auction as a unique opportunity to buy a certain object, such as a business firm. Therefore they might be consider their private valuation of the items' future value as more relevant than that of a stock market evaluation.

Furthermore, when the number of bidders is increased the signals from other bidders' strategies become more congested and the bidding becomes more aggressive. Due to the market volatility the bidders need to be more conservative in their bidding (Bazerman & Samuelson, 1983) and the bids should be adjusted downwards so as to avoid overbidding. If bidders fail to understand this auction rule they may bid excessively and thereby become the victims of the winner's curse.

The winner's curse is defined as a systematic failure to adjust the estimation of an item's value downwards so that the risk of paying too much for the good is offset (Kagel et al, 1986). It is an a posteriori problem for the bidder and is measured as a negative gap between the individual's bid and the objective value of the item as it is known subsequently.

Thaler (1988) suggested that the definition of the winner's curse should be extended to include auctions where the item could be sold at a profit in the post-auction market but where this value turned out to be lower than that which had been anticipated by the winners. The experience of disappointment and regret would here be sufficient criteria for the experience of the winner's curse.

However, regret need not follow a loss if the reference outcome is selected so as to also include the possibility of a loss. For example, the differentiation and consolidation theory (Svenson, 1992) suggests that regret may be avoided if people select and evaluate the different alternatives carefully before they make their choice. If for instance a loss is one of many possible outcomes from a selected bidding strategy in an auction with both private-value and common-value components it need not render an experience of the winner’s curse. Weick (1995) suggested that: “Negative emotions are likely to occur when an organized behavioral sequence is interrupted unexpectedly and the interruption is interpreted as harmful or detrimental.” (p. 47)

2.3. Rationality and bidding behavior

To determine whether a selected bidding strategy renders a rational outcome the concept of rationality must be defined. Mainstream economic theory states that individuals act rationally if their judgment and choice is built on a stable and well-organized value system. Furthermore, for a choice to be rational the selected alternative should provide the individual with the highest utility with respect to both present and future order of preference. Thus mainstream economic theory does not
allow for time varying preferences and context to have any impact on the selection of alternatives.

The assumption in expected utility theory is that the probability for an outcome of for example a gamble to occur in a near future should be the same as for this outcome to occur if it the gamble was repeated infinitely (see e.g., von Neuman & Morgenstein, 1947). By using the expected-value strategy as a rule, the decision makers will secure the best long-term payoff on their investments. A good decision rule in a common-value auction is therefore to bid the item’s expected future value since this value secures an optimal return on the investment in single risk situations as well as in repeated risk situations.

However, researchers have found that people have difficulties to apply a long-run perspective on their probability estimations for an outcome to occur in a short-run (Wedell & Böckenholt, 1990). Wedell and Böckenholt found that subjects were able to adopt a long-run perspective to decision task in an experimental situation only if the structure of the task was consistent with the ‘long-run frame’ (p. 437).

Without the long-term perspective in their mind the subjects might be more inclined to build their bidding strategy on simple reference points that are more striking or instantly available to them. Subject who enter into an auction experiment might be less prone to apply a long-term perspective to their actions than they would in a real-life auction context. The bidders might be more inclined to perceive the experimental situation as for instance a gambling situation.

Elster (1990) described rational behavior as a physical expression of desires and beliefs: ‘Rational actions .... involve three optimizing operations: finding the best action, for given beliefs and desires; forming the best-grounded belief, for given evidence; and collecting the right amount of evidence, for given desires and prior beliefs’ (p.21).

Furthermore, people can be rational in that they are able to select actions in accordance with for example prevailing norms in a certain social setting or in line with the consensus among similar members of their society. This type of rationality is referred to as contextual rationality (White, 1988).

As in most auction experiments the subjects in the present auction experiments lacked full liability for the financial outcome of the auction. Hansen and Lott (1991) observed in their experiments that subjects were frequently submitting bids in excess of the item’s technical value. They concluded that overbidding should be perceived as a rational reaction to a market condition where the subjects lack full responsibility for the financial outcome of their bidding. Their claim for overbidding as a rational bidding behavior is that bidders can only be expected to bid the objective value of an auctioned item when they have full responsibility for the outcome of the auction.
2.4. Risk behavior in auctions

Willingness to take risks and accept uncertainty may be enhanced in an experimental situation because in this context, which resembles a gambling situation, the risk can be kept to a manageable level and within a controllable time frame. Gambling can be seen as an expression of people's general need for arousal-stimulating activities (Berlyne, 1963; Scitovsky, 1976). Berlyne claimed that people actively seek for their optimal level of stimulation and arousal. Scitovsky suggested that: “Gamblers enjoy gambling because they have full control over the amount they risk, and they will not risk more than they enjoy risking. In addition they usually have control over the time dimension of the uncertainty involved.” (1976, p. 57)

In the search for their individual arousal-stimulation optimum people curb the stimulation when it is too intense by withdrawal from too powerful stimuli (Scitovsky, 1976). Likewise they can activate their stimulation by attending to new stimuli when it is too low. This process is a balancing act between avoiding pain and experiencing pleasure. However, need for arousal-stimulation varies from person to person.

Zuckerman (1979) called people who have a strong interest in variety, novelty and complex experiences sensation seekers. Zuckerman found that sensation seeking is a relatively consistent individual characteristic, but variations in intensity and expression occur at different ages and between the sexes. Zuckerman found in his studies that sensation seekers tend to get involved in activities that are normally regarded as risky and they are willing to take physical and social risks to achieve these kinds of experiences. Harlow and Brown (1990) used a sensation seeking scale in a first-price auction experiment to investigate the relation between financial risk taking and sensation seeking attitudes. They reported that financial risk tolerance was significantly related to the subjects' sensation seeking attitude.

Arousal can be induced by interruptions of an ongoing activity (Mandler, 1984). Mandler suggested that people can experience interruptions because an event is unexpected or because an event that is expected does not occur.

Weick (1995) suggested that: “... the perception of arousal provides a warning that there is some stimulus to which attention must be paid in order to initiate appropriate action” (p. 45). An arousal experience stimulates people “... to comprehend, understand, explain, attribute, extrapolate, and predict.” (Starbuck & Milliken, 1988, p. 337)

For example, each separate bidding event in an auction experiment could be perceived as an interruption (Weick, 1995) or as a decision event (Orasanu & Connolly, 1993). A

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2 Arousal is defined as a response to stimulus change such as decrease or increase in intensity, frequency, or novelty of stimulation (Geen, Beatty & Arkin, 1984) or as a discharge in the autonomic nervous system (Mandler, 1984).
winning experience is a further example of action interruption in the decision process which can trigger the bidders' arousal.

Cox, Smith and Walker (1988) suggested that there is a value attached to winning an auction and that a winning experience is regarded differently by different people. Some bidders are intrigued by the possibility of winning and others find no attraction in a winning experience per se. Cox et al also postulated that if winners lose money from their purchases, utility of winning to them will decrease and they will lower their bids in subsequent auctions.

2.5. Biases in the decision process

Studies on decision making have presented several pieces of evidence that people systematically deviate from economic rationality and the principles of expected utility in their decision and choice. One field of particular interest is the securities market where many researchers have observed economic anomalies for which economic theory does not offer adequate explanation (e.g., de Bondt & Thaler, 1985; Shefrin & Statman, 1985).

When encountered with a new problem people first construct a mental ‘framework’ for their future actions in the decision making process. When people make decisions, they start the problem analysis by composing a reference point or an anchor. At this initial stage, called the framing and editing stage in prospect theory (Kahneman & Tversky, 1979) a decision maker selects, from the information available, that information which is perceived as relevant for solving a problem. This first stage of the reasoning process is crucial for the development of the entire decision process because the anchor point then constitutes the foundation from which the information processing and evaluation is made.

The selection of the anchor, or reference point, should be as objective and unbiased as possible since future outcomes are then assessed from this reference point (Kahneman & Tversky, 1979). Once the anchor is selected the adjustments and reevaluations are made from the anchor point and with respect to anticipated changes in conditions. New information leads to adjustments in relation to the initial anchoring point. This strategy is called the anchoring-and-adjustment strategy (Tversky & Kahneman, 1974).

If subjects have selected formally irrelevant information as vital and/or if they have paid too little attention to information that is formally relevant for their final decision there is a risk that the outcome of their analysis will be biased (Tversky & Kahneman, 1981). A cognitive or a motivational bias in the decision making process occurs if the selected anchor hinders appropriate adjustments in decision and choice after new information is presented or conditions are altered. For instance, subjects who are attracted to winning an item in an auction might focus on the possibilities of winning while subjects who are risk averse might focus on the possibilities to avoid a loss. If for instance the subjects' attraction to winning is very strong they might be less open to changes in the bidding sentiment and overbid.
In summary, the theories presented above suggest that bidding behavior in real-world is contingent of the bidding environment, such as bidding aggressiveness in the auction, the individual, such as the attraction to arousal-stimulating activities, and the task content, such as whether the bidders perceive the auctioned items as holding only a common value or whether also private values, such as the desire to win an auctioned item, will guide their bidding behavior.

3. PURPOSE AND PROPOSALS

3.1. Overbidding in auctions

The main purpose was to investigate whether the bidders were able to optimize their bids so as to gain as much money as possible from the laboratory auctions or whether subjects overbid and thus lost money from their purchases of the auctioned items. Overbidding in the auction experiment might be due to personal preferences, such as desire to win an item in an auction. Overbidding could also occur because the subjects are unable to utilize available auction information or the auction rules correctly.

3.2. Strategic bidding in auctions

It was further investigated whether the subjects displayed a consistent bidding pattern in the auctions this could be interpreted as an effect of the bidders' strategic thinking. Subjects who were attracted to winning an item in an auction might focus on the possibilities of winning while subjects with lower desire to win or who were risk averse might focus on the possibilities to avoid a loss.

The calculated expected value (see section 2.3.2) was exposed to the subjects in order to induce an objective value as a point of departure for their future bidding. Earlier research has found that when subjects perceive base rates to be causally appropriate for a certain judgment, most of them incorporate the statistics into their judgments (Bar-Hillel, 1990).

Economically rational bidders with a low desire to win an auctioned item were expected to consistently bid the calculated expected value of the auctioned items. Alternatively, subject who wanted to attain a winning experience might use the calculated expected value as a starting point but thereafter adjust their bid to in order to win an auctioned item.

3.3. Need for arousal-stimulating activities and bidding behavior

It was further investigated if subjects who expressed a higher need for stimulation would be willing to take more risks in the auction experiments than subjects who expressed a lower need for stimulation. It was assumed that the subjects who find pleasure in arousal-stimulating activities would presumably assign a higher value to winning an auctioned item than other bidders.

The bidders with a stronger craving for sensation seeking activities were expected to increase their bids above the items' calculated expected value in order to increase their
chances of winning an item in an auction round even at the cost of overbidding and thus at the risk of decreased profit or even of losses.

3.4. Awards and bidding behavior

Reinhart (1992) claimed that the results from most auction experiments are not particularly relevant as replications of a real-world auction because the experimenters, in their experimental design, do not consider that the profit motive is crucial for security dealers' bidding behavior. In these experiments the subjects were offered an award to the best performer(s).

The purpose of offering an award to the best end-of auction performer(s) was twofold. By offering an award to the best performer(s) the subjects were encouraged to fulfill their task in the auction experiments to the best of their ability. Some researchers (e.g., Plott, 1986; Smith, 1976) have suggested that individuals optimize and therefore adjust their market behavior to the awards and monetary incentives that are attainable. However, although economic learning can be acquired as a direct consequence of rewards and punishments (Bandura, 1977) there is no guaranty that rewards and punishment will provide a certain behavior. Vagueness in the causal relations between action and outcome might hinder efficient learning (Orasanu et al, 1993; Wärneryd, 1988).

Furthermore, by offering two different awards to the best performer(s) in the auction experiments it was possible to investigated whether the size of awards had an impact on bidding behavior and whether bidders who were promised a higher award for best performance in terms of money would bid differently than the bidders who were promised a small award for best performance.

4. THE AUCTION EXPERIMENTS

4.1 Participants

93 second-year students of business administration and economics at the Stockholm School of Economics and 9 professional actors in the money market participated in the auction experiments. When the subjects were asked to participate in the experiments they were told that the experiments concerned decision making.

One group of students were randomly selected from a seminar participant list and then asked to participate in an auction experiment (n=37). A second group of students were asked to participate in an auction experiment as part of their education program (n=56). All students had taken courses in probability judgments and were therefore expected to know how to calculate the objective value of the auctioned items.

A group of fifty actors were randomly selected from a memberlist for money market dealers. Although thirty-five professional actors in the money market had accepted the invitation to participate in the experiment only nine of them finally showed up.
4.2. **Experimental design**

The current study on bidding behavior in auctions was conducted in a laboratory setting. Auction experiments have proven to be a useful method for studying market behavior (Plott, 1986). In a laboratory auction context it is possible to study the actual behavior of a group of individuals.

In this auction experiments the subjects were asked to make a choice from a set of possible outcomes that were obtained from their own imagination. However, there is a cost for using this type of design since the experimenter must give up some degree of control over the process in the laboratory. To maintain control over the process in the laboratory is an important requirement in psychological experiments on decision making. Therefore in most experiments on decision making and choice the subjects are asked to make a theoretical choice among a set of anticipated outcomes that have already been selected by the experimenter (Arkes & Blumer, 1985; Romanus, Hassing & Gärling, 1996; Tversky & Kahneman, 1981).

Although an experimenter makes efforts to induce a specific perspective for the problem to be studied there is no guarantee that he/she succeeds. The subjects may still use a different frame which lead them to different inferences than those anticipated by the experimenter (Frisch, 1993).

4.2.1. **The auction model**

The auction experiments was designed to emulate a Treasury securities auction market so as to create a more 'realistic' context for the experiment. A real-world Treasury securities auction market can be described as consisting of three parts, namely the pre-auction market, or the when-issued market, the auction and the post-auction market. In the pre-auction market the bidders prepare themselves for participating in the auction. Besides, to reduce the risks for overbidding in the auctions the bidders need to gather as much information as possible regarding the demand for the auctioned items.

The Treasury securities auction is most frequently designed as a multiple-unit, sealed-bid, common-value auction (McAfee & McMillan, 1987). As mentioned above, in a common-value auction the item for sale is assumed to have no personal value to the bidders as it would have in a private-value auction. In the sealed-bid auction the bids are presented in writing. When more than one object is sold at the same auction, the auction is called a multiple-unit auction. The price rules are commonly either uniform, which means that all winning bidders pay the same price, or discriminatory, which means that the winning bidders pay the price of their individually accepted bids. Since the winning bids are linked to the bids submitted by others, namely the highest rejected bids, the risk for overbidding is lower in uniform price auctions. Therefore this price rule was used in the current auction experiments.
The study was divided into two auction experiments that were named the *BONUS auctions* and the *TICKET auctions*. The names of the auctions refers to the type of award that was offered in the auctions (see below section 2.4).

The students that were randomly selected from a seminar participant list (n=34) and the professional money market actors (n=9) belonged to the BONUS auctions.

The students who were participating in an auction experiment as part of their education program (n=56) belonged to the TICKET auctions.

To be able to study the dynamics in the decision making process each experiment included a series of auction rounds. In total, six auctions were conducted. The BONUS auctions comprised two sections containing five and seven auction rounds, respectively, and the TICKET auctions comprised four sections. Two sections contained three auction rounds, respectively, and two sections contained five auction rounds, respectively. Four imaginary items were sold in each round of the two BONUS auctions while three items were sold in each round in the first two TICKET auctions and two items were sold in each round in the two succeeding TICKET auctions. The items were referred to as 'the bonds' in the experiment.

In analogy of the description of a Treasury securities auction market, above, a ‘bid cycle’ was created for the analysis in the current study. As in the Treasury securities auction market the bid cycle also included three ‘segments’. The midpoint of the bid cycle was the purchase round, \( P \). The round immediately preceding the purchase round, \( BFR \), and the round succeeding the purchase round, \( AFT \), completed the bid cycle. All bid cycles are presented in Table 1. Since the first round of each auction experiment was not preceded by an auction round and the final round was not succeeded by an auction round these two rounds were excluded as midpoints of a bid cycle in each experiment.

**Table 1.**
Price conditions in the separate auction rounds.

<table>
<thead>
<tr>
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<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
<th>Round 4</th>
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<tbody>
<tr>
<td>MaxRP</td>
<td>15.00</td>
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<td>90.00</td>
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<td>5.00</td>
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<td>10.00</td>
<td>25.00</td>
</tr>
<tr>
<td>( V_{eq} )</td>
<td>10.00</td>
<td>16.00</td>
<td>22.50</td>
<td>32.00</td>
<td>76.00</td>
<td>30.00</td>
<td>50.00</td>
</tr>
<tr>
<td>( p; 1-p )</td>
<td>50/50</td>
<td>30/70</td>
<td>90/10</td>
<td>60/40</td>
<td>30/70</td>
<td>40/60</td>
<td>50/50</td>
</tr>
</tbody>
</table>

The creation of the bid cycles made it possible not only to study the outcome of the subjects’ separate decisions but also to observe the dynamics in the entire decision process.
4.3. Procedure

4.3.1. General conditions

The same procedure was employed in the two experiments. In a written instruction, presented before the experiment took place, the subjects were informed about the number of rounds in the experiment. The instructions that were given to the participants before the auction experiments is presented in Appendix 1.

All subjects were notified that information about the price conditions would be distributed simultaneously among the bidders immediately before each separate auction round. The subjects were only allowed to bid for one item in each round. They were instructed to follow up their own financial position carefully on a cash flow chart that was distributed to them before the auction.

The auction experiments opened with a practice round. The auction rules were communicated to all participants several times during the auction experiments in order to ensure that the subjects were aware of this information and could take it into account in the bidding procedure. The subjects were informed that there was a risk-free alternative in each round, namely the lowest repurchase price in an auction round (MinRP; see below).

The bids were delivered directly to the experimenter. After each auction round the subjects received correct feedback regarding the auction result. They were informed about the range of the accepted bids and the repurchase price. The names of the winners were not disclosed to the participants.

In order to restrain the subjects from bidding too aggressively in the experiment they were warned that if their cash balance, real or imaginary, went below zero they would no longer be allowed to bid. However, they had to remain in the room until the end of the auction experiment.

4.3.2. Price conditions

As mentioned above, the experimenter wanted to establish the calculated expected value as a point of departure for future bidding. Before each round information about the two alternative repurchase prices was published together with the probabilities for their outcomes (p; 1-p) in a distinct manner so as to make the link between this price information, the items’ calculated expected value and its true value clear. The subjects were instructed how to calculate the expected value of the items. The price conditions in the separate rounds of the auction experiments are presented in Table 2.
Table 2.  
The 22 bid cycles in the BONUS and the TICKET auctions.

<table>
<thead>
<tr>
<th>Exercise round</th>
<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
<th>Round 4</th>
<th>Round 5</th>
<th>Round 6</th>
<th>Round 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>BONUS 1 (n=12)</td>
<td>Bfr</td>
<td>P</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
</tr>
<tr>
<td></td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td></td>
</tr>
<tr>
<td>BONUS 2 (n=34)</td>
<td>Bfr</td>
<td>P</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
</tr>
<tr>
<td></td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td></td>
</tr>
<tr>
<td>TICKET 1 (n=16)</td>
<td>Bfr</td>
<td>P</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td></td>
</tr>
<tr>
<td>TICKET 2 (n=15)</td>
<td>Bfr</td>
<td>P</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td>Aft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td></td>
</tr>
<tr>
<td>TICKET 3 (n=19)</td>
<td>Bfr</td>
<td>P</td>
<td>Aft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TICKET 4 (n=12)</td>
<td>Bfr</td>
<td>P</td>
<td>Aft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bfr</td>
<td>Bfr</td>
<td>Bfr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: A bid cycle includes a purchase round (P) which is the midpoint of the bid cycle, the round immediately preceding the purchase round (Bfr) and the round immediately succeeding this round (Aft).

The items were to be repurchased by the experimenter at either a high price (MaxRP) or a low price (MinRP). To reduce the risk of unintentional judgment errors the expected value of the auctioned item was set to be easily calculated:

\[ V_{exp} = p*\text{MaxRP} + (1-p)\text{MinRP} \]

After each auction round the price at which the item was to be repurchased by the experimenter was randomly drawn from an urn containing 100 tickets each marked with either the text 'HIGH' or 'LOW'. The proportion of the two texts in the urn represented the given probability distribution for the repurchase price in each auction round. The subjects were informed that there was a risk free bid alternative, namely the low repurchase price.

All winners paid a price for their purchased item that was identical to the first rejected bid in the current round. The first rejected bid was selected as the price for the item that all the winners paid since it will approximately represent the item’s market value. This bid would represent the price at which an individual should be indifferent to buying or not buying a
bond and the bonds would be sold to the bidders who most wanted to buy them. As mentioned above, this price system is commonly called 'uniform pricing'.

The winners' financial outcome of an auction round was calculated as the difference between the price paid for the item in the current round and the randomly drawn repurchase price.

4.3.3. Participation earnings

In the BONUS auctions the subjects received a participant fee of SEK 50.00. (SEK 50.00 ~ USD 8.00.) They were told that they could either use the fee as risk money in the auction experiment or just accept it as a participation fee.

In the TICKET auctions the subjects received no real money for participating in the auction experiment. They were instead told to bid with an imaginary starting balance of SEK 50.00.

4.4. Awards and bidding behavior

In the BONUS auction an award of SEK 500.00 was offered to the participant with the best end-of-series cash balance. If two or more subjects had the same final cash balances they had to share the bonus equally. In the TICKET auction two cinema tickets were offered to each of the participant(s) who had gained the best end-of-series imaginary cash balance. There is a weakness in the design of auction experiments in that no randomization between the two experiments with respect to the size of award was made.

4.5. Questionnaire regarding interest in arousal-stimulating activities

After the auction the subjects were asked to answer a set of questions regarding their interest in activities with high and low levels of arousal-stimulation or sensations to investigate whether a psychological factor, sensation seeking, could explain the variations in bidding behavior in auction experiments.

The subjects were presented with seven pairs of statements, based on a questionnaire developed by Zuckerman, Kolin, Price and Zoob (1964), each pair including one statement of low and one of high interest in arousal-stimulating activities (see Appendix 2). The subjects were asked to select the alternatives that best matched their own interests.

Two statements were related to financial risk taking and the other five statements were related to general arousal-stimulating activities. The statements were given the score (0) for the alternative representing low interest in arousal-stimulating activities and the score (1) for high interest in arousal-stimulating activities. The scale was from (0) to (7) where the score (0) is interpreted as low interest and score (7) indicates a high interest in arousal-stimulating activities.
The participants were also asked whether they would have agreed to participate in the auction experiments if they had been requested to risk their own money. A positive response to the question gave the subjects the score 1 and a negative response was given the score 0. The scores from this question were then added to the scores for interest in arousal-stimulating activities.

4.6. Statistical analysis

The bid cycle was one of the tools used for analyzing whether there were any patterns in the bidding behavior that could indicate that bidders were bidding strategically.

To make a distinction between the results from the analyses of the bid cycles and the analysis of the general bidding in the auction experiments and in the analysis of variations in interest in arousal-stimulating activities the subjects were classified both as (1) winners and others and (2) buyers and nonbuyers. The first classification was used when examining the 22 bid cycles in the experiment. ‘Winners’ were the subjects who bought an item in a bid cycle and the ‘others’ were the subjects who did not buy any item. By definition, the members of the two groups could vary from one round to another.

The second classification was used in the analysis of the general bidding behavior and also in the analysis of variations in interest in arousal-stimulating activities. The subjects who had bought items at any time in the auction experiments belonged to the ‘buyers’ group and the ‘nonbuyers’ were those who had bought no item at any time in the auction experiments.

4.7. Results

To make a comparison between the data in the different auction rounds possible all bids were transformed to a bid index. The base for this index was set at 100 which then represented the calculated expected value of the items in each round. All bids in an auction round were thereafter transformed in accordance with this index.

4.7.1. The profit and loss scheme

Table 3 presents the profit and loss scheme for the auction experiments. Fifteen auction rounds ended in a loss when the purchase price was compared with the randomly drawn repurchase price, eleven auction rounds ended in a profit and in two auction rounds the repurchase price was identical to the randomly drawn repurchase price.
Table 3.
Profit and loss scheme in the auction experiments.

<table>
<thead>
<tr>
<th></th>
<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
<th>Round 4</th>
<th>Round 5</th>
<th>Round 6</th>
<th>Round 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>BONUS 1 (n=12)</td>
<td>Profit</td>
<td>Profit</td>
<td>Profit</td>
<td>Profit</td>
<td>Loss</td>
<td>Loss</td>
<td>Loss</td>
</tr>
<tr>
<td>BONUS 2 (n=34)</td>
<td>Loss</td>
<td>Loss</td>
<td>P/L</td>
<td>Profi</td>
<td>Loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TICKET 1 (n=10)</td>
<td>Loss</td>
<td>Loss</td>
<td>Profit</td>
<td>Loss</td>
<td>Loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TICKET 2 (n=15)</td>
<td>Profit</td>
<td>Profit</td>
<td>P/L</td>
<td>Profi</td>
<td>Loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TICKET 3 (n=19)</td>
<td>Profit</td>
<td>Loss</td>
<td>Loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TICKET 4 (n=12)</td>
<td>Loss</td>
<td>Profit</td>
<td>Loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 shows the distribution of items among the buyers. Almost fifty percent of the subjects purchased one or more items in the auction experiments. A majority of the buyers, eighty percent, purchased two items or less. In fact, more than fifty percent of the buyers bought only one item.

Table 4.
Distribution of items among the buyers in the auction experiment.

<table>
<thead>
<tr>
<th>Number of items purchased</th>
<th>1 item</th>
<th>2 items</th>
<th>3 items</th>
<th>4 items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of buyers in each item purchase category (n=49)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>15</td>
<td>2</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 shows the number of award winners and the profit distribution among the award winners in each auction. The award winners with the best financial outcome (before the award) purchased more than one item in the auctions. Only in one of the auctions, TICKET 1, were the award winners nonbuyers. All award winners who purchased one or more items in the auctions made a net profit, imaginary or real, before the awards.
Table 5.
Profit distribution among the award winners in the auction experiment.

<table>
<thead>
<tr>
<th>Award winner(s)</th>
<th>BONUS 1 (n = 12)</th>
<th>BONUS 2 (n = 34)</th>
<th>TICKET 1 (n = 10)</th>
<th>TICKET 2 (n = 15)</th>
<th>TICKET 3 (n = 19)</th>
<th>TICKET 4 (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of award winners</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number of bonds purchased by the award winner(s)</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Profits (SEK) exl. of awards</td>
<td>76.70</td>
<td>59.90</td>
<td>50.00*</td>
<td>53.20*</td>
<td>52.00*</td>
<td>52.45*</td>
</tr>
</tbody>
</table>

* The profits were only imaginary in the TICKET auctions.

4.7.2. t-tests comparing bids in the BONUS and the TICKET auctions

Table 6 shows the results from the t-tests which compared the mean bids in the exercise rounds, the auction rounds, and the final rounds in BONUS and TICKET auctions. Since subject with two different professional background participated in the BONUS auction a complementary t-test was conducted to test whether the mean bid differed significantly in the two groups. The mean bid for professional money market dealers and the mean bid for the students in business administration are presented in Table 6.

Table 6.
t-tests comparing mean bids in exercise rounds, auction rounds, final rounds and end financial statements in BONUS and TICKET auctions.
The bidders in the two experiments submitted bids that were, on average, close to the calculated expected value of the auctioned items. With the exception of the bids in the exercise round in the BONUS auctions the bidders in both auction types were submitting bids that were on average less than 10% above the auctioned items’ calculated expected value (Table 6).

As is shown in Table 6 the mean bid in the BONUS auctions did not deviate significantly from the mean bid in the TICKET auctions. Neither did the subjects in the BONUS auctions who were offered a high bonus for best performance become more risk loving in the final round than the subjects in the TICKET auctions where only two cinema tickets were at stake. The size of the award to the best performers in the auction experiments did not have a significant effect on the general bidding behavior in the two auction types.

An interesting exception from the general bidding behavior was the bidding in the exercise round of the BONUS auctions. The mean bid in this auction round of the BONUS auctions was significant higher than that in the TICKET auctions. The high award seemingly stimulated the bidders in the BONUS auctions to bid in excess of the calculated expected value in order to win an item when they did not have to take a financial risk. Their first experience tended to have an instant effect on the bidders’ subsequent bidding in the auctions in that they submitted bids closer to the calculated expected value.

In Table 6 the means and standard deviations for the bids from the professional money market dealers (n=9) who participated in the BONUS auctions are presented within brackets. The t-tests showed that the professional bidders’ mean bid was not significantly different from the student bidders’ mean bid in any of the comparisons.

Table 6 also shows the end financial statements for the buyers and the nonbuyers. The net financial outcome of the auctions, real or imaginary, was less favorable to the buyers than to the nonbuyers. To consistently bid close to the calculated expected value allowed them to optimize their financial outcome from the auctions.

t-tests compared the bids in round preceding the purchase round, the bids in purchase round and the bids in the round succeeding the purchase round in the 22 bid cycles. No significant differences in bids submitted by the bidders in the BONUS auctions and by the bidders in the TICKET auctions were found (Table 7).

---

3 One bidder submitted a bid in the final round of one TICKET auction which was far in excess of the second highest submitted bid in the final round as well as in any other auction round. The data in this observation would have had a large influence on the results. To avoid biases in the analysis due to an outlier this data was excluded from the analysis.

4 The end financial statements are presented exclusive of the bonus.
Table 7.
Mean bids in the 22 bid cycles in BONUS and TICKET auctions: rounds preceding purchase round (BFR), purchase rounds (P) and rounds succeeding purchase round (AFT).

<table>
<thead>
<tr>
<th></th>
<th>BONUS AUCTION (n=46 subjects)</th>
<th>TICKET AUCTION (n=55 subjects)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>St dev</td>
</tr>
<tr>
<td>BFR</td>
<td>107</td>
<td>31</td>
</tr>
<tr>
<td>P</td>
<td>105</td>
<td>30</td>
</tr>
<tr>
<td>AFT</td>
<td>102</td>
<td>32</td>
</tr>
</tbody>
</table>

4.7.3. t-tests comparing bids from the ‘winners’ and the ‘others’ in BONUS and TICKET auctions

In this section t-tests comparing bids from the ‘winners’ and the ‘others’ in BONUS and TICKET auctions are presented (Tables 8a and b). As mentioned above the ‘winners’ are the bidders who ended up as purchasers in each separate bid cycle. The ‘others’ are those bidders who purchased no item in each separate bid cycle. The comparison was made over the 22 bid cycles.

When totaling the bids from the winners and the others in each of the 22 bid cycles, the analysis showed a significant different bidding behavior between those who ended up as purchasers of an item and those who did not buy an item in a bid cycle.

Both in the BONUS auction and in the TICKET auction the winners’ bids were significantly higher than those of the others. In both auction experiments the winners selected a strategy which allowed them to make a shift in the magnitude of the bids in an auction round where they seemingly aimed at becoming winners. Thereafter they returned to a more moderate bidding. The subjects who never bought an item were bidding closer to the calculated expected values during the entire auction.

The sets of cases in Tables 8a, 8b and 9 could be viewed as populations of decision events (Orasanu et al., 1993). Since all subsets of the auction experiments did not consist of the same number of auction rounds the number of cases could vary in the bid cycles. The decision events are then in turn part of the larger dynamic decision process, namely the subsets of the BONUS auction and the TICKET auction, respectively (Table 1).

Although the winners submitted bids that were on average in excess of the auctioned items’ calculated expected value their purchase price was not always in excess of the items’ randomly drawn repurchase price.

As was shown in Table 4 above the group of winners varied between auction rounds. The succeeding winners-to-be did not seem to take previous winners’ losses from winning an item in an auction round as a signal to avoid future overbidding. The bidding pattern
among the bidders who aimed at becoming winners was the same in rounds immediately after auction rounds in which winners had lost money and in rounds immediately after rounds in which the winning bidders had gained money from their purchase.

**Table 8.**
The bids of ‘winners’ and of ‘others’ in the 22 bid cycles: rounds preceding purchase rounds (BFR), purchase rounds (P) and rounds succeeding purchase rounds (AFT).

(A) THE BONUS AUCTIONS

<table>
<thead>
<tr>
<th></th>
<th>WINNERS (n=40 cases)</th>
<th>OTHERS (n=168 cases)</th>
<th>Mean</th>
<th>St dev</th>
<th>Mean</th>
<th>St dev</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFR</td>
<td>110</td>
<td>39</td>
<td>106</td>
<td>29</td>
<td>n.s.</td>
<td>103</td>
<td>25</td>
</tr>
<tr>
<td>P</td>
<td>138</td>
<td>36</td>
<td>97</td>
<td>23</td>
<td>&lt;0.01</td>
<td>103</td>
<td>25</td>
</tr>
<tr>
<td>AFT</td>
<td>101</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(B) THE TICKET AUCTIONS

<table>
<thead>
<tr>
<th></th>
<th>WINNERS (n=32 cases)</th>
<th>OTHERS (n=130 cases)</th>
<th>Mean</th>
<th>St dev</th>
<th>Mean</th>
<th>St dev</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFR</td>
<td>102</td>
<td>20</td>
<td>103</td>
<td>23</td>
<td>n.s.</td>
<td>105</td>
<td>29</td>
</tr>
<tr>
<td>P</td>
<td>138</td>
<td>28</td>
<td>99</td>
<td>23</td>
<td>&lt;0.01</td>
<td>105</td>
<td>29</td>
</tr>
<tr>
<td>AFT</td>
<td>107</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9 presents the shifts in bids from the purchase round to the round succeeding the purchase round for winners in the ‘profit’ rounds and the winners in the ‘loss’ rounds. On average, the winners lowered their bids after the auction round in which they had purchased an item. The winners who lost money decreased their bids more after their purchase than the winners who made a profit from their purchase but the difference in the shifts was nonsignificant between the two groups.

**Table 9.**
Shift in bids from purchase round to succeeding round in the 22 bid cycles: winners in profit rounds (WPROFIT) and winners in loss rounds (WLOSS).

<table>
<thead>
<tr>
<th>WPROFIT (n=30 cases)</th>
<th>WLOSS (n=35 cases)</th>
<th>Mean</th>
<th>St dev</th>
<th>Mean</th>
<th>St dev</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>-26</td>
<td>60</td>
<td>-38</td>
<td>48</td>
<td>n.s.</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>
t-tests were also conducted to investigate whether some bidders took advantage of the possibilities to increase their risk taking in the final round when the bidders no longer were to be excluded from the auctions for violating the auction rules. Table 10 shows a comparison between the shifts in the winners' mean bids from round preceding final round to final round in BONUS auction and in the TICKET auction. Finally, shows a comparison between the shifts in the winners' and the others mean bids from round preceding final round to final round in BONUS auction and in the TICKET auction, respectively. Table 11 shows the shift in bids from round preceding final round to final round for the winners and others in BONUS and TICKET auctions respectively.

**Table 10.**
Shift in bids from round preceding final round to final round: winners in BONUS and TICKET auctions.

<table>
<thead>
<tr>
<th>WINNERS IN BONUS AUCTION (n=46 subjects)</th>
<th>WINNERS IN TICKET AUCTION (n=55 subjects)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td><strong>St dev</strong></td>
</tr>
<tr>
<td>36</td>
<td>70</td>
</tr>
</tbody>
</table>

The winners in the BONUS auctions increased their bid in the same manner as winners-to-be had done in previous round while the winners in the TICKET auctions decreased their bids in the final round. The difference was nonsignificant.

The results shown in Tables 10 and 11 indicate that the size of the award may have increased the sensitivity to expected profit but in the sense that most subjects become less risk prone in the final round. As mentioned above, the winners-to-be in the TICKET auction and all others lowered their bids in comparison with their bids in rounds preceding the final round. The only increase in bids was found for the winners-to-be in the BONUS auctions. However, the magnitude of this increase was in line with that among winners-to-be in earlier rounds.

**Table 11.**
Shift in bids from round preceding final round to final round: winners and others in BONUS and TICKET auctions respectively.

<table>
<thead>
<tr>
<th></th>
<th>WINNERS</th>
<th>OTHERS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BONUS AUCTION</strong></td>
<td>Mean</td>
<td>St dev</td>
</tr>
<tr>
<td></td>
<td>36 (n=7)</td>
<td>70</td>
</tr>
<tr>
<td><strong>TICKET AUCTION</strong></td>
<td>-5 (n=9)</td>
<td>43</td>
</tr>
</tbody>
</table>
In summary, the results in this section indicate that the utility of winning was not only decreased after winners had lost money as suggested by Cox et al (1988). The winning experience per se tended to decrease the attraction of becoming a winners, at least temporarily.

4.7.4. t-tests comparing bidding behavior in nonbuyers' and buyers' groups in BONUS and TICKET auctions

More than 50 percent of the participants, in all 52 subjects, remained nonbuyers in the auction experiments (Table 12).

*Table 12.*
Distribution of buyers and nonbuyers in the BONUS and the TICKET auctions respectively.

<table>
<thead>
<tr>
<th></th>
<th>Nonbuyers (n=52 subjects)</th>
<th>Buyers (n=49 subjects)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BONUS AUCTIONS</strong></td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td><strong>TICKET AUCTIONS</strong></td>
<td>31</td>
<td>24</td>
</tr>
</tbody>
</table>

The nonbuyers in the BONUS auctions and the TICKET auctions were bidding significantly more carefully than the buyers (Table 13). The disposition to avoid risks was most clearly manifested among the nonbuyers in the BONUS auctions. These nonbuyers might very well have noticed what financial effects aggressive bidding could have on the financial outcome in an auction round.

The group of nonbuyers maintained their strategy to bidding closer to the calculated expected values during the entire auction while the buyers made a shift in the magnitude of the bids in the auction rounds where they seemingly aimed at becoming winners, as was shown above in Table 8.

The analysis in Table 13, comparing the bids of the nonbuyers with the bids of the buyers, indicates that the nonbuyers in the auction experiments demonstrated a bidding behavior that contrasted with that identified for the buyers. The nonbuyers revealed a bidding strategy that seemed to be in accordance with that suggested in auction theory. They remained conservative in their bidding during the auction.

The nonbuyers in the BONUS auctions displayed the lowest mean bid. They became even more risk averse in their bidding in the final round. A possible explanation to their risk aversive bidding is that the nonbuyers bid more carefully in order to increase their chances of winning the bonus and/or keep their starting balance of SEK 50.00 intact.
Table 13.
t-tests comparing bids in exercise rounds, auction rounds and final rounds in 'nonbuyers' and 'buyers' groups.

<table>
<thead>
<tr>
<th></th>
<th>Nonbuyers (n=52 subjects)</th>
<th>Buyers (n=49 subjects)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>St dev</td>
<td>Mean</td>
</tr>
<tr>
<td><strong>EXERCISE ROUNDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
<td>25</td>
<td>110</td>
</tr>
<tr>
<td>BONUS auctions</td>
<td>109</td>
<td>24</td>
<td>120</td>
</tr>
<tr>
<td>TICKET auctions</td>
<td>100</td>
<td>25</td>
<td>98</td>
</tr>
<tr>
<td><strong>AUCTION ROUNDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>99</td>
<td>15</td>
<td>114</td>
</tr>
<tr>
<td>BONUS auctions</td>
<td>95</td>
<td>12</td>
<td>113</td>
</tr>
<tr>
<td>TICKET auctions</td>
<td>101</td>
<td>16</td>
<td>116</td>
</tr>
<tr>
<td><strong>FINAL ROUNDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>24</td>
<td>117</td>
</tr>
<tr>
<td>BONUS auctions</td>
<td>88</td>
<td>22</td>
<td>118</td>
</tr>
<tr>
<td>TICKET auctions</td>
<td>99</td>
<td>25</td>
<td>116</td>
</tr>
</tbody>
</table>

As mentioned above, the subjects in the TICKET auctions received no real money for participating in the auction experiments.

The buyers' bids were, on average, notably more aggressive. Their mean bids were significantly higher than the nonbuyers' bids in all auction rounds, with the exception of the exercise round.

4.7.5. Attitudes to financial risk-taking and arousal-stimulating activities among nonbuyers and buyers

Although the result was not statistically significant, there was a tendency among the buyers to express a higher interest in financial risk taking and arousal-stimulating activities in comparison with the nonbuyers in the auction experiments\(^5\). The result is presented in Table 14.

---

\(^5\) The additional t-tests showed no significant differences between the means for interest in financial risk-taking and arousal-stimulating activities in the student group and the group of professional actors in the money market.
Table 14.  
t-tests comparing interest in financial risk-taking and arousal-stimulating activities among 'nonbuyers' and 'buyers'.  

<table>
<thead>
<tr>
<th>NONBUYERS (n=52)</th>
<th>BUYERS (n=49)</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean 4.8</td>
<td>Mean 5.2</td>
<td>1.6 n.s.</td>
</tr>
<tr>
<td>St dev 1.8</td>
<td>St dev 1.6</td>
<td></td>
</tr>
</tbody>
</table>

5. DISCUSSION AND CONCLUSIONS

The main purpose was to investigate whether the bidders were able to optimize their bids so as to gain as much money as possible from the laboratory auctions or whether subjects lost money from their purchases of the auctioned items. The results in the current study showed that due to the competitive auction context the bidders who intended to buy an item consistently had to submit bids in excess of the calculated expected value. However, the purchase price was not always in excess of the items' randomly drawn repurchase price.

The analyses present evidence that both the calculated expected value of the items, preferences and context influenced the bidding behavior. The calculated expected value tended to be employed as the subjects' initial reference point. The mean bids in both auction types were close to the calculated expected value.

It was also investigated whether the subject were displaying a consistent bidding pattern in the auctions this could be interpreted as an effect of the bidders' strategic thinking in order to reach a specific goal. Two main bidding strategies were distinguished. The subject who purchased no item, the nonbuyers, accommodated early to the strategy of bidding close to the items' calculated expected values. They tended to be able to apply a long-run perspective (Wedell et al, 1990), as suggested in the expected utility theory, on their short-run decisions. The assumption in expected utility theory is that the probability for a gambling outcome occurring in a near future should be the same as the probability for that gambling outcome occurring if repeated infinitely.

The nonbuyers' bidding was also in agreement with the suggestions in auction theory, namely that when bidding becomes more aggressive a rational bidder should lower his/her bid in order to avoid overbidding.

The second strategy was used by the subjects who purchased one or more items in the auction experiments, the buyers. They tended to anchor their bidding in a desire to win one or more items in the auction and therefore they allowed themselves some temporary 'controlled' gambling. The analysis of the bid cycles revealed that the potential buyers made a shift in their bids in the auction rounds where they aimed at becoming a winner. Their bids in their winning auction round were significantly higher than the bids from the nonbuyers.
However, the buyers' bids did not deviate from those submitted by other bidders in the rounds before and after their 'winning' rounds. After their winning experience most bidders conformed to the general bidding behavior and submitted bids in line with the calculated expected value of the auctioned items. The drop in the bids was larger, but not significantly larger, for winners who lost money from their purchase in comparison with winners who made a profit from their purchase. This result indicates that the utility of winning not only decreased after winners had lost money as suggested by Cox et al (1988). The winning experience per se tended to decrease the attraction of becoming a winners, at least temporarily. These results do not indicate any strong anchoring effect on their bidding.

The bidders who aimed at becoming winners in subsequent rounds did not seem to take previous winners' losses from winning an item in an auction round as a signal to avoid future overbidding. The potential buyers increased their bids in the same way in rounds immediately after auction rounds in which the winners had lost money as in rounds immediately after rounds in which the winning bidders had gained money from their purchase.

No bidder was excluded from further bidding in the auctions due to violation of the bidding rules. It therefore appears that the buyers also tended to consider the 'opportunity cost' for excessive bidding. Yet it is clear that the buyers' bidding strategy provided most of them a lower profit than had they submitted bids in line with the items' calculated values. However, all award winners who purchased one or more items in the auctions made a financial net profit, imaginary or real, before the awards.

It has earlier been suggested (Hansen et al, 1991) that when subjects participate in an auction experiment under limited financial responsibilities profit maximization and a 'long-run perspective' (Wedell et al, 1990) may seem less relevant when selecting a bidding strategies. Keeping in mind that the auction rules limited their responsibility for the financial outcome of their bidding the buyers' bidding behavior could be interpreted as contextually rational. Their strategy to bid in excess of the calculated expected value when aiming at winning an item could be perceived as an accommodation to the bidding among 'similar others' (Weick, 1995) the 'gambling society' and to the prevailing auction 'market' conditions.

It was also investigated whether the size of awards had an impact on bidding behavior and whether bidders who were offered a higher award for best performance in terms of money would bid differently than the bidders who were promised a small award for best performance. Although the results from the comparisons between the two award types are less reliable due to lack of randomization between the two experiments, they indicate that the size of the award did not significantly affect the general bidding. Besides the award tended to increase the sensitivity to a potential profit in that most subjects become less risk prone in the final round. The potential buyers in the TICKET auction and all others lowered their bids in the final rounds in comparison with the rounds preceding the final round. The only increase in bids was found for the potential buyers in the BONUS
auctions. However, the magnitude of this increase was in line with that among potential buyers in earlier rounds.

It was suggested that the subjects who found pleasure in arousal-stimulating activities would assign a higher value to winning an auctioned item than other bidders. The results from the t-test showed that the buyers tended to express a higher interest in financial risk taking and arousal-stimulating activities than the nonbuyers in the auction experiments.

In summary, in economic terms the buyers used a bidding strategy that provided them, as a group, a lower profit than that of the nonbuyers. Yet it seems reasonable to conclude that the subjects were bidding in accordance with their perception of the auction context and with their preferences. Overbidding in these auctions therefore tended to primarily be an effect of the bidders' selected strategies rather than an effect of a bias due to misinterpretation of the auction rules.

As mentioned above, researchers have often reported that business corporations have paid excessive prices for the auctioned items (e.g., Roll, 1986, and Thaler, 1992). In business auctions a bidding strategy that provides a bidder with a loss, or at least a lower profit, due to excessive bidding might have more serious consequences for the winning bidders than in an auction experiment.

An important issue for future research is therefore to investigate more deeply whether overbidding in real-world auctions is a cognitive bias due to misinterpretation of various auction rules and statistical rules or whether overbidding occurs because bidders are not capable of adopting a long-term perspective to a single auction event (Wedell et al, 1990).

Finally, an increased understanding of the causes for overbidding might be achieved by examining whether overbidding occurs because bidders in business auctions let the prevailing norms for risk taking in their society guide them in their price estimation of an auctioned item rather than an evaluation made by for instance the stock market. For example, MacCrimmon and Wehrung (1986) found that executives in Canada and in the US perceived the social norms for risk taking as crucial for their business risk attitude.

As mentioned above, Bruner (1990) claimed that adaptation to similar others in their environment is a crucial element for people's framing and future decisions. This claim is a challenge to meet in future research in economic psychology.

The auction market is a huge market for trading commodities. It is therefore suggested that future research on bidding in auctions should integrate the findings in behavioral decision making research with proposals in auction theory in order to better understand the causes for overbidding in real world auctions. Another important issue for future research is to search for cues in the environment and in the mind of the decision maker that activate and deactivate a risk prone behavior. Also a more comprehensive scale to measure sensation-seeking among risk managers should be developed in order to identify potentials for excessive risk taking in the financial market.
6. REFERENCES


APPENDIX 1. Instructions given to the participants before the auction experiment

GENERAL CONDITIONS:

To the BONUS groups:
* You will be paid SEK 50 for participating in the experiment.
  You can use this money as risk money in the auction experiment.
* You can win or lose money, but at most lose your fee. After the auction a bonus of
  SEK 500 will be paid to the participant(s) with the best end-of-series cash balance.

To the TICKET groups:
* You will act as if you are paid SEK 50 for participating in the experiment.
  You can use this imaginary money as risk money in the auction experiment.
* After the auction two cinema tickets will be paid to the participant(s) with the best end-
  of-series cash balance.

To all participants:
* The auction is divided into X separate rounds (exclusive of a practice round).
* You are only allowed to buy 1 (one) bond in each auction round.
* We will give you precise information about the conditions for buying and selling the
  bonds.
* The conditions will vary in each round. Consider each auction round as a separate
  market.
* The bonds for sale will be repurchased by the experimenter. You will be informed
  about the repurchasing conditions well in time BEFORE you place your bid.
* The repurchase prices will vary in the separate rounds. There will ALWAYS be a risk
  free alternative. Therefore you can decide whether you want to be active or passive in
  the bidding. In each round you will be informed about the risk free alternative.
* The bids should be delivered in writing and anonymously. You are asked to write down
  each bid on a special form.
* After the auction we will ask you to answer some questions.
* You are allowed to participate in the auction as long as you have any money left. You
  must run your own account over bond purchases and sales on a special form. You must
  check your own cash position after each round.
* If you run out of money ( = your balance goes below zero) you must stop bidding.
  You must continue to fill in your code on the remaining forms but omit the bids. To be
  able to accomplish the experiment we must ask you to remain in the room until the end
  of the experiment.
* We will start the auction experiment by running a practice round so that you will have a
  chance to understand the rules and procedures in the auction. We beg you to be silent
  and not to display your reactions during the auction experiment. Collaboration is not
  allowed under any circumstances.
* We thank you for participating in this experiment and wish you luck.

The experimenters.
APPENDIX 2. Statements in the questionnaire on attitudes to financial risk taking and arousal-stimulating activities

The statements in the questionnaire were:

1.a: It is good to switch jobs to avoid getting stuck in the same old routine
    b: You should find a job that gives you contentment and then stay with it.

2.a: I dislike investments which vary in value.
    b: Trying to match the price movements in the financial market seems to add flavor to life.

3.a: I get annoyed when people say and do things only to startle others or to create sensations.
    b: If you can foresee almost everything a person does or says, he or she is a bore.

4.a. A sensible person avoids risky activities.
    b: I like to do new things from time to time just to have a new experience even if danger is involved.

5.a: A piece of art attracts me only if I am challenged or confronted by it.
    b: I prefer a picture that expresses peace and harmony.

6.a: I find no attraction in taking risks with money.
    b: I like to take risks with money.

7.a: I appreciate when something unexpected happens.
    b: I do not like unexpected events.
WHO IS CURSED IN A TREASURY SECURITIES AUCTION?
AN EMPIRICAL ANALYSIS OF THE SWEDISH 6-MONTH TREASURY BILL AUCTIONS FROM 1991 TO 1994
This study investigated whether information is perfectly distributed in the Swedish 6-month Treasury bill auctions or whether any private auction information systematically affected the price system and thereby the efficiency in the distribution of the issued securities in the auction market. It was furthermore investigated whether the prevailing auction rules generated strategic trading among the bidders. The study covers a period from January, 1991, to June, 1994. With a time series technique, the auction variables were each divided into an anticipated and an unanticipated component from the variable’s past history as derived from an established time series model. The anticipated component shows the publicly known information about the value of a security while the unanticipated component shows information that is new to the market for instance information about recent deals and liquidity needs. Regression analyses showed that the winning bidders succeeded in purchasing the Treasury bills in the auctions at prices that were, on average, lower than that of an identical bill in the secondary market. Furthermore, results from the regressions indicate that some privileged bidders traded strategically in the auction market by withholding private auction information and utilized their information so as to gain a more advantageous position in the auctions. The stable bidding environment provided the bidders in the Swedish 6-month Treasury bill auctions regular and correct feedback. This in turn may explain the bidders’ efficiency in selecting and implementing their bidding strategies and to act rationally and adaptively. In summary, signs of price manipulation indicates that the Swedish 6-month Treasury bill auctions are not fully efficient. It is therefore suggested that it should be further analyzed whether alternative auction rules, in accordance with new findings in research on auction behavior, could be implemented in the Swedish Treasury bill auctions in order to reduce the opportunities for price manipulations. Thereby it may be possible that auction market efficiency will obtain further improvements.

Key words: Auctions, information asymmetry, price manipulation, learning and feedback
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**APPENDIX.** Results from the time series analysis on auction variables
WHO IS CURSED IN A TREASURY SECURITIES AUCTION? - AN EMPIRICAL ANALYSIS OF SWEDISH 6-MONTH TREASURY BILL AUCTIONS FROM 1991 TO 1994

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April, 1996

1. INTRODUCTION

In many studies on real-world auctions researchers have reported that business corporations pay excessive prices for auctioned items (Roll, 1986; Thaler, 1992). If the winners overestimate the auctioned item and they stand the risk to lose money or at least to decrease their profit they are said to experience the winner's curse. An interesting contrast to these findings is the observation that bidders in Treasury securities auctions often have succeeded in purchasing the securities at prices below their 'true' value (Umlauf, 1990; Cammack, 1991; Bikhandani & Huang, 1993; Simon, 1994). The Treasury securities' true value is assumed to be the price paid for the security in the post-auction secondary market.

The main purpose of this study was to investigate whether the bidders were able to adjust their bids to the auction rules and the auction market conditions so as to avoid overbidding. The study focuses on bidding behavior in a field setting, namely in the Swedish Treasury bill auctions. It compares prices for the 6-month Treasury bill auctions with prices for an identical bill in the secondary market from 1991 to 1994. To be able to obtain an illustration of the information distribution process in as large a part of the auction market as possible the current study incorporated price adjustments in both the pre-auction and the post-auction market. Thus the auction market was defined as consisting of the pre-auction secondary market (often referred to as the when-issued market in studies on US Treasury securities auctions), the auction and the post-auction secondary market.

Earlier studies on government securities auctions have analyzed only parts of the auction market (Cammack, 1991; Wachtel & Young, 1990; Simon, 1994). For instance, Cammack (1991) analyzed how auction prices were related to the post-auction secondary prices for 3-month US Treasury bills for the 1973-84 period after the auction information had been made public. However, Cammack did not incorporate the pre-auction market in her study. This limitation in her analysis make some of her conclusions less reliable. If the pre-auction secondary prices are excluded from the analysis of the information distribution in a Treasury securities auction market it is less feasible to distinguish whether relevant auction information is in fact recognized by the public before they submitted their bids in the auctions or if
information was being withheld from the public by the better informed bidders until
the auction has started.

2. THEORETICAL FOUNDATIONS

This section first presents a brief description of a government securities auction
(section 2.1). Thereafter the theoretical foundation for the proposals in the current
study is presented.

The major risk in Treasury securities auctions is the risk of overbidding. The most
frequent explanation of overbidding in common value auctions is that bidders are
unable to adjust their bids properly to the prevailing auction rules and auction
conditions, such as information asymmetry among the bidders (Kagel & Levin, 1986)
and the number of bidders participating in the auctions (Bazerman & Samuelson,
1983).

A second risk in these auctions is the quantity risk. If the issued volume (i.e. the
volume for sale in the auction) is large relative to the current market liquidity and
there is uncertainty about the demand for the issued securities the winning bidders
may be locked in with an unwanted package of bills in their money market portfolios.
However, the quantity risk is to some extent reduced since the bidders in the Swedish
Treasury bill auctions, unlike in most other business auctions, can purchase an
identical Treasury bill in the secondary market at any time during the auction day.

The issue of information asymmetry in common value auctions is discussed in section
2.2. The information of the number of bidders who participate in the auctions is
important for the price estimation. The effects of auction price on variations in the
number of bidders that participate in auctions is discussed in sections 2.3. In section
2.4 it is discussed whether the auction rules facilitate for bidders to trade strategically
in order to purchase the securities at a discount in the auctions. In section 2.5 the
issue of learning, feedback and bidding in Treasury securities auctions is discussed.

2.1. Brief description of a government securities auction

Government securities auctions are often designed as multiple unit, common value,
sealed bid auctions (McAfee & McMillan, 1987). In a common value auction the
auctioned item has no personal value to the bidders as it is assumed to have in private
value auctions. If an auction is primarily a common value auction, the technical
valuation of the item's future value is more important for the outcome than in a
private value auction. To avoid overbidding in a private value auction, bidders must
focus mainly on the 'strategic forces' that are inherent in the auction procedure before
submitting their bids (Kagel & Levin, 1993). However, most real-world auctions
seem to include both private value and common value components. For example, the
Treasury bill auctions hold private value elements for those bidders who aim at buying
the securities to keep them until their maturity date.
In a sealed bid auction the bids are presented in writing. When more than one object is sold at the same auction, the auction is called a multiple unit auction. The winning bidders may pay a price for the items that is either uniform, which means that all winning bidders pay the same price for the item, or discriminatory. In the Swedish Treasury bill auctions the price rule is discriminatory, meaning that bidders can submit bids at various prices for various units of the auctioned volume.

2.2. **Information asymmetry in common value auctions**

A general finding on major security markets is that specialists have monopolistic access to private information as a result of the market making function (Fama, 1991). Due to the dealer authorization in the Swedish Treasury bill auctions new information about the market sentiment and the investors' interest in the auction can be expected to be first accumulated among one or more authorized dealers before others will have access to the information. The authorizing system in these auctions allows only a limited group of authorized dealers are appointed as distributors of bids from all other investors to the seller. Information is said to be asymmetric if the precision of the signals is observed irregularly among the participants in for instance an auction (Hendricks & Porter, 1988). If only one participant is better informed than others, then the information is asymmetrically distributed.

The theoretical common value auction models (the CVA-models) are based on the assumption that bidders have different sets of information about the auctioned item's 'true' value. Besides, the bidders are assumed to know that the information they have access to is not the complete set of relevant auction information. Others have additional information that is relevant for the estimation of the item and therefore also relevant for the outcome of the auction. Each bidder must therefore lower his/her bid to adjust for the missing information. When bidders fail to include in their price estimation some kind of correction due to information asymmetry they might end up submitting bids that are higher than the item's true value.

Another assumption in the CVA-models is that the bidders are risk neutral and that they aim at maximizing their profit. Furthermore, the CVA-models assumes that the auctioned item has the same value to all bidders and that the bidders buy the items with the intention of selling them after the auction at a price that is established by the post-auction market.

The bid for bidder \(_i\), \(\text{BID}_i\), can be modeled as a function of the technical value of the security which is based on the current market information, \(V_{\text{exp}}\). The auctioned item's future value is also affected by strategic considerations regarding the price effect from the item evaluation made by other bidders. Each bidder must also make an estimation of how other bids will affect the price, \(V_{\text{unexp}}\). The bid function could be expressed as follows:

\[
\text{BID}_i = f(V_{\text{exp}}, V_{\text{unexp}})
\]
Each bidder calculates the probability that his/her bid is the highest submitted bid in
the auction. The bidder has to consider that to increase the probability of winning the
auction, the bid must be raised but then the possibility that the price paid for the
security will be higher than the price in the post-auction market also increases. On the
other hand, to avoid the risk of paying too much for the item, the bidder can lower
the bid but at the expense of decreasing the probability of winning the auction.

It has been suggested in imperfect information models that a securities market can be
efficient although the prices do not reveal all private information. For instance, in
their model of competitive equilibrium, Grossman and Stiglitz (1980) conclude that
there is a fundamental conflict between the efficiency with which markets spread
information and the incentives to acquire information. Since the prices do not reveal
all the private information, the securities prices should be adjusted so that those who
spend resources to obtaining information in order to ensure efficient market prices
will receive compensation. They also suggested that the cost for gathering information
will have an impact on the demand for auction information so that when the cost
increases the percentage of actors who are willing to pay for being informed will drop. But also, when the number of informed traders increases the price system
becomes more informative and the need for the less informed to obtain relevant price
information decreases.

Information asymmetry can yield inefficiency in for example profit distribution among
the bidders in the Treasury securities auctions also when bidders on average succeed in
paying a price for the auctioned item in the auctions that is lower than its true value.
Cammack (1991) suggested that information was asymmetrically distributed in the US
3-month Treasury bill market although the results showed that the mean auction price
for the 3-month Treasury bills were on average lower than the post-auction secondary
marker price for an identical bill on auction day. She suggested that the secondary
market and the auction aggregated the private auction information differently since the
dealers in the US secondary market reacted upon the published auction result as if it
was new information. She concluded that this result indicated that new auction
information was not fully revealed in the secondary market prices until the auction
information was revealed by the seller.

To reduce the risk for overbidding the bidders can choose to trade private auction
information with other bidders in exchange of private information from other bidders.
A consequence of their trading would then be that the price system would convey
their private information also to the uninformed bidders already in the pre-auction
secondary market. Price efficiency will increase because then the less informed
bidders will also be able to adjust their bids to the new auction information.

Alternatively, the better informed bidders may choose to keep information secret from
the public until the auction procedure has started and instead incorporate the
information in their own bids. By withholding their private information from the
public the bidders may reduce their chances of being in the far end of the bid-price
distribution and becoming prey to the winner's curse. The second strategy is an
example of collusive market behavior (McAfee & McMillan, 1992). Bidders who neither know that information is missing nor that other bidders hold private information may still submit bids. Then the risk of overbidding among those bidders is increased. Alternatively, if the less informed bidders know that other bidders hold private information, they might choose not to bid at all. In both cases the market efficiency will be harmed.

As rational agents in the Treasury securities markets the authorized dealers can be expected to strive for the highest possible profit at the lowest possible risk. They know that they can purchase a Treasury security that is identical to the one issued in the secondary market before, during and after the auction on auction day. Thus they can be expected to search for compensation for any risks and information costs inherent in the auctions. For example, if the cost for reducing uncertainty is high relative to the cost for trading in the secondary market, bidders may choose to buy their bills in the latter market to avoid the risk of becoming victims of any prices manipulation in the Swedish Treasury bill auctions. The Treasury securities auctions will be less liquid and thereby less price efficient.

2.3. The size of bidders' group and auction market behavior

The number of bidders competing in an auction has been found to affect the estimation of the value of an item (Bazerman & Samuelson, 1983). The larger the group of bidders the more conflicting directions among the bids. In their studies the authors found that most bidders fail to understand that they have to be more conservative to avoid overbidding when bidding becomes more volatile.

When information about the number of bidders competing in the auctions is known, the price estimation is facilitated. In their finite bidders' assumption French and McCormick (1984) considered how a predictable number of bidders affects an auction. They showed that in first-price common value auctions where the number of bidders is finite the rational bidders will most likely exploit the conditions and submit bids that are below what they believe to be the true value of the bill. The bidders then know that the probability that there will be a bid above their own decreases when the number of bidders is finite. French and McCormick stressed that there is no guaranty that the winners will profit from this kind of bidding behavior when the number of bidders is finite since there is always an information cost to consider.

2.4. The price rule and auction market behavior

As mentioned above, the Swedish Treasury bill auctions are discriminatory price auctions. The discriminatory price rule allows bidders to submit bids at various prices for the different units of the auctioned volume. The winning bidders then pay the prices of their own accepted bids. The highest bidder is first secured his/her demanded volume of bills. The remaining volume is then sold to the winning bidders at decreasing prices until the quantity has been fully allocated. If more than one bid is
submitted at the lowest price the remaining volume of bills is allocated proportionally among those who submitted bids at this price.

Since the winning bidders will be paying different prices for the issued securities, some may be paying a price that is higher than the post-auction prices. Therefore, the demand becomes very price-sensitive. Chari and Weber (1992) suggested that the need for gathering new information before the auction is increased in auctions with discriminatory price rule since this price rule heightens uncertainty regarding the auction price.

Due to the higher risk of overbidding under the discriminatory price rule than under for instance the uniform price rule bidders may be more tempted to participate in collusion and price manipulation (McAfee & McMillan, 1992).

Milgrom (1989) argued that sellers probably will do better to adopt an auction in which the price paid by each bidder is linked to the bids made by others such as the uniform price, second price auction or the average accepted bid instead of using the present discriminatory auction rule.

In auctions with a uniform price rule the securities are awarded to all winners at one single price. This price is linked to the bids submitted by the other bidders, namely the highest rejected bids. Therefore, the risk of overbidding is lower and thus the need to keep information secret before the auction is decreased. When the risk for collusion is reduced the less informed bidders dare to bid more aggressively to obtain a certain volume without running the risk of becoming victims of the winner’s curse.

Milgrom’s proposal was tested by Umlauf (1990) and Nyborg et al (1994). Umlauf found that the seller’s revenue from the Mexican Treasury securities auctions was increased when the price rule was switched from discriminatory pricing to uniform pricing.

In the US Treasury securities auctions both discriminatory price rule and uniform price rule are used. Nyborg et al studied the effects on auction prices in the US when-issued market and in auctions using the two different price rules. They found evidence that uniform pricing rendered lower ‘markups’ in the auctions than in discriminatory price auctions. A markup is the gap between the pre- or post-auction secondary market price and the quantity-weighted, mean auction price. Nyborg et al also found that the when-issued rates were initially more volatile ahead of a uniform price auction but decreased successively and faded out after the auction result had been released. They interpreted this price behavior as evidence that bidders were more willing to share their information in the when-issued market in exchange for information gathered by other bidders under the uniform price rule in order to avoid overbidding in the auctions.
2.5. Learning and feedback

It has been suggested that a major cause of overbidding is that many business auctions, such as book publishing right auctions or auctions for a business firm, are rarely repeated. Therefore the opportunities to learn from earlier events and modify behavior in order to bid more rationally in a future auction are few or even nonexistent (Roll, 1986). In his studies on corporate takeovers Roll found empirical evidence that the companies who were bidding for another firm were frequently willing to pay a price that was higher than what the stock market considered to be the true value.

Goldberg (1968) identified three important requirements for efficient learning. First, he claimed that feedback is necessary for efficient learning. Secondly, decision makers are supported in their decisions if they are given the opportunity to repeatedly reflect on the relation between their expectations that an outcome will occur and the actual outcome. This is seldom possible in most real-world decision situations since events are rarely repeated. A third requirement for efficient learning and improved decision making is that decision makers should be given the opportunity to keep records of their predictions and the outcomes. Moreover, the bidders' price estimation can be associated with a special context as well as a special behavioral pattern. All these requirements are possible to obtain in the Swedish Treasury bill auction market.

All the above factors have also been found to facilitate a rational and adaptive decision making (Hammond, Summers & Deane, 1973; Estes, 1976; Hogarth, 1987; Arkes, Christensen, Lai & Blumer, 1987). For instance, meteorologists (Estes, 1976; Murphy & Brown, 1985; Yates & Curley, 1985) and odds dealers (Hoerl & Fallin, 1974) have proven to be better decision makers within their professional field than naive subjects in laboratory settings.

In comparison with most other business auctions, the Treasury securities auctions are stable institutions. The auction rules are rarely altered and the structure of the bidders' task in the auctions is well defined. Besides, as an effect of the authorizing system this group of dealers is quite stable over time.

Furthermore, an interesting finding in research on decision making is that people in general tend to justify incorrect decisions by enhancing their positive aspects and searching for features in the alternatives that were ruled out in order to make them appear more negative (Festinger, 1957, Weick, 1995). However, in the securities market decisions must be made quickly and time is a scarce resource. It may be costly to consume time in justifying incorrect decisions. To succeed in the task of making fast decisions rational actors can be expected to be more inclined to accept an incorrect decision and move on to the next decision rather than to make efforts to justify it.

By using simpler rules the bidders can save cognitive efforts while keeping the accuracy in the decisions fairly stable. Payne, Bettman & Johnson (1993) argued that
although the use of decision heuristics must be contingent of the environment in which the decision is to be made some decision heuristics fairly well approximate the accuracy of normative decision rules (p.99). The auction market is a decision environment where decision heuristics may be useful since the decision tasks are fairly simple and the time period for making a decision is brief (Hammond, Summers & Deane, 1973). Besides, the secondary market is open all day long. Therefore the bidders in the Swedish Treasury bill auctions could adjust their trading portfolios in this market at any time during the auction procedure if they learned that new auction market information would render a different price for the auctioned securities than that represented in their submitted bids.

In summary, this section described the risks inherent in Swedish Treasury bill auctions. In these auctions there is a risk for overbidding due to information asymmetry and there is a quantity risk in since the winning bidders may be locked in with an unwanted package of bills in their money market portfolios. However, these risk are to some extent offset for instance by the fact that bidders achieve training on accurate decision making. The bidders are not only consistently presented with correct feedback on their decisions. They are given several opportunities to learn and adjust their behavior in the secondary market. An incorrect decision can be corrected both by themselves and by other better informed actors in the market who might trade on their 'mistakes'.

3. THE SWEDISH TREASURY BILL AUCTIONS

3.1. General description

The Swedish Treasury bill auction is part of the Treasury securities market. This market comprises a primary and a secondary market. In the primary market, or the Treasury bill auctions, securities are issued by the seller, the Debt Office, regularly through a limited group of authorized dealers while the Treasury bills are sold continuously ‘over the counter’ in the secondary market. The Debt Office is authorized by the Treasury as the seller of Treasury bills in the primary market, i.e. the Treasury securities auctions. Its major goal is to manage and finance the government debt at the lowest possible cost. In order to obtain this goal it is in the seller’s interest to facilitate for as many a bidder as possible to participate in the auction.

Figure 1 presents a schematic description of a Swedish Treasury bill auction.
Figure 1.
Schematic description of a Swedish Treasury bill auction. (The open arrows show the direction of information while the filled arrows identify the direction of an action and/or a settlement.)
Due to the current authorization system in the Swedish Treasury bill auctions, the Debt Office cannot decide for certain that the actions taken by the authorized dealers before the auction were optimal or not with respect to the seller's interest and given the available information. The relationship between the Debt Office and the authorized dealers shows similarities to that of a principal-agent relationship. In a principal-agent relation, two main problems can occur in a principal-agent relation (Strong and Waterson, 1987, p.23):

1. **THE MORAL-HAZARD PROBLEM**: moral hazard arises when the principle and agent share the same information up to the point at which the agent selects an action, but thereafter the principal is only able to observe the outcome or payoff.

2. **THE ADVERSE-SELECTION PROBLEM**: the agent, but not the principal, has access to information which is relevant to the action and can make use of this information in selecting the action. The principal cannot decide whether the taken action was optimal given the available information. The agent can also have asymmetric information before the contract has been agreed.

To avoid the disadvantage of asymmetric information and reduce uncertainty in the Swedish Treasury auctions, it is therefore in the seller's interest to publish all available auction information before the auctions (Milgrom, 1989; McAfee & McMillan, 1987).

Finally, an important characteristic of the Swedish Treasury bill is that one single bidder is allowed to purchase the entire volume that is issued. In for instance US Treasury bill auctions, there is a restriction for how large a share of an issued volume that can be purchased by one single bidder. If a small group of bidders can control the supply of new bills and the information distribution, the potential scope for collusion is considerable (McAfee and McMillan, 1992).

Trading in Treasury securities is built upon trust between actors in the money market. Therefore, if the occurrence of collusive behavior in the auction market was revealed to the public, it may cause severe damages for those involved (Reinhart, 1992). To some extent, the risk of collusion in the Swedish Treasury bill auctions is curtailed by the fact that the authorized dealers and the investors meet in the secondary market after the auction and then again act as counterparts.

### 3.2. The auction procedure

In the period studied, the Swedish Treasury bill auctions were held every second Thursday. The timetable for the auctions was published 6 months ahead. The seller followed the announced schedule very strictly. Figure 2 presents the timetable for the Treasury bill auctions.
Figure 2.
Timetable for the Swedish Treasury bill auctions.
On auction day the seller published information about the volume of Treasury securities that was to be issued in the forthcoming auction before the opening of the trading in the secondary market and well before the auction.

Directly after each auction, the seller presented the auction result on computer screens. This announcement included information about the number of offered and accepted bids in the auctions, the high, low and quantity-weighted, accepted mean auction yields, the dispersion of accepted bids and the volume that was actually sold in the auction. (Part of this information is used as auction variables in the present study. These auction variables are defined in section 5.2., below)

The auction result reveals the shape of the total demand curve which is not publicly known in the secondary market until the auction results is published. The demand curve contains information about the bidding behavior which is not generally known in the secondary market price. For instance, Arrow (1986) claimed that the demand curve contains information about other actors' behavior. In the secondary market the traders normally can see only one point on this curve at a time.

3.3. The formal agreement between the seller and the authorized dealers

The authorized dealers were granted a commission from the seller which is related to their share of the issued volume and also to their market share in the secondary market. The formal agreement between the seller and the authorized dealers also included obligations. For example, the authorized dealers were required not only to participate regularly in the auctions but also to continuously 'make markets' in the secondary market for the full range of Swedish government securities among a reasonably diverse group of customers.

In the agreement with the authorized dealers, the seller has the right to use a reserve price and reject bids if they diverge to far from the auctioned securities' true value. Although it is known from auction theory that a monopolist seller, who wants to avoid collusion, should alter the rules and price condition and use the reserve price more frequently to increase efficiency in the auctions (McAfee & McMillan, 1987 and 1992) the auction rules were rarely altered in the period studied.

There are, however, disadvantages to altering the rules too often. The costs would probably be increased both for seller and bidders due to increased entry risk and entry and information costs. The authorized dealers will then have less incentives to maintain both an active auction market and an active secondary market for government securities. For administrative reasons, such as the need to sell the Treasury bills rapidly to avoid further price risks, the seller might prefer to keep the auction rules stable and accept some inefficiency in the information distribution. But
the mere existence of a collusive behavior might induce concerns over the fairness in the auction system.\footnote{In 1991 the investment firm Salomon Brothers, a major actor in the US Treasury securities auctions, was expelled from the auctions due to collusive behavior and violations of the auction rules.}

4. PURPOSE AND PROPOSALS

As mentioned above, the main purpose in the current study on Swedish Treasury bill auctions was to investigate whether the bidders were able to avoid overbidding. Although overbidding occurs in many business auctions, bidders in Treasury securities auctions have been shown to be able not only to avoid overbidding but also to purchase securities at a discount.

It was investigated whether the price paid for the items in the Swedish 6-month Treasury bill auctions and the secondary market price for an identical security on the auction day corresponded so well that any gap between the two prices would only be perceived as a compensation for risks incurred in the auctions or whether the two prices diverged systematically from each other. The former result would be an indication of an efficient auction market. If the auction price would be found to be lower than the secondary market price, this could either be an indication of price manipulation or an indication that the bidders were able to compensate themselves for the costs they incurred in their 'price discovery role' (Nyborg & Sundaresan, 1994, p.5). If the auction price would be found to be higher than the secondary market price, the overbidding could be an indication of the winner's curse.

It was also investigated whether the auction and the secondary market aggregated the private auction information differently as was found in Cammack's study. This would be an indication of inefficiency in information distribution. A strict interpretation of information efficiency in the Swedish 6-month Treasury bill auction market would be that all private auction information should be known to the public in the pre-auction secondary market before bids were delivered to the seller. New auction information should be assimilated continuously in the pre-auction market prices and therefore the published auction result would not reveal any new auction information. Then it would not be possible for some privileged bidders to utilize pieces of private information regarding for instance the spread in the bids or the level in the tender ratio in their own bids in order to increase their profits. The tender ratio measures the monetary value of the bids that were submitted in the auction divided by the monetary value of the volume of the Treasury bills that were sold in the auction.

However, if the better informed bidders succeeded in withholding information from the public, a price reaction on new auction information could not be expected in the secondary market until the new information had lost its strategic value in the auctions or until the information was made public by the seller. The post-auction secondary market would then react so as to (a) increase the demand for the Treasury bills when...
the public interpreted the new auction information as an indication that the competition for the bills in the auction had been stronger than they had anticipated and (b) decrease the demand for the Treasury bills when the public interpreted the new auction information as an indication that the competition for the bills in the auction had been weaker than they had anticipated.

5. ANALYSIS OF THE SWEDISH 6-MONTH TREASURY BILL AUCTIONS FROM 1991 TO 1994

5.1. The design of the current study

A series of analyses were conducted on auction and secondary market data in the Swedish money market for the period from February 1, 1991, to June 30, 1994. A critical aspect in field studies is that it is seldom possible to fully assess market complexity due to lack of reliable secondary data. Examples of information that would have been valuable to obtain in order to better understand the results in the current study on the Swedish Treasury bill auction market are the supply of complementary securities and the money market and in a wider trading environment, such as the stock market, the foreign exchange market and the international securities markets.

An important event in the Swedish financial market was the day in December, 1992, when the Swedish Central Bank had to let the krona float against the dollar and other currencies. Before this occurred there had been a series of central bank interventions in the secondary market as well as in the foreign exchange market aimed at defending the Swedish krona and preventing it from coming under severe pressure to devalue or depreciate. After having struggled to defend the Swedish krona repeatedly for a long time, the Swedish Central Bank finally in December, 1992 let the krona float against the dollar and other currencies.

It could be expected that this event would affect the trading behavior in the Swedish money market. It was therefore investigated whether the auction market behavior was significantly different in the period before and after the depreciation of the Swedish krona. The first analysis was conducted on data from January, 1991, to December, 1992 (subperiod A)\(^2\). A second analysis was conducted for a subperiod extending from January, 1993, to June, 1994 (subperiod B). The descriptive analysis is presented in section 5.5.1. The results indicated significant differences between the two subperiods. Therefore the regression analyses were conducted separately for subperiods A and B. These results are presented in section 5.5.2.

In subperiod B it was also possible to use reliable secondary market prices for the analyses of Swedish 6-month Treasury bill price adjustment in the secondary market.

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\(^2\) One observation was an extreme outlier and was therefore excluded in the analysis. The data in this observation would for instance have had a very large influence on the dependent variables in the regression analysis. The excluded data were obtained from an auction that was administered on September 17, 1992. At this time the speculation against the Swedish krona was severe and the interest rates moved periodically in full percentages between deals rather than in fractions of a percent as is typical of the Swedish secondary market.
from a period closer to the auction. The results from these analyses are presented in section 5.5.

5.2. Variables in the analysis

The variables that were employed in the analysis on the Swedish 6-month Treasury bill auctions were selected so as to (a) measure price adjustments in the auction market and (b) measure auction information. The variables measuring adjustments in Swedish Treasury bill prices on auction day are presented in Figure 3.

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**Figure 3.**
Variables measuring adjustments in Swedish Treasury-bill prices on auction day.

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3 The bid price of the bid-ask quotes for the security in the secondary market was employed in the current analysis since this price was the only reliable price available from the Central Bank. Yet, it has been suggested that a midpoint price could be more accurate since the bidders in auctions are market makers as well as investors in the secondary market. A bid-ask quote is assumed to be set symmetrically around the expected value of a security, given all public information (Hasbrouck, 1991).
The return variables are defined as follows:

(1) **ACRETURN**: 100 * \((P_C/P_J)\); the percentage change of the quantity-weighted, accepted mean auction price for the Treasury bills \((P_C)\) over auction day price in the pre-auction secondary market \((P_J)\), i.e. the secondary market price at ‘fixing’ time (11.00 AM).

(2) **CERETURN**: 100 * \((P_E/P_C)\); the percentage change of auction day Treasury bill price in the secondary market at closing hour \((P_E)\) over the quantity-weighted, accepted mean auction price \((P_C)\).

The variable **ACRETURN** measures the pre-auction price adjustments and the variable **CERETURN** measures the post-auction price adjustments. Since it was possible to collect data on secondary market prices closer to the auction in the period from 1993 to 1994 the return variables **ABRETURN**, **BCRETURN**, **BDRETURN** and **DERETURN** were added to the first two return variables, **ACRETURN** and **CERETURN**, in the analyses that were conducted in subperiod B. The new variables are defined below:

(3) **ABRETURN**: 100 * \((P_B/P_J)\); the percentage change of auction day secondary market price for the Treasury bills at 12.30 AM, \((P_B)\), which is the latest point in time when bids were accepted by the seller over secondary market price at ‘fixing’ time on auction day, i.e. at 11.00 AM \((P_A)\).

(4) **BCRETURN**: 100 * \((P_C/P_B)\); the percentage change of the quantity-weighted, accepted mean auction price for the Treasury bills \((P_C)\) over auction day secondary market price at 12.30 AM, \((P_B)\).

(5) **BDRETURN**: 100 * \((P_D/P_B)\); the percentage change of auction day Treasury bill price in the secondary market directly after the auction result has been made public, i.e. at 2.05 PM, \((P_D)\), over auction day secondary market price at 12.30 AM \((P_B)\).

(6) **CDRETURN**: 100 * \((P_D/P_C)\); the percentage change of auction day Treasury bill price in the secondary market directly after the auction result has been made public, i.e. at 2.05 PM, \((P_D)\) over the percentage change of the quantity-weighted, accepted mean auction price \((P_C)\).

(7) **DERETURN**: 100 * \((P_E/P_D)\); the percentage change of auction day Treasury bill price in the secondary market at closing hour \((P_E)\) over auction day price in the secondary market directly after the auction result has been made public \((P_D)\).

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4 Log is here the natural logarithm. \(\log(P_t/P_{t-1})\) is a measure of return that is commonly employed in financial economics. The formula is a *Taylor expansion* of a function.
The variables measuring auction information are defined as follows:

(8) DIVBIDQ: $100\log\left(\frac{P_c}{P_{c\text{ low}}}\right)$; the percentage gap between the quantity-weighted, accepted mean price for the Treasury bills and the lowest accepted price for the Treasury bills in the auctions.\(^5\)

(9) TENRATI: the monetary value (SEK) of bids submitted divided by the monetary value (SEK) of bids accepted in the Treasury bill auction, i.e. the tender ratio.

(10) KONCA: the percentage share of the accepted volume that was sold to the three highest bidding authorized dealers in each auction.\(^6\)

(11) ISSUE: the volume of 6-month Treasury bills that was offered to the money market in the Swedish Treasury bill auctions.

The variable DIVBIDQ measures the dispersion of accepted bids in the auctions. This variable was calculated as the natural logarithm of the quotient of the quantity-weighted, accepted mean auction price ($P_c$) and the lowest accepted auction price, $P_{c\text{ low}}$. A larger value of DIVBIDQ discloses a wider dispersion of accepted bids. The size of the dispersion of accepted bids was made public in the presentation of the auction result. A wide dispersion of accepted bids is assumed to indicate a large dispersion of opinion about the future market value of the bills. An alternative explanation to the spread in the accepted bids could be found in the relative presence of competition in the auctions.

The variable TENRATI measures the demand for the issued volume of securities in an auction. An alternative measure of the demand is the bid ratio, i.e. the number of bids that were submitted divided by the monetary value (SEK) of the accepted bids in the Treasury bill auction. On first reflection the latter variable matches the definition of competition as suggested in auction theory, namely that the price paid for an item sold in an auction is an effect of the number of bidders in the auction (Bazerman & Samuelson, 1983; French & McGormick, 1984). But since the discriminatory price rule permits bidders to submit more than one bid each in a Swedish Treasury bill auction, the variable TENRATI was used as a more comprehensive measure of the demand for the securities.

The variable KONCA is an additional measure of competition in the Swedish 6-month Treasury bill auctions. The concentration ratio has often been used to classify competition in a market or in an industry for instance when it has been investigate

\(^5\) Cammack (1987) used a variable, the 'tail', measured as the logarithm of the difference between the lowest accepted price and the quantity-weighted, accepted average price in the auction, to represent the dispersion of opinion in the market on auction day. An alternative measure of the dispersion of bids was used by Wachtel and Young (1990). They defined the tail as the difference between the weighted average accepted yield and the lowest accepted yield.

\(^6\) The concentration ratio is not public information in the Swedish Treasury-bill auctions.
whether a market should be perceived as an oligopoly, a bargaining situation or an efficient and open market (Hannah & Kay, 1977).

Finally, the variable ISSUE, which measures the volume of 6-month Treasury bills that was issued to the market in the Swedish Treasury bill auctions, is employed in the analysis in order to reflect the government’s requirement for issuing new securities in the money market.

5.3. The time series analysis

The technique used in the current study for dividing each auction variable into an anticipated and an unanticipated component corresponds to that employed by Cammack (1991) and by Hasbrouck (1991).

As a motive for using, Hasbrouck motivated this ‘split-component’ technique by arguing that in formal models of information asymmetry trade is driven not only by the information that is publicly known but also by private information and by liquidity needs. The quotes that are submitted by traders ‘on the floor’ contain both publicly known information about the value of a security and private information for instance about recent deals and limit orders.

Rather than using the total trade as the ‘driving force’ in his analysis, Hasbrouck split the trade variable into two components, the anticipated and the unanticipated component. He suggested that the anticipated component contained no new information since it only contained the predictable portion of the trade while the unanticipated component measures information in the quotes that were not publicly known until the quotes were presented. The unanticipated component is also known as the innovation in the financial literature (see e.g., Hasbrouck, 1988 and 1991).

In the current study a time series model was established for the auction variables TENRATI and DIVBIDQ. The unanticipated component in the auction variables was given the prefix U. The anticipated components of the auction variables were given the prefix E (as in expected) to avoid confusion with one of the return variables that started with an A.

To create a process in the time series analysis in which the anticipated component was separated from the unanticipated component in the two auction variables respectively the procedures outlined by Box and Jenkins (see Vandaele, 1983) were followed. The anticipated component measures the anticipated portion in the variable that is derived in the time series procedure from the variable’s past history. The unanticipated component of the variable was then calculated as the difference between the actual value of the variable and its anticipated component. The anticipated component in the current auction data was assumed to contain the publicly known auction information while the unanticipated component was assumed to contain the new auction information.
It was assumed in the time series analysis that individuals act linearly and that they update their prices in each period based on their previous experiences of how the auction prices have been established in earlier periods. For a survey of adaptive economic models, see Johnson and Plott (1989). The results from the time series analysis are presented in detail in the appendix.

5.4. Model for testing the hypotheses in the current study on Swedish 6-month Treasury bill auctions

A regression model was first used in subperiods A and B to test whether the post-auction secondary market reacted upon the auction result as if it contained new information. In line with the suggestion by Hasbrouck, above, the anticipated components in the auction variables are not included in the regression model since they are assumed to contain information that was publicly known in the secondary market at the time when the auction procedure started. Instead the unanticipated components were assumed to measure information in the auction variables that were not publicly known until the the auction information was presented to the public either by the better informed bidders or by the seller.

The model that was use in the regression of the price adjustments in the post-auction market, CERETURN, on the unanticipated components in the auction variables DIVBIDQ and TENRATI is presented below. These auction variables' unanticipated components are called UDIVBIDQ and UTENRATI, respectively. The regression coefficient $\beta_1$ was expected to be positively related and the regression coefficient $\beta_2$ was expected to be negatively related to the post-auction price adjustments, measured as CERETURN, if the post-auction secondary market reacted upon the auction result as if it contained new information. The model is presented below:

$$\text{CERETURN}_t = \alpha + \beta_1 \times \text{UDIVBIDQ}_t + \beta_2 \times \text{UTENRATI}_t + \epsilon_t \quad (1)$$

In the complementary regressions that were conducted in subperiod B the dependent variables were ABRETURN, BCRETURN, CDRETURN and DERETURN.

First regression of the price adjustments in the pre-auction market, ABRETURN, BCRETURN and BDRETURN, on the unanticipated component in the auction variables DIVBIDQ and TENRATI were conducted. The auction variables were here assumed to represent the information that was still unpublished but which may be known to some better informed bidders.

$\beta_1$ was expected to be positively related and $\beta_2$ was expected to be negatively related to the pre-auction secondary price adjustments, measured as ABRETURN, if a price reaction on the new information occurred already in the pre-auction secondary market.

$\beta_1$ was expected to be positively related and $\beta_2$ was expected to be negatively related to the pre-auction price adjustments, measured as BCRETURN, if some better
informed bidders succeeded in withholding their private information from the public in the secondary market until the new information had lost its strategic value in the auction.

Furthermore, $\beta_1$ was expected to be positively related and $\beta_2$ was expected to be negatively related to the price adjustments from immediately before the auction until immediately after the auction, BDRETURN, if the new information was distributed in the secondary market during the auction procedure.

Finally, $\beta_1$ was expected to be positively related and $\beta_2$ was expected to be negatively related to the price adjustments after the auction result had been published, DERETURN, if the secondary market reacted upon the auction result as if it was new information.

5.5. Results

The results\textsuperscript{7} from the analyses in this study are presented in three sections. Section 5.5.1 describes statistically the auction and secondary market variables in subperiods A and B. Thereafter, in section 5.5.2, the results from the regression analyses of post-auction price adjustments CERETURN on auction variables are presented for the two subperiods. Complementary regression analyses of price adjustments ABRETURN, BCRETURN, BDRETURN and DERETURN, respectively on auction variables were conducted in subperiod B and are finally presented in section 5.5.3. These dependent variables were based on the price information closer to the auction which was available for the period from 1993 to 1994.


This section presents the results from a comparison between auction variables and return variables respectively in subperiods A and B. First, a t-test compared the means and standard deviations for auction variables measuring \textit{dispersion of accepted bids, tender ratio, concentration ratio} and the \textit{issued volume} in the auctions in subperiod A with the means and standard deviations for those variables in subperiod B. The results from this analysis are presented in Table 1. The t-test showed that that the auction market conditions varied significantly between the two subperiods.

\textsuperscript{7} The statistical program SYSTAT was used for the analyses in the following sections.
Table 1.
t-test for the auction variables dispersion of accepted bids, tender ratio, concentration ratio and issued volume in subperiods A and B.

<table>
<thead>
<tr>
<th></th>
<th>SUBPERIOD A (n=44)</th>
<th>St dev</th>
<th>SUBPERIOD B (n=34)</th>
<th>St dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersion of accepted bids</td>
<td>0.04 **</td>
<td>0.06</td>
<td>0.01 **</td>
<td>0.01</td>
</tr>
<tr>
<td>Tender ratio (TENRATI)</td>
<td>2.08 **</td>
<td>0.98</td>
<td>2.95</td>
<td>1.62</td>
</tr>
<tr>
<td>Concentration ratio (%) (KONCA)</td>
<td>65.7</td>
<td>17.8</td>
<td>72.7</td>
<td>19.5</td>
</tr>
<tr>
<td>Issued volume (mn SEK)</td>
<td>4.400 **</td>
<td>1.340</td>
<td>1.680</td>
<td>1.260</td>
</tr>
</tbody>
</table>

P = Positive skewness (= long right tail); * p < 0.05; ** p < 0.01

In subperiod A when the government’s borrowing needs were consistently high the bidders guarded against losses due to the quantity risk by spreading their bids over a wider range and reducing their demand for the issued securities. The issued volume in the Swedish 6-month Treasury-bill auctions was more than twice as large in subperiod A than in subperiod B. The dispersion of accepted bids was on average wider and the demand for the securities, measured as the tender ratio, was lower in subperiod A than in subperiod B.

In subperiod B the government’s borrowing requirements were reduced. As a reaction to reduced supply of issued securities the tender ratio increased and the dispersion of bids narrowed.

The high and stable concentration ratio showed that competition was very low in the Swedish Treasury-bill auctions. More than sixty five percent of the issued volume was purchased through the three largest authorized dealers in an auction. No significant difference was found in the size of the concentration ratio between the two periods. Normally, the composition of this group varied from one auction to another.

In two auctions in subperiod A and in seven auctions in subperiod B one single authorized dealer purchased the entire volume of issued securities in an auction. The 'cost' incurred for winning the entire volume was 4 basis points in subperiod A and 0 basis points in subperiod B in comparison with the comparable price in the secondary market.

In Table 2, the means, the medians and standard deviations for the pre-auction secondary market prices, the quantity-weighted, accepted mean auction prices and the post-auction secondary market prices in subperiods A and B, respectively, are presented (all prices are defined in section 4.1.1 above).
Table 2.
Means, medians and standard deviations for the Swedish 6-month Treasury bill prices on auction day in subperiods A and B.

<table>
<thead>
<tr>
<th>SUBPERIOD</th>
<th>Mean (St dev)</th>
<th>Median (St dev)</th>
<th>SUBPERIOD</th>
<th>Mean (St dev)</th>
<th>Median (St dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n=44)</td>
<td>93.95 N (0.64)</td>
<td>93.99 N (0.64)</td>
<td>B (n=34)</td>
<td>96.12 N (0.59)</td>
<td>96.31 (0.59)</td>
</tr>
<tr>
<td>11.00 AM</td>
<td></td>
<td></td>
<td>12.30 AM</td>
<td>na</td>
<td>96.11 N (0.60)</td>
</tr>
<tr>
<td>Secondary market price at 12.30 AM</td>
<td>na</td>
<td>93.93 N (0.67)</td>
<td>93.98 (0.67)</td>
<td>96.10 N (0.60)</td>
<td>96.30 (0.60)</td>
</tr>
<tr>
<td>Quantity-weighted, accepted mean auction price</td>
<td>na</td>
<td>96.11 (0.60)</td>
<td>96.32 (0.60)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.05 AM</td>
<td>na</td>
<td>93.95 N (0.67)</td>
<td>94.02 (0.67)</td>
<td>96.12 N (0.58)</td>
<td>96.33 (0.58)</td>
</tr>
<tr>
<td>Secondary market price at 3.30 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N = Negative skewness (= long left tail)

The markup, which was measured as the difference between pre-auction secondary market price ACRETURN and the quantity-weighted, accepted mean auction price was on average two basis points in both subperiods. When the pre-auction price immediately prior to the auction was used (in subperiod B) the difference between the secondary market and the mean auction price was only one basis point.

The systematically lower prices for an identical 6-month Treasury bill in the auctions present evidence that the bidders were able to adjust their bids so as to avoid overbidding and even to compensate themselves for the additional risks that they incurred in the auction (Table 2).

A correlation on price adjustments in the pre-auction market, measured as ACRETURN, and price adjustment in the post-auction market, measured as CERETURN, showed that a price adjustment before the auctions was accompanied by an additional price adjustment after the bids had been delivered to the seller in the auctions in subperiod A (r=0.24; p=n.s.). In subperiod A there seemed to be auction information that still had a price impact after the auction procedure had started. The correlation in subperiod B showed that a price adjustment instead was followed by a price reversal (r=-0.41; p <0.01).

A complementary correlation in subperiod B between the variable measuring price adjustments in the auction market just before the auction, measured as BCRETURN,
and the variable measuring price adjustments in the auction market just after the auction procedure had started, measured as CDRETURN, was strongly negative ($r = -0.87$; $p < 0.001$). This price reversal is a fairly strong indication that the bidders could compensate themselves for the costs they incurred in their price discovery role.

Table 3 presents the results from the correlations between the unanticipated components in auction variables DIVBIDQ and TENRATI and the variable ISSUE, respectively and (a) the variables measuring price adjustments in the pre-auction secondary/auction market, ACRETURN, and in the post-auction secondary market, CERETURN, respectively in subperiod A, and (b) the new variables measuring price adjustments in the pre-auction secondary market immediately prior to the auction, BCRETURN, and variables measuring price adjustments in the secondary market during the auction procedure, BDRETURN, respectively in subperiod B.

Table 3.
Correlations between auction variables UDIVBIDQ, UTENRATI and ISSUE and return variables AC- and CERETURN in subperiod A and BC- and CDRETURN in subperiod B.

<table>
<thead>
<tr>
<th>CORRELATIONS</th>
<th>Subperiod A</th>
<th>CORRELATIONS</th>
<th>Subperiod B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($n = 44$)</td>
<td></td>
<td>($n = 34$)</td>
</tr>
<tr>
<td>ACRETURN/UDIVBIDQ</td>
<td>0.54**</td>
<td>BCRETURN/UDIVBIDQ</td>
<td>-0.51**</td>
</tr>
<tr>
<td>ACRETURN/UTENRATI</td>
<td>0.22</td>
<td>BCRETURN/UTENRATI</td>
<td>0.56**</td>
</tr>
<tr>
<td>ACRETURN/ISSUE</td>
<td>-0.22</td>
<td>BCRETURN/ISSUE</td>
<td>0.11</td>
</tr>
<tr>
<td>CERETURN/UDIVBIDQ</td>
<td>0.05</td>
<td>CDRETURN/UDIVBIDQ</td>
<td>0.32</td>
</tr>
<tr>
<td>CERETURN/UTENRATI</td>
<td>0.31*</td>
<td>CDRETURN/UTENRATI</td>
<td>-0.34*</td>
</tr>
<tr>
<td>UDIVBIDQ/ISSUE</td>
<td>0.17</td>
<td>UDIVBIDQ/ISSUE</td>
<td>0.00</td>
</tr>
<tr>
<td>UTENRATI/ISSUE</td>
<td>-0.23</td>
<td>UTENRATI/ISSUE</td>
<td>-0.04</td>
</tr>
<tr>
<td>UTENRATI/ISSUE</td>
<td>-0.63**</td>
<td>UTENRATI/ISSUE</td>
<td>-0.60**</td>
</tr>
</tbody>
</table>

* $p < 0.05$; ** $p < 0.01$

The t-test in Table 3 shows that the correlation between the anticipated portion in the tender ratio and the issued volume was significant and negative in both periods. An additional t-test showed no significant correlations between the unanticipated components in the auction variables DIVBIDQ and TENRATI and the pre-auction price adjustments ACRETURN nor between this auction variable and the post-auction price adjustments CERETURN in subperiod B.

As mentioned above, the information regarding the government's borrowing requirements in the upcoming auction was published in the secondary market before it opened on auction day. The strongly significant and negative relation between issued
volume and the anticipated component in tender ratio in both subperiods present further evidence that the bidders were able to adjust their demand for the securities so that it corresponded to the change in the supply of the issued security. These results support the suggestion by McAfee and McMillan (1987) that the price efficiency increases when the seller publishes auction information before the auction.

5.5.2. Results from the regressions of price adjustments in auction market on auction variables in subperiods A and B

In this section the results from the regressions of price adjustments in the secondary market and the auction on auction variables in subperiods A and B are presented. First, regressions were conducted to investigate how well the unanticipated components in the auction variables DIVBIDQ and TENRATI could explain the variance in the post-auction return, CERETURN.

Table 4 presents the results from the regression of the price adjustments in the post-auction secondary market, CERETURN on the auction variables UDIVBIDQ and UTENRATI in subperiods A and B.

In subperiod A, the analysis of the regression of the post-auction price adjustments, CERETURN, on the auction variables revealed that the unanticipated component in the tender ratio explained the variance in the post-auction price movements. The price reaction in the post-auction market on demand for the securities indicates that the public in the secondary market tended to perceived the auction result as new auction information. In subperiod B these auction variables did not contribute to explaining the variance in the post-auction price adjustments.

Table 4.
Regressions of price adjustments in during the auction procedure, CERETURN, on auction variables UDIVBIDQ and UTENRATI in sub periods A (n=44) and B (n=34).

<table>
<thead>
<tr>
<th>SUBPERIOD</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep. variable</td>
<td>Coeff</td>
<td>Coeff</td>
<td>Std error</td>
<td>Std error</td>
<td>Std coeff</td>
<td>Std coeff</td>
<td>t</td>
<td>t</td>
</tr>
<tr>
<td>CERETURN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
<td>2.30*</td>
<td>2.80*</td>
</tr>
<tr>
<td>UDIVBIDQ</td>
<td>0.02</td>
<td>-0.10</td>
<td>0.04</td>
<td>0.74</td>
<td>0.07</td>
<td>-0.03</td>
<td>0.44</td>
<td>-0.13</td>
</tr>
<tr>
<td>UTENRATI</td>
<td>0.06</td>
<td>0.01</td>
<td>0.03</td>
<td>0.02</td>
<td>0.32</td>
<td>0.10</td>
<td>2.13*</td>
<td>0.47</td>
</tr>
</tbody>
</table>

* p < 0.05
Subperiod A: R2 (Adj R2) = 0.10 (0.06); Durbin-Watson D-statistics: 1st order autocorrelation = -0.14
Subperiod B: R2 (Adj R2) = 0.01 (0.00 ); Durbin-Watson D-statistics: 1st order autocorrelation = 0.11

Noteworthy is that the constants of both regression equations in subperiod A were significant. A significant constant is an indication that there are one or more factors other than those that are employed in this analysis that could explain the variance in the two price adjustments.
In subperiod B (1993-1994) a series of complementary regression analyses were conducted. The aim was to use return variables were based on price information closer to the auction in order to improve the quality of the analysis of price reactions on the auction information. By using the new price information as input for the price adjustments in the auction market it was for instance possible to investigate whether private auction information was known to the public in the secondary market before the bids were submitted in the auction or whether this information was revealed in the secondary market thereafter.

Regression analyses were conducted of price adjustments (a) in the pre-auction secondary market before the auction, ABRETURN (Table 5), (b) from the pre-auction secondary market immediately prior to the auction to the auction, BCRETURN (Table 6), (c) in the secondary market from immediately prior to the auction to immediately after the auction, BDRETURN (Table 7), and (c) in the post-auction secondary market, DERETURN (Table 8) on the unanticipated components in the auction variables DIVBIDQ and TENRATI, namely UDIVBIDQ and UTENRATI.

The regression of ABRETURN presented no significant relation between any of the auction variables and this price adjustment in the pre-auction secondary market (Table 5). The regressions of the pre-auction price adjustment immediately prior to the auction, BCRETURN, on unanticipated components in the auction variables showed that a significant contribution to the explanation of the variance in this price adjustment came from the unanticipated component in tender ratio (Table 6). This result may indicate price manipulation in the pre-auction market. The adjusted $R^2$ was 0.33.

The regression of the price adjustments in the secondary market during the auction procedure, BDRETURN, on the auction variables supports the suggestion above that there was information regarding the demand in the auctions that was not revealed to the public until after bids had been delivered to the seller and the auction procedure had started. The unanticipated portion in tender ratio provided a significant part of the explanation of the variance in the price movements in the period during which the seller was administrating the auction. The adjusted $R^2$ was 0.31 (Table 7).

When the auction result was known to the public the major part of the auction information was absorbed in the secondary market prices as is shown in the regressions of the price adjustments in the post-auction secondary market, measured as DERETURN, on the auction variables (Table 8).
Table 5.
Regression of price adjustments in the pre-auction secondary market, ABRETURN, on auction variables UDIVBIDQ and UTENRATI in subperiod B (n=34).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Coeff</th>
<th>Std error</th>
<th>Std coeff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.01</td>
<td>0.01</td>
<td>-</td>
<td>-1.65</td>
</tr>
<tr>
<td>UDIVBIDQ</td>
<td>0.04</td>
<td>0.62</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>UTENRATI</td>
<td>-0.01</td>
<td>0.02</td>
<td>-0.13</td>
<td>-0.60</td>
</tr>
</tbody>
</table>

R2 (Adj R2) = 0.02 (0.00); Durbin-Watson D-statistics: 1st order autocorrelation = 0.24

Table 6.
Regression of price adjustments from the pre-auction secondary market immediately prior to the auction, BCRETURN, on auction variables UDIVBIDQ and UTENRATI in subperiod B (n=34).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Coeff</th>
<th>Std error</th>
<th>Std coeff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.02</td>
<td>0.01</td>
<td>-</td>
<td>-3.18**</td>
</tr>
<tr>
<td>UDIVBIDQ</td>
<td>-0.80</td>
<td>0.48</td>
<td>-0.29</td>
<td>-1.65</td>
</tr>
<tr>
<td>UTENRATI</td>
<td>0.03</td>
<td>0.01</td>
<td>0.40</td>
<td>2.30*</td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01
R2 (Adj R2) = 0.37 (0.33); Durbin-Watson D-statistics: 1st order autocorrelation = 0.12
Table 7.
Regression of price adjustments in the secondary market during the auction procedure, BDRETURN, on auction variables UDIVBIDQ and UTENRATI in subperiod B (n=34).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Coef</th>
<th>Std Error</th>
<th>Std Coef</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDRETURN</td>
<td>0.00</td>
<td>0.00</td>
<td>-</td>
<td>-0.98</td>
</tr>
<tr>
<td>UDIVBIDQ</td>
<td>-0.37</td>
<td>0.25</td>
<td>-0.26</td>
<td>-1.50</td>
</tr>
<tr>
<td>UTENRATI</td>
<td>0.01</td>
<td>0.01</td>
<td>0.41</td>
<td>2.31*</td>
</tr>
</tbody>
</table>

R2 (Adj R2) = 0.35 (0.31); Durbin-Watson D-statistics: 1st order autocorrelation = 0.08

* p < 0.05

Table 8.
Regressions of price adjustments in the post-auction secondary market, DERETURN, on auction variables UDIVBIDQ and UTENRATI in subperiod B (n=34).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Coef</th>
<th>Std Error</th>
<th>Std Coef</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>DERETURN</td>
<td>0.01</td>
<td>0.01</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>UDIVBIDQ</td>
<td>-0.53</td>
<td>0.77</td>
<td>-0.14</td>
<td>-0.69</td>
</tr>
<tr>
<td>UTENRATI</td>
<td>0.02</td>
<td>0.02</td>
<td>0.24</td>
<td>1.15</td>
</tr>
</tbody>
</table>

R2 (Adj R2) = 0.12 (0.06); Durbin-Watson D-statistics: 1st order autocorrelation = 0.08
6. DISCUSSION AND CONCLUSIONS

By defining the auction market as consisting of the pre-auction secondary market, the auction and the post-auction secondary market in this study it was possible to better illustrate how auction information was distributed in the auction market. Thereby it was also possible to investigate whether relevant auction information in fact was recognized by the public in the secondary market before they submitted their bids in the auctions or whether information was held secret by the better informed bidders until the auction has started.

6.1. Compensation for risks in the auctions

The analyses conducted to investigate how the Swedish 6-month Treasury bill auction prices and the secondary market prices were related showed that these two prices corresponded well. The results showed that the mark up was on average two basis points in both subperiods. When the pre-auction price immediately prior to the auction was used (in subperiod B) the difference between the secondary market and the mean auction price was only one basis point. The difference between the pre-auction price and the auction price was, however, quite small in terms of real money. These results is also in line with earlier results from studies on Treasury securities auctions.

The systematically lower prices for an identical 6-month Treasury bill in the auctions present evidence that the bidders were able to adjust their bids so as to avoid overbidding. Furthermore, this result is an indication of an efficient auction market in which traders are compensated for the cost they incur when gathering information and setting prices that are in agreement with available information regarding the security.

6.2. Response to altered market conditions

In subperiod A when the government's borrowing needs were consistently high the bidders guarded against losses by spreading their bids over a wider range and by reducing their demand for the issued securities. As a reaction to reduced supply of issued securities due to lower government borrowing requirement in subperiod B the tender ratio increased and the dispersion of bids narrowed. The supply of issued securities was twice as high in subperiod A than in subperiod B. Both the dispersion of accepted bids was wider and the demand for the securities, measured as the tender ratio, were significantly lower in subperiod A than in subperiod B.

As mentioned earlier, the information regarding the government's borrowing requirements in the upcoming auction was published in the secondary market before it opened on auction day. Both in subperiod A and subperiod B the correlation between the anticipated portion in the tender ratio and issued volume was significant and negative. These results present evidence that the bidders could adjust to the shifts in supply of issued securities in order to avoid the quantity risk. These results also support the suggestion by McAfee and McMillan (1987) that the price efficiency increases when the seller publishes auction information well in advance of the auction.
6.3. Post-auction reactions on auction information

A correlation on price adjustments in the pre-auction market and price adjustments in the post-auction market showed that a positive price adjustment before the auction was accompanied by an additional positive price adjustment after the bids had been submitted in the auction in subperiod A. Furthermore, the analysis of the regression of the post-auction price adjustments on the auction variables in subperiod A revealed that the unanticipated component in the tender ratio explained the variance in the post-auction price movements. The price reaction in the post-auction market on demand for the securities tended to be perceived by the public in the secondary market as new auction information. These results indicate that there was auction information that still had a price impact after the auction procedure had opened.

A complementary correlation in subperiod B between the price adjustments in the auction market immediately prior to the auction and the price adjustments in the auction market after the auction procedure had started was strongly negative. These results also support the suggestions above, namely that the bidders were able to compensated themselves for the costs they incurred in their price discovery role with lower auction prices.

6.4. Price manipulations in the auctions

By using the new price information as input in the regressions in subperiod B for the price adjustments in the auction market it was possible to investigate whether private auction information was known to the public in the secondary market before the bids were submitted in the auction or whether better informed bidders were shading relevant auction information for the public until after the auction information had lost its strategic value in the auctions.

The regression of the pre-auction price adjustment immediately prior to the auction on auction variables in subperiod B showed that a significant contribution to the explanation of the variance in this price adjustment came from the unanticipated component in the tender ratio. Furthermore, the regression of the price adjustments in the secondary market during the auction procedure showed that the unanticipated portion in tender ratio provided a significant part of the explanation for the variance in the price movements during this procedure, supports the results above. These results indicate that better informed bidders in the Swedish Treasury bill auctions were trading strategically. By keeping their private information secret from the public and integrating it in their bids the better informed bidders were able to position themselves better on the demand curve to reduce the risk of overbidding in the auction.

As was shown in the regressions of the price adjustments in the post-auction secondary market on the auction variables the major part of the auction information was absorbed in the secondary market prices at the time when the auction result was published by the seller.
6.5. Concluding remarks

The stable bidding environment provided the bidders in the Swedish 6-month Treasury bill auctions regular and correct feedback. This in turn may explain the bidders' efficiency in selecting and implementing their bidding strategies and to act rationally and adaptively.

The analysis of the Swedish 6-month Treasury auctions presented evidence that although a major part of the auction information was absorbed in the Treasury bill prices before the seller published the auction results the results also present evidence of some price manipulation before the auctions.

As mentioned above, researchers have found that price rules, such as the uniform price rule, decrease the risk of overbidding in auctions in comparison with auctions where the discriminatory price rule is used. Since it has been shown that there is little to gain from collusive behavior under for example the uniform price rule it can be assumed that the professional bidders will adjust to the new auction market conditions and abstain from such a behavior. It is therefore suggested that it should be further analyzed whether alternative auction rules, in accordance with new findings in research on auction behavior, could be implemented in the Swedish Treasury bill auctions in order to reduce the opportunities for price manipulations. Thereby it may be possible that auction market efficiency will obtain further improvements.
7. REFERENCES


APPENDIX. Results from the time series analysis on auction variables

For the variable DIVBIDQ an ARMA-model with two AR-parameters and one MA-parameter was found to be sufficient (see Table 1). The AR-parameters were identified at lag 2 ($B^2$) and at lag 3 ($B^3$) while the MA-parameter was identified at lag 5 ($B^5$). Level shifts, or intervention points, were found at the time periods 60 (N1), 78 (N2), 110 (N3), 111 (N4), and 114 (N5).

Table 1.
The estimated transfer function model for auction variable DIVBIDQ ($t$-ratios in brackets).

<table>
<thead>
<tr>
<th>DIVBIDQ + 0.02 = 0.12 N1 + 0.41 N2 + 1.09 N3 + 0.07 N4 + 0.04 N5</th>
</tr>
</thead>
<tbody>
<tr>
<td>($7.02$) ($9.95$) ($34.95$) ($91.64$) ($5.50$) ($2.98$)</td>
</tr>
<tr>
<td>+ $[(1 + 0.19 B^5) / (1 - 0.23 B^2 - 0.24 B^3)] *_{a_t}$</td>
</tr>
<tr>
<td>($2.08$) ($-2.73$) ($-12.97$)</td>
</tr>
<tr>
<td>Ljung-Box Q-statistics: $Q(5) = 2.003$ Significance level = 0.37</td>
</tr>
<tr>
<td>$Q(10) = 8.711$ Significance level = 0.27</td>
</tr>
<tr>
<td>$\sigma_a = 0.02 \quad R^2 = 0.98 \quad n = 152 \quad df = 143$</td>
</tr>
</tbody>
</table>

The variance of the variable TENRA TI was stabilized by taking the square roots of the original series. The square root of the variable TENRA TI was modeled as an ARMA - model with one AR-parameter at lag 1 and one MA-parameter at lag 8 ($B^8$). Level shifts were found at time periods 13 (L1), 132 (L2), 135 (L3), 138 (L4) and 150 (L5).

Table 2.
The estimated transfer function model for auction variable TENRA TI ($t$-ratios in brackets).

<table>
<thead>
<tr>
<th>SqrTENRATI + 1.81 = -0.33 L1 + 0.42 L2 + 1.02 L3 + 0.80 L4 - 0.73 L5</th>
</tr>
</thead>
<tbody>
<tr>
<td>($12.86$) ($-2.26$) ($3.33$) ($4.55$) ($3.57$) ($-4.10$)</td>
</tr>
<tr>
<td>+ $[(1 + 0.27 B^8) / (1 - 0.46 B^3)] *_{a_t}$</td>
</tr>
<tr>
<td>($3.27$) ($-6.15$)</td>
</tr>
<tr>
<td>Ljung-Box Q-statistics: $Q(5) = 5.11$ Significance level = 0.16</td>
</tr>
<tr>
<td>$Q(12) = 7.88$ Significance level = 0.45</td>
</tr>
<tr>
<td>$\sigma_a = 0.25 \quad R^2 = 0.51 \quad n = 154 \quad df = 146$</td>
</tr>
</tbody>
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IS CONFIDENCE IN ONE'S BELIEF A MATTER OF KNOWLEDGE OR OF COGNITIVE ILLUSION?
ABSTRACT

In many studies on judgment and choice it has been found that people have a tendency to be overconfident in their decisions. Overconfidence in experiments is defined as the general tendency to overestimate the likelihood of having selected the right alternative among a set of available answers. In order to investigate whether the selection method is the key to creating as well as eliminating overconfidence two types of two answer-alternative questions were employed in the present study, namely informally selected and representatively selected items. Moreover, to investigate the extent to which perceived difficulty and familiarity could explain the confidence level the subjects were also asked to report whether they perceived an item as difficult or familiar. 102 university students participated in two confidence experiments. It was found that a representative selection of items decreased the subjects' overconfidence but at the cost of poor resolution. Moreover, the results showed increased 'realism' when the subjects were asked to make frequency assessments compared with when they were asked to make confidence assessments. Also, a reversal of the hard-easy effect was found for perceived difficulty. The results showed that the confidence level could be explained to a significant extent by the subjects' perception of a question as either difficult or familiar. The subjects tended to display decreased confidence when items were perceived as difficult or very unfamiliar and they displayed increased confidence in the opposite condition. The results in the present study demonstrate the importance of making a distinction between objective and perceived difficulty as determinants of the subjects' confidence level. It is suggested that in order to improve our understanding of the overconfidence phenomenon the role of perceived difficulty and item familiarity should be further explored.

KEYWORDS: Overconfidence, ecological models, objective difficulty, perceived difficulty, cognitive biases
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1. INTRODUCTION

The securities markets are flooded with information which professional traders and analysts are expected to interpret accurately when making judgments and decisions. As their clients we can merely guess the realism of the beliefs underlying the recommendations of the experts upon whose advice we depend. At best we can value the quality of their probability judgments from the outcome of their recommendations.

When decision makers are too positive in their judgments they are said to be overconfident. Overconfidence is a special case of lack of calibration. It is here defined as the general tendency to overestimate the likelihood of having selected the right alternative from a set of available answers. If a person's subjective probability estimation is identical to an externally defined objective probability then he/she is said to be well-calibrated.

The explanation given for the findings of overconfidence in experiments differ among different researchers (see Fischhoff & MacGregor, 1982, Allwood & Granhag, 1994, and McClelland & Bolgar, 1994, for overviews). Fischhoff (1982) claimed that overconfidence in one's ability to make accurate probability estimations is a very robust phenomenon and that neither warnings nor rewards can make it disappear. Others have found that correct feedback is an efficient means to reduce overconfidence (Arkes, Christensen, Lai & Blumer, 1987; Allwood & Granhag, in press).

Gigerenzer, Hoffrage and Kleinbölting (1991), Juslin (1993) and Björkman (1994) argued that there is no general overconfidence bias. To them the proper selection of items is an important requirement for achieving good calibration in experiments. They claimed that overconfidence occurs in many experiments because the general knowledge items are selected as if to test the subjects' knowledge. From their point of view people will display less overconfidence if items are randomly selected from a well-defined natural environment.

Allwood and Granhag (in press) classified earlier attempts to explain the degree of realism of confidence judgments with respect to three different aspects of the conditions which can
influence an individual's confidence level. These aspects are the time scale which is considered in the explanation, the focus of description (the individual or the relation between the individual and the environment) and the degree of stability in prevailing conditions. All three aspects need to be considered in studies on overconfidence in order to achieve a more complete picture of the this phenomenon.

The effect of objective difficulty on overconfidence has been studied in several experiments (see e.g. Fischhoff & MacGregor, 1982). A phenomenon of interest in this connection is the hard-easy effect. This effect is a common finding in experiments and can be described as an increase in overconfidence with difficult questions and a tendency towards underconfidence with easy questions. This effect will be discussed further below in section 3.

Decision makers have been shown to unveil biases in their evaluation and choice processes primarily when they select information. In the current study four aspects of the causes for overconfidence were tested in two experiments. First, it was investigated whether the method of selecting the items, either informally or representatively, is the key to creating as well as eliminating overconfidence (see below in section 3.1). Secondly, it was investigated whether the objective difficulty level, expressed as percentage correct answers, or the perception of an item, or a set of items, as difficult or as familiar could explain the variations in the confidence level (see section 3.2).

In this study it is proposed that overconfidence will be better understood if a distinction is made between objective difficulty and perceived difficulty.

Furthermore, the present study investigated whether the subjects were better calibrated in their confidence judgments when they were asked to make frequency assessments compared with when they were asked to make confidence assessments (see section 3.3). Finally, it was investigated whether information about overconfidence and its causes would have an impact on the subjects in their confidence judgments (see section 3.4).

2. DETERMINANTS OF THE CONFIDENCE LEVEL

In the contingency models, suggested by Beach and Mitchell (1978) and by O'Connor (1989) confidence judgments are seen to be affected by the interaction between the characteristics of the task, such as familiarity, ambiguity, complexity and stability, the task environment and, finally, the individual.

These three characteristics are also considered in a model presented by Hammond (1990). Hammond integrated the 'lens model' (Brunswick, 1955) with theories about cognitive biases from the Tversky-Kahneman tradition in a common conceptual framework. An example of cognitive bias is the tendency to stereotype events with respect to their similarity to other related events. This bias has been named representativeness heuristics by Kahneman and Tversky (1972). Another example of a cognitive bias is the availability heuristic (Tversky & Kahneman, 1973) according to which people base their probabilistic judgments on information about similar events which are easily available to them, either
physically or mentally. For instance, a person is likely to overvalue the probability that an event will occur again if it happened recently or if the experience had a strong impact.

According to Hammond, the lens model and the cognitive bias approach are complementary since they explain the effects on cognition from two different aspects. The first theory, which is system-oriented in its approach, has been useful in demonstrating that people can make use of the functional relations between cues and distal variables. The second theory has demonstrated that individuals can make use of their perception of similarities although there is a risk that people overestimate the validity of their perception (see e.g. Kahneman & Tversky, 1972).

Hammond suggested that by combining the two approaches in a new model the understanding will increase of how a decision maker can improve his/her use of information that is provided by the reference points, or cues, that are available within a specific context. He argued that when steps are taken to better recognize the task conditions 'people appear highly adaptive in responding to changes in structure of available alternatives and to the presence of time pressure'. By using a representative design it is possible to ‘...understand how cognition functions under that variety of conditions representative of those in which a given organism functions” (p. 249).

In the lens model Brunswik (1955) suggested that ecological validity is important because the interpretation and generalizability of the accuracy of predictions of an outcome in an experiment depends on the extent to which the individual’s model matches the context (figure 1).

Brunswik argued that most judgments are the result of a probabilistic reasoning based on a number of comparisons between different cues (or signals) in a specific system. More specifically, the lens model focuses on understanding the interrelation between two main systems of cues. One system is the ‘real’ network between cues in the environment, such as the present price volatility or the number of competitors in a Treasury securities market) and the events to be predicted, such as the future value of a specific Treasury security. The second system is the network of relations between cues in the individual’s mind, such as previous experience from Central Bank interventions, and his/her predictions, such as the future value of a Treasury security.

The key aspect in the lens model is thus that the accuracy of the judgment depends upon the extent to which the mind mirrors the environment in which the judgment is to be made. This approach to the judgment problem is based on the assumption that human judgment is a function of the person, the task and the task environment (in other words a system orientation).

According to Brunswik (1955) there is ecological validity if the sampling of situations and the subjects are representative of the natural setting which the experiment is aimed at investigating. Behavior and perception should be allowed to vary naturally with regard to the distal cues (i.e. the cues or signals that are not immediately apparent) or to the target event.
Note: A,B,...N = the cues in a person's environment. (The accuracy of the judgment is assumed to depend on the extent to which the relations on both sides of the 'lens' are the same.)

*Figure 1.*
Brunswik's lens model. (From Hogarth, 1987, p. 9)
In correspondence with the suggestions above the relation between the individual, the task and the environment is in focus in the ecological models of confidence judgments (Gigerenzer et al., 1991; Juslin, 1993; Björkman, 1994). Representatives for the ecological school argue that overconfidence often occurs in laboratory settings because the questions are not selected to represent a specific ‘reference class’. A reference class is a class of objects or events which is defined by the constraints of a well-defined natural environment.

According to the ecological models a major cause of overconfidence in many experiments is that the only criterion for the selection of items in a questionnaire is that they are ‘typical’ general knowledge items. This technique of item selection is called the informal technique of item selection. If instead a representative selection technique is used, i.e. if laboratory tasks are selected randomly from a relevant reference class on each occasion and if the assessors have a reasonable knowledge of the domain in which they are to make predictions, overconfidence will be eliminated.

In the Probabilistic Mental Models Theory (the PMM theory) of Gigerenzer et al. (1991) it is assumed that overconfidence is largely determined by a person’s ‘probabilistic mental model’ of the task and the task environment, i.e. the correspondence between the representation of a known task environment in a person’s long-term memory and the structure of the task. The requirement in the PMM theory for good calibration is that the task context in an experiment on judgments should resemble the representation of the natural environment which the individual identifies as relevant for the task.

Moreover, as noted above, a representative set of items should be sampled from this particular environment. Higher ecological validity can be achieved if a reference class is defined correctly, i.e. if the assessor naturally relates single facts to a particular reference class. It is therefore important to define the reference class and its boundaries correctly.

Gigerenzer et al assumed that people start to solve a problem by using a local mental model (a local MM) in which a subject attempts to directly retrieve or recognize one answer as correct. This problem solving model is a local, direct cognitive process and not a probabilistic inference process like the probabilistic mental model (PMM). An example of the local MM type of cognitive process is a wine connoisseur who is asked to tell whether a bottle of wine is produced in Bourgogne or in Bordeaux. By experience the

2 A typical general-knowledge question is: “What city was elected as the capital of the United States of America in 1793? (a) Boston (b) Washington”

3 Gigerenzer later clarified that PMM is a model of bounded rationality (see Simon, 1955) because it explains judgment and choice under “...given limited knowledge, limited attention and limited computational capacities” (1993, p. 23).

4 In the framework of mental models theory subjects are assumed to construct mental models to represent possible states of the world to test whether a conclusion is true. A person’s mental model is based on the information that is available to him/her (Evans, 1994).
connoisseur knows that two different types of bottles are commonly used for the two types of wines. By looking at the shape of the bottle the connoisseur will most probably be capable of giving a correct answer.

A PMM is used when the subject neither directly knows the answers nor can retrieve the answers through 'elementary logical operations' (Gigerenzer et al, 1991, p. 507). In the cognitive process of solving the task PMM uses a network of indirect variables or cues and through a probabilistic inference process, i.e. by connecting the specific structure of the task with a probability structure of a corresponding natural environment, an answer can be retrieved. To determine whether a wine is produced in Bourgogne or in Bordeaux is a complex task. The reference class for this task could be all wines in France. Various cues can be generated for solving this task, such as the shade of the color, the bouquet and the body of the wine. By weighing the one alternative against the other and against the target of the task, namely the origin of the wine, in an inductive inference process the wine taster can arrive at an answer.

The Internal Cue Theory (ICT; Juslin, 1993) is an approach similar to PMM. Here the cognitive adjustment is seen as the correspondence between a person's internal cue validity and the ecological validity. The internal cue validity can be explained as a person's confidence in a selected answer. Similar to PMM, ICT also predicted that people rely on probabilistic cues when they select their answers to almanac (or general-knowledge) items. Each cue has a specific validity extension which is constrained by the environment. This extension is defined by the set of situations, or 'potential' items in the subject's environment, where the cues can be used for correctly selecting an answer.

Juslin (1993) assumed that long-term experience in a specific naturally constrained environment leads to greater internal cue validity. Moreover, when the selected item sample reflects the cue validities in the environment the subjects are assumed to be better calibrated than if the items had been informally selected as 'typical' general knowledge items. It has been demonstrated by Gigerenzer et al (1991) and Juslin (1993) that overconfidence can be eliminated when items are randomly sampled from a larger pool of systematically generated items. The extent to which this way of generating items creates ecological validity is somewhat unclear.

The in the ecological models that the identification of an appropriate reference class will work as the key to reducing overconfidence has however been in the focus of criticism. For example, Griffin and Tversky (1992) did not accept that the degree of realism in confidence judgments is simply a matter of the relationship between the task and a natural environment. Nor did they accept that random sampling of knowledge items will eliminate overconfidence as suggested by Gigerenzer et al (1991). In their paper this was demonstrated empirically. Griffin and Tversky claimed that Gigerenzer and his colleagues did not make a clear distinction between the item selection technique and the task difficulty (p. 428) in their experiments. Therefore Gigerenzer et al cannot conclude what caused the overconfidence reductions in their study.
To Griffin and Tversky (1992) overconfidence is an effect of cognitive illusion or of an error in probabilistic reasoning. Griffin and Tversky distinguished between the influence of the strength and the weight of the evidence when making a confidence judgment in their interpretation of the overconfidence problem. The strength represents the impression that the evidence makes on the subjects, for example how the individual is affected by the evidence, while the weight represents the predictive validity of the information such as the base rate, the size of a sample and the accuracy of the message. Griffin and Tversky suggested that one cause for overconfidence is that people tend to rely on the strength of the information rather than its weight although they presumably make some adjustments in response to its weight when they make intuitive predictions.

3. PURPOSE AND PROPOSALS

3.1. Informal and representative selection of question items

To test the proposal that confidence judgment is a question of the relation between a task and its natural environment and that random sampling of knowledge items within this context will eliminate overconfidence, as suggested in the ecological models, two types of items were employed in the present study. The first type of items were informally selected from a Trivial Pursuit game (the informal selection condition) and the second type of items was randomly selected from two natural contexts (the representative selection condition). These two contexts were (a) the money market domain (money market rates) and (b) domestic train fares from Göteborg to various locations at different distances.

3.2. Objective difficulty and perceived difficulty

Earlier research on overconfidence has not attempted to distinguish the effects on confidence judgments of, on the one hand, actual or objective difficulty (measured as the actual proportion correct items), and on the other hand, perceived difficulty and perceived familiarity. As mentioned above, objective difficulty is defined as the percentage correct items in a binary alternative questionnaire. Perceived difficulty is defined as the subjects’ expressed perception of the difficulty level of a two answer-alternative question (or a set of two answer-alternative questions).

It is proposed here that by distinguishing objective difficulty from perceived difficulty, the confidence level could be better explained. Besides, by this division it is possible to test if the subjects react in a similar manner to objective and perceived difficulty. If they do then overconfidence will increase in relation to an increase in both objective and perceived difficulty.

However, Juslin (1993) found a slight tendency towards the reverse of the hard-easy effect. The tendency among the subjects in his study was to display underconfidence for very unfamiliar items and to display overconfidence for very familiar items. Juslin defined difficulty in terms of perceived familiarity of the (representatively selected) item contents. If perceived difficulty may render a reversed hard-easy effect then overconfidence will increase in relation to a decrease in perceived difficulty.
Moreover, it is assumed that perceived familiarity is the reversal of perceived difficulty. Thus perceived familiarity should be negatively correlated with perceived difficulty.

Fischhoff and MacGregor (1982) briefly considered the two aspects of difficulty when they argued that familiarity and objective difficulty are two sides of the same coin and that familiarity with the subject matter does not affect the calibration level unless the actual difficulty is also changed.

Furthermore, as noted above, in the contingency model (Beach & Mitchell, 1978, and O'Connor, 1989) it is assumed that the calibration of an individual is contingent both on internal factors such as familiarity with the task, the actual knowledge in a domain and also on the context in which the task is performed. O'Connor reports several studies which showed that overconfidence not only increased in domains where the tasks were more difficult (the hard-easy effect) but also that subjects displayed underconfidence with topics that the researchers believed to be more familiar to the subjects.

To test the above proposals all subjects in the frequency estimation experiment were asked to report the perceived difficulty level after every ten questions. In the confidence judgment experiment the subjects were not only asked to report the perceived difficulty level but also to report the perceived item familiarity after each question. The purpose was to determine the extent to which perceived familiarity, in addition to perceived difficulty, contributed to the explanation of the variance in the confidence level.

3.3. Confidence judgment and frequency estimation

Gigerenzer (1993) made a distinction between confidence judgments (or probability assessments) and frequency estimations (a frequency assessment is a report on the number of correct items out of, for example, the last ten items in a questionnaire). He argued that overconfidence occurs in experiments because people are asked to assess their probability estimations. From his point of view probability theory is not intended to be applied to unique events (p 8). Instead, frequency assessments are more appropriate when events are isolated. Besides, frequencies are more easily understood by most people since “...the mind infers the structure of the world through monitoring event frequencies.”(1993, p. 9) while a probability judgment calls for higher intellectual sophistication. Gigerenzer also suggested that a frequency statement (‘4 out of 10’) contains more information than the probability judgment (‘40 percent’). The former statement gives additional information about the size of the sample from which the estimation is made.

Griffin and Tversky (1992) argued that frequency estimations and confidence judgments have different foundations. They claimed that a confidence, or probability, judgment is “...a judgment of confidence in a particular case ... [while] ...estimated frequency of right prediction... is likely to be based on a general evaluation of the difficulty of the task, the knowledge of the judge, or past experience with similar problems” (p. 431).

Two experiments were carried out in order to investigate whether the subjects were better calibrated when making frequency estimations than when they made confidence judgments
as has been found in earlier research (Gigerenzer et al, 1991). However, Allwood and Granhag (in press) found that these results are somewhat unstable.

In the frequency experiment the subjects were asked to make a frequency assessment of correct items from every set of ten questions (in total four frequency assessments were made). In the confidence experiment the subjects were asked to assess the probability of the selected response alternative being right after each question.

It is here proposed that if people understand the concept of frequencies better than that of probabilities the frequency gap will be lower in the frequency experiment in comparison with the confidence gap in the confidence experiment, all other things being equal. The frequency gap is here defined as the difference between the mean estimated frequency multiplied by 10 and the mean percentage correct items. The corresponding confidence gap in the confidence experiment is defined as the difference between the mean confidence and the mean percentage correct items.

3.4. Warnings

A common manipulation in psychological experiments in the bias tradition has been to give warnings about various psychological anomalies in order to investigate whether subjects adjust behavior after a warning in order to avoid the bias against which subjects have been warned. In order to investigate whether information about the overconfidence phenomenon and its the causes before the experiment would reduce overconfidence fifty percent of the subjects in each experiment received information about the overconfidence phenomenon at the beginning of the experiment.

The proposal is that the subjects who initially receive relevant background information regarding overconfidence will not be better calibrated than other subjects in the experiment.

4. THE EXPERIMENTS
4.1. The models

For the regression analyses of the frequency experiment and the confidence experiment, the model below (equation 1) was used to test the proposals in section 3 above:

\[
\text{CONFIDENCE (FREQUENCY)} = \alpha + \beta_1 \times \text{PERCENTAGE CORRECT ITEMS}_t + \\
+ \beta_2 \times \text{PERCEIVED DIFFICULTY}_t + e_t \quad (1)
\]

\(\beta_1\) is assumed to be negative if the relations between confidence and frequency, jointly and separately, and the percentage correct items are related in correspondence to the hard-easy effect. (As mentioned above the hard-easy effect suggests an increase in overconfidence with difficult questions and a tendency towards underconfidence with easy questions). On the other hand, if a higher percentage correct items leads to a higher confidence or frequency estimation the regression coefficient \(\beta_1\) can be assumed to be positive.
As a result of the suggestion that higher *perceived* difficulty will lead to lower confidence (and lower frequency estimation) the regression coefficient $\beta_2$ is assumed to be negative.

The variable perceived topic familiarity was added in an additional regression analysis of data from the confidence experiment in order to determine its relation to the confidence level. The model for the analysis of the confidence experiment can be formulated as below in equation 2:

$$CONFIDENCE = \alpha + \beta_1 \times \text{PERCENTAGE CORRECT ITEMS}_t + \beta_2 \times \text{PERCEIVED DIFFICULTY}_t + \beta_3 \times \text{PERCEIVED FAMILIARITY}_t + \epsilon_t \quad (2)$$

The regression coefficient $\beta_3$ is expected to be positive since *perceived* familiarity is assumed to be the reverse of perceived difficulty.

The variables in the two models are defined below:

**CONFIDENCE** = the confidence judgment given for the selected item to be right. Confidence was reported on a scale with six confidence response categories. The scale was anchored at the fifty percent confidence level to represent chance or a random selection and at the one hundred percent level to represent a 'completely sure' selection. This scale is called a half-range confidence scale.

**FREQUENCY** = the frequency estimation. The subjects were asked to rate the frequency of right answers in each of four sets with ten two answer-alternative questions.

**PERCENTAGE CORRECT ITEMS** = the percentage correctly selected items in each selection condition.

**PERCEIVED DIFFICULTY** = the perceived difficulty of the question or set of questions. The perceived difficulty was reported on a scale from 1 to 5. The subjects were requested to score 1 when the question or the set of questions were perceived as very easy and 5 when the question or the set of questions were perceived as very difficult.

**PERCEIVED FAMILIARITY** = perceived familiarity with the two answer-alternative question. This dimension was reported on a scale from 1 to 5. The subjects were requested to score 1 when a question was perceived as totally unfamiliar and to score 5 when a question was perceived as very familiar.

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5 Ronis and Yates (1987) investigated the scale, or method, effect in confidence rating. Although a reduction in overconfidence was found when a full-range scale was used the decline in confidence was partly due to a misuse of the probability scale. Some subjects chose probabilities below .50 which was an indication of lack of understanding of the probability scale. In summary, they recommended the half-range scale as a more appropriate method for testing confidence levels.
4.2. Methods
4.2.1. Subjects

Sixty-two subjects participated in the frequency estimation experiment. Forty-one of these subjects were students at the Department of Psychology, Göteborg University. The other twenty-one subjects were doctoral students at the Department for Business Administration at Göteborg University. In the confidence judgment experiment forty students from the Department for Business Administration at Göteborg University participated. The subjects from the Department for Business Administration had all been introduced to the technique of probability judgments. To control for possible differences due to varying educational background separate analyses were also made for the three student groups mentioned above. The subjects in the frequency experiment received a lunch coupon for the equivalent of SEK 50.00 and the subjects in the confidence experiment received SEK 50.00 for participating in the experiment.

4.2.2. Experimental design

The experimental design in each of the two experiments, the frequency experiment and the confidence experiment, was a 2x2 design. In the frequency experiment the tasks involved frequency estimations and in the confidence experiment the tasks involved confidence judgments. Two types of items were employed in each of the two experiments in the present study. These were the informally selected and representatively selected items (see below in section 3.1 for a description of the two selection types). In each experiment the subjects either received information or received no information about the overconfidence phenomenon at the beginning of the experiment (see figure 2). With the exception of the frequency-estimation and confidence-judgment instructions the same procedure was employed in the two experiments.

4.2.3. Materials

An identical set of 40 two-alternative general knowledge questions was presented to the subjects in both experiments. Binary answer alternatives were used because they provide minimal, while still reasonable, processing assumptions (Juslin, 1993). 20 binary alternative questions (or tasks) were randomly selected from two subsets of items in the Trivial Pursuit game namely (a) art and literature (n=10) and (b) history (n=10) to represent the informal selection condition. The second type of questions was used in order to fulfill the requirements in the ecological models that events should be randomly selected from a certain population or a reasonably natural context. Ten two answer-alternative questions were randomly selected from the money market domain (money market rates) and ten questions were randomly selected from domestic train fares from Göteborg to various locations at different distances within Sweden.
<table>
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<th>CONFIDENCE–JUDGMENT EXPERIMENT</th>
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<td>Type of task</td>
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<td>Confidence judgment</td>
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</tr>
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<td>Representative items (30 items)</td>
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<tr>
<td>Information about overconfidence before experiment</td>
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</tr>
</tbody>
</table>

*Figure 2.*

Experimental design with two factors in each experiment: Informal selection/representative selection condition and information/ no information about overconfidence phenomenon at the beginning of the experiment.
4.2.4. Procedure

For each of the 40 questions in the questionnaire the subjects were to choose one of the two given answers as the most probable correct alternative. After each set of 10 questions the subjects in the frequency experiment the subjects were asked to (a) make an aggregated frequency assessment of the number of questions (out of the last ten) they had answered correctly and (b) to rate the perceived level of difficulty of the last ten questions. This means that they were asked to report how many items among the last ten that they believed to have answered correctly and to report the perceived difficulty level of the same ten items.

After each choice of answer alternative the subjects in the confidence experiment were asked to (a) assign a probability estimation (or a confidence assessment) that the chosen alternative was correct on a half-range confidence scale with the levels 50%, 60%, 70%, 80%, 90% and 100%. In the confidence experiment the subjects were also asked to rate both (b) the perceived level of difficulty of the task and (c) the perceived item familiarity after each question.

In order to investigate whether information about the overconfidence phenomenon would affect the subjects’ confidence level, half the group of subjects in the frequency experiment and half the group of subjects in the confidence experiment received information about the overconfidence phenomenon at the beginning of the experiment. They were presented with a set of eighteen explanations of overconfidence which have been presented by various researchers and they were asked to report in a questionnaire their relative acceptance of these explanations of overconfidence on a scale ranging from 1 (‘extremely unimportant’) to 5 (‘extremely important’).

4.2.5. Measurements of calibration, over/underconfidence and resolution

The measurements of calibration, over/underconfidence and resolution are regularly employed in research on calibration and they were also used in the present study (for technical definitions of the measurements see Lichtenstein & Fischhoff, 1977). Calibration basically measures the relation between the level of the confidence ratings and the percentage correct items in each confidence response category. The formulas for calibration and over/under-confidence only differ in that in the former the difference between the confidence ratings and the percentage correct items in each confidence response category is squared:

\[
\text{Calibration} = \frac{1}{n} \sum_{t=1}^{T} n_t (r_t - c_t)^2
\]

\[
\text{Over/underconfidence} = \frac{1}{n} \sum_{t=1}^{T} n_t (r_t - c_t)
\]
where
\( n \) = the total number of items selected
\( T \) = the number of response alternatives for the confidence ratings
\( n_t \) = the number of items selected in a response category
\( r_t \) = the confidence rating in a response category
\( c_t \) = the percentage correct items in a response category

Resolution is defined as the ability to ".. discriminate different degrees of subjective uncertainty by sorting the items into categories whose respective percentages correct are maximally different from the overall percentage correct." (Lichtenstein & Fischhoff, 1977, p. 162). A higher value for resolution tells us that extreme response categories relative the percentage correct of all items, \( c \), have been better utilized. The formula for resolution is:

\[
\text{Resolution} = \frac{T}{n} \sum_{t=1}^{T} n_t (c_t - c)^2
\]

where
\( c \) = the percentage correct of all items

4.3. Results

4.3.1. The questionnaire: Item difficulty in the informal and the representative selection condition

An analysis, including the data from both experiments, of the 40 questions in the questionnaire showed that the percentage of individuals scoring correct varied from 7.5% to 95% among the different questions. The mean of correct answers for all participants in the current study (n=102) was 56.6% (st dev: 10.0) in the informal selection condition. For the representative selection condition the percentage correct items varied less, from 21.3% to 76.3%. The mean of correct answers was lower, 54.8% (st dev: 10.2). A dependent t-test for the paired samples of selection types displayed no significant difference in the percentage correct answers in the two selection types.

4.3.2. t-tests and correlations: Informal and representative selection conditions in the frequency and the confidence experiment

The mean differences between the frequency experiment and the confidence experiment were analyzed in an independent t-test for the two conditions, informal and representative selection (Table 1).

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6 The SYSTAT program was employed for all statistical analyses in the current study.
Table 1 shows that the mean frequency assessment was lower than the confidence assessment in both selection conditions. Yet, no significant difference in percentage correct items was found for the informal selection condition and the representative selection condition, respectively, between the two experiments. An additional t-test further showed that there were no significant differences in percentage correct items between the two selection conditions. When all the frequencies, that were rated below the score of 5 were set to the score of 5 (and the means of the frequency estimations were multiplied by 10) the differences were still significant.

In order to also be able to investigate calibration in connection with the frequency experiment two alternative measures were created for the current study and applied for the analysis, namely a frequency gap and a confidence gap. As mentioned above the frequency gap was defined as the difference between the mean estimated frequency multiplied with 10 and the mean percentage correct items. (For the comparison in the t-test of the confidence judgments and frequency estimations the means of the frequency estimations were multiplied by 10.)

The corresponding confidence gap in the confidence experiment was defined as the difference between the mean confidence and the mean percentage correct items. The t-tests showed that the mean frequency gap was significantly lower than the mean confidence gap in both the informal and the representative selection condition (Table 1).

Dependent t-tests were conducted for the informal selection and representative selection condition in the frequency experiment and the confidence experiment, separately. The first dependent t-test compared means and standard deviations for frequency, percentage correct items, perceived difficulty and frequency gap in the frequency experiment. The second dependent t-test compared means and standard deviations for confidence, percentage correct items, perceived difficulty, perceived familiarity and confidence gap in the confidence experiment.

Since the means and standard deviations for these variables are presented in Table 1, Tables 2a and 2b show only the significance levels for the differences between the informal selection and representative selection conditions in the two experiments respectively.
Table 1. t-tests for the frequency experiment and the confidence experiment. Means and standard deviations for confidence and frequency, percentage correct items and perceived difficulty, frequency gap and confidence gap for informal selection and representative selection condition.

<table>
<thead>
<tr>
<th></th>
<th>The frequency experiment (n = 62)</th>
<th>The confidence experiment (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal selection condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency/confidence</td>
<td>56.29 (15.47)**</td>
<td>55.80 (7.24)</td>
</tr>
<tr>
<td>Frequency adjusted/ confidence</td>
<td>59.92 (10.30)**</td>
<td>55.80 (7.24)</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>55.57 (10.91)</td>
<td>54.15 (6.14)</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>3.74 (0.77)</td>
<td>3.51 (0.65)</td>
</tr>
<tr>
<td>Frequency gap/confidence gap</td>
<td>0.73 (14.02)**</td>
<td>10.65 (2.84)</td>
</tr>
<tr>
<td>Frequency gap (adjusted)/conf. gap</td>
<td>4.36 (10.65)**</td>
<td>10.65 (2.84)</td>
</tr>
<tr>
<td>Representative selection condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency/confidence</td>
<td>39.76 (14.12)**</td>
<td>59.11 (7.30)</td>
</tr>
<tr>
<td>Frequency adjusted/confidence</td>
<td>51.21 (3.23)**</td>
<td>59.11 (7.30)</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>55.40 (10.57)</td>
<td>57.88 (6.87)</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>4.65 (0.48)**</td>
<td>4.16 (0.67)</td>
</tr>
<tr>
<td>Frequency gap/confidence gap</td>
<td>-15.65 (19.72)**</td>
<td>5.24 (10.97)</td>
</tr>
<tr>
<td>Frequency gap (adjusted)/conf. gap</td>
<td>-4.19 (11.50)**</td>
<td>5.24 (10.97)</td>
</tr>
</tbody>
</table>

* = p < 0.05; ** = p < 0.01

7 To be able to compare the means for frequency and confidence the mean estimated frequency was multiplied by 10.

8 Before the t-test all frequencies that were rated below the score of 5 were set to the score of 5 and the means of the frequency estimations were multiplied by 10.

9 The calculation of the adjusted 'frequency gap' was based on the adjusted frequency rating (see footnote 8).
Table 2a. Significance levels for the differences between means and standard deviations for frequency, adjusted frequency, percentage correct items, perceived difficulty and frequency gap in the informal selection and representative selection conditions: The frequency experiment.

<table>
<thead>
<tr>
<th>The frequency experiment (n=62)</th>
<th>Informal and representative selection condition: Significance levels in the dependent t-tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Frequency (adjusted)</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>p = n.s.</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Frequency gap</td>
<td>p &lt; 0.01</td>
</tr>
</tbody>
</table>

Table 2b. Significance levels for the differences between means and standard deviations for confidence, percentage correct items, perceived difficulty and confidence gap in the informal selection and representative selection conditions: The confidence experiment.

<table>
<thead>
<tr>
<th>The confidence experiment (n=62)</th>
<th>Informal and representative selection condition: Significance levels in the dependent t-tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Perceived familiarity</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Confidence gap</td>
<td>p &lt; 0.05</td>
</tr>
</tbody>
</table>

The dependent t-tests showed that nearly all variables were significantly different in the informal selection and representative selection condition of the frequency experiment. Only the percentage correct items was not significantly different between the two selection conditions in this experiment. Moreover, these results showed underconfidence in the representative selection condition and overconfidence in the informal selection condition. In the informal selection condition the frequency gap was significantly higher and the subjects perceived the questions' difficulty level as significantly lower than in the representative selection condition.

In the confidence experiment the dependent t-tests showed significant differences for all variables between the informal selection and representative selection condition. The overconfidence level as well as the confidence gap was significantly higher in the informal selection condition than in the representative selection condition. The percentage correct items was significantly higher in the informal selection conditions.

Finally, to investigate whether there were any significant differences in the responses from the two groups of students who were participating in the frequency experiment and who had different educational backgrounds (the students in psychology and the
doctoral students in business administration) additional t-tests were conducted for this experiment (Table 3).

Only one significant difference in responses from the two student groups that participated in the frequency experiment (Table 3). The doctoral students at the Department of Business Administration gave higher frequency estimations than the student psychologists. However, their higher frequency estimation was also followed by a higher percentage correct items. Neither the original nor the adjusted frequency gaps were significantly different between the two subgroups.

Table 3.
The frequency experiment: t-tests for students in business administration and students in psychology. Means and standard deviations for confidence and frequency, percentage correct items and perceived difficulty, frequency gap, confidence gap and frequency gap (adjusted) for the informal selection and the representative selection condition.

<table>
<thead>
<tr>
<th>THE FREQUENCY EXPERIMENT</th>
<th>Students in business administration (n = 21)</th>
<th>Students in psychology (n = 41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal selection condition:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>56.91 (13.55)</td>
<td>55.98 (16.52)</td>
</tr>
<tr>
<td>Frequency (adjusted)</td>
<td>59.05 (10.20)</td>
<td>60.37 (10.45)</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>55.00 (9.35)</td>
<td>55.85 (11.72)</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>3.71 (0.90)</td>
<td>3.75 (0.70)</td>
</tr>
<tr>
<td>'Frequency gap'</td>
<td>1.90 (10.18)</td>
<td>0.12 (15.70)</td>
</tr>
<tr>
<td>'Frequency gap'(adjusted)</td>
<td>4.05 (8.75)</td>
<td>4.51 (11.61)</td>
</tr>
</tbody>
</table>

Representative selection condition:

| Frequency | 44.76 (11.99)* | 37.20 (14.58) |
| Frequency (adjusted) | 52.38 (4.90) | 50.61 (1.66) |
| Percentage correct items | 52.62 (9.83) | 56.83 (10.77) |
| Perceived difficulty | 4.62 (0.57) | 4.67 (0.43) |
| 'Frequency gap' | -7.86 (14.28) | -19.63 (21.05) |
| 'Frequency gap'(adjusted) | -0.24 (10.78) | -6.22 (11.44) |

* = p < 0.05; ** = p < 0.01

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10 See footnote 7.
11 See footnote 8.
12 See footnote 9.
An additional t-test was also conducted for the two subgroups of students in business administration, namely the doctoral students of business administration in experiment 1 (n=21) and the students in business administration in experiment 2 (n=40). This t-test displayed only one deviation from the results shown in Table 1, in that the adjusted frequency gap was not significantly different between these two subgroups (p=0.06).

Above a distinction was made between objective difficulty and perceived difficulty. This section also reports an analysis of the correlation between confidence (frequency) on the one hand and objective difficulty and perceived difficulty on the other (Table 4). These correlations were computed for each of the informal and representative conditions separately.

Table 4
Correlations between confidence and frequency, respectively, and percentage correct items and perceived difficulty for the informal selection condition and representative selection condition in the frequency experiment and the confidence experiment. (The correlation between confidence and perceived familiarity is also included for the informal selection and the representative selection condition in the confidence experiment.)

<table>
<thead>
<tr>
<th></th>
<th>Informal selection condition</th>
<th>Representative selection condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FREQUENCY</td>
<td>FREQUENCY</td>
</tr>
<tr>
<td>THE FREQUENCY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXPERIMENT (n=62):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage correct</td>
<td>0.48**</td>
<td>-0.26*</td>
</tr>
<tr>
<td>items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.42**</td>
<td>-0.29*</td>
</tr>
<tr>
<td></td>
<td>CONFIDENCE</td>
<td>CONFIDENCE</td>
</tr>
<tr>
<td>THE CONFIDENCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXPERIMENT (n=40):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage correct</td>
<td>0.34*</td>
<td>0.17</td>
</tr>
<tr>
<td>items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.42**</td>
<td>-0.54**</td>
</tr>
<tr>
<td>Perceived</td>
<td>0.78**</td>
<td>0.46**</td>
</tr>
</tbody>
</table>

* = p < 0.05; ** = p < 0.01

As is shown in Table 4, most correlations between percentage correct items and frequency and confidence, respectively, for each of the two selection conditions in the frequency and the confidence experiment were positive. The only correlation between those variables that can indicate a relation similar to a hard-easy effect was shown for the representatively selected items in the frequency experiment. The pattern was more distinct for the correlations between perceived difficulty and frequency and for the correlations between perceived difficulty and confidence. The relations were negative and significant for the informal as well as the representative selection condition in both experiments. The correlation between confidence and perceived familiarity was positive and significant for
both selection conditions in the confidence experiment. Finally, the correlation between perceived difficulty and perceived familiarity was significant and negative for the informally selected items ($r = -0.46; p < 0.01$). However, the correlation was nonsignificant for the representatively selected items ($r = -0.26; p = \text{n.s}$).

4.3.3. Regression analyses of informal and representative selection conditions in the frequency and the confidence experiment

Multiple regression analyses were carried out in order to analyze the contribution of perceived difficulty and perceived familiarity to the frequency and the confidence assessments, respectively. The enter option was used in all analyses reported below, meaning that a pre-specified model was used in each separate analysis.

The variable frequency measured the relative estimated frequency of correct answers among 4 sets of 10 questions each and the variable confidence measured confidence assessments as single-event probabilities. The variables percentage correct items and perceived difficulty were used as regressors in the model used in the first set of regression analyses to investigate how perceived and objective difficulty can explain the confidence level and the level of the frequency estimates for informally and representatively selected items in the two experiments. The regression analyses were estimations of the model that was specified in equation 1 above.

An additional set of multiple regression analyses was conducted on the data from the confidence experiment. These analyses were made in order to investigate how well the proportion correct items, perceived difficulty and perceived familiarity could explain the variance in the confidence level. Separate analyses were made for the informal selection condition and the representative selection condition. The multiple linear regression analysis was modeled as specified in equation 2 above.

In Appendix 1 the regressions are presented for the informal selection and the representative selection condition for all subjects both before and after data in the frequency and the confidence experiment had been pooled. Thereafter (in Appendix 2 and 3) the regressions are presented for the informal selection condition and the representative selection condition in the frequency experiment and the confidence experiment respectively.

To investigate whether there are differences in the results that can be explained by the education background regressions are also presented separately for the three subgroups (psychology students, business administration students and doctoral students in business administration) in Appendix 3. Thus, first the regression of frequency on percentage correct items and perceived difficulty for (a) all subjects in the frequency experiment is presented. The same regression are presented for (b) the doctoral students at the department of business administration and (c) the students in psychology. The regressions for the subjects in the confidence experiment (the students in business administration) are presented.
Finally, the regressions of confidence on percentage correct items, perceived difficulty and perceived familiarity in the confidence experiment are presented for the informal selection and the representative selection condition in Appendix 4. Summaries of the results of the regressions are presented in Tables 5 and 6 below.

The regressions show that both percentage correct items and perceived difficulty contributed to the explanation of the variation in frequency/confidence in both selection conditions after data in the two experiments were pooled (Appendix 1: Tables 1 and 2). The relations between frequency/confidence and percentage correct items were positive and significant in the regression on the informal selection condition (Appendix 1: Table 1). The regressions on the representative selection condition on frequency/confidence showed a negative relation between the dependent variable and the percentage correct items (Appendix 1: Table 2).

Separate regressions were also conducted on the frequency and the confidence conditions (Appendices 2 and 3). The percentage correct items and perceived difficulty in the informal selection condition in both the different educational samples in the frequency experiment (Appendix 2: Tables 2 and 3) and in the confidence experiment (Appendix 2: Table 4) revealed the same tendency as for the pooled data. The relation between frequency and perceived difficulty was however not significantly negative for the psychology students in the frequency experiment.

For the representative selection condition (Appendix 3) frequency was significant and negatively related to the percentage correct items for the business administration doctoral students only (Appendix 3: Table 1) while no significant relation was found between frequency and percentage correct items for the psychology students (Appendix 3: Table 4). Likewise, the relation between confidence and percentage correct items was not found to be significant (Appendix 3: Table 4). Both frequency and confidence were again negatively related to perceived difficulty. The finding was however not significant for the psychology students in the frequency experiment.

When perceived familiarity was added to the regression in the confidence experiment (Appendix 4; Tables 1 and 2) the regression showed that confidence was neither significantly explained by percentage correct items nor by perceived difficulty in the informal selection condition. The major share of the contribution to the explanation of the variation in confidence came from perceived familiarity in this selection condition (Appendix 4; Table 1). For the representative selection condition both perceived difficulty and perceived familiarity explained the variation in confidence as suggested in the proposals (Appendix 4; Table 2).
Table 5.
Summary of results from regressions of frequency/confidence on percentage correct items, perceived difficulty and perceived familiarity for informally selected items in the frequency experiment and the confidence experiment. An additional regression on confidence (CE) includes perceived familiarity.

<table>
<thead>
<tr>
<th></th>
<th>FE and CE</th>
<th>FE DSBA and PS (n = 62)</th>
<th>FE DSBA (n = 21)</th>
<th>FE PS (n = 41)</th>
<th>CE STBA (n = 40)</th>
<th>CE STBA (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>Freq/Conf</td>
<td>Freq</td>
<td>Freq</td>
<td>Freq</td>
<td>Conf</td>
<td>Conf</td>
</tr>
<tr>
<td>Indep. variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent correct items</td>
<td>Pos**</td>
<td>Pos**</td>
<td>Pos*</td>
<td>Pos*</td>
<td>Pos*</td>
<td>Pos n.s.</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>Neg**</td>
<td>Neg**</td>
<td>Neg*</td>
<td>Neg n.s.</td>
<td>Neg**</td>
<td>Neg n.s.</td>
</tr>
<tr>
<td>Perceived familiarity</td>
<td>Pos**</td>
<td>Pos**</td>
<td>Pos*</td>
<td>Pos*</td>
<td>Pos**</td>
<td>Pos**</td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.30</td>
<td>0.29</td>
<td>0.57</td>
<td>0.17</td>
<td>0.23</td>
<td>0.60</td>
</tr>
</tbody>
</table>

*p < 0.05; **p < 0.01; n.s. = nonsignificant

Note: FE = the frequency experiment; CE = the confidence experiment; Freq = frequency estimation; Conf = confidence judgment; Pos = A positive tendency in explaining the variance in the dependent variable; Neg = A negative tendency in explaining the variance in the dependent variable; DSBA = doctoral students in business administration; PS = psychology students; STBA = students in business administration;

Table 6.
Summary of results from regressions of frequency and confidence on percentage correct items, perceived difficulty and perceived familiarity for representatively selected items in the frequency experiment and the confidence experiment. (An additional regression on confidence (CE) includes perceived familiarity.)

<table>
<thead>
<tr>
<th></th>
<th>FE and CE</th>
<th>FE DSBA and PS (n = 62)</th>
<th>FE DSBA (n = 21)</th>
<th>FE PS (n = 41)</th>
<th>CE STBA (n = 40)</th>
<th>CE STBA (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>Freq/Conf</td>
<td>Freq</td>
<td>Freq</td>
<td>Freq</td>
<td>Conf</td>
<td>Conf</td>
</tr>
<tr>
<td>Indep. variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent correct items</td>
<td>Neg**</td>
<td>Neg*</td>
<td>Pos n.s.</td>
<td>Neg*</td>
<td>Pos n.s.</td>
<td>Neg n.s.</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>Neg**</td>
<td>Neg*</td>
<td>Neg*</td>
<td>Neg n.s.</td>
<td>Neg**</td>
<td>Neg**</td>
</tr>
<tr>
<td>Perceived familiarity</td>
<td>Pos**</td>
<td>Pos**</td>
<td>Pos**</td>
<td>Pos**</td>
<td>Pos**</td>
<td>Pos**</td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.27</td>
<td>0.12</td>
<td>0.14</td>
<td>0.10</td>
<td>0.26</td>
<td>0.36</td>
</tr>
</tbody>
</table>

*p < 0.05; **p < 0.01; n.s. = nonsignificant

Note: see note in Table 4
4.3.4. Calibration, confidence and resolution in the confidence experiment

The calibration curves for the informal selection and the representative selection conditions in the confidence experiment are shown in figure 3. The total number of items for each response category and selection condition are also shown in this figure.

![Calibration curves](image)

**NOTE:** Inf.sel = informal selection condition
Rep.sel = representative selection condition
Ideal = perfect calibration

**Figure 3.** The confidence experiment: Calibration curves for the informal selection and the representative selection conditions.

Underconfidence occurred for the fifty percent response category in the representative selection condition but not in the informal selection condition. In both selection conditions the fifty percent confidence ratings were most common. However, it is noteworthy that this tendency was much more extreme in the representative selection condition. Here, more than half of the confidence ratings were given on this confidence level and very few ninety and hundred percent ratings were registered. Moreover, the few ratings that were reported in these response categories in the representative selection condition displayed extreme overconfidence. As can be seen, the calibration curve for the informal selection condition displays overconfidence for all response categories.

Table 7 shows the measures for calibration, over/underconfidence and resolution for the informal selection and the representative selection conditions in the confidence experiment.
Table 7.
The confidence experiment: Means and standard deviations for calibration, over/underconfidence and resolution for the informal and representative selection conditions.

<table>
<thead>
<tr>
<th>The confidence experiment (n = 40)</th>
<th>Informally selected items</th>
<th>Representatively selected items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>0.07 (0.04)</td>
<td>0.07 (0.05)</td>
</tr>
<tr>
<td>Over/underconfidence</td>
<td>0.11 (0.09)*</td>
<td>0.05 (0.11)</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.06 (0.04)*</td>
<td>0.04 (0.03)</td>
</tr>
</tbody>
</table>

* = p < 0.05

Both over/underconfidence and resolution differed significantly in the two conditions. Overconfidence was higher in the informal condition. Taken together, the lower resolution score for the representative selection condition and the large number of items that registered in the 50% response category for this selection condition indicates that the subjects in this condition did not utilize the entire probability scale as fully as they did in the informal selection condition. Calibration was not significantly different in the two selection conditions.

4.3.5. Warning condition: Information about overconfidence

A t-test was computed in order to analyze if information about overconfidence prior to the experiment had any impact in reducing the cognitive bias of overconfidence (see Table 8). As expected, neither the percentage correct items among the subjects, their confidence assessments nor their frequency assessments were influenced by the received information about the overconfidence phenomenon.

Table 8.
t-tests comparing means and standard deviations for percentage correct items, confidence (frequency) and perceived difficulty between the two conditions information about overconfidence before the experiment and no information about overconfidence before the experiment: frequency experiment and the confidence experiment, respectively.

<table>
<thead>
<tr>
<th>Information before the experiment</th>
<th>No information before the experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE FREQUENCY EXPERIMENT</td>
<td></td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>53.56 (7.21)*</td>
</tr>
<tr>
<td>Frequency</td>
<td>4.72 (1.25)</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>4.21 (0.44)</td>
</tr>
<tr>
<td>(n=33)</td>
<td></td>
</tr>
<tr>
<td>THE CONFIDENCE EXPERIMENT</td>
<td></td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>55.50 (6.52)</td>
</tr>
<tr>
<td>Frequency</td>
<td>64.15 (6.87)</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>3.76 (0.50)</td>
</tr>
<tr>
<td>(n=21)</td>
<td></td>
</tr>
</tbody>
</table>

* = p < 0.05; ** = p < 0.01
5. DISCUSSION AND CONCLUSIONS

The aims of this study were (1) to investigate whether ecological validity matters for calibration and (2) to investigate whether subjective, or perceived, difficulty can provide additional explanation for the variance in confidence. Furthermore, (3) the aim was to compare the realism in judgments about the probability of one's separate answer being correct with the effects on realism in assessments of the frequency correct answers among a set of 10 questions. Finally, (4) it was investigated whether the realism of one's confidence judgment and frequency estimation was affected by information about the existence of the overconfidence phenomenon. The results will be discussed in this order.

The analysis showed that a representative selection of binary alternative questions can decrease the subjects' overconfidence, as suggested by Gigerenzer et al (1991). However, the decrease in overconfidence occurred at the expense of poorer resolution. The subjects did not vary their confidence scores to the same extent in the representative selection condition as they did in the informal selection condition. Underconfidence was found for the fifty percent response category in the representative selection condition in the confidence experiment. It should be noted that the results for the fifty percent items contributed strongly to the lower overconfidence in the representative selection condition. More than half the confidence ratings were given on this confidence level. Furthermore, very few ninety and hundred percent ratings were registered for this selection condition and the few ratings that were reported in these response categories displayed extreme overconfidence.

A reflection on the results in the current study gives rise to the question whether representative selection creates less overconfidence among the subjects because the tasks are selected from a well-defined natural environment or if the lesser overconfidence is due to the fact that the representative selection of items facilitates the thought process through repeated activation of the same memory structure (the questions in the representative selection condition tended to come from the same content domain).

The regression analysis of the informally selected items showed that ratings of frequency (in the frequency experiment) as well as confidence (in the confidence experiment) were explained to a significant degree by the percentage correct items and perceived difficulty.

The hypothesis that a reversed hard-easy effect would be observed for perceived difficulty was confirmed in the entire analysis. Overall, the results from the regressions on the confidence experiment showed that a decrease in confidence was associated primarily with an increase in perceived difficulty (or a decrease in perceived familiarity) when this variable was included in the analysis. Likewise, the subjects tended to increase their confidence rating when they perceived a question as less difficult. A similar result was found for item familiarity by Juslin (1993).

When perceived familiarity was added to the regression on confidence in the current study the variance was to a large extent explained by negative contributions from the perceived difficulty as well as by positive contributions from perceived familiarity for the
representative selection condition. However, in the informal selection condition only perceived familiarity explained confidence.

These observations suggest that the subjects followed their perception of the difficulty of the items when giving their confidence assessments. This behavior was most clearly observed in the representative selection condition where the subjects, on average, perceived the items as significantly more difficult than in the informally selection condition. As mentioned above, in the confidence experiment more than half the confidence ratings were given on the fifty percent confidence level for the representatively selected items. It is therefore possible that once the subjects had established their impression of the questions' relative difficulty (or familiarity) among the set of items in the representative selection condition they may have used this impression as an anchor for their actual confidence ratings. These findings indicate that people's probabilistic reasoning may be largely influenced by their first impressions when making confidence assessments, as was suggested by Griffin and Tversky (1992).

The correlations between perceived difficulty and perceived familiarity were strongly negative in both selection conditions. Thus, perceived familiarity can to some extent be understood to be the inverse of perceived difficulty in explaining confidence.

Further, the results showed a higher degree of realism when the subjects were asked to make frequency assessments than when they were asked to make confidence assessments. The subjects gave significantly lower frequency assessments than confidence assessments both for informally selected and for representatively selected questions. Yet no significant difference in percentage correct items was found between the two experiments for the separate selection conditions. This result supports earlier research showing that subjects were better calibrated when making frequency estimations than when they make confidence judgments (Gigerenzer et al, 1991).

Since randomization of subjects only took place within the two experiments and not between them in the current study the results of the comparisons between the frequency estimations and the confidence judgments could be explained as an effect of the fact that subjects with different educational backgrounds were participating in the two experiments. However, this explanation does not seem very likely since additional t-tests and regressions on the different student groups showed a matching pattern in the relations between the dependent variables, frequency and confidence, and the independent variables, percentage correct items and perceived difficulty for the three subgroups.

One alternative cause for the lower frequency scoring in the current study can be that different types of scales were used for the two types of ratings. As in many experiments on calibration, a half-range scale was used for the confidence ratings while the subjects were allowed to rate the estimated frequency over the full range of items. However, in an additional t-test all frequencies that were rated below that of chance, namely the score of 5, were set to the score of 5. The results from this t-test did not deviate significantly for the two conditions in comparison with the results when the full scale for frequency estimation was used (see Tables 1 and 2). For an improved understanding of the causes of
the confidence-frequency effect in experiments future research may still need to focus on the effects on frequency and confidence assessments of the different types of scales that are commonly used for the two types of ratings.

Finally, as in earlier studies by for instance Fischhoff (1982) and Gigerenzer et al (1991) where debiasing techniques have been used to reduce overconfidence the present study revealed no improvement in calibration after subjects had been informed about the overconfidence phenomenon.

One of the most important results in the present study is that the analyses show the importance of making a distinction between objective and perceived difficulty. Perceived difficulty and perceived familiarity both seem to be relevant measures of the subjects' reaction to the items in the present context. Perceived difficulty and perceived familiarity have been shown in the current study to contribute independently of objective difficulty to the subjects' confidence judgments and thus conceivably to the interpretation of the causes of the overconfidence phenomenon. It is suggested that in order to improve our understanding of the overconfidence phenomenon future research should further explore the role of perceived difficulty and item familiarity in confidence judgments.
6. REFERENCES


APPENDIX 1.

Regression of frequency/confidence on percentage correct items and perceived difficulty for informally selected items and representatively selected items in the frequency experiment and the confidence experiment, jointly.

Table 1.
Regression of frequency/confidence on percentage correct items and perceived difficulty for informally selected items in the frequency and the confidence experiment (all subjects in the two experiments; n=102).

<table>
<thead>
<tr>
<th>Frequency experiment and confidence experiment</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informally selected items (All subjects in the two experiments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dep var: frequency/confidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>5.42**</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.36</td>
<td>4.17**</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.34</td>
<td>-3.95**</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.31 (0.30);
Durbin-Watson D-statistics (1:st order autocorrelation): 1.64 (0.14)
* = p < 0.05; ** = p < 0.01

Table 2.
Regression of frequency/confidence on percentage correct items and perceived difficulty for representatively selected items in the frequency and the confidence experiment (all subjects in the two experiments; n=102).

<table>
<thead>
<tr>
<th>Frequency experiment and confidence experiment</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representatively selected items (All subjects in the two experiments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dep var: frequency/confidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>0.79**</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>-0.20</td>
<td>-2.16**</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.50</td>
<td>-2.50**</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.28 (0.27);
Durbin-Watson D-statistics (1:st order autocorrelation): 1.42 (0.27)
* = p < 0.05; ** = p < 0.01
APPENDIX 2.

Regression of frequency and confidence on percentage correct items and perceived difficulty for informally selected items in the frequency experiment and the confidence experiment

Table 1.
Regression of frequency on percentage correct items and perceived difficulty for informally selected items in the frequency experiment (students in psychology and doctoral students in business administration; n=62).

<table>
<thead>
<tr>
<th>Dep var: frequency</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-</td>
<td>3.37**</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.39</td>
<td>2.40**</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.30</td>
<td>2.01**</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.30 (0.29); Durbin-Watson D-statistics (1:st order autocorrelation): 1.94 (-0.00)
* = p < 0.05; ** = p < 0.01

Table 2.
Regressions of frequency on percentage correct items and perceived difficulty for informally selected items in the frequency experiment (doctoral students in business administration only; n=21)

<table>
<thead>
<tr>
<th>Dep var: frequency</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-</td>
<td>2.35**</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.41</td>
<td>2.40*</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.49</td>
<td>2.91**</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.61 (0.57); Durbin-Watson D-statistics (1:st order autocorrelation): 2.49 (-0.34)
* = p < 0.05; ** = p < 0.01
Table 3.
Regressions of frequency on percentage correct items and perceived difficulty for informally selected items in the frequency experiment (students in psychology; n=41)

<table>
<thead>
<tr>
<th>The frequency experiment</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informally selected items (Students in psychology)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dep var: frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-</td>
<td>2.24*</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.41</td>
<td>2.55*</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.49</td>
<td>-1.33</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.22 (0.17)
Durbin-Watson D-statistics (1:st order autocorrelation): 1.86 (-0.03)
* = p < 0.05; ** = p < 0.01

Table 4.
Regression of confidence on percentage correct items and perceived difficulty for informally selected items in the confidence experiment (students in business administration; n=40).

<table>
<thead>
<tr>
<th>The confidence experiment</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informally selected items (Students in business administration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dep var: confidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-</td>
<td>6.55**</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.30</td>
<td>2.13*</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.39</td>
<td>2.75**</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.27 (0.23);
Durbin-Watson D-statistics (1:st order autocorrelation): 2.12 (-0.07)
* = p < 0.05; ** = p < 0.01
APPENDIX 3.

Regression of frequency and confidence on percentage correct items and perceived difficulty for representatively selected items in the frequency experiment and the confidence experiment.

Table 1.

Regressions of frequency on percentage correct items and perceived difficulty for representatively selected items in the frequency experiment (students in psychology and doctoral students in business administration; n=62).

<table>
<thead>
<tr>
<th>Dep var: frequency</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>-0.25</td>
<td>2.07*</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.28</td>
<td>2.36*</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.14 (0.12);
Durbin-Watson D-statistics (1:st order autocorrelation): 1.80 (0.08)
* = p < 0.05; ** = p < 0.01

Table 2.

Regressions of frequency on percentage correct items and perceived difficulty for representatively selected items in the frequency experiment (doctoral students in business administration; n=21)

<table>
<thead>
<tr>
<th>Dep var: frequency</th>
<th>STD COEFF</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.02</td>
<td>0.10</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.47</td>
<td>2.14*</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.22 (0.14);
Durbin-Watson D-statistics (1:st order autocorrelation): 1.22 (0.37)
* = p < 0.05; ** = p < 0.01
Table 3.
Regressions of frequency on percentage correct items and perceived difficulty for representatively selected items in the frequency experiment (students in psychology; n=41)

<table>
<thead>
<tr>
<th>Representatively selected items</th>
<th>STD COEFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Students in psychology)</td>
<td></td>
</tr>
<tr>
<td>Dep var: frequency</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>-0.34</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.13</td>
</tr>
</tbody>
</table>

R\(^2\) (Adjusted R\(^2\)): 0.15 (0.10);
Durbin-Watson D-statistics (1:st order autocorrelation): 1.97 (0.00)
* = p < 0.05; ** = p < 0.01

Table 4.
Regressions of confidence on percentage correct items and perceived difficulty for representatively selected items in the confidence experiment (students in business administration; n=40).

<table>
<thead>
<tr>
<th>Representatively selected items</th>
<th>STD COEFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Students in business administration)</td>
<td></td>
</tr>
<tr>
<td>Dep var: confidence</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>8.77**</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.01</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.54</td>
</tr>
</tbody>
</table>

R\(^2\) (Adjusted R\(^2\)): 0.30 (0.26);
Durbin-Watson D-statistics (1:st order autocorrelation): 2.27 (-0.14)
* = p < 0.05; ** = p < 0.01
APPENDIX 4.

Regression of confidence on percentage correct items, perceived difficulty and perceived familiarity for informally selected and representatively selected items in the confidence experiment.

Table 1.
Regression of confidence on percentage correct items, perceived difficulty and perceived item familiarity for representatively selected items in the confidence experiment (students in business administration; n = 40).  

<table>
<thead>
<tr>
<th>The confidence experiment</th>
<th>STD COEFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informally selected items</td>
<td></td>
</tr>
<tr>
<td>(Students in business administration)</td>
<td></td>
</tr>
<tr>
<td>Dep var: confidence</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>4.71***</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>0.13</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.08</td>
</tr>
<tr>
<td>Perceived Familiarity</td>
<td>0.70</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.63 (0.60);  
Durbin-Watson D-statistics (1:st order autocorrelation): 2.60 (0.31)  
* = p < 0.05; ** = p < 0.01

Table 2.
Regression of confidence on percentage correct items, perceived difficulty and perceived item familiarity for representatively selected items in the confidence experiment (students in business administration; n = 40).  

<table>
<thead>
<tr>
<th>The confidence experiment</th>
<th>STD COEFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representatively selected items</td>
<td></td>
</tr>
<tr>
<td>(Students in business administration)</td>
<td></td>
</tr>
<tr>
<td>Dep var: confidence</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-2.28***</td>
</tr>
<tr>
<td>Percentage correct items</td>
<td>-0.03</td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td>-0.46</td>
</tr>
<tr>
<td>Perceived Familiarity</td>
<td>0.35</td>
</tr>
</tbody>
</table>

R² (Adjusted R²): 0.41 (0.36)  
Durbin-Watson D-statistics (1:st order autocorrelation): 2.34 (0.17)  
* = p < 0.05; ** = p < 0.01
 EFI
The Economic Research Institute

Published in the language indicated by the title

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