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Voluntary information acquisition in an asymmetric-Information game:comparing learning theories in the laboratory

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ABSTRACT

This paper uses an experimental design of voluntary information acquisition to assess the information assumptions of different learning models. The design is implemented in two-stage asymmetric-information games. Subjects' information-seeking behavior reveals that they tend to choose certain information sets that are consistent with belief-based learning theories rather than reinforcement theories. A hybrid-learning model with information acquisition that is a variant of the Generalized Experience-Weighted-Attraction (GEWA) model (Shafran, 2012) is also proposed. It successfully captures the different learning speeds of two groups of subjects (i.e., informed and uninformed subjects), and shows that once information acquisition data is added into a structural model that focuses on action data alone, the performance is enhanced. Additional individual analysis indicates that the information acquisition behavior assumed by learning models appears to suggest the learning rule subjects follow. The results suggest that tracking subjects' voluntary information choices is a useful tool for analyzing their learning behaviors.

1. Introduction

Learning is an important topic in game theory and economics. Learning models have been widely used by experimental economists as an alternative to equilibrium predictions in game theory. These models vary in the way in which they theorize how learning occurs. The extant models can be largely categorized into one of two broad classes, or as a mixture of the two classes: (i) reinforcement learning (RE) (e.g., Roth and Erev, 1995 and Erev and Roth, 1998) - which assumes that players' strategies receive reinforcement related to the payoffs they earn, and over time players adjust their play so that strategies leading to higher payoffs become more likely; and (ii) belief-based learning (BE) (e.g., Fudenberg and Levine, 1998) - which assumes that players update beliefs about what others will do based on historical outcomes and will use those beliefs to determine the best strategies to employ. Information implicitly forms a part of the majority of these learning models; however, the issue of whether individuals adhere to the information assumptions of models has received little attention.

Broadly speaking, information that can be used to make predictions can be divided into two types: (i) information that focuses on payoffs or the payoff functions that individuals may face; and (ii) information that focuses on the use of past actions and payoffs to make predictions. The voluntary information-seeking behaviors of individuals reveal how they strate-

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gically think and learn.[1] Few studies have explored the technique of tracking subjects' searches for information that focuses on past actions and payoffs when studying learning theory. The current study contributes to this topic. Specifically, it compares whether subjects' information acquisition behaviors are consistent with the information assumptions of the learning models, and then assesses any performance improvements in the learning models when information acquisition data is added.

This study adopts a design of voluntary information acquisition. Subjects are asked to play a two-stage game repeatedly for 50 rounds in a laboratory. As subjects make their action decisions, they are offered a menu of historical information by way of six buttons that they can select from. Clicking any of these buttons reveals a piece of information from the last 10 rounds in relation to either the subjects' own past choices, their own received payoffs, or their partners' past choices and payoffs (also referred to as their partners' history). Subjects can click as many buttons as they wish and can also click the same button multiple times. However, once a subject clicks a different button, the previously revealed information is overwritten. Subjects' information acquisition choices and their frequencies are recorded.

The design is inspired by Camerer (2003, p. 273) who observed that examining what information is used to update beliefs may be the best way to judge which learning model better characterizes subjects' learning behaviors, as some learning models work in low-information environments, while others only work in high-information environments. RE models generally assume that players care only about the history of their own payoffs and these models can be applied in low-information environments. BE models are more sophisticated and they require information regarding the partner's history to enable belief updating. Thus, tracking which information is used to update beliefs helps to discriminate between RE and BE models. In this study, subjects are presented with different information choices and are free to choose which information they would like to acquire. The environment of voluntary information acquisition provides a seemingly low-information condition that helps discriminate among different theories and also offers (but did not impose) the possibility of a high-information condition. This method is better than the one that compares subjects' behaviors under different information environments, as the latter could restrict individuals' information needs and change the learning rules that they would otherwise adopt.[2]

The two-stage asymmetric-information game adopted in this study has some especially desirable attributes. Typically a non-cooperative game with a relatively large action space is desirable for learning identification, as the convergence to Nash equilibrium would be less likely to be immediate. In each stage, the asymmetric-information game is a 2×2 constant-sum game; however, due to its stochastic nature, this simple non-cooperative game could be transformed to a 4×8 normal-form game, which provides an opportunity that has rarely been seen in other constant-sum games studied in the learning literature. Additionally, the subtleties of the decision problems faced by the two types of players in such asymmetric-information games, particularly the inter-temporal (i.e., cross-stage) optimization for the informed players (details are provided in Section 2), have been understudied in the context of learning.[3]

Two versions of the two-stage asymmetric-information game are adopted for this study. The first game is employed by Feltovich (1997, 1999, 2000) and the second game is based on the first, with the difference being that the payoffs are doubled in the second stage. Doubling the payoffs should have, hypothetically, induced informed players to place more weight on payoffs in the second stage and more frequently adopt non-stage-dominant strategies to hide their private information in the first stage. In the laboratory, due to the interactions between the informed and uninformed subjects, both the informed and uninformed subjects are found to learn faster in the game with doubled payoffs in the second stage than they do in the original game; however, the learning speeds of these two groups of subjects are not equally affected. Additionally, the voluntary information acquisition method introduced in this study shows that both informed and uninformed subjects tend to choose to know their partners' histories in the games. This information acquisition choice is consistent with BE models rather than RE models.

To further investigate the interactions between information acquisition and learning behaviors, a hybrid learning model which embraces both RE and BE models is extended to include information acquisition data. Under this framework, informed players are assumed to be Experience-Weighted-Attraction (EWA for short) learners (Camerer and Ho, 1999), while uninformed players are assumed to be expected EWA (EEWA for short) learners due to the stochastic nature of the payoffs (Shafran, 2012). There are two main findings as follows. First, the maximum likelihood estimations show that the reduced-

[1] Several studies on strategic thinking have explored the technique of tracking subjects' search for information that focuses on payoffs or payoff functions (Brocas et al., 2014; Camerer et al., 1993; Costa-Gomes et al., 2001; Costa-Gomes and Crawford, 2006; Johnson et al., 2002). In these studies, subjects were invited to play games in which the payoff information was not initially provided. When subjects chose to intentionally acquire payoff information (either by moving the computer mouse over game boxes to show the information or by clicking or click-and-holding the mouse), their search paths were tracked. Information on subjects' search behaviors provides researchers with evidence of subjects' cognitions. Crawford (2008) summarized these findings and argued for the methodological value of information acquisition measures.

[2] Subjects were provided with information of previous interactions (i.e., feedback on their own past actions and/or payoffs, and/or information on their partners' previous actions and/or payoffs) across different laboratory treatments. By comparing subjects' actions across different information conditions, researchers were able to draw conclusions as to which models characterized subjects' behaviors more successfully across certain interactive situations. This group of studies included Mookerjee and Sopher (1994), Cheung and Friedman (1997), Mc Kelvey and Palfrey (2001), Nyarko and Schotter (2002), Duffy and Hopkins (2005), and Danz et al. (2012).

[3] Aumann and Maschler (1995) were the first to theoretically study the asymmetric-information game; however, until recently it has been empirically understudied. Jacquemet and Koessler (2013) manipulated the number of stages of the games and focused on whether the theoretical value of information was empirically supported. Lugo and Chaparro (2016) used games with an uncertain number of stages to examine whether information disclosures by informed players and the use of information by uninformed players matched their theoretical predictions.