

# Learning through Categories in Social and Economic Interactions

## LTCSEI

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The analogy-based expectation equilibrium (Jehiel, 2005) has been introduced to cope with strategic environments in which agents form their expectations by bundling data that come from different sources (see also the valuation equilibrium defined in Jehiel and Samet, 2007). An essential next step is to make progress on when and how subjects bundle data to facilitate learning. Various principles are proposed to discipline the choices of analogy partitions in ABEE and of similarity classes in VE: the observation-based principle views the bundling as a consequence of a lack of accessibility to missing information in past interactions, the psychologically-based principle views categorizations as the consequence of observed similarity in early interactions, the culturally-based principle views the bundling of actions into similarity classes either as a consequence of a common labelling of actions or as a consequence of ethical considerations that lead us to think of different actions as having similar consequences. The impact of such principles will be studied both theoretically and experimentally with the goals of explaining a number of new phenomena and shifting the conventional wisdom in behavioural economics that has pointed out a number of anomalies in behaviors without systematically relating them to imperfections in the learning process. In addition, I will be concerned with the aggregation of different types of feedback such as data on one own performance or data on others' attitudes in multi-context environments, as well as putting the proposed approach of learning through categories in the broader perspective of the literature on bounded rationality

## **Extended Synopsis of the scientific proposal**

### **1. Background and objective**

Standard solution concepts in game theory (and economic theory) typically assume that economic agents hold rational expectations about the consequences of their actions and about the attitudes of other economic agents including chance moves. While it seems implausible that economic agents would be able to reach this state of knowledge by pure introspection, modern approaches have viewed the rational expectation assumption as the outcome of successful learning processes in which as evidence is observed, economic agents would gradually correct their mistakes and eventually behave as the standard concepts assume.

Yet, in complex environments, expectations concern so many different situations that it is unlikely that economic agents would be able to collect enough evidence to correct any conceivable mistake. Moreover, strictly speaking, a given economic environment is never encountered twice in exactly the same conditions, thereby forcing economic agents to pool evidence/data coming from different sources (the pooling of data is a routine exercise made by statisticians and analysts and I would suggest it structures also how economic agents form their view of the world).

In the past fifteen years, I have developed two solution concepts to describe the limiting outcome of learning processes in which agents would pool data coming from different games/situations/states/nodes. In the analogy-based expectation equilibrium (ABEE), players pool the data about other players' behaviors coming from different situations where the categorization of data described by the analogy classes is part of the description of the environment and is given exogenously (Jehiel, 2005). In ABEE, players get to know the aggregate distribution of others' behaviors over bunches of situations (referred to as analogy classes) and players are assumed to best-respond to the belief that other players behave according to the aggregate distribution in every situation attached to the analogy class. The concept has been applied to a variety of contexts shedding light among others on reputation and deception (Ettinger and Jehiel, 2010, Jehiel and Samuelson, 2012), on social learning (Guarino and Jehiel, 2013), or on the role of feedback in auction houses (Jehiel, 2011, Jehiel and Lamy, 2015).

In the valuation equilibrium (Jehiel and Samet, 2007)- the second concept I have introduced in relation to learning through categories- players pool the data about the performance attached to different actions/moves that can be chosen in different contexts/nodes and the categorization of moves into similarity classes is again given exogenously. The valuation equilibrium can be viewed as the reinforcement learning counterpart of the analogy-based expectation equilibrium and it has not been developed as much as ABEE.

While the two proposed solution concepts ABEE and VE enrich the toolkit of game theory, one missing aspect in both cases is how categories are chosen. A key objective of the project is to suggest some ways to discipline the choices of analogy partitions in ABEE and the choice of similarity classes in VE, often taking inspiration from fields other than economic theory including econometrics, as well as cognitive and social psychology. Another objective is to propose combined approaches when subjects receive data that concern both the behaviour of others (as in ABEE) and their own performance (as in VE), which the ABEE and VE did not allow for. A final objective which would be conducted in parallel with the first two objectives is to develop a general view on how the existing approaches to bounded rationality in social and economic interactions can be articulated in a unified framework. The main motivation for the latter objective is that recent years have witnessed a flurry of new approaches (among others and in addition to ABEE and VE, the Quantal Response Equilibrium (McKelvey and Palfrey, 1995), the level k approach (Stahl and Wilson, 1995), the cursed equilibrium (Eyster and Rabin, 2005), the sampling equilibrium (Osborne and Rubinstein, 1998), and a frequent reaction is that it is not so clear how to choose among them. The aim would be to clarify the

scopes and limitations of the various approaches and also their links between them and to the more primitive concepts of Nash equilibrium with subjective prior (Harsanyi, 1967), self-confirming equilibrium (see Fudenberg and Levine, 1998) or rationalizable outcomes (Bernheim, 1982 and Pearce, 1982).

## 2. Methodology

### 2.1 Principles of categorizations

I plan to consider three principles to put discipline on the categorization devices.

#### **Observation-based principles:**

As has been emphasized in empirical work, the data we see are often subject to selection bias. For example, when assessing the prospect of a project, if an entrepreneur only looks at seemingly similar projects that were implemented, the corresponding distribution of observed returns is typically biased because the decisions made by others to implement their projects cannot be considered to be independent of the variable of interest (the prospect and return of the project). Econometricians have stressed how analysts should correct for selection bias typically assuming that economic agents are perfectly rational (see Heckman, 1979). But if correcting the selection bias is difficult for analysts/econometricians, it is likely to be difficult for economic agents as well. What I wish to investigate is the possibility that entrepreneurs would categorize projects according to their apparent similarity and extrapolate from the data of the corresponding implemented projects to form their view about the potential of their project. Preliminary analysis of this (see the working paper Jehiel, 2015) suggests that such an evaluation method would lead decision makers to be overly optimistic. The take-away here is that some heuristic method based on categorization and extrapolation (which can be modelled using the apparatus of ABEE) can explain the overconfidence bias in the context of entrepreneurship, which has been documented in a number of studies. More broadly, the objective here would be to understand the kind of biases, extrapolations of this sort (i.e. based on implemented decisions) may cause on decision making.

A more general formulation of the principle at work here is that the data that are accessible to economic agents typically do not include every detail that would be needed to form correct expectations. Because of this, economic agents who have to form their expectations on the basis of the data they see are led to extrapolate based on biased and/or coarse statistics. A different illustration of this is as follows. It is typically difficult to have access to the information possessed by economic agents at the time they made their decision. According to ABEE, this would lead economic agents in the face of this to form a view of others' attitudes as if those agents behaved independently of that information, a categorization device that was referred to as the payoff-relevant analogy partition in Jehiel and Koessler (2008). In turn, this suggests a new perspective on the robust mechanism design literature (Bergmann and Morris, 2005). Instead of requiring robustness with respect to any belief that agents may hold –this is typically too demanding as shown in Jehiel et al. (2006)- one may require robustness with respect to how many extra details agents observe in the database beyond what is payoff-relevant. My hope is that this may shed a new light and allow me to make progress on this important line of research while allowing me to move away from some disturbing results in the mechanism design literature such as the full rent extraction result in the correlated case.

#### **Psychologically-based principles:**

As a second approach, I plan to take inspiration from the field of cognitive psychology, which has suggested that categories are formed early and are rarely revised later on even if less well suited (see for example, Slutzky, 2010). I wish to put to an experimental test such a view. As an illustration, under some circumstances, it may be a good idea for an agent/player to categorize interactions according to characteristics of the interaction/game that concern the agent himself (this is so in team problems in which all team members share the same objective). But, if later on, other players' incentives are changed (they

turn from being friendly to being competitive), such a categorization device may be less well suited. The question to be addressed experimentally is whether agents would stick to their initial categorization device that was possibly optimal initially but not so later on. Turning to the theory side, the objective would be to understand the consequences of such early and (assumed to be) long-lived categorizations, and possibly how to reduce the inefficiencies that result from these (for example, the approach may shed light on the costs induced by stereotypical attitudes that would be based on inefficient categorizations).

### **Culturally-based principles**

As a third approach, I plan to take inspiration from the fields of linguistics and social psychology. In relation to linguistics, a number of scholars have suggested that language structures a lot our ways of forming categories (see for example Chomsky, 1980). Along these lines, I plan to study experimentally whether changing the labels of actions in a collection of binary decisions that subjects would face in the lab affect the long run decision making after sufficient experience has accumulated. Based on VE and the linguistics input, one could speculate that agents attach a single aggregate value to a course of action sharing the same label where according to VE this aggregate value would simply be the expected payoff obtained conditional on playing at least one of these actions with a common label (the weight given to the various actions being endogenously determined by how frequently the various actions are chosen). By varying the labels of actions in otherwise identical decision problems, one can test such a theory.

In relation to social psychology, some scholars have suggested a tendency for subjects to attach values to ethical behaviours per se independently of their material consequences. A possible interpretation of this is that the ethical traits correspond to values attached to families of behaviours. As such, the VE seems well suited to study this where the family of actions attached to an ethical trait would be considered as forming one similarity class in the VE framework. Of course, putting various actions in the same similarity class does not pin down the value attached to that class in VE, since valuations are endogenously determined by how much payoff on average is obtained by playing an action in a given similarity class. From this perspective, the question I wish to investigate is whether the grouping of moves suggested by the ethical approach would give rise to the reduced form values generally (exogenously) assumed (or observed) in the social psychology literature and for what kind of socio-economic environment. As an application of this, I plan to revisit the study of cooperation in ongoing interactions (the categorization could then bear on whether or not the partner has behaved nicely so far independently of other details such as the monitoring technology or the discount factors which have generally received the greatest attention from repeated game theorists) as well as the study of some principles developed in the persuasion science typically outside economics (Cialdini, 1993).

### **2.2 Aggregation of multiple heuristics**

In a number of instances with multiple interactions in the background, subjects are exposed to different kinds of feedback. For instance, one may receive feedback about others' attitudes on the one hand and on how well the strategy one follows performs on the other. It may be challenging to develop subjective representations of the world that would fit these various pieces of evidence as the self-confirming equilibrium (Battigalli et al., 1992) would require. When the various types of feedback are available in isolation, ABEE and VE have proposed simple and I would say natural heuristics to be used by agents. A challenge is to propose comparably natural heuristics when agents are exposed to the various kinds of feedback simultaneously.

One idea would be to think of this as a situation with multiple heuristics, the one attached to each type of feedback, and subjects would switch from one to the other heuristic depending on which one is perceived to perform better. From a dynamic perspective, the process would look like a reinforcement learning process in which the heuristic itself would be the subject of reinforcement (of course, this would require that the subject has access to data that relate the performance to the type of heuristic used to reach that performance).

Another idea would be to view the various heuristics as derived from the various kinds of feedback as different experts providing assessments about how good the various strategies are. From this perspective, it would then sound natural to rely on the literature on the aggregation of multiple experts' opinions either using some analogy with the work on multiple priors in decision theory (Gilboa and Schmeidler, 1989) or relying on some analogy with some concrete fixed point method such as the one used by Google to rank pages, for example stipulating that the weight attached to a heuristic should be proportional to the frequency with which the heuristic is followed.

In parallel to the development of theories dealing with the aggregation of different kinds of data, I would also design experimental settings to assess the empirical merits of the various possible approaches and understand better the contexts in which performance-based data vs other behaviour-based data receive more attention. In some sense, this would parallel, for multi-game interactions, the work of Camerer and Ho (1999) that was developed to weigh how much learning subjects rely on reinforcement vs belief-based procedures in simple normal-form games. Beyond the coverage of multi-game interactions (that was absent in Camerer and Ho), I suspect, maybe in contrast to Camerer and Ho, that the answer is likely to be context-specific, in particular depending on how accessible/salient the various types of data are (this can be varied in the lab).

### 2.3 An overview of models of bounded rationality

The final part of the project would be concerned with the flurry of approaches to bounded rationality and cognitive limitations that have been developed in economic theory so far (these include QRE (McKelvey-Palfrey, 1995), level  $k$  (Stahl-Wilson, 1995), the sampling equilibrium (Osborne-Rubinstein, 1998), the cursed equilibrium (Eyster-Rabin, 2005) in addition to ABEE, VE and the limited foresight equilibrium (Jehiel, 1995)). I believe it is time to think of these various approaches in a unified way and put them in a more general perspective, in particular showing how they relate to/differ from each other and how they relate to the more primitive concepts of rationalizable outcomes (Bernheim 1982 and Pearce 1982), Nash equilibrium with subjective prior (Harsanyi, 1967) and self-confirming equilibrium (developed by a series of scholars, see Fudenberg and Levine 1998). I also think it is worth emphasizing the informational and cognitive requirements attached to each of these approaches in the hope of facilitating the use of these in future academic research.

The final part of the project to be developed at the same time of the first two would consist in the writing of a book that attempts both at presenting the various approaches and at providing interpretative comments on the relative merits/shortcomings of those (relying when appropriate on experimental evidence).

### 3. Expected impact

The proposed project aims to have an impact on the way economists model interactions in strategic contexts. While many economists have expressed the need to go beyond the rational paradigm, the response of the profession has been a polarization between behavioural economics which has often adopted ad hoc modelling of anomalies typically documented in other fields (such as psychology) and theoretical economics which has pursued the full rationality agenda as if no alternative were possible.

My past attempts to develop solution concepts with bounded rationality have contributed to propose theoretical frameworks that go beyond the full rationality paradigm, but somehow the missing aspect in both the ABEE and VE concepts were that the categorization device used by agents to bundle data was left exogenous. The present project aims at putting structure on the bundling device used by agents taking inspiration from other fields. The hope is that in doing so, I will get the best of the rigour/elegance developed in traditional game theory on the one hand and of the behavioural tradition on the other that has often been praised for raising interesting questions but criticized for relying on ad hoc methodologies.



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Given the flurry of approaches in behavioural game theory, I believe it is also time to take a step back and present a comprehensive overview of the various existing approaches.

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