Games and Economic Behavior 110 (2018) 50–57

Contents lists available at ScienceDirect

Games and Economic Behavior

www.elsevier.com/locate/geb

Signaling to analogical reasoners who can acquire costly information

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ARTICLE INFO

Article history:
Received 30 March 2017
Available online 3 April 2018

JEL classification:
D01
D82
D83

Keywords:
Analogical reasoning
Costly acquisition of information
Signaling without single crossing
Reverse separation

ABSTRACT

We show that separation in signaling games can be obtained without the single crossing condition, in a model where the receiver reasons analogically across a pair of states and can acquire costly information on the sender's type. Beyond ordinary separation (high type sends high signal, low type sends low signal) we find that also reverse separation is sustainable in equilibrium (high type sends low signal, low type sends high signal). Further, reverse separation in one state is obtained only if ordinary separation occurs in the other state. Pooling is possible and can go along with ordinary separation in one state.

1. Introduction

Separating equilibria have a prominent role in signaling games, both in theory and in applications (Riley, 2001). Typically, the existence of a separating equilibrium crucially relies on the *single crossing condition*: in a two-type two-signal setting, the condition means that the additional cost of a high signal over a low signal is smaller for high types relatively to low types.

In this paper we provide a novel set of assumptions under which separation is obtained in the absence of the single crossing condition. In particular, we show that *analogical reasoning* and *costly acquisition of information* by the receiver allows ordinary separation to arise in equilibrium. Moreover, under the same assumptions we obtain that also *reverse separation* can occur in equilibrium: the high type chooses the low signal, and the low type chooses the high signal.

Analogical reasoning is a reasonable feature of belief revision whenever a decision-maker is faced with a large variety of possible alternatives, each of which differs from the others under many respects. In such cases it may be unfeasible to form specific beliefs conditional on every informational detail of every possible alternative. Rather, the decision-maker can feasibly focus on a few dimensions that are relevant for the decision to be made and then form analogy classes on the basis of such dimensions. As an example, consider purchase decisions: a consumer may well form a belief on the quality of a specific product by averaging over all products with the same or similar packaging.

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https://doi.org/10.1016/j.geb.2018.03.008
0899-8256/

Also, individuals can often exert effort and acquire the information that is relevant for the decision to be made. Consider again purchase decisions: a consumer can invest time and cognitive resources to carefully read product information reported on packaging, in the attempt to acquire a more precise knowledge of the product quality.

Our result that separation can be sustained by analogical reasoning and costly acquisition of information is important, we think, because the single crossing condition is likely to fail in a non-negligible number of cases. Carrying on the example about purchase decisions, we see no compelling reason why different packaging options should cost relatively more for low quality sellers than for high quality sellers. Further, the possibility of reverse separation might help to rationalize situations where low types engage more than high types in signaling activities, as it may happen when low quality producers make use of fancy packaging to overcome a careful scrutiny by consumers.

In our model, the receiver can face signals in two different states, and exhibits analogical reasoning across them. This means that he is able to condition his action on the state he is actually in, but at the same time he is unable to exploit this information when updating his belief on the sender's type; so, the receiver's decisions are based on the average type that is believed to send the observed signal. In addition, the receiver can acquire information at a cost: after observing the signal and prior to taking an action, he can incur a cost to learn the actual sender's type.

The main intuition for our results is that separation becomes possible since the receiver's act of acquiring information has different consequences for the two types of sender: the receiver does purchase the good if quality is high, and does not purchase the good if quality is low. Also, analogical reasoning over distinct states helps prevent that all the information is revealed in case of separation: acquiring information can be optimal for the receiver even when separation occurs in one state, provided that a different outcome occurs in the other state.

Importantly, both analogical reasoning and costly acquisition of information are crucial for our results. If we remove either of the two assumptions, we lose the possibility of any kind of separation (ordinary and reverse). To our knowledge, we are the first to explore the relevance of jointly assuming analogical reasoning and costly acquisition of information.

The rest of the paper is organized as follows. In Section 2 we relate our contribution to the relevant literature. In Section 3 we present the model and we provide a few preliminary definitions. In Section 4 we provide a motivating application. In Section 5 we define separation outcomes and we state all our results. Finally, in Section 6 we briefly discuss pooling outcomes, we summarize our findings and we comment on the crucial role of our main assumptions.

2. Related literature

Analogical reasoning has been formally introduced by Jehiel (2005) with the equilibrium notion called *analogy-based expectation equilibrium*, and then extended by Jehiel and Koessler (2008) to games of incomplete information. The analogy-based expectation equilibrium captures a form of bounded rationality that concerns expectation formation by agents, rather than best-response selection. This solution concept has been fruitfully applied to explain a number of phenomena (Ettinger and Jehiel, 2010; Jehiel and Samuelson, 2012; Hagenbach and Koessler, 2017). Analogical reasoning is related to, but different from, the so-called *coarse reasoning*, where agents interpret messages by means of a limited number of categories, and are unable to distinguish objects falling in the same category (Mullainathan, 2002; Mullainathan et al., 2008).[1]

Among the many contributions that consider the acquisition of information as a costly strategic choice, Dewatripont and Tirole (2005) is particularly relevant since they focus on a sender-receiver setup, developing a theory of costly communication.[2] The cost to acquire information can be cognitive in nature, stemming from the limited amount of cognitive resources (Simon, 1955),[3] or it can measure the search effort to acquire information on products' characteristics, as more typical in models of advertising (see, e.g., Gardete and Guo, 2014).

The reverse separation that emerges in our model can be related to *counter-signaling* (Feltovich et al., 2002): a situation where a sender has a quality that can be mistaken only for close qualities, and this allows the emergence of a signaling outcome where medium-quality senders choose high signals to separate from low-quality senders, while high-quality senders choose low signals to separate from medium-quality senders, thus yielding an inverted U-shaped relationship between types and signals.[4] Reverse separation, instead, produces a negative monotonic relationship between types and signals.

The only other paper, to our knowledge, where separation does not rely on the single crossing condition is Daley and Green (2014). Even if they assume single crossing in their model, their results hold also when the cost of signals is independent of the sender's type, as they note in Remark 3.5. Indeed, in their model, in addition to choosing a signal, senders undergo a test that provides a noisy grade about their actual type. Such a grading mechanism has different effects on low types and high types, indirectly making the benefits of signaling type-dependent, and hence allowing separation outcomes.

[1] A different bound to belief revision is implied by the notion of *cursed equilibrium* (Eyster and Rabin, 2005). Interestingly, Eyster and Rabin (2005) observe that in a classical signaling game a partially cursed equilibrium might allow for separation when Nash equilibrium does not.

[2] Other recent contributions considering the costly acquisition of information are Dewatripont (2006), Caillaud and Tirole (2007), Tirole (2009) and Butler et al. (2013).

[3] See also Bilancini and Boncinelli (2018) for a model of signaling where the costly processing of information is related to dual process theories in psychology, and Bilancini and Boncinelli (2017) for an application to persuasion games with labeling. We stress that agents in both these contributions are coarse reasoners, and not analogical reasoners.

[4] Harbaugh et al. (2017) and Harbaugh and Rasmusen (2018) explore a similar idea in the setup of certifiable quality disclosure. Mayzlin and Shin (2011) obtain a counter-signaling equilibrium where medium quality firms choose to make informative advertising, while high and low quality firms opt for uninformative advertising, which works as an invitation to search for consumers.