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Minority games, diversity, cooperativity and the concept of intelligence

Bernardo A. Mello[a], Daniel O. Cajueiro[b,*]

[a] *Secretariat for Management and Strategy, Embrapa, 70770-901, Brasilia, DF, Brazil*
[b] *Department of Economics, Catholic University of Brasilia, 70790-160, Brasilia, DF, Brazil*

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Abstract

In this paper we revisit some minority games formed by two different types of agents. There are some games where the differences of power processing among the agents are fundamental for achieving success. In other games, which are characterized by a dynamical phase transition, the results can only be explained by cooperative intelligence and diversity. In both cases the concept of informational efficiency plays an important role in the understanding of the dynamics. Finally, aiming to explain the results of these games, we try to make a link among diversity, informational efficiency and the concept of intelligence.

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1. Introduction

Intelligence may be defined as the mental capacity of an individual to learn new knowledge, process information and to adapt himself to the environment.

The psychometric view of intelligence [1] which is based on what is understood by "general intelligence" takes into account different types of abilities defining different types of dimensions where each dimension is a different kind of aptness [2,3]. Two special correlated dimensions [4–6] which take different types of abilities into consideration are the so-called fluid intelligence and crystallized intelligence. While fluid intelligence is the skill for coping with new problems, crystallized intelligence is the capacity of applying formerly learned solutions to the problem you are facing currently [7].

Cognitive psychology provides a different view of the concept of intelligence by not worrying about the content of the information, but how the information is processed. According to this view, in order to comprehend a person's thinking, one has to assess the potential that a person has in general to process information. In Ref. [8], it has been

* Corresponding author. Tel.: +55 61 34487135; fax: +55 61 34487127.
E-mail address: danoc@pos.ucb.br (D.O. Cajueiro).

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pointed out that differences in intelligence in individuals may be explained by individual differences in memory capacity, speed and reliability.

One may clearly establish relations between the concept of intelligence provided by the psychometrics and by the cognitive psychology. The ability considered by the fluid intelligence or crystallized intelligence depends strongly on how people load and process information. More details about the psychological view of intelligence today may be found for instance in Ref. [7].

In economic theory or social science, an agent is said to be intelligent [9] if he knows everything that one knows about the game and he can make inferences about any situation that one can make. Clearly, this assumption that all agents in a system are perfectly intelligent may never be satisfied. However, it is important to formulate a theory to predict economic behavior.

One interesting point in this debate was provided by Ref. [10] investigating a population of artificial agents, each of them controlled by a simple biologically motivated neural network model, when they are competing against each other for scarce resources in the minority game. First, they showed that the capacity of memory measured explicitly by the history kept by each agent and also by the number of neurons in the intermediate layer of the artificial neural network of each agent has influence on the ability of each agent to win the game. This finding is an empirical evidence of the cognitive psychology view of intelligence. Second, they suggested that for dealing with the issue of valuing how intelligent a system is can only be answered in the context of a given surrounding environment. The notion of surrounding environment in Ref. [10] is given by the attributes of the population that is playing the game against a given agent.

After [10], there is no doubt that a minority game due to Ref. [11] as a simplification of Arthur's El Farol Bar [12] attendance problem offers a very interesting framework to discuss the concept of intelligence. Actually, it presents a very interesting structure to study the dynamics and the collective behavior of populations of agents who compete for limited resources.

The so-called minority game (MG) [11] is one of the simplest complex systems introduced in order to study the dynamics and the collective behavior of populations of agents who compete for limited resources. This game can be described in the following way. At a given instant of time, an agent who belongs to a population of size N chooses between two opposing actions, namely $a = \pm 1$.[1] The difficulty is that each agent does not know what the others will choose. Since the resources are limited, the objective of each agent is to choose the side shared by the minority of the population. The agent chooses his next action based on a strategy, which is a mapping that defines the action to be taken as a function of the global information, which is the sequence of the last M outcomes of the game, where M is the history remembrance of the agents. The strategy books are randomly assigned to each agent before the beginning of the game. Therefore, there is no best solution for the problem, i.e., the agents do not know what is the best strategy to choose in the game. Since there are only two possible choices, the number of states is 2^M and there are, at the maximum, 2^{2^M} strategies. In Ref. [11] each agent has a fixed number of strategies s that do not change over time. To express the fact that agents have different beliefs, the strategies differ from agent to agent. At every turn of the game the agents use their strategies with the highest scores: those which were the most successful in the prediction of the minority side in the previous turns of the game.

In this paper we explore the properties of competing types of strategies by mixing different types of agents in the same MG and use this framework to discuss the concept of intelligence. In particular, in a manner similar to Ref. [10], we are interested here in analyzing how having different attributes may help an agent to improve his *performance*, defined as the fraction of the times that the agents of a given type choose the side of the minority.

In the standard MG the agents share the same type of strategies but are said to be heterogeneous because they use different strategy books. In our paper the agents are different not just because their books vary but because they employ different decision schemes. The different types of agents present in our simulations are:

Standard agents use the strategy of the standard MG [11], i.e., at each turn of the game the agents choose, within his book of strategies, the most successfull one;

Batch agents as in Refs. [13–15]. They only differ from the standard agents because these agents choose their strategies in batches of period T_b and follow the same strategy until the next period;

Coin-tossing agents (CT) instead of following a strategy book, these agents make random decisions.

[1] In a financial market, for instance, this means to buy or to sell an asset.