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Social cognition, artefacts, and stigmergy: A comparative analysis of theoretical frameworks for the understanding of artefact-mediated collaborative activity

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Abstract

Collective behaviour is often characterised by the so-called ‘coordination paradox’: looking at individual ants, for example, they do not seem to cooperate or communicate explicitly, but nevertheless at the social level cooperative behaviour, such as nest building, emerges, apparently without any central coordination. In the case of social insects such emergent coordination has been explained by the theory of *stigmergy*, which describes how individuals can effect the behaviour of others (and their own) through artefacts, i.e., the product of their own activity (e.g., building material in the ants’ case). Artefacts clearly also play a strong role in human collective behaviour, which has been emphasised, for example, by proponents of activity theory and distributed cognition. However, the relation between theories of situated/social cognition and theories of social insect behaviour has so far received relatively little attention in the cognitive science literature. This paper aims to take a step in this direction by comparing three theoretical frameworks for the study of cognition in the context of agent–environment interaction (activity theory, situated action, and distributed cognition) to each other and to the theory of stigmergy as a possible minimal common ground. The comparison focuses on what each of the four theories has to say about the role/nature of (a) the agents involved in collective behaviour, (b) their environment, (c) the collective activities addressed, and (d) the role that artefacts play in the interaction between agents and their environments, and in particular in the coordination of cooperation. © 2001 Published by Elsevier Science B.V.

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1. Introduction

Until the mid-1980s the main concern in classical cognitive science, following the dominant computer

metaphor for mind, was to analyse cognitive processes such as attention, perception, memory, categorisation, and problem solving. These processes were considered as taking place within the heads of individuals, while the environment, including other agents and external artefacts, was largely disregarded, i.e., reduced to inputs and outputs. However,

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since the mid-1980s this view has been criticised from various directions. From the rather narrow view of cognition as abstract information processing, the focus has shifted during the late 1980s and the 1990s, to considering agents as situated in their specific context as it was realised that people are strongly effected by, and possibly dependent on their environment. With a shift of focus, new interactive theories of cognition emerged, approaches such as situated action (Suchman, 1987) and distributed cognition (Hutchins, 1995a). Furthermore, during the 1990s, there has been a growing interest in the interaction between individuals and, in particular, the role of artefacts. Interest has grown in considering the importance of the socio-cultural context of cognitive processes, and the development of artefacts over time. Thus there is now a growing interest in issues such as context, culture, agents acting in an environment, social interactions, situated and distributed theories, etc., and a lot of research has been conducted concerning various artefacts and cognitive processes.

While interest in social behaviour and artefacts is relatively new in cognitive science, the behaviour of social insects has been studied for a long time in biology. In the 1950s Grassé (1959) formulated the concept of *stigmergy*, which is “a class of mechanisms that mediate animal–animal interactions” (Theraulaz & Bonabeau, 1999). The concept has been used to explain, or understand, mechanisms underlying emergence, regulation, and control of collective activities in social insects. Initially the concept was introduced to explain the *coordination paradox* in collective activities: looking at the behaviour of a group of social insects, they seem to be cooperating in an organised, coordinated way, while, at the same time, looking at each individual, they seem to be working as if they were alone and not involved in any collective behaviour. The explanation to the coordination paradox provided by stigmergy is that insects interact *indirectly*. Each insect effects the behaviour of other insects by indirect communication through use of artefacts, e.g., building material in the case of collective nest building. Hence

each animal's activity is organizing the environment in such a way that stimulating structures are created; these structures can in turn direct and

trigger a specific action from any other individual from the same species that comes into contact with them (Theraulaz & Bonabeau, 1999, p. 102).

Thus the activities in a colony are partly recorded in the physical environment, which in turn is used for organising collective behaviour. During the 1990s a renewed interest in stigmergy has arisen in the areas of Artificial Life (e.g., Bonabeau, 1999; Beckers, Holland & Deneuborg, 1994) and so-called ‘ant algorithms’ (e.g., Di Caro & Dorigo, 1998; Dorigo & Gambardella, 1997). However, so far, to the best of our knowledge, there has been no detailed analysis of possible common principles, such as the role of stigmergy, behind social insect behaviour on the one hand, and human social cognition and cooperative work on the other hand. Such an analysis is not to be considered as placing human activity on an equal footing with the activities of insects, rather our interest lies in finding out to what degree stigmergic principles can contribute to explaining human collective activities.

It might at first appear inappropriate trying to relate social insect behaviour, and the seemingly very limited concept of stigmergy, to human social processes, as the agents and artefacts involved are obviously of very different complexity. At a second glance, however, there seem to be some common basic elements in both types of social behaviour: in both cases a number of *agents*, interacting with each other and their common *environment*, achieve some *collaborative activity*, which is (to some degree) mediated by *artefacts*. Hence, following the well known scientific principle of Occam's razor, one should not a priori assume that the underlying mechanisms necessarily have to be radically different. Although there might be objections to using biological theories in the social sciences, the transfer “must not necessarily lead to biologization of the social”, as pointed out by Wulf (1999, p. 59). Another case of applying a biological theory to social sciences is Luhmann's extension of autopoiesis,¹ i.e., a generalisation of autopoiesis to comprise not only living organisms, but social systems as well.

¹The concept of autopoiesis was originally used by Maturana and Varela (1980) to describe the organisation of living systems, such as cells or complete organisms.

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