A computational framework for modelling inter-group behaviour using psychological theory

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ABSTRACT

Psychological theories of inter-group behaviour offer justified representations for interaction, influence, and motivation for coalescence. Agent-based modelling of this behaviour, using evolutionary approaches, further provides a powerful tool to examine the implications of these theories in a dynamic context. In particular, this can enhance our understanding of the escalation of hostility and warfare, and its mitigation, contributing to policy and interventions. In this paper we propose a framework through which social psychology can be embedded in computation for the examination of inter-group behaviour. We examine how various social-psychological theories can be embedded in evolutionary models, and identify ways in which visualisation can support the objective assessment of emergent behaviour. We also discuss how real-world data can be used to parameterise scenarios on which modelling is conducted.

Keywords: group modelling, psychology, evolutionary behaviour, in-group, out-group

1. INTRODUCTION

Humans have evolved with the ability to coordinate through groups, which provide a survival advantage.[1,2] In environments characterised by scarce resources, success from working together against threats has promoted selection in favour of those groups with strong in-group loyalty and cooperation, and strong out-group combativeness against rivals.[3,4] Aspects of this behaviour are well seen in today's society, reflecting conflict situations on the one hand through to extraordinary acts of altruism and in-group support on the other. Cultural evolution, through the ability to socially interact and copy others plays an important role in this coordination.[5,6]

Understanding the dynamics that underpin behaviour and interactions remains an important area of study that spans a range of disciplines, with potentially diverse methodological approaches. In this paper we are particularly interested in exploring the extent to which computation can be used to increase understanding of how group level interactions occur, and lead to the fracture and formation of groups. This is particular relevant to the importance of groups in threats to world peace. While previously the cold war and its associated arms race was characterised by clearly identifiable actors, formal administrations, territorial boundaries and observable behaviour,[7] many modern conflicts are less clear cut and much more challenging to explicitly model and understand.[8] Groups play a particularly important role in this context, but rationally modelling and understanding group behaviour and conflict is a challenge, particularly in extreme situations.

One approach to making progress is through computational modelling. Generally speaking, the advantage of this methodological approach is that scenarios can be developed and assumptions tested that allow a deeper understanding of complex dynamics to be ascertained. Users may rerun and interpret many different and

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hypothetical situations that allow insights to be built. It is also possible to address large-scale scenarios and emulate thousands of interactions that are difficult to observe by any other means. However the complexity of human behaviour necessitates some form of abstraction takes place, because it is impossible to model or even represent every facet of human behaviour in a computational or quantitative form.

In this paper we argue that progress can be made however, by basing computational models on established theory, or testable assumptions, that represent different aspects of human psychological behaviour. This approach has a number of important aspects. Firstly it means that due diligence has been paid, through development of the theory itself, to actions and consequences of human behaviour. Secondly it allows static theory, which has been developed on the observation individuals or small samples, to be examined in a dynamic setting, such as when many individuals interact based on specific assumptions about each response behaviour. Thirdly it allows dynamics from assumptions about individual behaviour to be better understood, in terms of the characteristics that groups represent.

However behaviour that can be represented through computation requires theory that can be readily detected and discretised into actions. Qualitative theory in particular is therefore challenging to translate, but theories based on interaction or representation through functions lend themselves more in this direction. We present examples of such theories and approaches from psychology, also giving insights concerning their implementation in a wider event-driven framework. This is focussed on in-group and out-group effects, which represent a fundamental starting point for modelling inter-group behaviour.

2. SNAPSHOT OF KEY THEORY CONCERNING INTER-GROUP BEHAVIOUR

The origins of relevant theory date back to the turn of twentieth century. Early psychological contributions on structural conflict theory[9] and realistic conflict theory[10, 11] were aligned with environments characterised by promoted selection in favour of those groups with strong in-group loyalty and cooperation, and strong out-group combativeness against rivals. However these early contributions fell short of explaining why biased group-based attitudes may persist even in the absence of conflict or resource scarcity. Allport[12] proposed that susceptibility to group-based stereotyping[13] was a contributory factor, being an efficient heuristic that avoids deliberation but leaves social judgements susceptible to erroneous influences and over-generalisation in respect of group members.[14]

Allport's Intergroup Contact Hypothesis[12] proposed that positive effects of intergroup contact occur only when there is equal group status, common goals, intergroup cooperation and the support of authorities, law or custom. Intergroup contact theory[15, 16] has subsequently extended these conditions and sought to explain processes by which contact changes attitudes and behaviour, specifically through learning about the out-group, changing behaviour, generating effective ties and reappraising the in-group. This theory predicts that patterns of contact between groups can counteract over-generalisation and mitigate prejudice when members of respective groups can identify with each other.

More generally, social identity has emerged as the predominant paradigm for understanding intergroup phenomena.[17–19] Self-identification of the in-group based on a common identity,[20] whether based on fixed traits (e.g., ethnicity or religion) or mutable beliefs (e.g., opinions or preferences), has been shown to predict in-group favoritism as well as out-group hostility.[18, 21, 22] Much of the research in this area has sought to understand the division between the in-group and out-group. Given the correspondence between the definitions of an in-group and out-group (i.e., one implies the other), in-group bias is often conflated with out-group prejudice,[23] resulting in an implicit and erroneous assumption that these concepts are interchangeable. Therefore the considerable research on the behaviour and conditions that support in-group favoritism[19, 24–26] is insufficient to determine the conditions that promote prejudicial attitudes. Current knowledge of the processes that support the in-group reinforcement are framed through advanced cognition, such as affective capabilities, social intelligence and intuition over deliberation.[13, 14, 27]

More recently, there has also been theorising on the role of an individual's identity in terms of group behaviour. The concept of identity fusion[28] has been developed, under which conditions are such that individual identity is lost and substituted for group identity. This is a contributory factor in understanding how individuals become compliant with extreme behaviours that are a function of the group[29] and represent "unconditional commitment and intractability".[30] Collectively these contributions represent influential aspects of the literature, describing ways in which individuals and groups could interact. The challenge comes in engaging these theoretical concepts in a computational form.

3. EMPLOYING COMPUTATION

There are diverse approaches to modelling group behaviour in a computational form. Different approaches represent a continuum between modelling the interactions of individual actors independent of groups, as opposed to recognising a group as an entity in its own right with characteristics capable of influence or action on others.[31] There are numerous approaches, at a high level, that seek to make deductions based on structure and interaction rather than explicit psychological theories. Examples include the biologically inspired "Blau space",[32] which functions based on homophily, - that is those with similar socio-demographic characteristics are more likely to be associated by involvement in similar groups. Blau spaces project this information and find equilibrium between potentially competing groups, using a system of differential equations to derive a competition matrix between finite resources (individual participation). Explicitly modelling systems dynamics is also possible. This uses non-linear relationships between the forces influencing group behaviour,[33] employing "stocks and flows" which are the abstract representations of virtual (or physical) commodities and their local connection and influence. Hybrid approaches to modelling have also emerged,[34,35] which combine multiple layers of cognitive modelling with a wide range of variables. However, to make progress on modelling while taking into account explicit psychological theory, it is reasonable to focus on representing individuals within the model. Agent-based modelling is a particularly useful vehicle to achieve this, and defines the scope of our interest in this paper.

3.1 Understanding in-group and out-group effects: a framework

In light of considerable previous work, we argue that a key point of reference for understanding inter-group behaviour concerns in-group and out-group effects, and therefore focussing attention on this is important. Conflict is frequently group-based and understanding how social and psychological dynamics support positive in-group behaviour and negative out-group behaviour is highly valuable. Bias and inter-group conflict remain a "problem of the century",[36] and frame many of society's divisions.

In-group assortment is well-seen in human behaviour, being easily triggered by attraction on the basis of some degree of similarity. Lab-based experiments have shown that this can occur based on trivial or arbitrary displays of similarity.[6,22,24,37] This has contributed to a misperception that positive discrimination to the in-group and negative discrimination to the out-group are inevitable.[23] Consequently understanding the separate roles of in-group and out-group discrimination is socially important, in particular understanding how it becomes manifested through social mechanisms. Psychological theory can be embedded in different aspects of agent-based computational simulation,[38] and is well-suited to exploring in-group and out-group effects. We focus on evolutionary modelling, where natural selection, after periods of interaction, is repeatedly applied. Psychological and social considerations can be embedded in such models and their effects observed.[39] In particular we highlight four key considerations where theory can be embedded to further understand group dynamics.

- **Scope of interactions.** This issue relates to how individuals are assumed to mix and interact. This can be affected by *a-priori* levels of discrimination, either positive towards the in-group, negative towards towards the out-group. Equally observation of the evolution of these factors may be the purpose. Modelling decisions can be informed by potential scenarios and there are a range of examples in the literature. For example, a-priori structure from placing agents on a regular lattice has been previously adopted,[26] using the lattice to control the possible interactions with only adjacent agents. Rewiring of this lattice has also been considered,[40] allowing the co-evolution of interactions alongside other agent-based behaviour. Other approaches have involved sampling agents on a probabilistic basis from sets (i.e., groups), and allowing agents to freely change sets.[25] Segregation of the population into islands is also possible.[41]

- **Form of interactions.** Interactions need to be characterised in terms of actions and responses. Social and psychological theories can be embedded at this point, ranging from assumptions about mimicry, social learning[42] or attraction through homophily.[25] Game theory is often (but not always) used in this context, being a mechanism through which individuals are faced with a social dilemma. Decision-making in this context occurs as a consequence of a social dilemma - where agents are faced with an interaction through which cooperation may occur.[43] Wide-ranging social, psychological and economic factors can have influence. For example, these may involve the social norms of a group,[44] strategies being inherited from others in the population, such as through cultural means,[42] as a consequence of identity,[28] or reinforcement of decisions from multiple sources. Social Impact Theory, proposed by Latané[45] is one example of how an individual may be influenced by multiple factors, as explored in contexts such as opinion formation, beliefs and culture.[46,47]

- **Basis for discrimination.** Within modelling, agents need to be able to identify[48] with others, individually or collectively, to determine the extent that they are in-group or out-group. The agent's disposition towards discrimination represents their attitude, framing an individuals world view. Humans are well-known to act on the basis of social comparison[49,50] and this has been found to be important for cooperation scenarios based on donation.[51] Various approaches to assessing similarity have been proposed. For example, may agents carry a number of discrete traits may compare themselves for similarity, with actions proportional to the extent of commonality.[42] More generally, a range of tag-based models[26,52–58] are known, that are used to spontaneously enable cooperation based on propagation of behavioural strategies. Social norms of the group may also be influential over group members' discriminatory behaviour,[59] and the role of social norms in cooperation is significant[44] in potentially supporting punishment.[60] Discrimination can also take the form of reputation distortion, preferential selection for interaction, or particular actions, such as out-group hostility concurrently with in-group favoritism.[3,4,61–63]

- **Consequences of interaction.** As the result of behaviour, individuals and groups are affected. This can be modelled in wide-ranging social or economic terms. Exit from a group, either as a consequence of the group (e.g., ostracism[64]) or by the individual walking away[65] is an important consideration. Humans are well-disposed to detecting potential ostracism in a group setting.[66] Additionally representation of activity in economic terms, through the potential costs and benefits of interaction are commonplace, particularly in game theoretic models that are cooperation based.[43] Reputation systems[67,68] are also a further way in which individual behaviours can be assessed, used as a measure of social standing.[69] These may operate in conjunction with social norms, that are the basis for judgements. Different groups may have different perspectives, as represented by social norms or group identity, leading to different forms of social penalty or reward. This may also take the form of punishment.[60]

3.2 Visualisation and interpretation

Finally we remark on the importance of visualisation and interpretation of generative models. Simulations involving large numbers of agents may result in complex feedback to the user which can be challenging to represent and assess.[70] This is also true with regard to real-world data sets,[71] and understanding the relationships between visually represented actions and system parameters (e.g., real time social network metrics) in human terms is a step which is critical in aiding consistent 'tellability' and interpretation. Users with different perceptions and experiences may well be susceptible to different types of bias in making judgements on observed changes to a scenario. If it becomes possible to make this connection between the metrics characterising a system and the visual behaviour of that system then prospects to enhance human-machine intelligence will be furthered.

3.3 Conclusions

In this paper we have presented insights into how social and psychological theory can be embedded into evolutionary agent-based simulations. There are a range of relevant social and psychological theories that can be incorporated into models. We focus on the importance of in-group and out-group behaviour, and highlight degrees of freedom concerning the incorporation of theory into the model. These choices relate to the scope and form of interactions between agents, the basis for discrimination and the possible consequences of interaction on the individual or group. We also remark on the importance of making further developments with visualisation and interpretation of models of this nature.

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