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Towards more realism in pedestrian behaviour models

First steps and considerations in formalising social identity

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Abstract. Agent-based models of group behaviour often lack evidence-based psychological reasons for the behaviour. Similarly, pedestrian behaviour models focus on modelling physical movement while ignoring the psychological reasons leading to those movements (or other relevant behaviours). To improve realism, we need to be able to reflect behaviour as a consequence of feeling part of a psychological group, so we better understand why collective behaviour occurs under different circumstances. The social identity approach has been recognised as a way of understanding within and between group dynamics, as well as the processes that make an individual act as a group member. However, as promising the social identity approach is, the formalisation is a challenging endeavour since different choices can be made to reflect the core concepts and processes. We therefore in this paper elaborate on a few of these formalisation challenges and the choices we made. To support the formalisation and use of social identity approach and finally for the increased realism in group behaviour models, such as pedestrian models that are so heavily used to manage real world crowds.

Keywords: Psychological group, Agent-based modelling, Social identity, Self-categorisation theory, Group dynamics

1 Introduction

Computational models of pedestrian behaviour primarily focus on physical movement in physical space. For example, through obtaining more realistic speeds [1], or navigation through the environment (e.g. social force, optimal steps models). Models of pedestrian behaviour in groups have ranged between observing walking formation of group members [2], or the impact of group size on evacuations [3] and route-choice.

However, behaviour encompasses more than (physical) movement which can be extremely important for the realism of pedestrian models. How we move is often a result of being in a social context, which can make pedestrian movement in crowds unexpected when only regarded from a physical point of view. Research from social psychology suggests that group dynamics are crucial to understand collective behaviour such as why members will put themselves in danger to help others [4], helping strangers

during a terrorist attack or fire in a discotheque, or protest in a location that has symbolic meaning [5, 6]. The group dynamics underpinning the collective behaviour in these examples are inherent to many crowd situations and are extremely important to understand why collective behaviour occurs in a range of contexts. However, little research in pedestrian models has focused on why collective behaviour occurs in groups.

To increase their realism, we argue that models of group behaviour should attend to the psychological underpinnings of how collective behaviour occurs between group members, and how two distinct psychological groups interact when in the same physical space. For example, theories of group behaviour are needed to explain why group members congregate together when there is physical space available around them, and why the proximity between group members increases when in the presence of another group [7].

A key challenge for those formalising social theory is that one needs to become more precise what a theory or explanation means, what causal relations need to be specified and one needs to make sure that the model is complete and coherent [8]. To make the theory a functional part of the agent-based simulation, the modeller is faced with gaps that allow for multiple interpretations and the mere act of adding or specifying changes to original description. Even though this is a strength of ABM as it contributed to theory development, the challenge remains: how do we fill the gaps? Our approach is to co-create these additions together as agent-based modeler and psychologist specialised in SIA. Not just to avoid the modeller trap of not understanding or appreciating the theory as intended, but also to engage in designing the parts of the theory that doesn't specify in ways one cannot do alone.

In this paper we make steps towards operationalizing core aspects of intra and intergroup behaviour in pedestrian movement. We draw from theoretical aspects of the social identity approach [9], and previous research on the role of group processes in pedestrian movement. Through the paper, we demonstrate our rationale for selecting necessary aspects of the theory, and our methodology for operationalising the theory based on previous research in two case study scenarios of pedestrian behaviour in intragroup and intergroup scenarios. Our aim is to enable deep discussions about formalising SIA as well as supporting others to formalise SIA in their respective domains or projects.

2 Social Identity Approach: the basics and pedestrians

The social identity approach is a prominent approach within social psychology to explain collective behaviour. It has been applied to understanding collective behaviour at mass gatherings [10], evacuations and disasters [4, 11], and event safety management [12]. It has been highlighted as a core social theory that should be used or at least in reach for social simulators to improve the realism of simulated group behaviour (for examples see, [7, 13, 14]).

The social identity approach consists of social identity theory [15] and self-categorisation theory [16]. Social identity theory posits that people have multiple cognitive concepts of the self, including both personal and social identities. Personal identities refer to individual-level idiosyncratic identities. Social identities refer to our membership in social groups. For example, one may have a social identity as a computer modeller or as a social psychologist. Previous research using social identity theory suggests that group members tend to have more favourable opinions of ingroup members (those in the group) compared to outgroup members (those outside the group). One of these social group memberships can be a member of a psychological crowd [17] where people in the crowd share a sense of belonging to the same group. This is different to a physical crowd which is composed of individuals or small subgroups who happen to be in the same physical space but without a sense that they are joined in a meaningful group. Having higher social identification (feeling more strongly like a group member) with others in the crowd can influence perceptions and behaviour such as feeling safer in close proximity with others [18], and wanting to be in more central, denser areas of crowds [19].

Self-categorisation theory explains how the self and others are categorised into groups. A person takes on a social identity through a cognitive transformation of depersonalisation, wherein their social identity becomes salient and they see others in their group as more similar to themselves than those outside of the group. The salience of a social identity can change depending on the context, and the meta-contrast ratio is particularly relevant for understanding the dynamic nature of intergroup relations. The meta-contrast ratio states that the salience of a social identity can increase when in the presence of an outgroup because the perceived differences between the ingroup members are less than the perceived differences between the ingroup and outgroup members. Thus, social identification with the ingroup can increase in the presence of an outgroup, and this can increase the effect of the group membership on behaviour. This can be seen in pedestrian behaviour where ingroup members move into closer proximity when in the presence of an outgroup compared to when they were walking without an outgroup present [20].

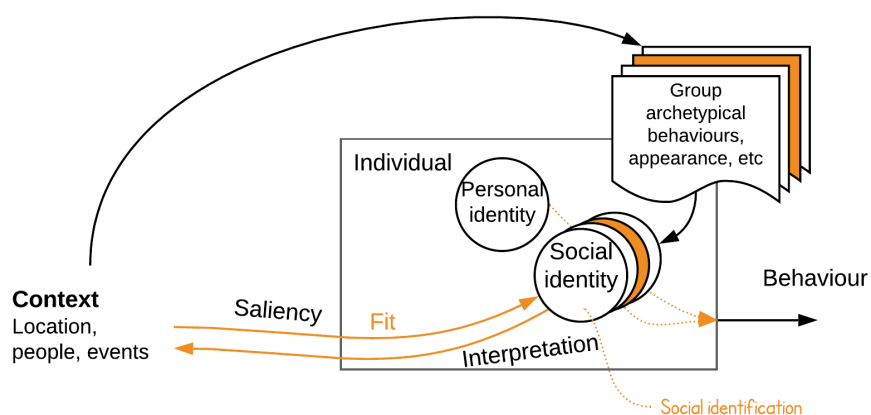


Fig. 1. Overview of core concepts and mechanisms/processes that SIA used to explain individuals as part of a group behaviour.

Crucially for pedestrian modelling, research from social psychology has shown that proximity to others is influenced by group relations. People who see others as ingroup members choose to be physically closer to them than outgroup members, and exhibit higher behavioural coordination across a range of scenarios including emergencies [21] and when walking together [20]. For example, Novelli, Drury and Reicher [22] demonstrated that we are more willing to sit closer to ingroup members. Alnabulsi and Drury [18] demonstrated that the more pilgrims at the Hajj felt others in the crowd were in the same group as them, the safer they felt. Results by Novelli et al. [19] suggest that the more festival-goers saw others in the crowd as being in the same group, the more motivated they were to go to denser, more central areas of a crowd because it was associated with a positive experience. It is notable that in these studies social identification is not treated as a binary, i.e., it is not on or off. Instead, the strength of identification exists on a continuum where higher strength of social identification with the group is associated with stronger effects on perceptions and behaviour.

Despite the breadth of research into how social identity processes influence group behaviour, pedestrian models have primarily focused on issues of topics such as obstacle avoidance, the role of group size on evacuations, and obtaining realistic heterogeneity of pedestrians. Very few models have addressed the theoretical underpinnings of what makes a group, nor have they incorporated principles of the social identity approach into their models. To increase the realism of pedestrian models, we set out our formalisation of different aspects of the social identity approach, and we lay out the challenges and decisions throughout the process of incorporating theoretical principles into an agent-based model.

Table 1. Overview core social identity approach concepts we highlight in this paper with a short description adapted from [7]

SIA concept	Description
Personal Identity	One's distinct individual characteristics and qualities
Social Identity	Cognitive self-representation as a member of a social group
Salience	The extent to which a social identity is cognitively present at a particular time.
Meta-contrast ratio	When differences between people in the ingroup are perceived as smaller than the differences with the outgroup.
Social identification	Refers to how much one identifies as a member of a particular social group.

3 Social Identity Approach formalisation

The SIA-PED model is a pedestrian model in which aspects of the social identity approach are formalised to increase social realism on agent level and thereby the actual movement dynamics of pedestrians to advance crowd evacuation research and management. Inspired by behavioural experiments [23] on the role of social identity on pedestrian movement, we adopt a similar experimental design with SIA-PED to explore:

- The difference of an individual being part of a physical versus psychological group on the movement of pedestrians walking in the same direction (flow | intra-group | top Figure 2); and
- How the presence of another group affects the movement (counter-flow | inter-group | Bottom Figure 2).

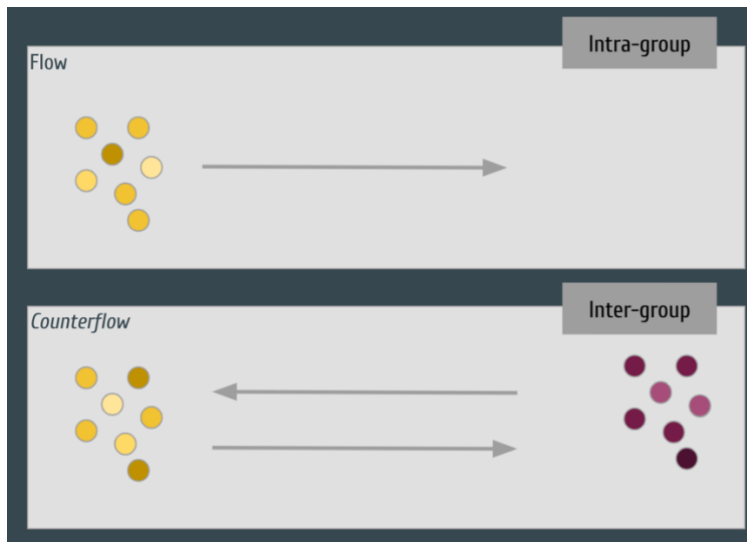


Fig. 2. The contextual setup we target with SIA-PED to formalise the social identity approach and explore the consequences of including one (top) or two (bottom) physical vs psychological groups.

In the SIA-PED ABM we formalise the relevant aspects of SIA to represent a **psychological group** and corresponding **influences on their behaviour** depending on whether they are walking alone or in the **presence of another group** walking in the opposite direction (counterflow). In SIA terms, for an agent to be part of a *psychological group* it has to have a *salient social identity* and describe how a salient identity affects behaviour. When the social identity is salient, then - depending on the *degree of social identification / importance of that social identity* - the behaviours that are considered appropriate are related to being part of a group, in we-terms. When including the presence of another group, *perceiving this group* as a psychological

(important) group increases the social identification with one's own group via the *meta-contrast ratio*.

While just restricting ourselves to this simple experimental design, already several core formalisation decisions need to be concerned with what concepts are and what they do. In the remainder of this section we will zoom in on some of these core formalisation decisions.

3.1 Formalisation 1: identity representation decision

From SIA, and specifically the social identity theory [15], we learn that we have a personal identity and social identities. The personal identity reflects aspects that characterise a person (in distinction of others), which is a matter of reflecting context relevant attributes on the individual level. Social identity however, conceptually reflects a group membership and its connected understandings of what it means to be part of a particular group (behaviours, appearances etc.). There are different ways imaginable to formalise having a personal and social identity. Whereas a personal identity can be imagined easily as something that is captured within an agent, the social identity is conceptually part of the individual and the group, it is a relational aspect of the self. How to represent this concerns a decision that balances pragmatism in what is easiest to programme and what is truest to your interpretation of the concept, that is mediated by the aim and research question addressed by the model.

Personal identity is characterised as agent attributes. The variable ID (personal identity) in combination with `IDSaliience` is used to identify which identity is dominant (personal versus social). However, in relation to behaviour, there may be a subset of agent variables related to the personal identity. In our pedestrian context, this could be reflected as a preferred walking speed variable. The social identity on the other hand is reflected by an agent having a link with a group, making the social identity a relational representation. This means that the model distinguishes pedestrian and group agents. The attributes of the group agent reflect those variables and actions that represent the group, which assumes consensus on what it means to be in a group or just what is common knowledge. These representation choices are summarised in class diagram in Figure 3. The biggest consideration lies in how to represent the social identity, is it part of the agent itself (individual) or not? We chose to reflect the social identity as a relational for two reasons:

1. Conceptual: it feels more reflective of the way social identity is described, as neither or both part of the individual and the group. It is something that connects an individual with a group, the group has certain characteristics, but merely exists through the connections of the individuals.
2. Practical: it is a straightforward way to represent common characteristics and behavioural options that are known to all group members, but at the same time allow for changes to emerge in these characteristics and behaviours over time, this

dynamism is important for the realism of such models as new norms may arise, e.g. helping behaviour during emergencies.

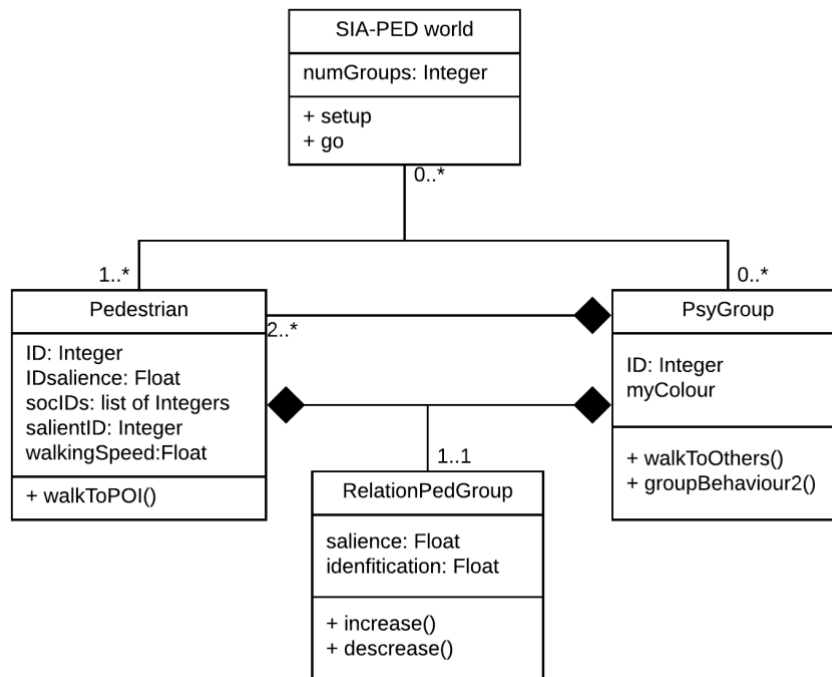


Table 2. Figure 2. Class diagramme of personal and social identity formalisation.

3.2 Formalisation 2: salience vs social identification

Another important mechanism in SIA describes that when one's social identity is salient one acts accordingly. It is thus more likely that one displays behaviour considered appropriate in the group. But before getting into how this affects behaviour (Formalisation 3), we focus on representing salience and social identification, two important concepts when one goes deeper into SIA. Recall that *salience* plays a role in *which* social identity is 'activated' or influencing behaviour at a certain moment. The context/situation makes one identity more or less salient, and strongly links to mechanisms as the 'meta-contrast ratio' discussed in the background. The meta-contrast ratio plays a role in how one categorises oneself through comparison with others. The current salience of identities are important in how this assessment is made.

Social identification on the other hand, plays a role in *how a salient* social identity affects behaviour. It indicates the prominence of a salient social identity, i.e. how

important this identity is to you, in how far you identify with the group and how much your behaviours are aligned with the group. To represent these concepts and the process towards behaviour we had several iterations of discussions and revisiting the literature to interpret and stressed the following:

- Social identities and personal identity can be seen as ends of a continuum, where the degree of social identification reflects how important that identity is to you.
- Salience determines which social identity is influential at that moment, and the context makes the identity salient (e.g., through the meta-contrast ratio).

We show the conceptualisation and connection of salience and social identification of social identities in Figure 3. Formalising this conceptualisation is done using two variables (*salience* and *identification*) that reside in the relation (link) between the agent and the social group.

To determine which identity is salient requires the comparison between the salience of all links and the choice of representing how social identities influence behaviour. We reflect that only one identity (the max salience relation) will influence behaviour, which is sufficient for the purpose we have in the model now. However, this representation also allows for reflecting a more complex take on salience when considering ‘social identity complexity’ that questions the idea of one salient social identity and allows for the role of multiple, conflicting social identities affecting behaviour [24]. Something we or others may want to unpack in the future.

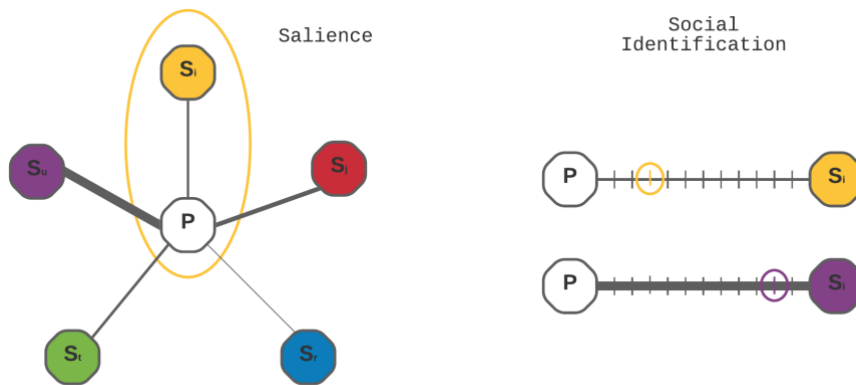


Fig. 3. Conceptualisation of salience and social identification. Salience indicates which social identity is active or influencing at a certain moment. Social identification is the degree of importance reflected as a continuum between personal and social identity.

3.3 Formalisation 3: Salient identity → behaviour

As described above the theory describes that a salient identity makes it more likely that one displays behaviour considered appropriate in the group. To make it concrete for our case, when the social identity is salient, the pedestrians tend to seek closer vicinity of others of their group, while walking forward. Often this is formalised as a flick of a switch, social identity is on/off and there is a direct relation to a particular behaviour [25]. From a modelling perspective this choice is understandably pragmatic, however for most real-life situations extremely simplified as this would mean that anyone who feels part of the group acts in one certain way. This is where the role of strength of social identification - the degree to which this social identity is important to you - can come in. For our model, we decided to make the behaviour more heterogeneous by making the agent try to stay together (affecting their walking speed, closeness and direction of movement) depending on the degree of social identification. Here we distinguish between low, medium and high levels of social identification, making the influence more granular. Although this is a decision in line with the empirical findings, of seeking closeness with one group when the identity is salient and the increase of closeness when social identification is higher, we still feel the linearity, determinism and heterogeneity in behaviours deserves more reflection, discussion and empirical insights on the processes that lead to adopting certain behaviours.

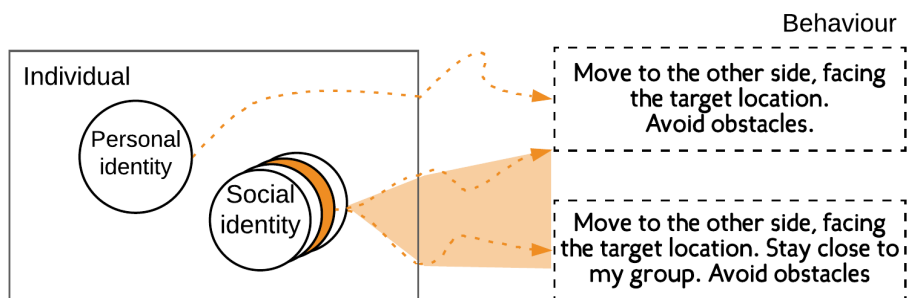


Fig. 4. Visualises the connection between the personal and social identity to typical behaviours when that identity is salient, however the pull one receives from being close to others relies on the level of social identification.

4 Discussion & Conclusion

In this paper we highlight some core conceptual-to-code decisions and reasonings in modelling Social Identity Approaches (SIA). SIA is considered a high potential approach to explain many in and between group dynamics relevant to many social science inquiries. For agent-based social simulation a valuable ability to contribute and connect to and between social science domains when having such wide explanations formalised. It is something that has been picked up by many and has over the last years gained momentum as a shared focus to formalise (e.g. siam-network.online).

Preliminary reviews also show that often SIA formalisations reflect very different ways of interpreting SIA mechanisms [26]. In our collaboration, being an agent-based social simulation modeller and a psychologist specialised in SIA, we seek to formalise SIA for a specific domain (pedestrian crowd models), however our considerations and decisions can be helpful to others applied to their own case/domain. For that reason, we shared our decision and reasoning about representing identity (personal and social), salience, social identification and finally the way social identity influences behaviour.

We have only just started to tackle the many aspects of SIA and are very much aware there is so much more that can and should be unpacked. Our immediate next step will for instance focus on the role of the presence of an outgroup. How this influences behaviour via perceiving an outgroup increases social identification with one's own group via the meta-contrast ratio. But also, how there can be a more specific description of reinforcing mechanisms of salience and social identification. Are there slow and fast changes distinguishable? For instance, in how important a social identity is to you overall, but may get higher in the moment and go back to a baseline after an event/incident? Etc. At the same time we are keen on having a discussion on this level of detail with peers during the conference, and are open to reconsider or refine what we have until now.

We hope to have enabled a conversation and provide support in formalising SIA. We feel that our positionality as interdisciplinary scientists in psychology and modelling, engaging with SIA and ABMs gives us a unique position to push the formalisation better when joining forces. This does not mean this is THE way to formalise, others will and may do this differently, however benefits anyone interested in formalising SIA, be it for their own work or to be critical of ours/others.

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