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Understanding crowd behaviour

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Chapter 3

CROSS - A Theoretical Crowd Model

The main topic of this thesis is behaviour patterns observable in a crowd. The understanding of the underlying mechanisms that give rise to the formation and changes of behaviour patterns are assumed to provide a deeper understanding of crowd behaviour. In chapter 1 some typical behaviour patterns were already addressed: *arcs, rings, lanes, companion-clusters*, see figure 1.1. J* was part of an arc in front of the stage, part of a lane while moving to the bar, and while doing all this he stayed in the vicinity of his friends. It is important to realize that crowd behaviour patterns are not restricted to detectable regularities in movement only. People who are acting in a similar way, like dancing or fighting, form a behaviour pattern as well. In this way subgroups in a crowd form, change and dissolve, i.e. the subgroups are dynamic. The formation and changes of such dynamic subgroups took place during the festival from the example given in chapter 1. People danced, laughed, sang, talked, drank, but there was also violence and a conflict between a group of 200-300 persons and the LEOs. All of these dynamic subgroups can be identified on the basis of the behaviour they exhibit.

To model the dynamic interplay of behaviour patterns the CROSS¹ model was developed. The CROSS model describes crowd behaviour using a multi-level approach where *individuals, context* and *interaction* play a crucial role. This description incorporates the view of the modern foundation of the crowd research, and it adds to it by including knowledge of human information processing, i.e. cognition. The rich description of an individual's internal world allows to understand *why* certain behaviour is chosen and helps to understand *how* behaviour patterns emerge at a group level. In this thesis, the particular focus lies on identifying general principles of crowd behaviour, rather than specific situations, e.g. riots or emergencies.

However, human behaviour cannot be described without incorporating the con-

¹CROSS stands for a model of crowd behaviour that simulates situated individuals. The two foci are: 1) theory and 2) methodology. Symbolically, CROSS also stands for the boundaries of the scientific disciplines that are being crossed. In addition, a cross, or an x, is also a variable representing the variability of each individual. So even when behaviour is caught in a rule (i.e. formula) the outcome will differ based on the value of x.

text, even when the focus is on a generic understanding of crowd behaviour. It is the context that specifies the details that concretise the behaviour shown. In addition, it makes the model testable in relation to reality. In this thesis, a festival scenario is chosen to develop the model. A festival represents a dynamic gathering of individuals and a variety of attractions points (e.g. the stage, the bar, the toilet, other people). It is a relatively simple scenario (e.g. the area is restricted and the range of behaviour shown is limited), but sufficiently rich for the study at hand. In addition, there are many empirical descriptions of festival situations, e.g. (Kemp, Hill, & Upton, 2004; Muller et al., 2009), which allows for a scenario that is close to reality.

The CROSS model represents crowd behaviour by describing as well as relating three levels of description: the group level (inter-individual), the individual level and the cognitive level (intra-individual). These levels are visualised in figure 3.1. The group level, figure 3.1a, represents an overview of a crowd, where a physical and social environment can be identified in the form of a stage and other individuals, both festival public and police. Figure 3.1b, zooms in on individuals constituting a crowd and shows how an individual is affected given the current context. These are local influences. Figure 3.1c, displays the internal world of an individual, the level at which influence actually takes place. This multi-level approach allows for an increased understanding of behaviour patterns in a crowd (i.e. a phenomenon at group level) that are generated at the individual level. Behaviour in itself does not inform *why* and *how* certain behaviour comes about. The CROSS model adds a new dimension by including the cognitive level. In this way, a richer description of behaviour generation can be given. Modelling crowd behaviour involves identifying relevant factors and processes at three levels (i.e. the group, individual and cognitive levels) and translating the effect into the cognitive level.

The following sections will describe the relevant factors for each level for the festival scenario, starting from the group level working down towards the cognitive level. Most detail is provided on the cognitive level, as it entails the translation of how the factors at the other levels can affect an individual.

3.1 The group level

At the group level a crowd can be described from a macro view. Imagine being at a festival or the beach festival described in chapter 1 and observing the crowd from above. From this perspective crowd behaviour can be observed in terms of behaviour patterns. To be able to say more about the situation, the context in which the individuals are situated must be included in the description of crowd behaviour. The context defines both a physical and a social environment for the individuals. The relevant factors from the physical and social environment that are relevant to crowd behaviour are incorporated in the CROSS model. They will be identified in the following sections.

3.1.1 The physical environment

In a crowd, individuals have gathered at the same physical location. All objects are part of the physical environment, including the individuals themselves. In the literature, several physical factors have been linked to crowd behaviour, such as density

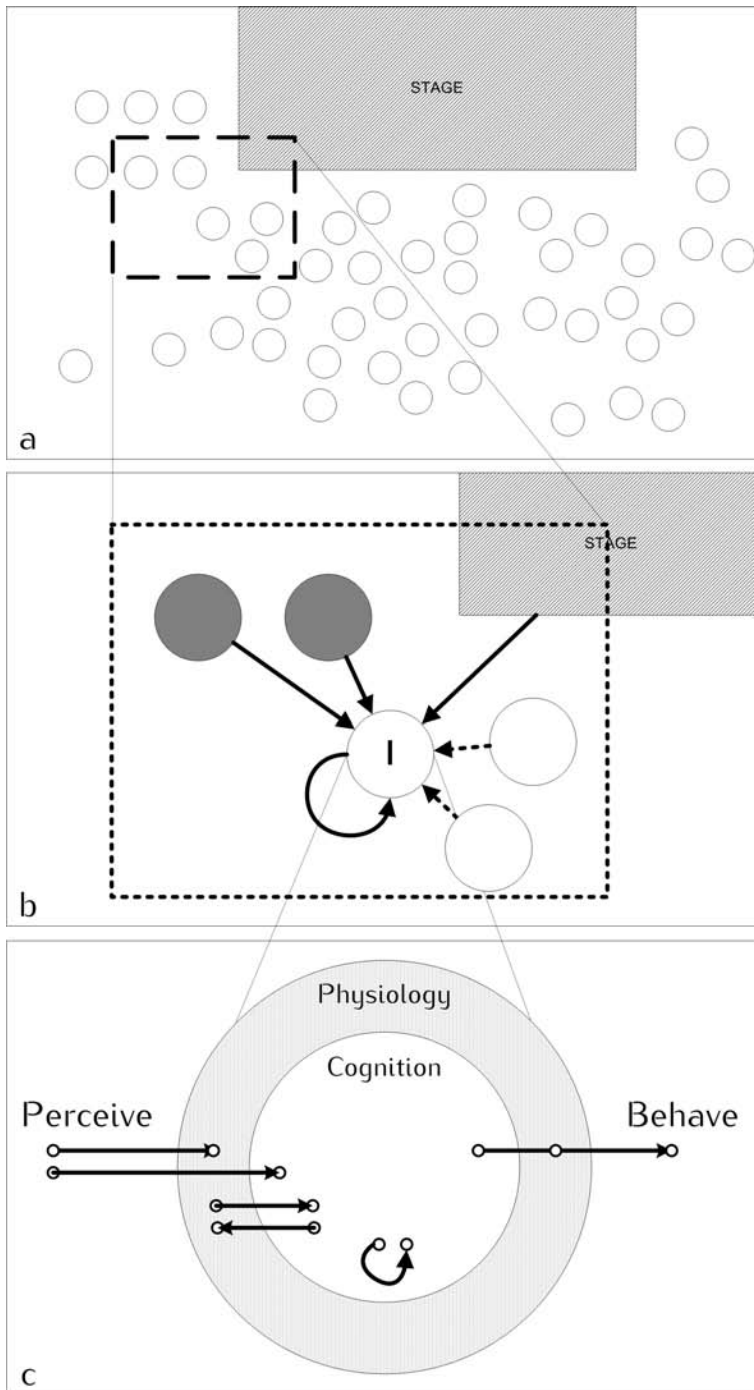


Figure 3.1: The levels at which crowd behaviour can be studied. The group level (a) where behaviour patterns emerge; the individual level (b) where behaviour is generated and the local influences of the physical and social environment originate from; and the cognitive level (c) where the individual is affected.

(persons/m²), noise, scent and weather conditions. Safety-related research on crowd behaviour is dominated by relating physical influence factors to behaviour (e.g. pressure, density, obstacles). In safety design, movement, flow and physical impact are mainly being studied from an engineering perspective (Sime, 1995). For example, an engineering approach would involve designing a building in such a way that paths and obstacles (fences, walls, etc.) will guide people, allowing them to leave quickly or to keep a steady flow. These design features evolve around manipulating human density and maintaining a density level far from one that leads to injury or death. Human density, i.e. ρ_{human} , is an obvious characteristic of crowds that cannot be neglected as a factor influencing behaviour. Therefore, density must be incorporated into the CROSS model. It will be dealt with in more detail below.

In research on riots, *noise*, *scent* and *weather* conditions are emphasised as relevant factors (Krahé, 2001; van de Sande, 2006). Noise and unpleasant scents appear to act as intensifiers in an already tense situation (Geen & O'Neal, 1969; Rotten, Barry, Milligan, & Fitzpatrick, 1979). Regarding weather conditions, several factors can be related to the type of weather, including temperature, atmospheric electricity and rain. For example, there seems to be a relationship between violence and temperature, with more violence in summer than in winter (Anderson & Anderson, 1998; Anderson, Bushman, & Groom, 1997). A similar correlation can be found between violence and atmospheric electricity (Charry & Hawkinshire, 1981). However, bad weather, i.e. cold, windy, foggy weather, seems to have a dampening effect on aggression in crowds (van de Sande, 2006). The weather seems to have an inverted U-shaped relationship with aggression. Extreme cold or hot temperatures will prevent aggression from happening, as the need to protect one's body from extreme temperatures will be dominant.

The above mentioned factors are the ones that are most often discussed in crowd research. In the CROSS model the choice was made to include density, as it has a direct impact on behaviour at the individual level, especially on freedom of movement and on behaviour patterns. For the other factors, it is less clear how they affect the behaviour of individuals and thus behavioural patterns at the group level. Furthermore, at this point in time the aim of the study is not to acquire a complete model in the sense that all relevant factors are incorporated, but in the sense that the relevant mechanisms that underlie crowd behaviour patterns should be reflected.

Density

Several theories relate density to crowd behaviour. Although the notions of density and crowd behaviour are the common denominators, these theories tend to focus on different types of crowds, e.g. extremely high-density crowds, uniform crowds or crowds in which a riot occurs, or they tend to explore different kinds of effects, e.g. long-term versus short-term effects. Lastly, different types of explanations are chosen either in terms of physiology or psychology notions. It is important to be aware of the differences and the range of explanations when applying existing theories to explain density. The focus in this thesis lies on the direct (i.e. short-term) and local effects of density on behaviour. Within this framework the existing theories will be judged on relevance.



Theories differ in focus on the type of crowd phenomenon. The first difference in focus concerns the crowd phenomenon dealt with in this thesis. Most attention is being paid to extreme or remarkable crowd situations, such as extreme high density levels, uniformity in behaviour, or violence. Research on safety management (Kemp et al., 2004; Kemp, Hill, Upton, & Hamilton, 2007; Fruin, 1985) mostly focuses on gaining knowledge to avoid extremely high density levels, keeping the human beings involved from bodily harm. The physical impact of density plays a crucial role in these extreme settings. However, a focus on physical impact only is not enough (Sime, 1995). Behaviour is not only driven by physical characteristics, the social context plays an important role as well and must be included in order to understand human behaviour in a social setting. Other research concerning density focuses on a phenomenon called *contagion*, which refers to uniform behaviour in a crowd, for instance applause. Theories dealing with behaviour contagion describe the circumstances under which a behaviour spreads within a group, like a disease contaminating others. Although the explanation remains rather speculative, Freedman et al (1980) relate density and size to behaviour contagion by indicating that these relatively simple environmental factors can be major determinants for contagion in groups. In addition, crowd research concentrates strongly on riots². There is a tendency exists to assign a link between riots and density, whereas in reality there is no such direct link between the level of density and the probability of a riot. Indirectly, density can be regarded as an intensifier in a given situation, intensifying the situation in a positive or a negative direction (Freedman, 1975). The focus that is employed by the existing studies can be described as too specific (e.g. a focus on physical impact, contagion or riots) for the general nature of this thesis, which is aiming to understand the formation and change of identifiable subgroups (behaviour clusters). To focus on a specific crowd event, such as applause, is not general enough for the level of explanation that is sought in this thesis. Focusing exclusively on the events after a performance, for instance, will not bring insights into the behavioural dynamics during an entire festival event. To gain an understanding of what is going on in a nonextreme or pre-extreme crowd situation, it is crucial to include the relevant context that affects behaviour.

Theories differ in focus on the effect of density. Apart from their different focus on types of crowds (e.g. emergency, uniform, riots) existing theories also differ in their focus on effects of density in terms of long-term or short-term effects. Not only the research conducted in the field of safety management, but also behaviour contagion research, focuses on the short-term effects of density on behaviour, a focus that is shared in this thesis. However, theories that describe long-term density effects are found in environmental psychology, where the notion of *crowding* is employed (Stockdale, Wittman, Jones, & Greaves, 1978; Severy, 1978; Schweizer-Ries & Fuhrer, 2006). Crowding describes the psychological effect of the perception of density³ on behaviour. The way density is perceived differs from one person to the another. To give an example, some people might find a crowded festival uncomfortable, while others experience these high levels of density as nice. In crowding

²Riots are crowd situations in which (a part of) the crowd is involved in aggressive and/or violent behaviour.

³Density is a physical measure that is observed in terms of number of people per m^2 , a the physical measure.

theories, the positive or negative experience of perceiving density is considered as an important factor. Research that takes crowding into account tends to focus on the long-term psychological effects of being exposed to high-density levels. An example includes a study of Milgram (1970) where he analysed the effect of living in the city versus living in a village using the notion of crowding. According to Milgram, city life, i.e. high density, can be experienced as an overload leading to mechanisms that give rise to typical patterns of city life (e.g. pace, helpfulness). However all mechanisms need more closer examination. Even though crowding research concerns a completely different scope in explaining crowd behaviour, it does address an important point: the subjective aspect of perceiving density.

Theories differ in the type of explanation The theories discussed tend to explain either a relationship between density and physiology or between density and psychology. Both safety management and Freedman's (1975) behaviour contagion theory describe density to affect physiology, whereas crowding describes a psychological effect. In safety management, what psychologically moves an individual is often not taken into account in the design of safe spaces. This is however necessary when the aim is to improve safety (Sime, 1995). When the scope of explanation is too narrow due to a focus on the physical side, one is not able to understand behaviour and thus unable to contribute towards safer surroundings. The Love Parade incident described in chapter 1 clearly illustrates the limitations of a purely physical focus. However, physiology (i.e. the physical side) cannot be ignored either. As simplistic as its the role might be, the bodily effect of being in high-density areas is strong, by the restrictions in movement and pressure that is created. As both physiology and psychology are important, their role and interplay should be included instead of being isolated when explaining crowd behaviour.

3.1.2 The social environment

A crowd is by definition a social phenomenon as the presence of other persons instantly establishes a social setting. A description of the social environment involves a social structure specifying the group composition which is based on the type of relationships that exist between the individuals in a group, such as friendship relationships, in-group/out-group relationships and power relationships, e.g. leader-follower relationships. Crowd events can be very different, recall the descriptions of the beach festival, the shopping crowd, the supporters of a sports match and the emergency situation at the Love Parade in chapter 1. The beach festival shows an audience and LEOs. Within the audience, small groups of friends and family (i.e. companion clusters) can be identified, but also in a group of football supporters. In the mall on the other hand one can only find companion clusters and single individuals, whereas at the football match two groups of supporters can be identified. Defining the social environment shows the different ways individuals are related. These relationships between individuals are an important factor influencing behaviour.

In most crowd research, the social environment is emphasised, except for the safety research mentioned where mainly the physical environment⁴ is emphasised.

⁴In safety research, the need to incorporate the social environment is receiving more attention in order to improve safety management (Sime, 1995).

The social environment in public order studies, however, is described in terms of the presence of identifiable groups and the relationships between these groups as an indicator for potential disorder. Both ESIM (Reicher & Levine, 1994) and Adang's (Adang, 1998) model, discussed in chapter 2, describe the initiation and escalation of violence as a consequence of a relationship gone awry.

Descriptions of crowds often involve a social structure in terms of friendship, in-group/out-group settings and power relationships. Friendship, for instance, is mentioned in relation to small groups of 2, 3 or 4 people who attend an event, e.g. a festival (Aveni, 1977). These companion clusters indicate the importance of being with acquaintances. An in-group/out-group setting, for instance, characterises a typical riot setting of two clearly opposing groups, where the individuals composing the groups perceive each other in in-group or out-group terms (van de Sande, 2006). The presence of an out-group makes in-group membership more salient, which gives rise to the so-called *in-group/out-group bias*. This bias reflects the tendency of group members to selectively favour the in-group, while looking more negatively upon the out-group (Forsyth, 2006). A second concept is the notion of power relationships, which is used to describe individuals in terms of initiators, leaders, or hard-core members versus followers or hangers-on. As Van de Sande (2006) points out, this notion can be viewed as a social structure of power and role relationships. Empirical data (Adang, 1998) allow to distinguish between behaviour patterns by describing individuals in terms of followers, hard-core groups and bystanders. Heterogeneity of behaviour in a crowd is thus confirmed. However, to our knowledge no theories concerning the role of power structures in crowds have been developed.

The social factors of in-groups and out-groups, power and friendship are all considered to be relevant and would in principle deserve to be incorporated into the CROSS model. For reasons of simplicity only friendship and leadership as a power-relationship are included. As indicated earlier, this thesis does not aim to be complete by encompassing all relevant factors.

Leadership

Leadership is an area that has been studied quite extensively by the social sciences. See Northouse (2004) for an overview. In general, theories on leadership focus on the leader itself by defining what attributes a leader must possess (*the trait-approach*); what kind of behaviour is required (*the skills or style approach*) in a given situation (*the contingency approach*); or what kind of interaction (*the transformational approach*) is required for good leadership. Leadership generally refers to a process in which an individual exerts more influence on others than is being influenced by those others. Though in this sense, all theories use the same notion of leadership, they explain it very differently, as leadership is seen as a personality trait, a skill or as the situational product of an individual being a leader.

Theories differ in the explanation of leadership. Most research focuses on explaining what it is that makes someone a leader. This seems to be driven by the need to be able to identify a good leader on the base of systematic knowledge. There are four types of leadership theories (Northouse, 2004) that define what makes someone a leader; they are based on trait, skills, situation and interaction effect. The first type

of theory is called the *trait approach* that regards leadership as something innate, a person is born as a leader. The focus lies on associating attributes with leadership. The identification of attributes includes physical factors (e.g. height, appearance), personality (e.g. extroversion, self-confidence), and abilities (e.g. speech fluency, intelligence) (Bryman, 1992). The trait approach fell in disfavour, as the findings were often weak, ambiguous or contradicting, and it thus failed to generate a list of leadership traits. The second type of theory focuses on skills that must be acquired to be an effective leader, the *skills or style approach*. These skills are considered to be learnable, which makes leadership available for everyone. Just like the trait approach findings from this approach were inconsistent. The third type of theory is the *contingency or situational approach* that focuses on the context, i.e. the situation in relation to the leader that arises. The contingency approach was a response to the difficulties of the skills or style approach. As it became clear that the explanation was more complex than a simple correlation between style and outcome. The approach has been particularly successful for practitioners, but has been criticised for its unstable theoretical basis due to the lack of body of published research. The fourth and last type of theory in leadership research is the so-called *transformational leadership approach or the new leadership approach*. This theory is a current approach that describes a leader as someone who is able to change and transform individuals with regard to emotions, values, standards, goals, motives, etc. The theory describes a process between leaders and followers and stresses the role of the follower. However, this type lacks conceptual clarity and the measuring used for its validity is not fully established yet.

Crowd behaviour is a complex social phenomenon in which the interaction between individuals must be involved in order to understand the social system. Existing studies on leadership neglect the role of a complex system such as a crowd. When incorporating these theories into the approach taken in this thesis, several problems arise. First of all, leadership will be addressed in a crowd context, not in an organisational context of a company for instance. Secondly, the research question is different. This thesis focuses on how a leader influences an individual, whereas all theories, except for transformational theories, are aimed at identifying what makes someone a successful leader. Thirdly, and most importantly, leadership is in this thesis regarded as a product of a reciprocal process that involves both leaders and followers (Barrow, 1977; Hollander, 1985; Hollander & Offermann, 1990; Hollander, 1993). Most theories do not include this aspect. The main critique that the present-day approaches receive involves this reciprocal process, as these approaches lack conceptual clarity and explanatory power (Northouse, 2004). A direct answer to the question ‘how do leaders in a crowd directly influence other?’ (i.e. in the short-term and with direct behavioural impact) remains unanswered.

3.2 The individual level

The individual level represents the level at which behaviour arises. Individuals interact with their environment by perceiving and acting. Including factors that play a role in this interaction is therefore important in describing behaviour in crowds. As both individuals and their physical positions are unique, their perception and behaviour

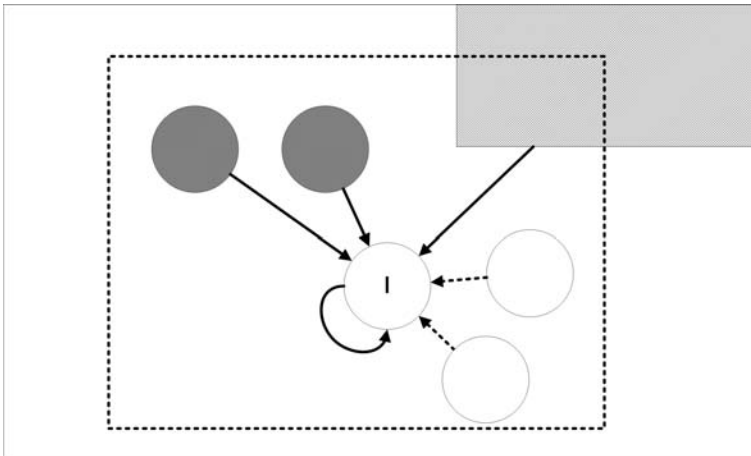


Figure 3.2: An individual in a crowd is influenced by himself and by his physical and social environment. In this social environment, the influences vary, depending on the relationship between individuals.

will differ. Based on what an individual perceives, his internal state is affected. Based on the internal state at that moment a particular kind of behaviour is chosen⁵. Theories that describe individual behaviour without any reference to an internal state are rare. However, an example includes the traditional behaviourist theories that describe behaviour as reflexes, such as Pavlov's classical conditioning theory (Pavlov, 1927). The internal state is not taken into account as it cannot be measured or observed (Watson, 1930), or it is regarded as nonexistent. The social sciences have abandoned these black-box approaches (Jorna, 2000) by including the internal state. In short, approaches can be said to range from very simple attributions (e.g. personality psychology, economics) and mental ascriptions (e.g. social psychology), to complex cognitive structures and neuromapping (e.g. cognitive psychology).

In figure 3.2 the influences on behaviour are visualised. It is important to note that the influence of environmental factors is local. This is true for both the physical and the social environment. However, the social environment can also involve group-level influences, through the existence of subgroups for instance. The local physical environment of an individual consists of physical objects. In the festival context, the physical environment involves the physical presence of other people, a stage, bars, toilets, fences, walls, etc. The physical characteristics of individuals on the one hand and the interplay between these characteristics and the environment result in restraints in both perception and behaviour. For instance, our eyes' range of sight makes it impossible to see what happens behind us, i.e. a physical object, such as a wall, directly restricts movement. Applying this individual-level notion of local influencing, density should be regarded as a local factor influencing individual behaviour. When density is high at group level, this does not necessarily imply that each individual is at a high-density location. Similarly, when density at group level is low, local density can be

⁵As a reminder, the use of the word 'chosen' does not imply a conscious choice: it implies that behaviour is a consequence of certain internal and external processes.

high, e.g. when a number of individuals are standing at the bar.

The social environment involves other individuals. Both the relationships between an individual and others and the perceived relationships between others represent the social environment of an individual. Relations can involve simply co-presence, membership of the same group or subgroup, or being friends or family. Perception of the social environment also involves aggregates that are perceived by the individual itself⁶. However, for the sake of simplicity, these group-level perceptions will not be taken into account in the CROSS model. Only the perception of context-relevant items, such as the stage, toilet, bar and friends will be included.

Perceiving behaviour of other individuals in the local social environment may also influence an individual. How perceived behaviour influences behaviour depends on the relationship between the perceiving and the observed individuals. For instance, being with friends has a different effect on behaviour than seeing a leader.


The situated individual

The interplay between the physical and social environment and the internal state of an individual gives rise to behaviour. The role of the internal and external state of an individual is captured in the term *situatedness* (Wilson & Keil, 1999). Situatedness is a term adopted from the cognitive sciences, where it is used to indicate that the behaviour and cognitive processes of an individual are first and foremost the outcome of a close coupling between agent and environment (Lindblom & Ziemke, 2002). In cognitive sciences the term is mostly used as physical situatedness. In this thesis, situatedness will refer to both physical and social situatedness. In that sense, the tendency to overestimate the influence of personality and underestimate the role of a setting in crowd situations (van de Sande, 2006) will be explicitly avoided. Influences on behaviour are considered dynamic and thus variable over time. A certain setting defines whether the main influence is either external, internal, physical or social.

A situated individual is both embodied and embedded (Wilson & Keil, 1999). *Embodiment* means having a human body, including all the behavioural and cognitive constraints that it entails (Ballard & Sprague, 2007). When attempting to understand or explain behaviour, it is important to be aware of these constraints, because your eyes determine what you can perceive, and your mental state determines how this perceived information is processed and how it affects your behaviour. *Embeddedness*, however, refers to the fact that an individual is always present in a specific context and that he is influenced by situational factors. These factors could be stable, such as the nationality of a person or his culture, or more changeable and linked to the knowledge or norms (i.e. rules of conduct) a person has. Social embeddedness relates to the social relationships of an individual, e.g. with friends or leaders. Embeddedness stands for the link between the internal world and the external world. Being embedded is what is taking place in one's head while being in a certain context.

For the CROSS model, the notion of situatedness has direct consequences for the way perception is dealt with. As a result of being embodied and having an internal state, limited and subjective perception can be distinguished. *Limited perception* re-

⁶The three levels according to which crowd behaviour is described and viewed given the three levels correspond to how an individual perceives a crowd he is part of. He will observe patterns, but also see the heterogeneity: some parts are more detailed than others.



stricts the way an individual perceives the world due to the physical constraints of being embodied or physically embedded, e.g. a tree in one's line of sight blocks a part of the perception. This affects what an individual knows and therefore how he is influenced by the world. Consequently, individuals will always have 'incomplete' information. An example of this awareness is the notion of *bounded rationality* (Simon, 1957). Bounded rationality refers to the cognitive and ecological limitations of both knowledge and the processing capability of individuals that play a crucial role in their behaviour. To neglect the fact that people do not have complete information would make their real behaviour puzzling, as 'rational'⁷ behaviour is expected. The acknowledgement of bounded rationality results in the differentiation of what influences an individual. Limited perception functions as a filter that discerns what information can be obtained by an individual. Perception is bounded by the spatial position at that moment, heading and specific limitations, such as gaze width, gaze depth, and hearing range. *Subjective perception*, however, describes the way information is interpreted taking into account the situational constraints. The restrictions in perceiving the world involve both previous experiences as well as the internal state of an individual at that particular moment. The 'subjective' perception requirement can be seen as a filter on 'objective' perception, i.e. a cognitive lens. Heterogeneity among individuals then becomes important, as each person has his own unique experiences and therefore his own unique filter to watch and interpret the world around him.

In short, the view of a situated individual in a crowd stresses the importance of incorporating both external and internal relevant factors. All external factors exert their influence on behaviour by affecting the internal state. On the other hand, the internal state itself shapes the way that information affects the internal state. When processing all influences, the external factors must be 'translated' into an intra-individual level to take effect. Figure 3.2 shows the individual level of behavioural influence, describing an individual being influenced by his physical and social environment and by himself. The remainder of this chapter will deal with the cognitive level of an individual in a crowd, providing a structure that allows for the translation of external influences to take effect as well as the relevant internal factors and processes.

3.3 The cognitive level

The cognitive level describes the way an individual processes knowledge in order to determine behaviour. The behaviour selection follows Newell's *principle of rationality*: actions are selected to attain the individual's goals (Newell, 1982). To describe crowd behaviour, this chapter started out by distinguishing three levels of descriptions (the group, individual, and cognitive levels). The cognitive level is further specified in this section. A multi-level analysis is considered necessary in this thesis. Defining multiple levels of description is considered a common method, for instance, from the biological to the cognitive, rational and the social levels of description (Newell, 1990). Three different levels can be distinguished to represent the internal world of an individual:

⁷Rational behaviour is in this context regarded as the view that individuals will always choose the optimal behaviour provided that they have complete knowledge of the world.

The intentional level ascribes beliefs, desires and intentions to persons in order to explain and predict human behaviour (Dennet, 1978, intentional stance). It concerns an abstract explanation of the behaviour of others by inferring between what we see and what we know of the situation and/or person. Theories in social psychology often operate on this level. The knowledge level (Newell, 1982) is substantially the same as the intentional level (Newell, 1990).

The functional level describes cognitive mechanisms and representations of an individual in order to explain behaviour. The description of the cognitive mechanisms entails an empirically validated theory (Anderson & Lebiere, 1998). Theories in cognitive sciences focus on this level, although they incorporate the other levels as well.

The physical/physiological level explains behaviour in terms of physical laws, chemical reactions, or physiological properties (Dennet, 1978, physical stance).

Each level (intentional, functional and physical) describes behaviour but differs in the amount of detail and precision. The theories concerning the intentional level tend to be more abstract and linked to a specific type of behaviour (e.g. violence, fleeing). The differences in precision and detail make it hard to integrate and combine the levels, as the lack of unifying theories shows. The aim of this thesis is to develop a concrete and generic model of crowd behaviour. Both the functional and the physical/physiological level will be adopted as they enable to merge existing theories of crowd behaviour. Furthermore, at the functional level, the individual is considered as a cognitive system that allows to adopt a framework within which the integration and translation of theories can take place. Cognitive sciences is the research area that aims to understand the human mind, focusing on conscious and subconscious mental processes, knowledge possession, knowledge storage, knowledge change, information processing, etc. The tendency in cognitive sciences is to work on a general theory of cognition. Examples include neuroinformatics (neurosciences and AI), neuropsychology (neurosciences and psychology), psycholinguistics (linguistics and psychology), computer linguistics (linguistics and computer science), and architectures of cognition (psychology and AI) (Hendriks, Taatgen, & Andringa, 1997; Posner, 1989). A generic theory that focuses on the interface between psychology and artificial intelligence relates best to crowd research, as it includes both situatedness and social phenomena at the group level. In cognitive sciences, theories are developed and tested within a larger structure representing a blueprint of the human mind, i.e. a cognitive architecture. A cognitive architecture describes the functional components that cooperate to process information, resulting in behaviour.

Examples of such architectures include ACT-R (Anderson & Lebiere, 1998), Soar (Newell, 1990), and Clarion (Sun, 2003). They all incorporate a structure in which the use, representation and change of knowledge is described in great detail. The level of detail enhances the explanatory power. In addition, these architectures are empirically validated, which makes the rich explanation cognitively plausible. These architectures have a unifying nature, representing a structure into which theories can be integrated and translated. They focus on the valid description and reproduction of higher cognition, such as learning and planning tasks, whereas this study focuses on understanding behaviour. Compared to these architectures, the context of the



individual is crucially different in this study. In cognitive sciences, an individual is studied in the context of performing a specific task, for example learning a language, whereas this thesis involves a crowd context. Moreover, embedding an individual in a social context is what distinguishes this study from most other research in the cognitive sciences (Sun, 2008). As embodiment is acknowledged in cognitive sciences, these architectures do incorporate ‘physical situatedness’ in terms of embodiment⁸ but the role of social embeddedness can only be found sporadically in cognitive sciences. Some exceptions are CLARION of Ron Sun (2000), and RBOT of Martin Helmhout (2006).

The focus on higher cognition in cognitive architectures does not cover the relevant cognitive processes and tasks of an individual in a crowd. For instance, planning what one is going to do next week is not a process that needs to be involved to understand behaviour at a certain moment in time based on the settings at a certain moment in time in a crowd. In this study, only those aspects of a cognitive architecture that are considered to be relevant to crowd behaviour will be used (see below). In addition, a new element will be added: a cognitively plausible framework will be used and filled with social theories. In this manner, the way in which an individual is dealing with his social world will be translated into functional terms.

Cognitive architectures have a strong explanatory power due to their high level of detail, plus they are empirically validated while using a generic framework. The structure of these cognitive architectures will be adopted in the CROSS model. In CROSS, an individual will therefore be represented as a cognitive system in terms of 1) architecture, 2) representations, and 3) processes, which is a division often used to describe human cognition (Helmhout, 2006). In general, these elements are used to describe human information processing. The architecture refers to a structure in which the representations and processes are placed. It includes the body of an individual with its physiological aspects, including the senses. The representations on the other hand contain information that is located in memory. The knowledge in memory allows an individual not only to understand the world around him, but also to act in accordance with a context and internal state at a given moment. The processes represent the dynamic aspect of the cognitive system, i.e. the interaction with the external environment by perceiving and acting. Perception involves receiving input via bodily sensors, whereas action concerns the behavioural output of an individual. The description of behaviour will be restricted to defining the relevant factors, characteristics or mechanisms that are either part of the architecture, representations or processes. In the following section, the different parts of the cognitive system of an individual in the CROSS model will be described, including the relevant aspects concerning the crowd context.

3.3.1 Architecture | physiology

The architecture represents the structure of cognition (Newell, 1990). It is the place where an individual’s memory (representations) and processes (perception and be-

⁸The role of embodiment has in fact caused a fundamental shift in cognitive sciences towards the end of the eighties (Pfeifer & Scheier, 1999). Cognition used to be studied in isolation from the environment. This provoked a counter movement in embodied cognition, e.g. the subsumption architecture (Brooks, 1991). It was acknowledged that cognition could not be studied in isolation from the real world in which individuals are situated.

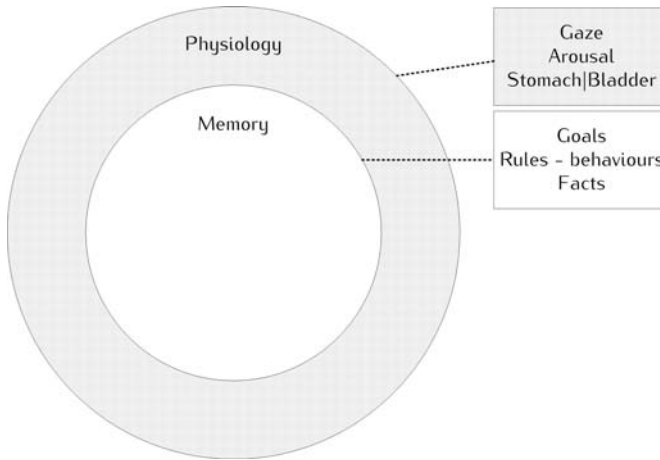



Figure 3.3: The cognitive framework that represents the internal world of an individual comprises physiology and memory.

haviour selection) can be found. The architecture also involves the physical properties of the natural system, it is embodied⁹. To represent behaviour in a crowd, there is no need to incorporate the whole functioning of the human body. Being embodied implies having behavioural and cognitive constraints. Not only does human anatomy define an individual's perceptual range and behaviour options (e.g. a hearing capacity of 20 to 20,000 Hz, not being capable to fly, etc.), it also has an impact on mental processes. Furthermore, several physiological factors, such as arousal, energy level, alcohol and drugs use, appear to be relevant in a festival context, as they affect behaviour via physiology (Challenger et al., 2009b; Wijermans, Jorna, Jager, & van Vliet, 2007; van de Sande, 2006).

Arousal is the attentional state of an individual, a state of alertness that is low when a person is sleepy, normal while being awake under normal conditions, and high in stressful or exciting situations. The notion of arousal involves the physiological measure of the heart rate and blood pressure of a person. This physiological state is related to an important basic mechanism of our sympathetic nervous system, namely *fight or flight*, which prepares us to act fast in a situation of threat (Baron & Richardson, 1994). Arousal often pops up when discussing riots, especially in relation to aggression (Berkowitz, 1981, 1988; Zillmann, 1988). Arousal also affects behaviour through the impact it has on information processing in demanding and complex situations. Under these circumstances, arousal increases and is associated with narrowing attention (Sanbonmatsu & Kardes, 1988). The resulting behaviour is limiting our perception. For instance, under dangerous circumstances, the emergency exits plates may not be registered and used in finding the way out. Arousal is considered in this thesis as a neutral state of alertness that supports an individual in dealing with a dynamic and complex environment, and should not be understood in a positive or negative valuation.

⁹To put it in Newell's words: "the architecture involves both hardware and software" (Newell, 1990, p. 80).



Energy is another important physiological measure that relates to the bodily resources of an individual. Energy is a necessary resource for life, enabling an individual to behave, think, recover, etc. A low energy level may direct people towards the decision to leave the crowd to get food, drinks or to rest and to restore the energy level. In a festival context, drinking and eating are relevant kinds of behaviour, and therefore the corresponding physiological elements of having a *bladder* and a *stomach* can be considered relevant. This brings us to the issue of *alcohol* consumption, which is obviously relevant in a festival setting, but often also linked with the occurrence of group violence. Even though there is no direct or simple causal relationship between alcohol use and aggression, evidence shows that a small amount of alcohol may lead to increased aggressive behaviour (Baron & Richardson, 1994; Russel, 1993). Other substances, such as marijuana, XTC or LSD are also relevant in a festival context. Marijuana seems to decrease the probability of violent behaviour, as it makes an individual less aware of his social surroundings (Baron & Richardson, 1994). However, the effect of drugs other than alcohol on behaviour, such as aggression in crowds has not been well explored (van de Sande, 2006)¹⁰.

Although many of the physiological factors mentioned are potentially relevant in a festival crowd context, it is mostly the group level correlations that are reported (rather than causality). For instance, the relationship between alcohol and aggressive behaviour appears to be positive (Baron & Richardson, 1994; Russel, 1993). However, the actual explanation of the relationship between alcohol and aggression in terms of influences on the intra-individual level remains open for discussion. For the CROSS model, the choice was made to incorporate only the most essential elements first, and to leave out elements for which there is no empirically validated theory. In this model, the incorporation of physiological factors or characteristics will therefore be restricted to limitations in perception (i.e. gaze width and depth), to arousal and to the possession of a bladder and a stomach. Limited perception involves a crucial filter on perception that cannot be neglected in describing behaviour. This filter is also a direct consequence of being embodied (Ballard & Sprague, 2007). Arousal corresponds to primitive/basic behaviour that is related to short-term survival mechanisms (e.g. fight/flight, (Baron & Richardson, 1994)). It allows human beings to respond to a potentially life-threatening situation. The bladder and stomach are factors that are relevant to the context. As people eat and drink, these represent the physiological characteristics to embed the festival context in an intra-individual level. Therefore, they must have a certain effect.

3.3.2 Representations | memory

Individuals use representations to be able to live in a complex and dynamic world. In the CROSS model, representations are represented by a memory structure. Memory represents the knowledge an individual has as well as the processes describing both the changes in the content of the representation and the interaction with the world. In this study, the concept of memory is based on the memory theory of Anderson et al. (2007) which lies at the base of the ACT-R architecture (Anderson & Lebiere, 1998). This theory describes how memory works in functional level terms, how mem-

¹⁰This is interesting, as the research report on the beach festival riot discussed in chapter 1, relates to the importance of both alcohol and drugs (Muller et al., 2009).

ory elements become more dominant (i.e. more highly activated) and play a role in behaviour. It describes how memory elements change (i.e. learn), and how they result in typical human errors in performing or learning tasks (e.g. in short term memory tests, or language learning). But also what the distinction is between declarative and procedural knowledge. The following sections will describe memory and its content for the CROSS model.

Memory

Memory consists of memory elements that together provide an individual with an internal representation of the world that allows him to interact with his environment. A memory element has two important properties: 1) it has content and 2) it has an action level (i.e. dominance). Three types of memory elements can be defined namely *goals*, *facts* and *rules*. Content refers to knowledge and how it is used. The activation level reflects which memory element will be more likely to affect behaviour. Both content and dominance of a memory element will change over time. A change in content represents learning, forgetting or reorganising, whereas a change in dominance represents what is of influencing behaviour at a given moment in time, i.e. the internal state.

All knowledge, i.e. the content of an individual's memory elements, is represented in either a goal, a fact or a rule. These types of memory elements imply that knowledge is a concept that does not only convey factual information, but also incorporates actions¹¹. A goal represents the desired state of an individual, making certain behaviour more or less relevant to choose. Facts, however, represent a piece of factual or declarative knowledge¹², a so-called chunk (Anderson & Lebiere, 1998). This kind of knowledge assists an individual in interpreting what he sees or distinguishing which behavioural option is preferable or more relevant given a particular situation. For example, when seeing a glass of beer, knowledge about beer and what it looks and smells like allows an individual to identify it as beer. When one is thirsty, the knowledge that this liquid is drinkable together with the experience of liking the taste, might lead to the choice of drinking the beer. However, knowing that the glass of beer belongs to someone else would lead to the choice of not drinking the beer. The last type of memory elements concerns *rules*. Rules involve the internal representation of actions, i.e. procedural knowledge. These representations can reflect a description of behaviour, like drinking or walking, but also an internal action, such as changing the content of a memory element, i.e. learning or reorganising.

The activation level of a memory element indicates the dominance of that element, and also how easy it is to access the content of this element. In that sense, forgetting involves the decay of the activation level below a threshold range, which means that the element is no longer retrievable. It is important to realise that the activation mechanism is related to the activation of memory components, as in a cognitive system only what is dominant will affect behaviour¹³. This is the functional interpretation of the concept of *saliency*. Saliency is a notion from psychology that is used

¹¹In that sense, an individual knows how to breath, which does not mean, however, that he can describe how breathing in the human body works.

¹²The word 'knowledge' often refers to facts or declarative form of knowledge.

¹³In that sense, telling someone "you know you shouldn't.." is not logical, as the knowledge should be salient.



to describe why certain behaviour (e.g. normative behaviour) arises in a particular setting. It relates to the phenomenon where a mental concept, such as specific norms or a specific identity, is in focus and therefore has more influence than other norms or identities (Kallgren, Reno, & Cialdini, 2000; Mullen, Migdal, & Rozell, 2003). The activation of memory elements changes over time. It increases due to perception, and it decays over time without stimulation¹⁴. Observing behaviour implies an increased activation of that particular cognitive representation of behaviour. Moreover, all the other elements that are associated with this memory element will be affected as well.

Goals. Human behaviour is goal directed (Kendrick, Neuberg, & Cialdini, 2005). In this thesis, behaviour will be described from an intra-individual perspective, rather than attributing a meaning or function to the behaviour that can be observed. What exactly is the internal representation of a goal that causes certain behaviour to be exhibited? In cognitive sciences, there is no clear-cut answer to this question, as Schoelles summarises: "the concept of goal has many senses. It can be used in a motivational sense; it is something we want to achieve in the future, something we are aspiring to. It can also be an endpoint for a problem-solving experience" (Gray, 2007, p. 325). Most cognitive architectures use the term 'goal' as an endpoint, as declarative control information that guides the direct interaction with the environment (Altmann, 2007). This is regarded as a goal in the sense of *intention* by Carlson (2007). In this thesis, the focus lies on understanding *why* an individual does what he does and on making explicit *how* an individual chooses his actions. This is in line with the motivational use of the 'goal' concept. Therefore, in this thesis, the definition of a goal follows the definition of motivation: "*a modulating and coordinating influence on the direction, vigour and composition of behaviour. This influence arises from a wide variety of internal, environmental and social sources, and is manifested at many levels of behavioural and neural organization*" (Wilson & Keil, 1999).

This definition raises the question of how a goal, used in the motivational sense, can be incorporated into a structure derived from a cognitive architecture? ACT-R focuses on problem-solving tasks involving executive tasks, and this differs considerably from a crowd behaviour domain involving social interaction. Therefore, in this thesis, only the structure and concepts from a cognitive architecture like ACT-R will be adopted. This structure, however, will be filled in a novel way. The reasoning that Sun (Sun, 2003) presents in his cognitive architecture Clarion (Connectionist Learning with Adaptive Rule Induction ON-line) will be followed. Clarion is different from other cognitive architectures, as it distinguishes between implicit and explicit processes and their interaction. In Clarion, goals are action-related, like in other architectures, but they are abstracted from drives, and thus provide specific motivation for behaviour. This is called 'the motivational subsystem' (Sun, 2003). In the CROSS model, the concept of goal is used as an abstract notion that is derived from the concept of 'motivation'¹⁵. For this reason alone, one concept will suffice, whereas Clarion employs two (i.e. drives and goals). More importantly, the model will incorporate multiple goals. In addition, the role of the changing dominance of goals due

¹⁴This functional description of memory elements resembles the behaviour of neurons that can also be stimulated or decay over time.

¹⁵This requires a translation of a motivation in terms of something an individual is aiming for, rather than being an individual's driving force.

to context will give rise to diversity of behaviour, as the relevance of a behaviour is related to the dominance of goals (Wijermans, Jorna, Jager, & van Vliet, 2008). In that sense, situatedness is reflected in goal dominance, as it is subjected to influences that depend on a particular situation. The dynamics of the goal dominance may cause perseverance in one selected behaviour or choosing another behaviour.

To select relevant goals for an individual in a crowd, knowledge is needed from the social sciences. In this study, several 'need' concepts from Max-Neef (Max-Neef, 1993) and Maslow's motivation theory (Maslow, 1943)¹⁶ were adopted. Subsistence, safety, social and personal identity needs are considered relevant in a crowd context. Both subsistence and safety are physiologically rooted drives that are related to staying alive, eating, drinking, sleeping etc. (subsistence goal) and that protect our physical and mental safety (safety goal). At a festival, people going to the toilet or to the bar are displaying behaviour that is typically related to the subsistence goal. Hence, the incorporation of a bladder and stomach in the CROSS model. Feelings of unsafety can be quite prone when standing in crowded areas or areas that are perceived to be crowded. The social and personal identity needs relate to the focus on 'belonging to a group' and to the focus on oneself. The difference between the two is similar to the difference between public and private self or identity, which involves different behaviour associations (Baumeister, 1998). For instance, when the public self is more salient, it is more likely that the individual in question will exhibit socially desired behaviour (Stapel & van der Zee, 2006; Wiekens & Stapel, 2003). Furthermore, it has been proven that the presence of other people primes the public self and makes it more dominant (Shah, 2005). Therefore, the social environment will play an important role in determining behaviour in the model. Each need is translated into a goal, a state an individual desires to reach.

The concepts of *subsistence*, *safety*, *social*, and *identity* are translated into abstract goals that can potentially be satisfied by multiple behaviours. The dominance of these goals influences the probability of certain potential behaviour to be selected. More specifically, the dominance of such an abstract goal makes a behaviour that is more likely to satisfy this particular goal more attractive to choose. The dominance of a goal depends on the difference between the preferred and the real level of satisfaction. This preference may differ from one person to another. For example, one individual feels more comfortable in a crowded area than another. Consequently, the setting of a goal depends on the situation, but can also reflect personal characteristics, such as being easily scared. Furthermore, a dominant goal makes certain kinds of behaviours more salient and thus more probable to be selected, as behaviour selection is based on activation levels. For example, J* standing close to his friends is fulfilling his social goal. In addition, as they are drinking a beer, his stomach is filled and his subsistence goal is being satisfied.

Facts. An individual who lives in a complex environment must be able to respond adequately in order to behave adaptively. This involves not only perceiving relevant elements but also responding adequately in accordance with the input. To be able to do this, an individual needs to add meaning to what he sees, but to act appropriately

¹⁶The resemblance in concepts to Maslow's need hierarchy does not imply an adoption of the hierarchical structure. This thesis incorporates a dynamical hierarchy and strongly rejects the view of a fixed hierarchy (Wahba & Bridwell, 1976).



Table 3.1: The types of behaviour in a crowd, adapted from the collective behaviour table by McPhail (McPhail, 1991, p. 164).

Locomotion		Manipulation		Vocalisation & Verbalisation	
Vertical	Horizontal	Object			
sitting	walking	grasping	clapping	wailing	singing
standing	running	carrying	finger-	yeaching	
jumping	jogging	lifting	snapping	booing	
lying	marching	passing		whistling	
bowing	dancing	waving		hissing	
kneeling	queueing	throwing		laughing	
		pushing		ooh-,ahh, ohing	

he should also be able to discern between potential actions. Factual or declarative knowledge allows an individual to interpret or distinguish between people, situations or behaviours. In any crowd context specific factual knowledge is needed: knowledge of the physical surrounding (*area facts*), knowledge of people (*person facts*) and knowledge of behaviour (*behaviour facts*). In a festival context, area facts allow an individual to recognise the stage, bar and toilets. Person facts allow an individual to recognise other people, but also to distinguish between people, for example, whether someone is a friend, or whether someone is considered as a leader. Person facts play a role in perceiving and interpreting the social aspect of a specific type of physical object (a person) that shows a certain kind of behaviour. Behaviour facts allow a person to recognise a type of behaviour when he sees it, but more importantly, they include the expectations an individual has for how certain behaviour can satisfy his goals. Using this information, the behaviour selection process can discern between the kinds of behaviour that are relevant or not.

Rules. To be able to exhibit behaviour, an individual needs to know these behaviours. A *behaviour rule* is an internal representation of a kind of behaviour describing how a particular action is being performed by the body. Behaviour can be defined at a range of levels, varying from muscular movement to ballistic movements. In this study, only behaviour shown in crowds is relevant, such as dancing, singing, talking, laughing, eating, walking into different directions, standing in line, etc. In table 3.1 a non-exhaustive overview of the kinds of behaviours that can be observed in a crowd can be found as described by McPhail in his observation studies (McPhail, 1991).

3.3.3 Processes | perception and behaviour selection

In the previous section, the static components of the cognitive system were discussed. Now attention will be paid to the processes of the cognitive system in order to describe the dynamic aspect. The internal state of an individual is changing constantly due to both internal processes and the interplay between the external and internal world. The CROSS model describes the following two main processes within a cogni-

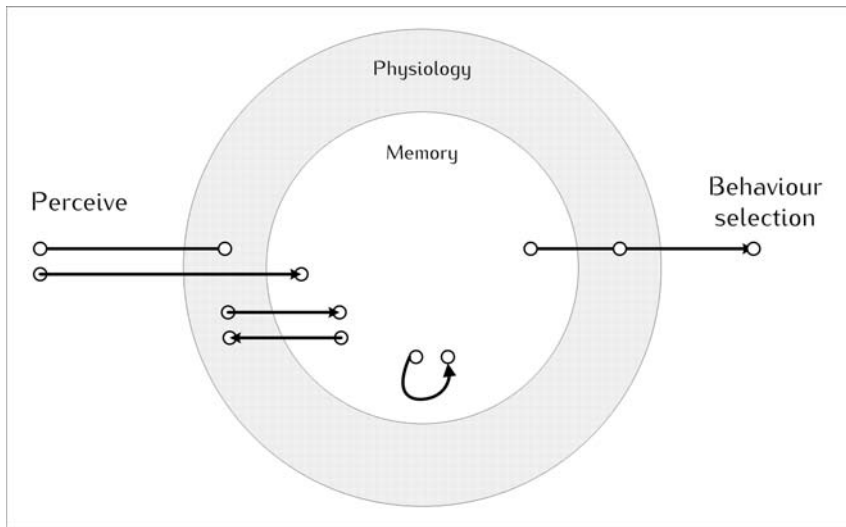


Figure 3.4: The processes within the cognitive framework that give rise to changes in the internal state (i.e. physiology and memory).

tive system: 1) *perception*, and 2) *behaviour selection*. Processes such as reasoning, thinking or deliberating can be considered part of behaviour selection. Perception affects an individual by activating and changing his physiological state or memory representations. Behaviour selection concerns the internal state at a particular moment, i.e. the content of the representations and the dominance of the elements, in order to select a behaviour. Figure 3.4 shows these main processes and the influence relationships between environment and physiology, environment and memory, physiology and memory, and within memory itself. These processes describe a continuous and parallel flow through which an individual is being influenced via perception and exerts influence on the world via exhibiting behaviour.

Perception

The moment an individual perceives, his internal state changes. In the physical world, objects and terrain are being observed, whereas in the social world, behaviours and people are being observed. In addition, the internal world, i.e. the bodily and mental state at a particular moment, is being perceived. In the CROSS model, the way perception affects the internal state of an individual is distinguished between three types of perceptual influences: the *priming*, *physiology update* and *memory update* of cognitive elements.

Priming is the increase in activation of a memory element due to perception (Anderson & Lebiere, 1998). The pure observation of an object, person or behaviour will increase the activation level of the corresponding representation. This makes it easier to retrieve (i.e. to remember) the element and thus more likely to act in accordance with the setting in question. This effect is clearly illustrated with regard to the behaviour rules. The activation levels of the different behaviours at that moment



represent an order. The behaviour with the highest activation level is most likely to be chosen, but this order is dynamic as the most dominant behaviour is something that changes from one moment to the other.

Physiology update represents the change in the physiological state. The CROSS model restricts itself to arousal and having a stomach and bladder. These are updated in terms of a lower or a higher level. An increase in arousal refers to a decrease in time to select a behaviour. (See behaviour selection for the details.) In addition, an increase in the stomach level reflects a full stomach, i.e. feeling less hungry. However, the bladder works in the opposite way, as a higher bladder level increases the urge to go to the toilet. Arousal is only affected by the external world. Although the fact that arousal can be affected by an individual's mental state is acknowledged, for reasons of simplicity, this second-order reflection will not be included. The stomach and bladder, however, are submerged to internal updates, as metabolism makes the stomach empty and the bladder fuller over time.

Memory update represents the change in the content of memory elements due to both external and internal perception. The change in memory element content that is based on external perceptions involves knowledge and preferences, i.e. interpretations, which act as a filter on perception. This implies that the same observation can have different effects on different individuals, based on how they interpret their perceptions (e.g. is he a friend or not?) in affecting facts, but also on an individual's preferences for satisfying a certain goal. A behaviour fact represents the expectations of a behaviour to satisfy one or more goals. On the basis of what an individual sees in the world, these expectations may change. With regard to goals, the satisfaction level is related to a current context and therefore it affects which goal is more dominant. As indicated under the physiological update, the subsistence goal is updated by the physiological state, whereas the identity, social and safety goals are affected by external perception.

Figure 3.5 visualises the influence relationships that are incorporated into the CROSS model. From the external world, these relationships convey behaviour being primed, goals being satisfied to a certain extent based on the setting at a given moment and on internal preferences, facts being updated based on observations, but they also convey the changes in physiology due to external triggers. Internal perception reflects physiology affecting the mental state as well as the mental state affecting itself.

Behaviour selection

Human beings exhibit behaviour all the time. The behaviour they exhibit is a consequence of their internal state. Behaviour selection involves a process of selecting an 'optimal' behaviour bounded by a certain amount of time. The most optimal behaviour is the behaviour that best satisfies the goal that is most dominant at that particular moment. Selecting the most optimal behaviour involves comparing the behaviours in one's repertoire to each other until all retrievable behaviours are compared or until one runs out of time¹⁷. Behaviours are compared to each other in a specific order. This order is based on the activation value of the behaviour rules (i.e. the

¹⁷To run out of time will usually be the case. This serves as an efficient way to go through search space by limiting the search in terms of time.

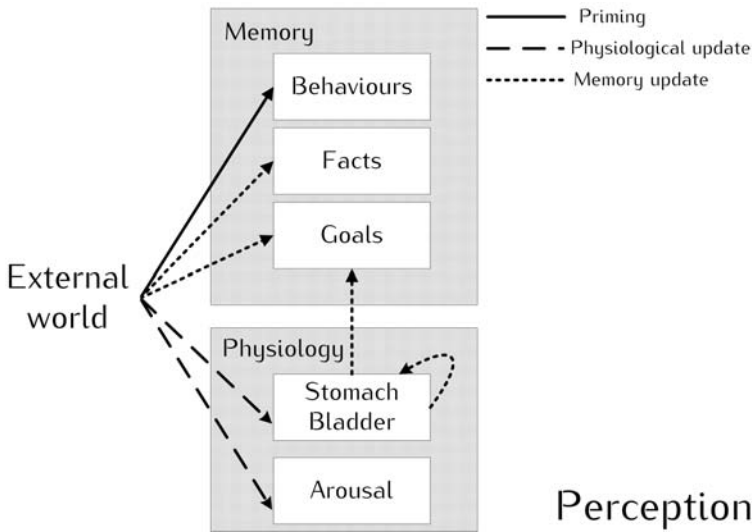


Figure 3.5: The three ways (priming, internal and external update) perception influences the internal world (physiology and cognition).

dynamical hierarchy). As activation is influenced by behaviours via perception, ordering the behaviour rules is dynamic and situated. In the behaviour selection process, time and comparison are two important notions. Time is related to the arousal level, a physiological state. Time functions as a restriction in addressing each single behaviour option and in comparing options to choose the most optimal. Comparing behaviours concerns a combination of the order of comparison, goal dominance and the knowledge of the behaviour under comparison (i.e. the expectations in the behaviour fact). The behaviour selection process is visualised in figure 3.6.

Time functions as an important restriction in the behaviour selection process. The amount of time available allows to compare behaviour and to select the most suitable behaviour for that particular moment. However, in a natural, dynamic environment, an individual will not have unlimited time to choose the best possible behaviour. He will have to find an optimal behaviour within the time available, especially in a crowd context where interactions between individuals occur at a high rate. Physiological influences, such as arousal, appear to influence this selection mechanism by increasing the ‘time-pressure’ as arousal gets higher. In the CROSS model, arousal is directly linked to the internal time an agent has to choose a behaviour. When arousal increases, time is restricted and vice versa. An increase in arousal results in less comparisons and thus in a higher probability for the behaviour with the highest activation level to be chosen, regardless whether this behaviour is optimal, suboptimal or even the worst choice. In this sense, an agent that has endless amounts of time will behave like a classical rational agent¹⁸. By describing behaviour selection

¹⁸A rational agent has complete knowledge. It addresses all options it has in order to select the most optimal, e.g. cost-efficient behaviour. Generally, the limitations of an individual as an information processing system is not taken into account. However, individuals do not have complete knowledge and do not have infinite amounts of time to search for the most optimal solution (Simon, 1996).

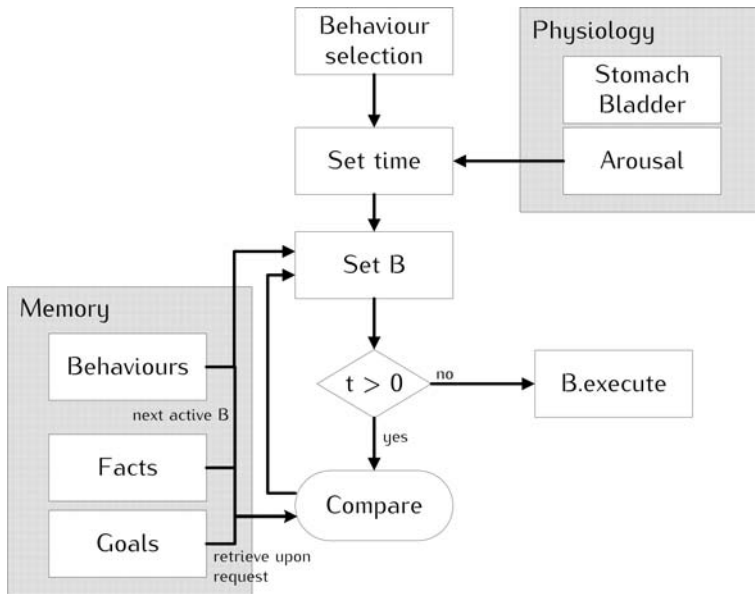


Figure 3.6: The behaviour selection process that compares the potential behaviour options within a restricted amount of time.

in this way, a more detailed description can be given of several notions in psychology, such as norm saliency, automatic versus deliberate processing, or the cognitive styles of repetition, imitation, deliberation or social comparison (Jager, 2000). The effect of arousal can be described as causing automatic processing at cost of deliberate, reasoned processing. It is considered to be automatic, as the increase in ‘time-pressure’ affects the selection of one of the most activated behaviours. Lower time-pressure can be related to reasoned processing enabling the comparison of multiple behaviours. Another relationship can be identified concerning the direction of the more abstract cognitive style description of repetition, imitation, deliberation and social comparison (Jager, 2000). Repetition and imitation are related to high time pressure with respectively a dominant identity goal and social goal. These two cognitive styles also match the expectation that a focus on oneself makes it more likely that behaviour will be repeated, as the last behaviour exhibited will still be highly activated. A focus on the social environment will convey a highly activated group norm, resulting in a higher probability to imitate. This thought is also consistent with the thought on norms that was expressed earlier, stating that norms, when salient, are strong determinants of behaviour. In short, arousal affects the time an individual has for the decision-making process, for comparing and selecting suitable behaviour.

Comparison: within the time available, a behaviour will be selected based on the behavioural options, goal dominance and behaviour expectation. The behavioural options are the behaviour rules residing in memory. As mentioned before, the behaviour rules in memory are ordered in accordance with their activation level. This activation level changes due to perception. The behaviour that is most active will be the first one to be used for the comparison, then the second, etc. The comparison of two be-

haviours involves the extent to which each behaviour is expected to satisfy the goals. The expectation of a particular behaviour (behaviour fact) together with the dominance of the goals, allows for a preference of a particular behaviour over the other. For example, when the social goal is dominant, walking towards other people is more 'optimal' than walking away from people. In a situation where safety is dominant, the optimality would shift to walking away. The role of situatedness and dynamics are fully incorporated here.

In short, to be able to choose a certain action or to sense the internal and external world, the functional part of an individual will perceive, interpret and be motivated to act according to a certain internal/external situation. To be able to do so, reference was made explicitly to several basic components that allow an individual to exhibit behaviour: physiology and memory as well as the processes of perception and behaviour selection. Perception and behaviour selection are the link with the outside world, affecting and using the internal state. Physiology gives rise to perceptual restraints and to a bodily state that affects perception and behaviour selection. Memory allows an individual to store knowledge about behaviour giving rise to a certain mental state.

3.4 Translating context into the cognitive level

To describe the behaviour of an individual in a crowd, all the ingredients have now been selected, both the relevant external influence factors and the internal world factors. In this section context will be included in the CROSS model by translating the environmental influence factors into the cognitive level that affects individual behaviour in a crowd context. Here, *translation* means specification at the functional level. On the one hand, the way an influence factor is represented will be described and, on the one hand, the influence path will be explained. The factors from the physical as well as the social environment will be discussed below.

3.4.1 Physical environment and the cognitive level

For an individual to live in a physical world, he must be able to be affected by the world he is situated in. In other words, there must be an internal representation of environmental factors, such as physical objects. In the festival context, scenario-specific physical objects, such as a stage, bar, toilet, walls, certain areas and other people, are part of the environment that need to be known. These objects are represented as facts in memory of an individual, ensuring that an individual is able to recognise a bar when he sees one. In addition to being able to identify the objects that surround him, the individual is also affected by them. Physiology is affected by the intake of food which fills the stomach, by going to the toilet which empties the bladder, and the perception of density which is related to the arousal level. Memory is updated in terms of goal satisfaction: standing close to the stage affects the identity goal, whereas density is related to satisfying the safety goal.



Density

In this thesis, *density* was identified as a relevant physical influence factor. Only density that is perceived locally can affect an individual (see section 3.2). On the basis of research that relates density and behaviour, it was deemed necessary to incorporate both a physiological and a psychological influence (see section 3.1.1). Density affects behaviour through the internal state of an individual. In the studies on density, three types of influence relationships can be distinguished: 1) density affecting physiology; 2) density affecting psychology; and 3) the indirect effect of physiology and psychology on each other. To explain the role of density, a description of all three relationships is needed. The third relationship concerns an interplay that requires an understanding of the role of the effects on both physiology and psychology. For the sake of simplicity, this study will be limited to the incorporation of the first two relationships.

In the first relationship, arousal¹⁹ is assumed to be affected by density. The link between external stimuli and arousal has been coined *the mere exposure effect* (Zajonc, 1980; Cottrell, 1972; Sanders, Baron, & Moore, 1978). The mere presence of other human beings causes an increase in arousal level. The mere exposure effect has been used to explain phenomena of social facilitation and inhibition by means of the stimulating or diminishing effect on performing tasks while others are present. Although this simple relationship between external stimuli and arousal does not fully cover the phenomenon at hand, the importance of social conditions (i.e. psychology) has become very clear. Arousal is not only affected by physical presence, but also by the interpretation of this presence itself (Brown, 2000; Baron & Kerr, 2003; Hewstone & Stroebe, 2001). This concerns the third relationship type: the combination of the roles of physiology and psychology. This insight supports the view that both a physiological as well as a psychological effect should be incorporated.

The second relationship concerns the psychological relationship of density, which is related to a feeling of safety. It is simply assumed that a local rise of is related to an increased feeling unsafety²⁰. This is motivated by the biological drive human beings have to remain safe. An individual is continuously alert for potential danger and has the corresponding bodily organisation for split-second action. This mechanism is organised by our autonomic nerve system, in particular by the dominance of the sympathetic nerve system that prepares an individual to deal with danger (Kalat, 2001), e.g. the 'fight/flight' mechanism (Baron & Richardson, 1994). Whether a person feels safe or unsafe due to the perception of density depends on personal attributes as well as on context. Personal differences in the way density is interpreted are quite common²¹. For example, a difference has been found between men and women. Men appear to be affected more by the restrictions of their personal space, which is related

¹⁹Arousal is the attentional state of an individual, a state of alertness that is low when a person is sleepy, normal while being awake under normal conditions and high in stressful or exiting situations. The latter is related to the physiological measure of the heart rate and blood pressure of a person (Kalat, 2001).

²⁰There are also situations where the opposite effect can occur i.e. being part of a group can result in a increased feeling of safety, for instance, when being confronted by a rivalry group. The CROSS model can be easily refined or adapted (with theories being replaced) while the basic framework of a situated individual still reflects the core idea of human information processing system.

²¹One could add that the same person probably will show differences too from one moment to another. Within the context of this research that would go too far.

to their territorial claims (Leibman, 1970; Patterson, Mullens, & Romano, 1971). It is important to take these differences into account while theorising. However, context must not be underestimated. A person might find a high density nice or safe during a festival, but uncomfortable or unsafe when standing on a train going home from work.

Both the role of arousal and safety perception convey the effect of density on the internal state of an individual, and thus on behaviour. However, the descriptions above concern the intentional level and must be translated to the functional and physical concepts of the CROSS model. Figure 3.7 visualises the internal representation and effect of density via the two routes: via the physiology update by affecting arousal, and via the memory update of the safety goal. This figure shows the role of density by moving from the group level to the cognitive level and back in six stages. At the group level, density may increase, but only a locally perceived increase of density will affect an individual (1). The perception of density directly affects arousal (2), i.e. when density rises, arousal will rise as well. The other effect of perception is established via a memory update of the satisfaction level of the safety goal (3). In this formulation, an increase in density will decrease the satisfaction of the safety goal. Given the preference level of a particular individual, dominance of the safety goal is derived. This dominance will affect the relevance of a certain behaviour that is used to compare the behaviours with each other. This simply means that some behaviours are more relevant in the situation in question (4). However, as a consequence of the rise of local density, the internal time to choose a behaviour will decrease. Because of this, the individual might not be able to address all behaviour options (5). Therefore, when density increases, the behaviours with the highest activation level are most likely to be chosen. After behaviour is chosen and exhibited by a number of individuals, behaviour patterns can be observed at the group level (6).

Density also has a side effect on the probability of a behaviour to be selected that is related to the concept of saliency²². Increased density simply indicates an increase of the amount of people that surround an individual in a crowd. More people in the surrounding of an individual leads to an increase in the amount of behaviours that are observed and thus primed, i.e. activated. A higher activation level increases the probability of exhibiting the same behaviours as one's local surroundings does, which in its turn increases the likelihood of that behaviour to be chosen.

3.4.2 Social environment and the cognitive level

For an individual to live in a social world, he must be able to distinguish between people in terms of different relationships. Being with friends or with strangers affects an individual in a different way. To be able to distinguish between people, these persons are internally represented as person facts in the individual's memory. In this thesis, the focus lies on the presence of friends and leaders representing the social environment. Like density, the influence of a friend or a leader can be translated into the cognitive level representing the effect at a functional level via memory updates

²²Recall that saliency implies that whatever is dominant in someone's cognitive system will affect behaviour. For instance, you feel that taking care of the environment is important and you are walking in a street with a lot of garbage on the ground. If your environmental attitude is not 'activated' (salient) at that moment in time, the probability of you throwing your garbage on the ground will be greater (Cialdini, Reno, & Kallgren, 1990).

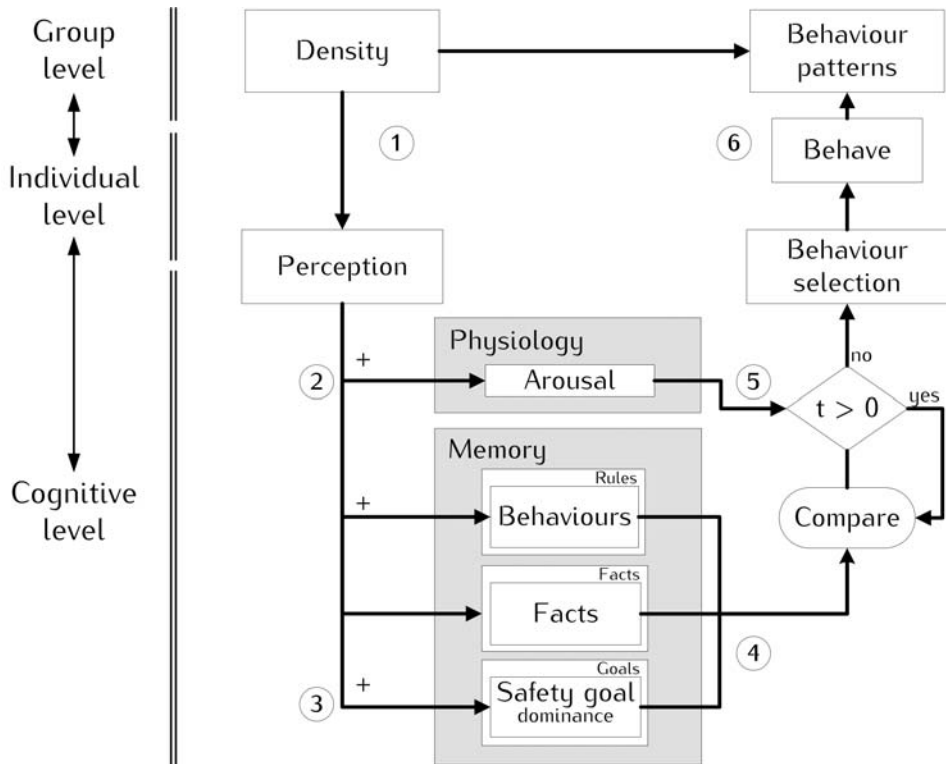


Figure 3.7: The role of density in crowd behaviour patterns at the cognitive level is described through physiology and memory update. A perception of a high density level increases the arousal level, which diminishes the time an agent has to choose his behaviour. Increased density together with a low or high safety perception together makes the safety goal more or less dominant at different density levels depending on the relevance of the different behavioural options.

(perception). When an individual perceives his local environment and identifies other people, his social goal will be satisfied, especially if one or more of these people is considered to a friend or a leader. Satisfying the social goal by the presence of others is related to an individual's drive to belong to a group. Although the direct hazard of being alone is not prone, the mechanism still works, humans are group animals. The role of friends can be described in a very simple manner, it just represents the people an individual prefers to be close to when attending a festival. This is based on the fact that people attend these kinds of events together with other people in small groups of 2, 3 or 4 people (Aveni, 1977). The role of leadership is more sophisticated. A person's influence is mediated through the perception of the person who sees either the other or himself as a leader. Considering a person as a leader affects whether certain behaviour is valued as 'suitable' in a given situation, which implies that the behaviour facts (expectations) are updated.

Leadership

As indicated before, in this thesis, leadership will be dealt with as a social environment factor. Within crowds leadership represents a social influence. This is not only because leadership can often be observed in crowds, but also because it magnifies the heterogeneity of the perceived social influence in a crowd (i.e. power relationships). In the literature, the following relevant effects of the presence of a leader can be distinguished: the tendency of followers to imitate leaders, and the coordinating effect of leaders by 'giving orders'. In this thesis crowd behaviour is described from the individual perspective. With regard to the perception of a leader, a distinction can be made between perceiving oneself as a leader or perceiving someone else as a leader. Perceiving oneself as a leader can influence behaviour in terms of manipulating or coordinating others in order to reach a common or individual goal. The tendency to manipulate or coordinate others is driven by maintaining or increasing personal power or status (*power distance theory*, (Mulder, 1977)). The 'obedient' behaviour of 'followers' serves as feedback, confirming the self-perception of a leader. Unlike the usual approach where the focus lies on the leader himself²³, in this thesis the focus is placed on the 'followers' perspective, i.e. perceiving someone as a leader. The reason for this nonstandard viewpoint is that this thesis aims to increase a general understanding of crowd behaviour. Therefore, a focus on the influences on people in general is more obvious in this thesis, than a focus on a few individuals that consider themselves leaders. In accordance with this focus, the CROSS model limits itself by incorporating only the effect of perceiving another person as a leader, leaving the perception of oneself as a leader out for now. Please note that this is not a distinction between different types of individuals, but between different types of relationships, which implies that the perception changes from one person to the other.

In this thesis, perceiving someone as a leader makes the behaviour this leader shows more suitable. Some behaviour becomes more suitable as a consequence of the behaviour a leader exhibits or of suggestions provided by a leader. This influence is based on the tendency of human beings to obey someone who is perceived as an authority (Milgram, 1974; Hofling, Brozman, Dalrymple, Graves, & Pierce, 1966). The way an individual is being influenced can be seen as both feedback that an individual receives on his own behaviour in terms of rewarding or punishment as well as following the directions indicated by this leader. In order to describe the effects of perceiving someone as a leader in the CROSS model, these effects must be translated into the functional level. Figure 3.9 shows the paths of leadership influence, moving from the group level to the individual level and vice versa in five steps. If a leader is perceived as such by an individual, this leader will be standing in the individual's range of sight (locally). Only then a leader can have an effect (1). The behaviour that a leader exhibits can be considered a form of feedback, stating that the behaviour is suitable in the social context in question. This is translated by changing an individual's expectation for this particular behaviour in satisfying the social goal, which is an update of a behaviour fact (2). The social goal dominance, together with making certain behaviour more suitable for a particular social setting, makes it more likely that the behaviour is selected and thus shown (3). Generally, after behaviour has been

²³For instance, leadership has often been described on the basis of personal traits, skills, or the context in which a person becomes a leader.

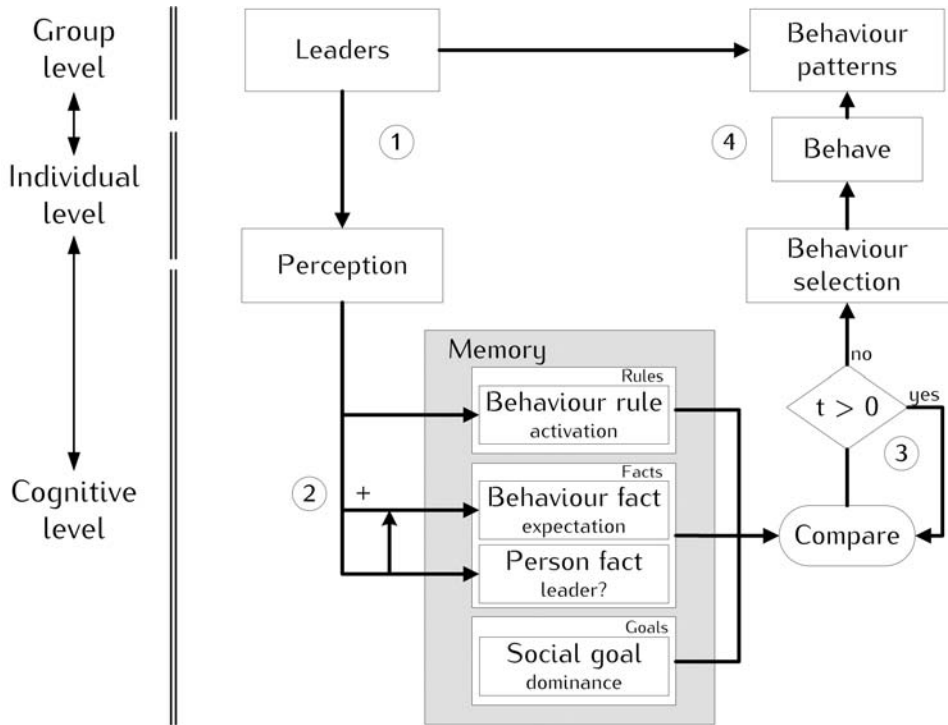


Figure 3.8: The role of leadership in crowd behaviour is described at the cognitive level via the perception (memory update) of another person as a leader. Perceiving someone as a leader increases the social goal satisfaction level as well as the expectation of the behaviour that a leader exhibits. In this way, when ‘social behaviour’ is more likely, this especially makes the behaviour performed by the leader more ‘suitable’.

chosen, group level patterns that incorporate the role of leadership can be observed (4).

3.5 Conclusion

In this chapter the theoretical model CROSS was described. This model incorporates the multiple levels where crowd behaviour emerges (group level) and is affected (individual and cognitive level). To understand crowd behaviour patterns, it is crucial to describe and explain potentially relevant factors at the level where the actual influencing takes place. In this thesis, the influences will be specified at the cognitive level, as it is important to know *why* and *how* behaviour is chosen in order to understand this behaviour and, consequently, the behaviour patterns that emerge in crowds. It is important to take both the environment and the characteristics of an individual into account in describing and explaining behaviour. The roles of the environment and the individual have no predefined order of importance. It depends on the situation

whether an internal or external factor will dominates behaviour. Context refers to the relevant physical and social factors of the environment. This thesis focuses specifically on the roles of density and leadership. The characteristics of an individual are described in terms of a situated individual who is represented as a cognitive structure with physiological and mental characteristics. A situated individual stands for an individual that is both embodied and embedded. The context and the intra-individual structure will be merged into a description of a crowd in a festival context, based on its dynamics, social situation and the individual.