Towards Aggression De-escalation Training with Virtual Agents: A Computational Model

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Abstract. Serious gaming based on Virtual Reality is a promising means for training of aggression de-escalation skills. By enabling trainees to interact with aggressive virtual characters that respond in a realistic manner to different communicative approaches, they can learn to apply the appropriate approach at the right time. To facilitate the development of such a training system, this paper presents a computational model of interpersonal aggression. The model consists of two sub-models, namely an 'aggressor model' and a 'de-escalator model'. In the long term, the former can be used to generate the behaviour of the virtual characters, whereas the latter can be used to analyse the behaviour of the trainee. The functioning of the model is illustrated by a number of simulation runs for characteristic circumstances.

Keywords: virtual training, aggression de-escalation, cognitive modelling.

1 Introduction

Aggressive behaviour against employees in the public sector, such as police officers, tram conductors, and ambulance personnel, is an ongoing concern worldwide. According to a recent study in the Netherlands, around 60% of the employees in the public sector have been confronted with such behaviour in the last 12 months [1]. Being confronted with (verbal) aggression has been closely associated with psychological distress, which in turn has a negative impact on work performance [12]. Responses to aggression range from emotions like anger and humiliation through intent to leave the profession, and verbal aggression by customers may even impair employees' recognition and working memory [17]. In case of severe incidents, employees may even develop symptoms indicating post-traumatic stress syndrome [5].

To deal with aggression, a variety of techniques are available that may prevent escalation [2, 16]. These include (verbal and non-verbal) communication skills, conflict resolution strategies, and emotion regulation techniques. The current paper is part of a project that aims to develop a serious game [18] for aggression de-escalation training, based on Virtual Reality. VR-based training has proven to be a cost-effective alternative for real world training in a variety of domains, including military missions [11], surgery [8] and negotiation [13].

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In the training environment envisioned in the current project, a trainee will be placed in a virtual scenario in which aggression plays a role (e.g., dealing with a domestic violence case), with the goal of handling it as adequately as possible. The emphasis is on dyadic (i.e., one-on-one) interactions. The trainee can observe the events that happen in the scenario (e.g., a virtual character starts offending her), and has to respond to this by selecting the most appropriate action from a multiple choice menu. During the task, she is 'monitored' by a software system that observes her behaviour, analyses this, and provides personalised support [9].

To realise an effective training system, it is crucial to understand the dynamics of the processes related to interpersonal aggression. More specifically, when focussing on dyadic interactions, knowledge is required about how aggression builds up in person A (the aggressor), and what person B (the de-escalator) can do to make it go down again. In the current paper, such knowledge is formalised in terms of a dynamic computational model of interpersonal aggression. Basically, this model consists of two separate sub-models, one for the aggressor and one for the de-escalator.

The remainder of this paper is structured as follows. In Section 2, a brief overview is provided on the literature on aggression and de-escalation of aggression. Based on this literature, the computational model of interpersonal aggression is presented in Section 3. Next, Section 4 describes a number of illustrative simulation runs that were produced on the basis of the model, and Section 5 is a conclusion.

2 Aggression and Aggression De-escalation

In this section, first an overview is presented on the relevant literature on aggression. This is followed by a description of a generic protocol for aggression de-escalation, and a more detailed description of some de-escalation approaches.

2.1 Aggression

According to a report by the Dutch Ministry of the Interior and Kingdom Relations, one of the main aspects to take into account when dealing with aggression is its *nature* (see [16], p.13). The psychological literature distinguishes two important theories regarding the nature of aggression. First, the *frustration-aggression hypothesis* [4] tells us that aggression flows forth from a person's goals being frustrated. Such a person is likely to be angry with respect to whatever stopped him from achieving his goal. By the carry-over effect, the anger can be transferred to new situations as well [3]. The second important theory is the *social learning theory* which states that aggressive behaviour is learned through positive reinforcement. The essence of this theory is that if a person has used aggression to achieve a goal in the past, and if this behaviour was successful, then by operant conditioning (s)he will be likely to follow the same behavioural pattern in the future.

Under the frustration-aggression hypothesis, aggression is of a *reactive* nature, meaning that it is an angry reaction to a negative event that frustrates a person's desires. In the social learning theory, aggression can be considered to be of a

proactive nature, since the aggression is not a response to a negative event, but is used instrumentally to achieve a goal. One of the primary means of differentiating between reactive and proactive aggression seems to be the respective presence or absence of anger [15]. Based on observations in animals, it has been proposed that reactive aggression is *hot-blooded*, and that proactive aggression is *cold-blooded*. In the former a lot of physiological arousal is visible, whereas this is not the case in the latter [7]. Although this physiological distinction seems strongly rooted in our culture, for example when we talk about a violent act being committed 'in cold blood' versus 'in the heat of passion', direct evidence for it in humans remains relatively sparse. As an example, in an empirical study on children from 6-11 years old, reactive aggression was found to correlate with both skin conductance reactivity and non-verbal signs of anger [10].

Anderson [2] interprets the anger in the frustration-aggression hypothesis as suggested by Lazarus [14], namely as an appraisal of injury to self-esteem that accompanies a loss of control over the situation. Verbal aggression then, is an attempt to regain control over the situation, and restore self-esteem. Aggressive behaviour thus serves the function of relieving the tension caused by the injury to the aggressor's self-esteem. According to this theory, escalation of aggressive behaviour into physical violence is caused by a continuous build-up of tension until a person loses all self-control. This process can be described as a cycle of escalating aggression; see Figure 1, taken from [2]. This paper provides us with a list of behavioural cues and warning signs that can typically be observed during the build-up of aggression, such as 'loud speech', 'tense posture', 'flushed face', and so on. Although these cues and signs will be subject to interpersonal differences, in general we should be able to assume that the more apparent they become in a person, the higher the tension. From here on out, we will also assume that the non-verbal behavioural cues we just mentioned are an expression of physiological arousal caused by anger, which in turn provides us with a way of distinguishing between reactive and proactive aggression.

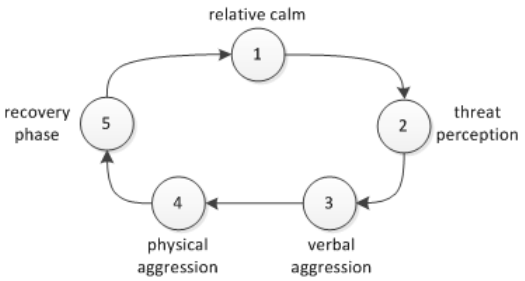

Fig. 1. Five phases in the cycle of aggression (taken and formatted from [2])

2.2 Aggression De-escalation

It is common for employees who are likely to be subjected to aggression to receive some form of training on how to manage these situations. Such training involves the

use of protocols that describe the decision making process for de-escalation. One such protocol is the 'exemplar protocol for aggression management' (Figure 2), used for training of people employed in the Dutch public services [16].

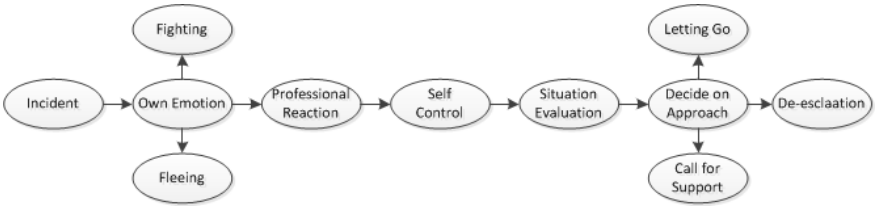

Fig. 2. Exemplar protocol for aggression management (translated and formatted from [16])

The model starts with an incident of aggression occurring. Such an incident invokes a certain amount of stress in an employee, i.e. an *emotional state*, following the naturally occurring fight-or-flight response. This response prepares the person to either flee or fight, both of which can be considered undesirable when dealing with mere aggression. Instead, what is required from employees is a professional reaction; they should recognize their own stress response and regulate it, for example by means of breathing techniques or controlling their thoughts. In the ensuing state of self-control, employees should be able to evaluate the situation on its relevant properties, most importantly on the *nature* of the aggression (reactive or proactive)[1] and the aggressor's level of *tension*. Both have been explained in the previous section.

Having evaluated the situation, there are three principal decisions employees can make. First, when it is not too severe, employees can choose to simply ignore it and let it slide. Second, if de-escalation is considered to be promising, it should be pursued. Third, if de-escalation seems impossible, employees should call for support from colleagues or the police. In case of letting things slide or calling for support, the interaction between employee and aggressor ends. In the next section, this decision making process is elaborated on in more detail.

2.3 Aggression De-escalation Approaches

In a model for aggression de-escalation used by the Dutch police [20], four approaches are distinguished, which depend on an evaluation of the state of the aggressor (see also [16]). First, in case a person is in danger of losing control, *supportive* behaviour from the officer is required, for example by ignoring the conflict-seeking behaviour, making contact with the aggressor and actively listening to what he has to say (see [2] for two lists of verbal and non-verbal *do's and don'ts*). Second, in case the person is actually losing control, a more *directive* approach is called for. In this case employees are to show the aggressor that there is a limit to how far he can pursue his behaviour, and point out its consequences. Third, in case the

[1] Discussions with domain experts in public transport confirmed that the ability to distinguish between reactive and proactive aggression is a key element in their training program.

aggressor is actually losing control to the extent that he becomes violent, employees have to *guarantee their own safety*, judging for themselves whether to abandon the conversation, leave, or call for support. And fourth, in case the aggressor starts to *relax*, it becomes possible for employees to do the same thing. They should now attempt to regain contact with the aggressor and re-evaluate the situation. When we relate these four approaches to the cycle of aggression (Figure 1), they seem to match with phase two to five of the cycle. However, it is important to realise that the influence of the de-escalator is not depicted in Figure 1. In other words, the figure shows the 'natural' development of aggression in case no intervention takes place; if instead the de-escalator uses one of the approaches mentioned above, other transitions are possible than the ones shown in Figure 1, (e.g., back from phase three to two). The four approaches mentioned above are of particular interest when dealing with reactive aggression. In [10] it is suggested that interventions aimed at reactive aggression should focus on hostile attribution biases. People with such a bias are more likely to perceive others as threatening. Hence, in such a case the supportive approach, in which the employee makes an attempt to understand the aggressor, may be beneficial. Instead, interventions aimed at proactive aggression should focus on an alteration of the contingencies associated with the aggression (e.g., by making the aggressor aware of what will happen if he continues to behave aggressively). This can be considered as an instance of the directive approach to phase three. Hence, when dealing with proactive aggression, it might be better to skip the supportive approach altogether and directly move to the directive approach. This distinction between the approaches recommended in case of reactive versus proactive aggression is an important feature of the model presented in the next section.

3 Computational Model

This section provides a description of the computational model of interpersonal aggression. First, in Section 3.1, a global overview is presented of the model and the modelling approach that was used. Next, Section 3.2 and 3.3 briefly describe the models of the aggressor and the de-escalator, respectively. Because of space limitations, the main part of this description is given on an abstract level. A complete description of the model is provided in [19].

3.1 Global Overview

The following model is meant to simulate the interaction between an aggressive person (the aggressor) and a person that attempts to calm the aggressive person down by means of de-escalation (the de-escalator). Both are modelled as individual agents that together form a multi-agent system (see Figure 3).

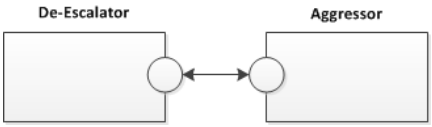

Fig. 3. Global overview of the interaction between de-escalator and aggressor

As for the communication between the two agents, we will distinguish between non-verbal and verbal communication and behaviour, globally corresponding to the verbal and non-verbal cues, and to the various approaches that can be taken towards aggression that we identified in Section 2. This behaviour is performed and observed by both agents. We will consider verbal behaviour to be what a person is saying and how this is being said, and non-verbal behaviour to be all other observable cues, such as pacing around or making erratic gestures.

To formalise the model, the LEADSTO language is used as a basis [6]. This language is based on the assumption that dynamics can be described as an evolution of states over time. The notion of state as used here is characterised on the basis of an ontology defining a set of physical and/or mental *state properties* that do or do not hold at a certain point in time. To formalise state properties, an *ontology* is specified in a (many-sorted) first order logical format as a finite set of sorts, constants within these sorts, and relations and functions over these sorts. State properties are formalised by n-ary predicates over an ontology, such as performs(aggressor, action(physical_violence)) or has_value(emotional_state, 0.8)). Next, dynamic relations can be expressed with the 'leads to' operator $\rightarrow\!\!\!\!\rightarrow$. More specifically, the expression A $\rightarrow\!\!\!\!\rightarrow$ B indicates that if state property A holds at time point t, then state property B will hold at time point $t+\Delta t$.

In the model presented below, most state properties refer to a concept that has a numerical value (e.g., the emotional state mentioned above). In such cases, the respective influence of state property A on state property B is represented as follows:

$$B(t+\Delta t) = B(t) + \eta_B(A(t)*\omega_{AB} - B(t))$$

Here, ω_{AB} is a connection strength indicating how much the activation of state A influences the activation of state B, and η_B is an update speed parameter used to give the updating of state B a gradual nature.

Similarly, it is also possible to have multiple state properties influence one state property. For example, the influence of states A1 and A2 on state B is denoted by:

$$B(t+\Delta t) = B(t) + \eta_B(A1(t)*\omega_{A1B} + A2(t)*\omega_{A2B} - B(t))$$

3.2 The Aggressor

A graphical representation of the aggressor model is provided in Figure 4. In this figure, state properties are depicted by circles and dynamic properties by arrows. The circles on the left denote observations of the agent, the circles on the right (communicative) actions, and the remaining circles internal states. Most of these states are formally represented as a real number between 0 and 1.

As can be seen from the figure, a central role in the aggressor's behaviour is played by the two internal states. The *emotional state* is a concept introduced to simulate the level of tension experienced by the reactive aggressor via a real number (where 0 represents no tension and 1 maximal tension). This state is assumed to reflect the phase of the cycle of aggression in which the aggressor resides. In a similar fashion, the *belief about benefit* is a concept introduced to simulate the proactive aggressor's tendency to show aggressive behaviour. However, since proactive aggression is referred to as more 'cold-blooded' (see Section 2.1) than reactive aggression, we here use the more neutral term 'belief'. Basically, this concept can be thought of as the agent's expectation about the benefit of pursuing aggressive behaviour, and its dynamics could be described by a 'cycle of believed benefit'[2]. To highlight the fact that the emotional state mainly plays a role in the reactive aggressor and the belief about benefit in the proactive aggressor, different colours are used in Figure 4: the red arrows are only used for the reactive, and the blue arrows for the proactive aggressor (and the black ones for both).

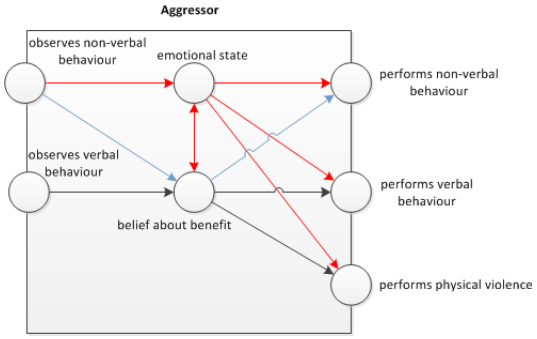

Fig. 4. Overview of the aggressor model

Regarding the dynamics of both internal states, for both of them holds that they are influenced by the observed (verbal and non-verbal) behaviour of the de-escalator. More specifically, the observed non-verbal behaviour (e.g., the extent to which the de-escalator has a flushed face, again represented in the domain [0,1]) has a direct (linear) impact on both states. Instead, the observed verbal behaviour is represented as a qualitative concept that has one of the following values: [letting_go, supportive, directive, call_for_support] (see the approaches discussed in Section 2.3). Depending on whether or not the observed approach matches the phase in which the aggressor resides (in the cycle of aggression or the cycle of believed benefit), the value of the relevant internal state will either increase or decrease.

[2] However, this cycle has only three phases, since the phase in which a supportive approach is effective (i.e., phase 2 of the cycle of aggression) does not exist. Hence, this phase is skipped for this cycle.

As an example, assume that a proactive aggressor who resides in phase 2 of the 'cycle of believed benefit' is confronted with a directive approach. Since this is the correct approach for this phase, the value of the believed benefit will decrease. This effect is represented by the following LEADSTO rule (where θ_{2a} and θ_{2b} are thresholds to define the lower and upper bound of phase 2, and η and ω play the role as explained in Section 3.1):

Example 1 - From observed directive approach to a decreased belief about benefit
has_nature(aggressor, proactive) &
observed(aggressor, has_value(verbal_behaviour, directive)) &
observed(aggressor, has_value(non_verbal_behaviour, NVB)) &
belief(aggressor, has_value(benefit, B)) &
B >= θ_{2a} & B < θ_{2b}
$\rightarrow\!\!\!\!\rightarrow$ belief(aggressor, has_value(benefit, B + η * (NVB * ω - B)))

Due to space restrictions, we will not provide the complete set of LEADSTO rules used for the model (see [19] for this purpose). However, a high-level overview of the knowledge used to determine the impact of the approach on the internal states of the reactive and proactive aggressor is shown, respectively, in Table 1 and 2. Note that phase 3 of the cycle of aggression (and also the corresponding phase 2 in the cycle of believed benefit) has been split into two sub-phases, to distinguish a phase in which the aggressor can still be reasoned with from a phase in which this becomes futile.

Table 1. Impact of de-escalator's approach on emotional state of reactive aggressor

observed approach	phase in cycle	impact on state
letting go	phase 1 up to 3a	remains constant
supportive	phase 1	remains constant
supportive	phase 2	decreases
supportive	phase 3a	increases
directive	phase 1 up to 2	increases
directive	phase 3a	decreases
call for support	phase 1 up to 3a	remains constant
any approach	phase 3b up to 4	increases

Table 2. Impact of de-escalator's approach on believed benefit of proactive aggressor

observed approach	phase in cycle	impact on state
any approach	phase 1	remains constant
letting go	phase 2a	remains constant
call for support	phase 2a	remains constant
supportive	phase 2a	increases
directive	phase 2a	decreases
any approach	phase 2b up to 3	increases

As shown in the right hand side of Figure 4, the intensities of the emotional state and the believed benefit determine on their turn the intensity of the (non-verbal and verbal) behaviour of the aggressor, as well as whether the aggressor erupts into physical violence. The details of these rules are not shown, but are relatively straightforward: the aggressiveness of both the non-verbal and verbal behaviour is represented by a real number in the [0,1] domain, of which the value is determined based on the relevant states (see Figure 4) by using the generic formula shown in Section 3.1. The (binary) decision whether or not to perform physical violence is implemented by checking whether the internal state exceeds a certain threshold.

3.3 The De-escalator

A graphical representation of the de-escalator model is provided in Figure 5. The input and output state of the de-escalator are similar to those of the aggressor, however the internal states are rather different. Roughly, the dynamics of the de-escalator's internal processes can be split into three sub-processes. First, as shown in the lower part of the figure, the emotional state of the de-escalator is updated based on the observed (verbal and non-verbal) behaviour of the aggressor, and has in turn an impact on her own non-verbal behaviour.

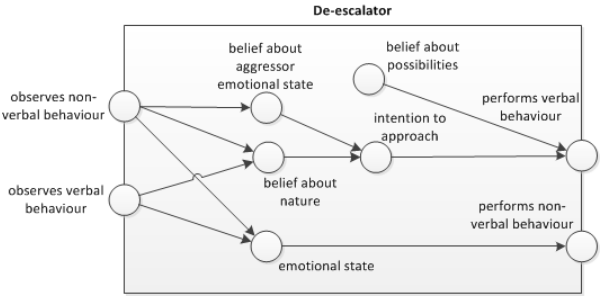

Fig. 5. Overview of the de-escalator model

Table 3. Knowledge used by the de-escalator to evaluate the nature of aggression

observed verbal behaviour	observed non-verbal behaviour	nature of aggression
non-aggressive	any intensity	non-aggressive
aggressive	low intensity	proactive
aggressive	high intensity	reactive

Next, as shown in the upper left part of Figure 5, there is a sub-process related to the evaluation of (both the nature and the intensity of) the aggressor's emotional state. This process corresponds to the 'situation evaluation' task shown in Figure 2. More specifically, evaluating the nature of the aggression boils down to deciding whether we are dealing with reactive or proactive aggression (or no aggression); this is done on the basis of the knowledge shown in Table 3. Evaluating the intensity of the aggression comes down to deciding in which phase of the cycle the aggressor resides.

Finally, as shown in the upper right part of Figure 5, the evaluation of the aggressor's emotional state serves as input for a decision about which approach to select. For this, the knowledge described informally in Section 2.3 is used, of which Table 4 gives a systematic overview. The 'belief about possibilities' serves as an extra condition that needs to be fulfilled before the de-escalator actually executes a selected approach. The possible values of this belief (and of the actual verbal behaviour that is performed) are again the following: [letting_go, supportive, directive, call_for_support].

4 Simulations

To study the behaviour of the model, a number of simulation runs under different parameter settings have been generated using the LEADSTO software [6]. These simulations have been chosen such that they cover the spectrum of possible scenarios that can be encountered. More specifically, they comprise scenarios in which successful de-escalation takes place and scenarios in which the situation escalates, both for reactive and proactive types of aggressors. The latter set of simulations includes cases of escalation that are caused due to different types of mistakes by the de-escalator, such as a failure to remain calm, to judge the nature or intensity of the aggression, and to correctly apply the protocol. The entire set of simulations is included in [19]. Because of the limited space, we restrict ourselves in this section to showing one illustrative simulation run. The scenario discussed here involves a case where the de-escalator is successful in calming down a reactive aggressor that resides in phase 3 of the cycle of aggression. Figure 6 shows the dynamics of the simulation run. Here, the horizontal axis represents time and the vertical axis represents the various state properties that are true during the scenario. The upper graph displays a state property with a numerical value (namely the aggressor's emotional state) and the lower graph shows a number of states of a qualitative nature.

Table 4. Knowledge used by the de-escalator to decide upon which approach to use

aggressor's nature	phase in cycle	selected approach
non-aggressive	any phase	letting go
reactive	phase 1	letting go
proactive	phase 1	letting go
reactive	phase 2	supportive
proactive	phase 2a	directive
reactive	phase 3a	directive
reactive	phase 3b or higher	call for support
proactive	phase 2b or higher	call for support

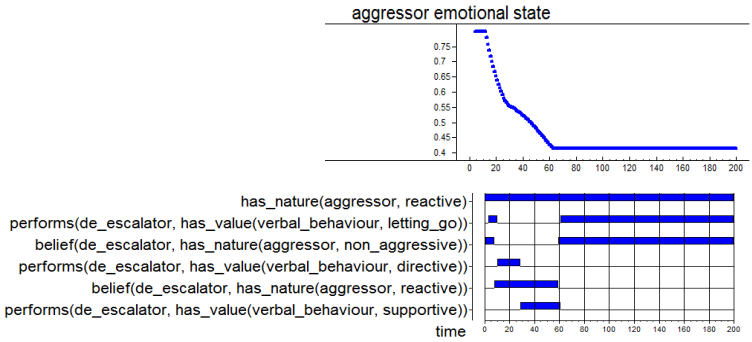

Fig. 6. Example simulation - scenario with successful aggression de-escalation

As shown in the graph, almost immediately the de-escalator (correctly) concludes that she is dealing with a reactive aggressor (time point 10). In addition, she judges the aggressor's level of tension as rather high, and as a result she decides to take a directive approach (time point 12-28). This causes the aggressor to calm down a bit, such that the de-escalator can now switch to a supportive approach (time point 28-60). Since this is again the 'correct' approach, the aggressor calms down even further, and eventually the situation is resolved. Although this is only one example, it clearly illustrates the dynamics of the interaction between the approach taken by the de-escalator and the nature and intensity of the other person's aggression.

5 Conclusion

Aggressive behaviour against public service workers is an ongoing concern worldwide. To improve professionals' de-escalation skills in encounters with aggressive individuals, Virtual Reality-based training is a promising means. By enabling trainees to interact with aggressive virtual characters that respond in a realistic manner to different communicative approaches, they can learn to apply the appropriate approach at the right time. In this paper, a computational model of interpersonal aggression was presented, which will be used as a first step in the development of a VR-based training system.

The model consists of two separate sub-models, namely an 'aggressor model' and a 'de-escalator model'. The aggressor model makes a distinction between reactive aggression (i.e., a response to a negative event that frustrates the person's goals) and proactive aggression (i.e., an instrumental type of aggression used to achieve a certain goal) [7, 15]. In addition, the dynamics of aggression are modelled as a cyclic process that passes through five consecutive phases [2]. The de-escalator model is based on a standard protocol used for training of employees in public services in the Netherlands [16]. This model prescribes appropriate reactions for a variety of circumstances, which can be related to the phases mentioned above. The functioning of the combined model was illustrated by a number of simulation runs for characteristic circumstances.

In follow-up research, a more extensive evaluation of the model is planned. While doing that, we will also explore the possibilities of the model to reproduce different emotion regulation strategies, as well as cognitive biases. Another interesting extension might be to include the role of context and environmental stimuli.

On the longer term, the results of this study are useful because the implemented models can be incorporated in the VR-based training system that is currently under development. In particular, the aggressor model will be used to control the behaviour of the 'aggressive virtual agents' that are displayed in the scenarios, whereas the de-escalator model will be used by the training system as a prescriptive model for adequate de-escalation. By comparing the behaviour of this de-escalator model with the actions performed by the trainee, the system will be able to make a detailed analysis of her performance, allowing it to provide personalised feedback in case of mistakes. Indeed, after further evaluation, both models will be integrated into our system, thus providing a more theoretical foundation to VR-based training of aggression de-escalation.

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