Modeling the influence of emotion on belief for virtual training simulations

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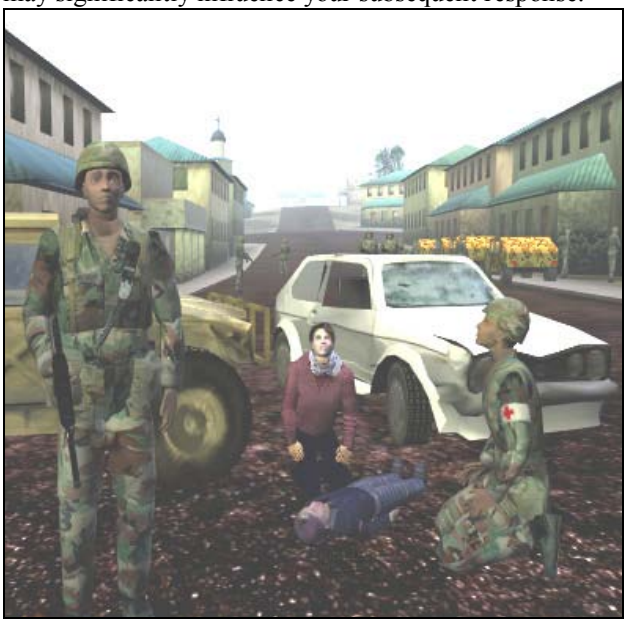
Keywords:
Emotion, Personality.

ABSTRACT: *Recognizing and managing emotion in oneself and in those under ones command is an important component of leadership training. Most computational models of emotion have focused on the problem of identifying emotional features of the physical environment and mapping that into motivations to act in the world. But emotions also influence how we perceive the world and how we communicate that perception to others. This paper outlines an initial computational foray into this more vexing problem.*

1. Introduction

Imagine yourself as a young lieutenant in the U.S. Army on your first peacekeeping mission. You must assist another group, designated as Eagle1-6, in inspecting a suspected weapons cache. You arrive at a rendezvous point, anxious to proceed with the mission, to see your platoon sergeant looking upset, smoke rising from one of your platoon's vehicles and a civilian car. A child lies on the ground, surrounded by a distraught woman (his mother?) and a combat lifesaver from your team. You ask what happened. Your sergeant pauses, casts an angry glance at the mother and responds, "they rammed into us sir. They just shot out from the side-street and our driver couldn't see them." How do you respond? Now consider a slight variation. You arrive at the same scene. "What happened here, sergeant?" Your sergeant pauses, lowers his head, avoiding eye contact. "We hit them, sir. They were coming from the side-street and our driver didn't notice them." Although describing the same event, these slight variations in word and gesture can lead to quite different situation assessment, will likely evoke different emotions, and may significantly influence your subsequent response.



Recognizing and managing emotion in oneself and in those under ones command is an important component

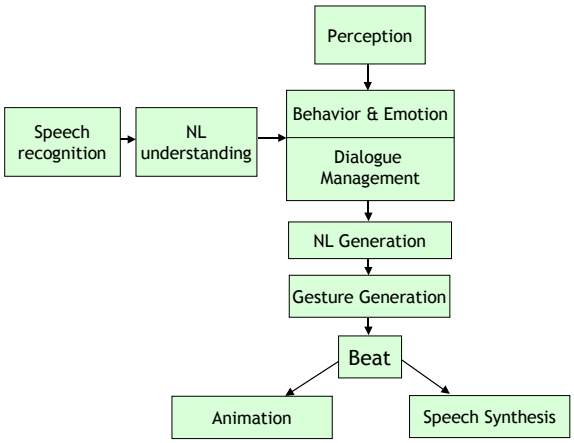
of leadership training. Most computational models of emotion have focused on the problem of identifying emotional features of the physical environment and mapping that into motivations to act in the world. But emotions also influence how we perceive the world and how communicate that perception to others. In the previous example, how do interpret the sergeant's anger? Did the civilian cause the accident (was this an attempt to impede our mission? Is this a possible trap?) or he simply trying to hide his own culpability? Role-playing has long been used to teach leadership skills in military and non-military settings. Research teams have begun to consider how role-playing methods could be automated (e.g., Gordon 2002, Marsella, Johnson & LaBore, 2000). Our focus is to support such automation by creating virtual humans to play a variety of social roles and engage in wide ranging interactions with a human trainee via natural language. The interactive and emotionally charged nature of such social simulations presents serious challenges for agent design. In addition to the standard problem of artificial intelligence, these virtual humans must generate plausible emotional responses to whatever circumstances the trainee is allowed to create.

This paper addresses a key function of emotional behavior that has been studied extensively in the psychological literature but has been largely ignored by computational approaches. Emotions act as powerful motivators, but computational models of this function have largely focused on the problem of selecting actions to perform in the world (e.g,. approach pleasant or retreat from threatening stimuli). In contrast, the psychological findings indicate that, in addition to action selection (which has been termed problem-focused, or task-orientated, coping), people employ other strategies for dealing with strong emotions, termed emotion-focused coping (Lazarus, 1991) and suppression (Parkes, 1984; Wells and Matthews, 1994). Rather than acting on the world, emotion-focused coping works mainly by acting on an individual's beliefs. For example an individual may alter beliefs about the importance of a goal that is being threatened. The angry behavior of the sergeant at the accident site could be seen as a form of emotion-focused coping: dealing with guilt by placing blame on some other agent. Suppression is an avoidance strategy that attempts to avoid thinking about or confronting an uncomfortable situation. A key aspect of leadership training is to learn to recognize these common coping strategies, both in oneself, but especially in team members under one's command.

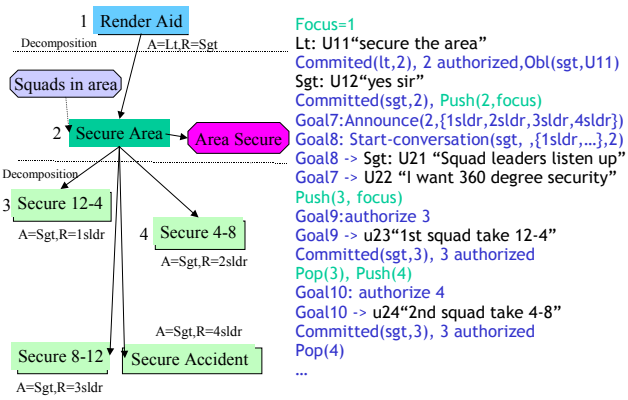
Our primary contribution is a preliminary model of emotion-focused coping, a functionality that is particularly important for modeling the type of stressful social scenarios that are typically used in military role-playing. We build on the work of Gratch and Marsella (2001) which presented a model of realistic human behavior in the context of the Mission Rehearsal Exercise system (MRE), a high-end virtual training environment designed to support dismounted infantry training between a human participant and elements of his command. The MRE combines immersive graphics, sound, and interactive characters controlled by artificial intelligence programs. We briefly discuss some recent extensions to this project and work through a detailed example of the use of emotion-focused coping in the context of this exercise.

2. Mission Rehearsal Exercise

The MRE is an experimental high-end simulation system designed to train leadership skills in high-stress face-to-face social situations. As part of this project, a team of researchers has developed an agent architecture that supports natural language with a realistic human character physically embodied in a virtual environment (Swartout et al, 2001). Recent progress in this project has centered on the natural language capabilities of the architecture. A trainee can speak to such agents using a limited subset of natural English. These utterances are parsed by a language understanding module. A dialogue manager maintains the state of the conversation and plans appropriate responses to orders and information requests (Traum & Rickel, 2001). A natural language generator derives the surface form of these responses that are then synthesized and coordinated with appropriate non-verbal gestures and facial expressions with the aid of the BEAT gesture scheduler (Cassell et al, 2001). The basic architecture is illustrated below:



The agent also has a domain model that describes actions that can be performed in the world, their preconditions and effects. Our previous work illustrated how this task model allows the agent to "appraise" the emotional significance of events in the environment (Gratch and Marsella, 2001). The natural language extensions are also closely integrated with the task model that allows us to infer the emotional significance of the various commands and information requests the trainee may utter. The subsequent figure illustrates some of the representations of the dialogue manager (on the right) and their relations to the task model (on the left):



In the MRE, the basic mission involves a human platoon leader that must interface with his platoon sergeant (modeled in the architecture described above), members of his platoon (modeled by scripted characters), and civilian characters (a mixture of agents and scripted characters). Although different characters in the virtual environment possess different domain knowledge, the sergeant character serves as the main interface to the student and has the most comprehensive model of the domain.

Emotional appraisal operates on plan knowledge, which is broken into three parts. The current world description contains a set of predicates that the agent can perceive or learn about through speech, marked with their current belief (true, false, unknown). The causal history contains all actions and events that were observed to have occurred or are currently occurring. The plan network contains intended actions that have not yet been initiated. As plans unfold, steps are moved into the causal history. Actions can have responsibility (the agent that performs the action) and authority (the agent who's permission must be obtained to perform the action). For example, securing an area is a task that is the responsibility of the sergeant but he must get the lieutenant's permission to do so. Securing the area decomposes into several more primitive actions that are the responsibility of squad leaders but the sergeant has the authority.

At startup, the causal history is initialized with knowledge that the squads of the platoon were moving to an assembly area to rendezvous with the lieutenant, the mother and the squads were driving into the same intersection and that a collision resulted. No one is obviously responsible for the collision event, but it has the effect that the driver has minor injuries and the mother's boy has critical injuries. The sergeant has several concerns, represented as states with associated utilities. The goal of supporting eagle1-6 has high utility. Injuries to other agents in the environment are assessed negative utility. The sergeant also has a model of the concerns of other agents, which can differ from his own (these are the sergeant's beliefs about the

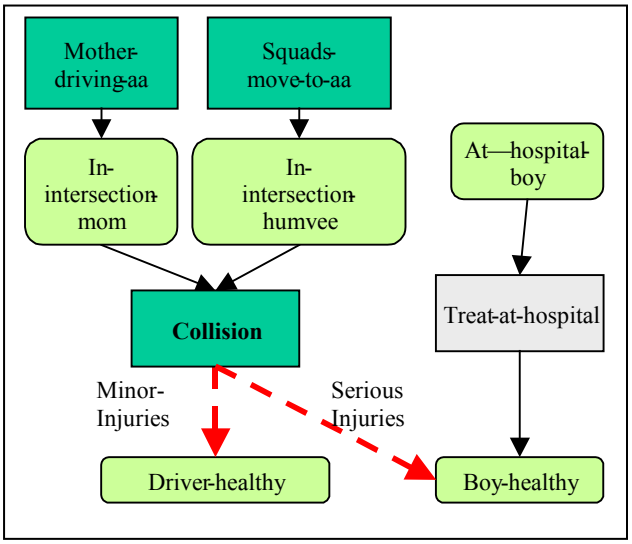


Figure 1: Portion of Plan Network/Causal History

concerns of other agents and do not necessarily reflect their true concerns).

Injuries with different severity must be treated by different means (on scene, by calling an ambulance, by calling a medical helicopter). Eagle1-6 can be supported in a number of ways as well. One can send all the squads forward, leaving the boy to his fate, one can fracture the outfit, sending two squads forward, or one can send one squad to recon forward to buy time till an ambulance or helicopter arrives. Actions have probabilities associated with them and these are updated as the plan is developed and executed. Figure 1 illustrates the portion of the plan network associated with helping the boy.

3. Detailed Example

Appraisal Frame: distress332

Emotion-type: Distress

Expected utility: -59.3

Intensity: 59.3

Type: facilitator

Annotation: progress-towards-undesired-state

Self: sergeant

Desire-self: undesirable

Status: confirmed

Object: health-status (child, critical-injuries)

Cause: collision (mom,driver)

Figure 2: Example Appraisal Frame

When the scenario begins, the accident has occurred and the sergeant has received the medic's evaluation that the child has critical injuries and the driver has minor injuries. The Émile model of emotional appraisal has examined the current state of plan memory and derived several instances of emotion that the sergeant should be feeling (Gratch, 2000). The two dominant emotions are distress over the critical injuries of the boy and distress over the minor injuries of the driver. These arise from the fact that some event occurred (the collision) that had effects with negative utility. The sergeant agent has not (as of yet) attributed any blame for the collision, so there are no feelings of guilt or anger arising from that event. He is also distressed that eagle1-6 is not currently supported.

The sergeant has two (contradictory) plans in memory – to help the child and to help eagle1-6, each of which is blocked pending authority of the lieutenant – and several emotions arise from these plans and their interactions. The sergeant has hope that the boy will be made healthy and that the eagle1-6 will be supported. The sergeant also has guilt arising from the fact that supporting eagle1-6 is a viable plan and its execution would require abandoning the boy. In addition to his own emotions, the sergeant infers that the lieutenant is distressed that eagle1-6 is not being supported and that the mother is extremely distressed about the child.

When the lieutenant arrives, the sergeant updates his belief about the lieutenant' s location. Any emotions associated with this belief are brought into focus (in a sense to be discussed below). In this case there is only a small amount of joy associated with the lieutenant's arrival (as his presence is a sub-goal of achieving some of the sergeant's concerns). This triggers a change in facial expression code but the emotion is of insufficient intensity to require any coping.

When the lieutenant asks, "what happened here," this is recognized as an information request about events in the causal history that occurred at the present location. This unifies with three events, the squads driving to the assembly area, the mother driving from the side street, and the collision. All emotions associated with these events are brought into focus: the sergeant's distress about the child and the driver, the lieutenant's distress over eagle1-6, and the mother's distress over the child. Each of these emotions is detailed in an appraisal frame. Figure 2 shows the most intense appraisal frame, the distress over the child's health. In this case, the emotions are sufficiently strong to induce coping. A data structure is also created to collect information about potential coping strategies and secondary appraisals are triggered. These domain independent rules note several social factors related to the events in focus: that the person asking the question is the sergeant's superior and that the agent driving the vehicle involved in the collision was under the sergeant's command. They also identify that the mother and the sergeant are potentially responsible for the accident, in that no one has yet been assigned responsibility and they (or their subordinates) were responsible for events that led up to the collision (the mother and driver are the responsible agents for actions who's effects are preconditions of the collision task).

Three coping strategies are proposed to deal with the intense emotions brought into focus: make amends, accept responsibility, and shift responsibility. Make-amends is a form of problem-focused coping and is proposed if there is an action that could "undo" some negative emotion. By examining the appraisal frame, the distress is arising because some event made progress towards an undesired state. Working backwards from the frame, the make amends strategy determines that the treat-at-hospital(child) action would undo this negative state. If selected, this strategy would form an intention to perform this action.

The accept-responsibility strategy is a form of emotion-focused coping and it is proposed if the agent has potential responsibility for the cause of the emotion. In this case, he has potential responsibility for the collision because his subordinate, the driver, was responsible for an action that was a precondition of the collision. If selected, this strategy would assert the belief that the sergeant is responsible for the accident. This triggers a reappraisal of the collision.

Appraisal rules will automatically fire, elaborating appraisal frames associated with the driver and child's injuries with the information that the sergeant is blameworthy. This, in turn, will cause new emotion instances to be created, indicating that the sergeant feels guilty and he believes that the lieutenant and mother will be angry at him.

Finally, the shift-blame strategy is a form of emotion-focused coping that is proposed if the agent's superior (power relation) is asking about an event that the agent is potentially responsible for (the collision) and there is another agent that is also potentially responsible (the mother). If selected, this strategy would assert the belief that the mother is responsible for the accident. As in accept-responsibility, this triggers a reappraisal. In this case, the sergeant will feel anger towards the mother and will infer that the lieutenant will be angry as well, and that the mother should feel guilty.

After performing the coping strategy, the sergeant will answer the question. The speech, facial expressions, and gestures are modulated by the coping strategy and the current emotions in focus. The impact on natural language generation is via lexical choice, based on a method proposed by Hovy (1988). Gestures and head movements are added to the syntactic structure that results from generation, based on the syntactic structure, the associated semantics and the affect tagged concepts in the utterance. The BEAT system (Cassell, Vilhjalmsson & Bickmore, 2001) is used to synchronize the gestures with the production of phonemes and visemes.

Currently, we use a crude model of personality traits to assert preferences over these coping strategies. Depending on the traits that were pre-assigned to the sergeant, different strategies are preferred.

4. A Model of Coping

Emotions don't serve just to modulate facial expressions and lexical choice. They are also powerful motivators. Many theories of emotion focus on how people use coping mechanisms or rules to deal with strong (unpleasant) emotions. People typically cope with emotions by acting externally on the world (problem-focused coping), or acting internally to change their beliefs or attention (emotion-focused coping). In the Bosnia scenario, the sergeant is under extreme duress due to the negative emotionality arising from the collision. If and when the student lieutenant asks about the accident, this will bring these strong emotions into focus and creates the opportunity to perform a coping behavior to "discharge" the affect.

Our realization of coping tightly couples the process of coping with the appraisal process that originally lead to the emotion. In essence, coping is the inverse of appraisal. To discharge a strong emotion about some situation, one obvious strategy is to change one or more of the factors that contributed to the emotion. Coping operates on the same representations as the appraisals, the agent's beliefs, goals and plans, but in reverse, seeking to make a change, directly or indirectly, that would have a desirable impact on the original appraisal. Coping could impact the agent's beliefs about the situation, such as the importance of a threatened goal, the likelihood of the threat, responsibility for the threat, etc. Alternatively, the agent might form intentions to change external factors, for example, by performing some action that removes the threat. Indeed, our coping strategies can involve a combination of such approaches. This mirrors how coping processes are understood to operate in human behavior whereby people may employ a mix of problem-focused coping and emotion-focused coping to deal with stress.

We model coping as a three-step process. First some focusing event occurs such as an event in the world or being asked a question. This brings into focus some concern, a part of the plan, or causal history, relevant to the event or question. Assuming the agent has a strong appraisal with respect to a concern, a coping elicitation structure is inferred that ties together the concern, the appraisal, as well as what and who caused the agent to focus on this concern (e.g., some person asked a question). The elicitation structure also ties together the social relations between the various players in this concern, their emotions as well as their responsibilities with respect to the concern. Figure 3 shows the elicitation structure for the collision that results from the lieutenant's question to the sergeant, "What happened here?" The fact that the speaker is the agent's superior is specified, as well what the agent believes the speaker feels about the event drawn into focus by the question (the accident). Also, the responsibility for the concern is annotated. The agent has not assigned responsibility for the event to anyone. However the drivers of the two cars have indirect responsibility. Further, the agent has inferred that he has potential responsibility since in this case he is the superior of one of the drivers.

Coping

Concern: Collision (mom.driver)

Emotion: Distress, 59.3

Focus-Event: Understand Speech

Type: Information Request

Agency: Superior

Emotion: Distress, 40.3

Responsibility:

Direct: Unspecified

Indirect: Humvee Driver, Mom

Potential: Sgt (superior of Humvee Driver)

Figure 4: Part of Coping Elicitation Structure

The next phase of the coping process involves the matching of potential coping strategies to the elicitation structures. As noted earlier, three strategies match the collision scenario; make-amends, assume-responsibility, shift-responsibility. We then use a simplistic model of personality traits to establish preferences over applicable coping strategies. Once a coping strategy is selected, the next phase applies the various internal and external behaviors that realize the strategy.

The final step of the coping process is the various impacts it has on the agent's internal state and external behavior. Currently, our coping strategies can impact the agent by combination of changing beliefs, forming intentions to act, forming an intention to communicate and finally expressing the agent's emotions over the concern. Different strategies differentially exploit and emphasize these behaviors. For making-amends, the intention to act in order to address the concern is fundamental. Shift-blame relies more on change in beliefs as well as the intention to communicate that belief.

The formation of intentions and changes in beliefs are done in a constrained fashion. The agent is not free to change any belief or form any intention. Currently, the formation of new intentions is based on what is feasible given the current plan. For example, if the sergeant is following a make-amends strategy in response to the collision's injuring the boy, he will search through the plan to find a task that addresses the boy's health, such as taking the boy to the hospital. He will then form an individual intention to perform that task. This intention is integrated within the rest of the agent's reasoning. If the user (the human playing the lieutenant) asks the sergeant what they should do, the sergeant will propose taking the boy to the hospital.

Similarly, the agent is not free to change any belief. For example, the sergeant cannot simply start believing the boy's healthy in the face of contradictory information. Currently, we only allow beliefs to be changed for which there is no current belief formed via perception or dialog with teammates. Along similar lines, we should note that we do distinguish between beliefs changed by perception and beliefs changed by coping, which are marked as derived and one might argue should be less permanent. In general, of course, the question of belief update is a difficult one. One might imagine that, as a counter example, an agent under extreme duress might change or hold onto a belief in the face of contradictory information if that coping by denial helped them deal with the stress.

Emotional expression is also integral to the coping. An agent that is making amends would be free to express their true underlying emotions. However, an agent who is shifting blame might express anger at the person they are shifting blame to, prior to any feeling of anger that might arise due to changes in beliefs about who is responsible. For such reasons, we allow emotional expression to be part of the coping mechanism even though the changed beliefs and intentions will also engender subsequent emotion.

It is important to note that this latter case of more feigned, communicative use of emotional expression raises the point that coping mechanisms can also employ feigned belief changes and intentions. For example, the sergeant's most intense concern may be that the lieutenant will be mad at him for the accident, and not his own concern for the accident. As such, he may feign believing the mother caused the accident. Although such subtlety, or perhaps duplicity, could readily be modeled in the current coping framework by adding a second shift-blame coping rule that simply did not changing beliefs, we have not yet added such a rule.

The expressive behaviors that can be triggered from coping spans the agent's gaze, facial expression, gesture, and posture. The coping strategy also impacts the agent's sentence planning and surface realization. The coping strategies have such a wide range of impact on expressive behavior for principally two reasons. First, we have a basic need to realize expressive behavior and second the coping strategies allow us to address this need in a principled way. The agents we design incorporate a wide range of outward behaviors in order to interact believably with the environment as well as other agents and humans. They interact within scenarios that would be very stressful in real life. The agent bodies have fully articulated limbs, facial expressions, and sensory apparatus. They can move in the environment, manipulate objects and direct their gaze in appropriate ways. They are capable of rich, multi-modal communication that

incorporates both verbal behaviors as well as nonverbal behaviors. In addition, they have facial expressions, body postures and the ability to perform various kinds of gestures. A key challenge for the agent design is to manage this flexibility in the agent's physical presence in a way that conveys consistent emotional state and individual differences. The coping strategy provides a framework, a focus, for achieving this consistency across modalities.

5. Conclusion

Emotions have a pervasive influence on human behavior. Modeling this influence in virtual humans is a difficult challenge. The interplay between emotions and behavior is not static or unidirectional. A person's response to emotion may subsequently impact their emotional state via reappraisals of their emotional reactions or other strategies for coping with emotional stress. A key component of this dynamic interplay is the impact of emotions on beliefs.

In the work reported here, we have set out a preliminary model of the impact of emotions on beliefs, using an agent's coping mechanisms to tie together changes in the agent's planning representations to the emotional appraisal mechanisms that reason over those representations. This has allowed us to model coping strategies that span both emotion and problem focused coping in a general fashion.

However, work remains in further developing these coping mechanisms and the underlying representations on which they operate. For example, the modeling of responsibility takes into account degrees of responsibility. It does not take into account the degree to which the responsible party intended to cause harm or to be helpful. This determination is critical to both appraisal and coping. Further, the modeling of personality's impact on coping behavior needs to be extended. Nevertheless, our overall approach looks very promising. We are now seeing unexpected, emergent coping behavior from our agents that at times can be disturbingly lifelike, even though it is not always by our design.

Acknowledgements

This research was funded by the Army Research Institute under contract TAPC-ARI-BR and by the U.S. Army under contract to the Institute for Creative Technologies. The content of this article does not necessarily reflect the position or the policy of the Government, and no official endorsement should be inferred.

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