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# Modeling Coping Behavior in Virtual Humans: Don't Worry, Be Happy

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## ABSTRACT

This article builds on insights into how humans cope with emotion to guide the design of virtual humans. Although coping is increasingly viewed in the psychological literature as having a central role in human adaptive behavior, it has been largely ignored in computational models of emotion. In this paper, we show how psychological research on the interplay between human emotion, cognition and coping behavior can serve as a central organizing principle for the behavior of human-like autonomous agents. We present a detailed domain-independent model of coping based on this framework that significantly extends our previous work. We argue that this perspective provides novel insights into realizing adaptive behavior.

**Keywords:** Emotion and personality; human-like qualities

## 1. INTRODUCTION

Emotions play a powerful, central role in our lives. They impact our beliefs, inform our decision-making and in large measure guide how we adapt our behavior to the world around us. While most apparent in moments of great stress, emotions sway even the mundane decisions we face in everyday life [1, 2]. Emotions also infuse our social relationships. Our interactions with each other are a source of many of our emotions and we have developed both a range of behaviors that communicate emotional information as well as an ability to recognize the emotional arousal in others. By virtue of their central role and wide influence, emotion provides a means to coordinate the diverse mental and physical components required to respond to the world in a coherent fashion.

We come to the study of emotion with a particular computational perspective. Imagine a computer system that simulates NASA's mission control during a crisis, allowing you to practice your crisis management skills. Or consider a system that allows you to confront your greatest social phobia in the relative safety of virtual reality. Such social training simulations are possible through the creation of *virtual humans*, software entities that look and act like people, but that live in simulated graphical environments [3]. To support such dramatic scenarios, virtual humans must model emotion and conveying it in a way that mirror human emotional behavior. This is essential for believability – if an agent looks like a human, people expect it to behave like one as well, and will be disturbed by, or misinterpret, discrepancies from human norms [4]. Further, it is essential for the learning experience: to support such social training, virtual humans must act and make decisions as if they are humans under stress. The potential of this virtual human technology is considerable. Applications include education and training [5], therapy [6], marketing [7] and entertainment [8].

In working on a number of such systems, we have come to the view that emotion must be treated as more than surface behavior, but as a central organizing construct that can help integrate the numerous computational modules that underlie virtual human architectures. Virtual humans must act and react in their simulated environment, drawing on the disciplines of automated reasoning and planning. To hold a conversation, they must exploit the full gamut of natural language research, from speech recognition and natural language understanding through natural language generation and speech synthesis. To effectively convey nonverbal behavior, emotion, and personality, they must draw heavily on psychology and communication. It is our view that emotion plays a central role in pulling all the agent's capabilities together into a believable virtual human. Thus the agent's planning, natural language generation, physical behavior, etc. must be consistent with its emotional state.

Our goal is to model the range of human emotions as well as their impact on behavior Although this may seem implausible at first, some significant advances in emotion psychology can shed considerable light on the design of emotional virtual humans. Specifically, cognitive appraisal theories characterize emotion as the result of a *cognitive appraisal* that assesses the relevance of events in terms of their personal significance for an individual. Smith and Lazarus' cognitive-motivational-emotive system is one instance of this class of theories [9]. Their model views emotion as a two-stage control system. Appraisal characterizes the relationship between a person and their physical and social environment, referred to as the *person-environment relationship*. Coping recruits resources to repair or maintain this relationship, by motivating actions that change the environment (problem-focused coping), or by motivating changes to its interpretation of this relationship (emotion-focused coping). Personality influences this process through stable biases in how an individual appraises and copes with events.

The focus of this paper is on a general model of coping, including its role, along with appraisal, as a central organizing principle for human-like autonomous agents. This framework has been realized in an implemented system that has been applied to a significant real world virtual human application, the Mission Rehearsal Exercise virtual training environment [10].

Although considerable research has addressed computational models of emotional appraisal [11-13], there has been almost no work on coping, at least as generally conceived in the emotion psychology community. Prior computational work on the impact of emotion on action selection (e.g., [14, 15]) can be viewed as problem-directed coping, however, no work captures the full range of human problem-directed and emotion-directed coping behavior. Our own prior work provided a preliminary, partial model of coping [16]. The work we present here significantly builds on that work. Specifically, we have extended the model to cover a wide range of both problem and emotion directed strategies. Additionally, coping strategies are now modeled within a more elegant, uniform framework based on select alterations of appraisal factors. The coping strategy selection process has also been improved in several ways. The potential for a coping strategy to be successful is now accounted for in the selection decision. Coping strategies can be combined and interleaved, allowing more subtle strategies to be realized. Also, we have incorporated a more flexible approach to how coping relates to eliciting events – allowing emotional state to "infect" the agent's decision-making in other situations and thus have a more pervasive impact, as happens in human behavior.

## 2. COGNITION-MOTIVATION-EMOTION

Smith and Lazarus' cognitive-motivational-emotive psychological theory organizes behavior around two basic processes, appraisal (which characterizes the person's relationship with their environment), and coping (which suggests strategies for altering or maintaining this relationship). Cognition informs both of these processes. It informs appraisal by building up mental representations of how events relate to internal dispositions such as goals. It informs coping by suggesting and exploring strategies for altering or maintaining the person-environment relationship.

### 2.1 Appraisal and Appraisal Variables

Appraisal is the process by which a person assesses their overall relationship with its environment, including not only their current condition but past events that led to this state as well as future prospects. Cognitive appraisal theory argues that people possess many distributed processes for interpreting this relationship (e.g., planning, explanation, perception, memory, linguistic processes) but that appraisal maps characteristics of these disparate processes into a common set of intermediate terms called *appraisal variables*. These variables serve as an intermediate description of the person-environment relationship – a common language of sorts – and mediate between stimuli and response (e.g. different responses are organized around how a situation is appraised). Appraisal variables characterize the significance of events from the individual's perspective. Events do not have significance in of themselves, but only by virtue of their interpretation in the context of an individual's beliefs, desires and intention, and past events. For example, the outcome of the latest presidential election might inspire joy, anger or indifference, depending on which candidate one desires and one's anger towards an individual may be mitigated by whether one believes they intended an offensive act.

There is broad agreement on the basic set of variables underlying appraisal (though the complete set and naming of variables differs considerably across theories). In our work, we model the following commonly implicated variables:

- *goal relevance* – are the consequences of an event relevant to an organism's goals
- *desirability* – how desirable are the consequences
- *likelihood* – how likely are the consequences
- *causal attribution* – who is the causal agent underlying the event and do they deserve credit or blame
- *coping potential* – a measure of an agent's ability to reverse negative or maintain positive circumstances.

### 2.2 Coping

Coping determines how one responds to the appraised significance of events. People are motivated to respond to events differently depending on how they are appraised [17]. For example, events appraised as undesirable but controllable motivate people to develop and execute plans to reverse these circumstances. On the other hand, events appraised as uncontrollable lead people towards escapism or resignation. Computational approaches that model this motivational function have largely focused on the former response, using emotion or appraisal to guide external action, however psychological theories characterize coping more broadly. In addition to acting on the environment, termed *problem-focused coping*, people employ inner-directed strategies for dealing with strong emotions, termed *emotion-focused coping* [18]. Emotion-focused coping works by altering one's interpretation of circumstances, for example, by discounting a potential threat or abandoning a cherished goal. Indeed, much of what counts as problem-focused coping in the psychological literature is really inner-directed in this sense. For example, one might form an intention to achieve a desired state – and feel better as a consequence – without ever acting on the intention. Thus, by performing cognitive acts like planning, one can improve ones interpretation of circumstances without actually changing the physical environment.

Beyond organizing coping strategies into these two broad categories (sometimes researchers add *suppression* as a third separate category), coping researchers have constructed several detailed taxonomies of different techniques people use to cope, often based on peoples' subjective reports. Table 1 illustrates a partial taxonomy adapted from [19].

Coping relies on appraisal to identify significant features of the person-environment relationship and to assess the potential to maintain or overturn these features (coping potential). Based on these assessments, coping selects among competing strategies to alter the person-environment relationship. For example, if one feels guilty about causing a traffic accident, one may be motivated to redress the wrong (problem-focused coping) or alternatively, shift-blame to the other driver (emotion-focused coping). Coping typically relies on cognitive process to actually realize these strategies. So, whereas coping may form the intention to redress the wrong, cognition must still devise a particular plan of attack. The ultimate effect of these strategies is to change a person's interpretation of their relationship with the environment, which can lead to a re-appraisal of this relationship. Coping, cognition and appraisal are tightly coupled, interacting and unfolding over time: an agent may "feel" distress for an event

| Table 1: Some common coping strategies | |
|---|---|
| Problem-focused Coping | Planning: Develop plans to remove stressor. |
| | Suppression of competing activities: put other projects aside or let them slide. |
| Emotion-focused Coping | Positive reinterpretation: look for silver lining; |
| | Acceptance: accept stressor as real. Live with it. |
| | Seeking social support for emotional reasons: getting moral support, sympathy. |
| | Denial: denying the reality of event. |
| | Behavioral disengagement: Admit cannot deal. |
| | Mental disengagement: Use other activities to take mind off problem: daydreaming, sleeping |

(appraisal), which motivates the shifting of blame (coping), which leads to anger (re-appraisal).

## 3. A COMPUTATIONAL PERSPECTIVE

A central tenant in cognitive appraisal theories in general and the Smith and Lazarus work in particular is that appraisal and coping center around a person's interpretation of their relationship with the environment. This interpretation is constructed by cognitive processes, summarized by appraisal variables and altered by coping responses. To capture this interpretative process in computational terms, we have found it most natural to build on plan-based causal representations, augmenting them with decision-theoretic planning techniques (e.g., [20]) and with methods that explicitly model commitments to beliefs and intentions [21, 22]. Plan representations provide a concise representation of the causal relationship between events and states, key for assessing the relevance of events to an agent's goals and for assessing causal attributions. Plan representations also lie at the heart of a many autonomous agent reasoning techniques (e.g., planning, explanation, natural language processing). Beyond modeling causality, attributions of blame or credit involve reasoning if the causal agent intended or foresaw the consequences of their actions, most naturally represented by explicit representations of beliefs and intentions. As we will see, commitments to beliefs and intentions also play a key role in implementing coping strategies. The appraisal variables of desirability and likelihood find natural analogues in the concepts of utility and probability as characterized by decision-theoretic planning methods.

In our conceptualization, the agent's current interpretation of its "agent-environment relationship" is reified by the output and intermediate results of those reasoning algorithms that relate the agent to its physical and social environment. We use the term *causal interpretation* to refer to this collection of data structures to emphasize the importance of causal reasoning as well as the interpretative (subjective) character of the appraisal process. At any point in time, this configuration of beliefs, desires, plans, and intentions represents the agent's current view of the agent-environment relationship, an interpretation that may subsequently change with further observation or inference. We treat appraisal as a set of feature detectors that map features of the causal interpretation into appraisal variables. For example, an effect that threatens a desired goal might lead to appraised fear. Coping directs control signals to auxiliary reasoning modules (i.e., planning, action selection, belief updates, etc.) to overturn or maintain features of the causal interpretation that lead to individual appraisals. For example, coping may resign the agent to the threat by abandoning the desire. Figure 1 illustrates a reinterpretation of Smith and Lazarus' cognitive-motivational-emotive system consistent with this view. The causal interpretation could be viewed as a representation of working memory (for those familiar with psychological theories) or as a blackboard (for those familiar with blackboard architectures).

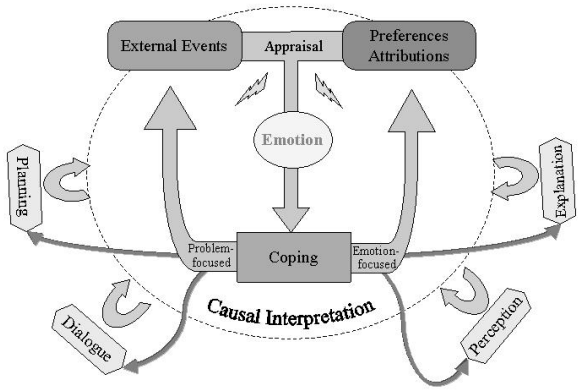


**Figure 1: Emotional Octopus**

## 4. MODEL OF APPRAISAL (A REVIEW)

Our approach to appraisal is based on Émile (Gratch, 2000), a computational model of appraisal that represents the agent-environment relationship through particular data structure we call the *causal interpretation*, so named to emphasize the importance of causal reasoning as well as the interpretative (subjective) character of the appraisal process. Émile treats appraisal a set of feature detectors that map features of the causal interpretation into appraisal variables. The interpretation represents the agent's current mental view of what events occurred in the recent past, the current value of state predicates, and future plans and goals. Events are represented as probabilistic STRIPS operators. The *desirability* of a state is equated with its expected utility. State predicates may either have intrinsic utility or may acquire extrinsic utility if they are along some causal chain towards an intrinsically important state. Similarly, the likelihood of an event or outcome is equated with its probability. Agents may form beliefs about the current value of state predicates and about the party responsible for individual events. Intentions may be associated with states (intend-that) and events (intend-to). Forward-directed intentions will influence planning in the typical fashion (e.g., an agent will attempt to plan to achieve an intended state as long as the intention holds.

Figure 2 illustrates a simple example of a causal interpretation from the perspective of a doctor agent. In this example, the doctor is considering giving morphine to a terminal cancer patient. Events leading up to the current moment are represented in the causal history (which, in the example, only contains a dummy **init** event who's effects define the initial state). The current world description summarizes the believed truth-value of current state predicates, which in the example is equivalent to the initial state: the doctor believes he has morphine, the patient is suffering and their death hasn't been hastened (by the doctor's treatment). The task network represents future possible events -- in this case the only envisioned future event is the act of giving morphine. This action has two effects: a desirable effect that the patient's suffering will end and an undesirable effect that their

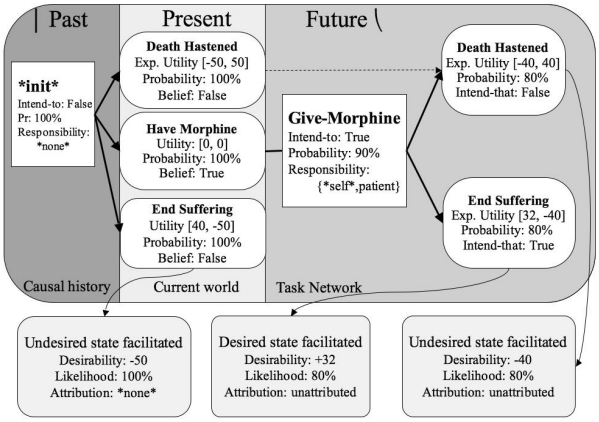


**Figure 2: Causal Interpretation**

death will be hastened (morphine weakens the patient). The likelihood of states and events is represented by probability values – the give-morphine action is 50% likely to occur. Desirability is represented by a utility distribution function over the truth-value of state predicates – if suffering has been eased the doctor expects a reward of 40 (out of a maximum of 100) but a penalty of 50 if it has not been eased. Events and states may have intentions – the doctor intends to provide morphine and intends that suffering be eased and that death not be hastened. Events have a responsibility slot that specifies the causal agency responsible for the event. In the example, the doctor considers that either he or the patient may have culpability, but has not committed to a specific agent.

Appraisal characterizes individual consequences of events in the causal interpretation in terms of the different appraisal variables. Figure 2 illustrates three different appraisal frames. For example, easing suffering is appraised as a likely desirable outcome of giving morphine. Rather than collapsing the consequences of an event into a single expected utility value, as in classical decision theory, Émile appraises each consequence separately. For example, giving morphine has near-zero expected utility but will generate strong negative and positive appraisals. This ability to separately consider different aspects of the same event is a key property of appraisal and will play an important role in certain coping strategies that attempt to focus on one aspect to the exclusion of the other.

## 5. FOCUS

A key issue in developing a computational model of appraisal and coping concerns the issue of focus: what causes the cognitive appraisal process to focus on some aspect of the person-environment relationship. Clearly, we are awash in potential emotions, stemming from our memories, daily experiences and events in the larger world. Our computational approach to appraisal acknowledges this fact by maintaining numerous simultaneous appraisals that are updated by any change to the causal interpretation. But this raises the issue of what focuses the virtual human on particular emotions that need to be coped with.

Our approach is to adopt a model analogous to a notion of attention. The agent possesses a number of operators that access or alter the causal interpretation. Such operators include planning related operators (e.g., update a belief, update an intention, etc.), dialogue related operators (e.g., understand speech, output speech, update dialogue state), and execution and monitoring operators (e.g. monitor an effect, action initiation, etc.). Collective we refer to these as *cognitive operators.* Whenever a cognitive operator accesses a portion of the causal interpretation, any appraisal frames associated with that portion of the data structure are brought into focus. For instance, in our doctor agent example, a question from another agent or user, such as "What are you going to do about the cancer patient?" brings into focus the patient and issues related to her suffering.

This approach is notable both in its simplicity and its explanatory power. For example, this coupling of cognitive operations and appraisal/coping ensures that not only are emotions guided by cognition but also that emotions and coping can facilitate the cognitive operations. For instance, by making their outputs available to the understand-speech operation, the appraisal and coping mechanisms help in disambiguating user statements by indicating which alternative interpretation of an ambiguous speech act has the most intense affective charge, and therefore is the most salient interpretation. Thus the doctor agent would interpret the previous question as being about the issue of relieving the suffering with morphine.

In addition, this focus mechanism provides an elegant explanation of why various distraction-based coping operations such as disengagement work. Certain coping strategies work by making portions of the cognitive interpretation less accessible to cognitive operations, and therefore making associated appraisals less likely to come into focus. For example, by dropping an intention, the planner is less likely to access the state or event that the intention was associated with. This mechanism could also support more subtle strategies like going to a party to distract oneself from thinking about a stressful term paper. Ensuring the cognitive operations associated with writing the paper will not come into focus effectively puts that stress out of mind.

## 6. A MODEL OF COPING

The challenge in our work is to translate coping strategies, like those presented in Table 1, into concrete guidance for future action or concrete changes in how the agent views its relationship with the environment. This challenge is made more difficult because the psychological literature defines coping strategies in a somewhat nebulous fashion. Nevertheless, we argue that coping strategies can be defined in terms of the same primitives that underlie appraisals. In our view, coping strategies act by altering the beliefs, intentions, probabilities and utilities that form an agent's causal interpretation. In doing so, their impact may be either immediate (abandoning a goal will alleviate stress arising from a blocked goal) or indirect (as when a changed intention alters future planning behavior).

Here we propose a concrete mapping between commonly identified coping strategies and these representational primitives. In laying out this mapping we must address several problems. Given that there are multiple appraisals, which appraisals lead to coping? What is the specific mapping from a strategy to representational primitives? If a strategy has multiple instantiations or multiple strategies apply, how do we arbitrate between strategies? How do strategies persist? How do we ensure the coherence of strategies over time?

In our model, coping is considered whenever an emotionally significant event is brought into focus by a cognitive operation (such as being asked a question about a stressful event). The

| Table 2 : Computational realization of common coping strategies | | |
|---|---|---|
| **Strategy** | **Conditions** | **Effects** |
| Planning | Possible future event has desirable effect (facilitates desired state or inhibits undesired state) | Assert intention that event occur |
| Acceptance | An intended future state (i.e. a goal) seems unachievable (e.g., no viable plan exists) | Retract intention |
| Positive reinterpretation | Past event or intended future event with undesirable effect has desirable side-effect | Increase intrinsic utility of desirable side-effect |
| Mental disengagement | Desired goal seems unachievable | Decrease intrinsic utility of desired goal |
| Denial/Wishful thinking | Effect of past event or intended future event has undesirable effect | Decrease probability of undesirable effect |
| Shift/Accept blame | Event has undesirable/desirable effect and ambiguous causal attribution | Assert blame/credit to one of the ambiguous causal agents |

selection of a coping strategy is a four-stage process: (1) identify a coping opportunity, (2) propose alternative coping strategies, (3) assess coping potential, and (4) select a strategy to apply.

## 6.1 Identify coping opportunity:

Whenever the agent performs a cognitive operation, for example, updating an intention or understanding speech, coping identifies any associated appraisal that could motivate coping. To do this, coping creates a *coping elicitation frame* that consists of a number of coping related fields including:

- **Focus Agency:** The *focus-agency* is the agent or object that "provoked" the cognitive operation (e.g., the speaker in the case of understand speech or the agent itself in the case of planning operations).
- **Interpretation-objects**: The *interpretation-objects* are any events or states in the causal interpretation referenced by the cognitive operation. There may be multiple referents. For example, if a speaker asks "what happened", the referents could be any event in the causal history. For each interpretation object, coping identifies the strongest positive and negative appraisals associated with the referent. For example, if "give-morphine" is the referent, the appraisals associated with hastening death and reducing suffering are the most negative and positive appraisals, respectively.
- **Agency-max:** Coping also identifies an *agency-max*, which corresponds to the max emotion that the agent believes the focus-agency has about the same referent.
- **Max-interpretation:** This is the interpretation object with the strongest appraisal. If the intensity of the max appraisal of the max-interpretation exceeds some pre-specified constant, the coping elicitation frame is identified as a coping opportunity.
- **Potential Responsibility:** Coping infers potentially responsible parties for the interpretation. This includes not only any agents that were causally attributed during appraisal but also any entity that may be inferred to be potentially responsible. For example, this includes the superior of a blameful subordinate or an individual whose actions indirectly impact the interpretation object.

## 6.2 Propose alternative coping strategies

Coping strategies are proposed for each coping opportunity based on features of the coping elicitation frame. Each strategy consists of two parts, a set of conditions that define its applicability, and an abstract characterization of its effect on the causal interpretation. We will detail the strategies in Section 6.5, but as a quick example, a problem directed strategy might have as its applicability conditions that the coping frame most intense appraisal be a threat to a desired goal (e.g. giving morphine hastens death). The effect of this strategy is that some change must be identified that overcomes this specific threat.

## 6.3 Assess coping potential

The assessment of coping potential takes a strategy's abstract effect and maps it into one or more elements of the causal interpretation that, if changed, would alter the appraisals in a desired way. There may be multiple ways to achieve this direction and the assessment of potential also ranks these alternatives in terms of their expected impact on the appraisal frame. For example, a problem directed strategy to address the threat caused by giving morphine might address the threat either by identifying one or more actions that could reverse the undesired effect of giving morphine (adding a "white knight") or by dropping the intention to give morphine. In the case of problem directed strategies, these assessment rules correspond to fairly standard plan critics (e.g., find some action that possibly confronts a precondition of a threatening event).

## 6.4 Select one strategy

Finally, coping picks a strategy and applies it. Several strategies have been associated with specific personality traits and coping prefers those strategies that share a pre-defined trait of the agent. We currently resolve remaining ties arbitrarily. Note this selection comes after the evaluation of coping potential, so the bias of personality is modulo the agent's assessment of the coping potential of a particular strategy in a particular situation.

There are several ways to associate strategies with personality. One simple model is to use psychological data on how personality factors associate with coping strategies. In particular, here is how the Revised NEO Personality Inventory factors correlate with coping [23]:

- Conscientiousness is associated with planful coping and negatively associated with self-blame and wishful thinking,
- Neuroticism is related to self-blame and daydreaming.
- Openness is associated with finding positive meaning/reinterpretation.

## 6.5 Coping Strategies

Table 2 illustrates our recasting of the strategies in Table 1.

### *6.5.1 Planning*

Planful coping involves forming an intention to take an action whose effect achieves the desired state or blocks direct or indirect threats to the desired state. If the max appraisal associated with a coping elicitation frame is positive (e.g., a desirable state was achieved or may be achieved in the future), the strategy asserts a preference to maintain this state. Alternatively, if the max appraisal associated with the coping frame is negative (e.g., a desirable state was threatened) the strategy identifies actions that would overturn the threatening circumstances. During the assessment of coping potential, plan critics fire, attempting to identify specific actions that, if they were augmented with positive or negative intentions, would have the desired effect. For example, if the doctor feels good about reducing suffering, he might form an intention to give morphine. The plan critics that assess coping potential correspond to conventional plan critics [24] – e.g., if a step clobbers a desired step P, considering adding a step that re-establishes P (a white knight).

Planful strategies impact appraisals indirectly by motivating future planning. For example, if coping forms an intention to perform an action, the planner will be invoked to attempt to achieve its preconditions. As this changes the causal interpretation, it may lead to new appraisals and subsequent coping.

### *6.5.2 Positive reinterpretation*

Positive Reinterpretation involves finding positive meaning in some otherwise negative event. Computationally, this means finding some direct or indirect consequence of the event that is desirable and emphasizing it by increasing its utility for the agent. For example, giving morphine has the negative consequence of hastening death but at least it reduces suffering. During the assessment of coping potential, rules identify any immediate consequences with positive utility, or any consequences that are facilitated indirectly via intermediate causally connected events. Currently we allow utility values to be incrementally adjusted within a user-specified range. If adjustment is possible, these consequences become candidates for change. If adopted, the utility of one of these candidates is adjusted upward.

Positive reinterpretation will lead negative events to be reappraised in a more positive light. This may lead indirectly to the formation of new intentions. For example, the doctor may initially not intend to give morphine because on balance the costs exceed the benefits. Following positive reinterpretation the expected utility may become positive, leading the doctor to form an intention to give the drug.

### *6.5.3 Acceptance*

Acceptance is the recognition that a negative appraisal is unavoidable. Computationally, this corresponds to the situation where the maximum appraisal is a threat to a desirable intended state. Under these circumstances, this strategy proposes dropping the intention, essentially dropping the commitment to achieve this state.

Acceptance will lead to planner to stop the search for plans to achieve the desired state. So while the threat will still be appraised as undesirable, through the focus of attention mechanism, the undesirable appraisal should come into focus less often as cognitive operations such as update-intention and update-belief will no longer reference the state. For example, if the doctor accepts that hastening death is unavoidable he may become less focused on that consequence and be more inclined to provide morphine.

### *6.5.4 Denial / Wishful Thinking*

Denial works by denying the reality of an event. The strategy is proposed if the most intense appraisal associated with the coping frame is negative. During the assessment of coping potential, rules identify factors leading to the negative appraisal that are candidates for denial. If selected, one of these candidates is manipulated to appear less likely. For example, one way to mitigate the distress associated with providing morphine is to deny to oneself that morphine hastens death. The strategy adjusts downward, within some user-specified range, the probability that an effect of an action will occur.

The consequence of denial is that certain threats or establishment relations will appear less likely. This will directly reduce the intensity of the negative appraisal. This may also indirectly impact planning and plan execution behavior. For example, the planner may not confront certain threats if they appear, through denial, to be unlikely.

### *6.5.5 Mental disengagement*

Mental Disengagement acts by reducing an agents "investment" in some state of affairs. Computationally, this corresponds to identifying a previously desired state or goal that seems unachievable and then coping by reducing the intrinsic utility of that state. For example, if the doctor is distressed about giving morphine, he may distance himself from the situation by lowering the intrinsic utility of all of the states associated with the action. This is different than acceptance where the agent drops the intention but still maintains the same investment.

Mental disengagement will lower the emotional charge associated with the event. It may also lead the agent to indirectly drop any intentions associated with the event as the overall desirability of the associated actions are reduced.

### *6.5.6 Shift Blame / Accept Blame*

People employ various coping strategies that revolve around manipulating blame, specifically self-blame and other-blame. For example, a person may shift blame to someone else. This is particularly the case if the focus-agency is a superior that feels negatively about the same event. In our model, shifting blame involves finding an event or action that has an undesirable effect and a potentially ambiguous causal attribution. The coping identifies potentially blameful individuals or causes for the event and shifts blame to them. For example, the doctor could decide that it is truly the patient's responsibility for give-morphine, in which case he would not feel so guilty.

### *6.5.7 Composition of coping strategies.*

In addition to operating in isolation, coping strategies may work in tandem. The doctor may accept that he will not end suffering by dropping the intention to give-morphine while simultaneously engage in wishful thinking that the suffering will be less probable or that some fortuitous event will intercede to reduce it. This tandem, combined operation is feasible as long as the various strategies don't conflict in their manipulations of the causal interpretations. By allowing coping strategies to combine, a few simple strategies can realize more complex coping behav-

ior. Further, this behavior can be allowed to unfold over time, as consistent strategies are applied in turn.

## 7. COMMENTS AND ISSUES

There are several issues raised by our model that we address here. First, our approach to coping was originally driven by taxonomies of human coping strategies developed in clinical psychology. Such work often fails to characterize precisely how the strategies work or when they are selected. As Table 2 indicates, we are restating these strategies in terms of specific mechanistic operations on the causal interpretation that impact subsequent appraisal and attention factors. These operations include asserting/retracting intentions, manipulating intrinsic utility estimates (i.e., desires), manipulating subjective probability of effects, asserting blame/credit, etc. This suggests that we could reconstruct a more principled ontology from a systematic exploration of such manipulations. This will not only benefit computational models but may be a useful counterpoint to the psychological work. For example, the psychological taxonomies rarely identify shifting blame as a coping strategy although it is a common enough strategy. Perhaps this is not surprising given that these taxonomies are often formed using people's subjective reports on how they coped.

Our work sees coping as a general response to all kinds of emotions, strong and weak, negative and positive, although our implementation focus has been on strong negative emotion. This view is supported by a careful consideration of the coping strategies. Strategies such as active problem solving, wishful thinking, seeking social support and suppression of competing activities are just as applicable to addressing fear over a threat as to increasing happiness via improving the subjective and objective likelihood of achieving a desire. For example, a child desiring a toy may engage in all the above strategies: getting a job after school to purchase the toy (planful problem solving), wish that some relative would give it to him (wishful thinking), ask his parents to buy it for him (seek social support), drop out of after school activities so he could earn more money to purchase it (suppression of competing activities).

Another issue concerns the composition of strategies mentioned earlier. Since strategies work on a set of components, they can operate in tandem as long as they are consistent in terms of the proposed changes to the causal interpretation. One simple approach to consistency is to not allow strategies to override each other's changes to the components of causal interpretation, specifically desirability of a goal, responsibility for an event, likelihood of an event, etc. It is open issue whether this is a sufficient approach.

This question of consistent changes raises an interesting challenge for intelligent agent design. Coping is making changes to beliefs about likelihood and responsibility, changes to desirability, forming wishful intentions, etc. Though psychologically plausible, it is clearly unorthodox from a traditional logical or decision-theoretic interpretation of these terms. One can view coping as an alternative, psychologically motivated calculus for updating subjective probabilities and utilities. But as we have presented it, this calculus is clearly constrained. An agent shouldn't be free to simply wish away important goals or beliefs. Our current approach to this problem is to make small incremental changes when possible. So, for example, the likelihood of a wished-for event only changes slightly. If the same coping strategy is selected again and no other observation or aspect of the causal interpretation is in conflict, these incremental changes could be further incremented. On the other hand, if the world intervenes and sets the agent straight, the changes are reversed. Although this approach is far from a complete solution, it is nevertheless interesting because it raises the issue of how certain coping strategies interact. For example, consider "avoiding social interaction" and "seeking emotional social support". In the former case, a person is protecting belief changes from contradiction. In the latter case, the person is trying to get confirmation for the belief changes.

The model currently maintains a direct connection between appraisals and coping strategies, however many psychologists argue for a more indirect connection [25]. For example, anger at a boss may lead to an angry outburst with a spouse over a minor annoyance later in the day, even though there is no causal relation between what caused the anger and the later outburst. Rather, the emotion seems to persist and impact later behavior. One way to model this behavior is by adjusting the focus mechanism. We could maintain some persistent mood (perhaps a decaying sum of past appraisals) and to add this "energy" to in-focus appraisals, allowing the mechanism to select an appraisal more relevant to the annoyance.

The model can be straightforwardly extended to account for social influences on emotional state. For example, people's interpretation of a situation is often influenced by the emotional responses of those around them (e.g., *social referencing*). Currently, we only account for such influences in the shift-blame coping strategy, where the focus agency's emotions may lead the agent to shift blame. We could incorporate this feature into the selection process of other strategies, thereby more broadly allowing social factors to impact the causal interpretation.

To date, this work has been implemented and informally evaluated within the MRE system. Does the model lead to coherent behavior and do people find the behaviors plausible? Evaluation of the appraisal model is particularly difficult as appraisal and coping are purely mental processes whereas a user only sees external behavior (facial expressions, dialogue, body language). While the model influences the presentation of this behavior, the connection is indirect and, unfortunately, we have a poor understanding of how people interpret computer-generated behaviors. For example, computer generated dialogue systems take longer to answer simple questions than people (due to the current state-of-the-art in natural language processing). People can attribute deep emotional significance to these delays, assuming the computer is in turmoil over how to answer (personal observation). As another example, graphical facial expressions are often interpreted in ways other than what was intended by the system designers [26]. As a first step towards a more comprehensive evaluation, we are engaged in a number of studies to get baseline understanding of external behavior [27].

## 8. CONCLUSION

Modeling the causes of emotions and their impact on behavior is a key, perhaps central, component of interactive virtual human design. The psychological literature has extensively studied emotions and provides us with insight on how to build these models. The work on appraisal, in particular, gave the computational community considerable guidance in building sophisticated models of the cause of emotions. However, the challenge of modeling the impact on behavior is largely unaddressed.

The work reported here on coping is a key step in addressing this challenge. It lays the framework for building a full computational model of the behavioral response to emotion. Our work is informed by research into human coping strategies but we have transposed these concepts into the crisper language of artificial intelligence reasoning techniques and we are currently systematically laying out the of range strategies that this crisper language has made salient. A key challenge we continue to face is how such a rich set of strategies can be manifested in verbal and non-verbal behavior. As we make progress on this challenge, our agents can gradually approach the subtlety and the extremes of human behavior heretofore unexplored in virtual characters.

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## REFERENCES

[1] G. L. Clore and K. Gasper, "Feeling is believing: Some affective influences on belief," in *Emotions and Beliefs: How Feelings Influence Thoughts, Studies in Emotion and Social Interaction: Second Series*, N. Frijda, A. S. R. Manstead, and S. Bem, Eds. Paris: Cambridge University Press, 2000, pp. 10-44.

[2] A. R. Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain*. New York: Avon Books, 1994.

[3] J. Gratch, J. Rickel, E. André, J. Cassell, E. Petajan, and N. Badler, "Creating Interactive Virtual Humans: Some Assembly Required," in *IEEE Intelligent Systems*, vol. July/August, 2002, pp. 54-61.

[4] C. Nass, K. Isbister, and E. J. T. Lee, "Truth is beauty: Researching conversational agents," in *Embodied Conversational Agents*, J. Cassell, J. Sullivan, S. Prevost, and E. Churchill, Eds. Cambridge, MA: MIT Press., 2000, pp. 374-402.

[5] W. L. Johnson, J. Rickel, and J. C. Lester, "Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environments," *International Journal of AI in Education*, vol. 11, pp. 47-78, 2000.

[6] S. Marsella, W. L. Johnson, and C. LaBore, "Interactive Pedagogical Drama," presented at Fourth International Conference on Autonomous Agents, Montreal, Canada, 2000.

[7] E. André, T. Rist, S. v. Mulken, and M. Klesen, "The Automated Design of Believable Dialogues for Animated Presentation Teams," in *Embodied Conversational Agents*, J. Cassell, J. Sullivan, S. Prevost, and E. Churchill, Eds. Cambridge, MA: MIT Press, 2000, pp. 220-255,.

[8] M. Cavazza, F. Charles, and S. J. Mead, "Agents' Interaction in Virtual Storytelling," presented at Third International Workshop on Intelligent Virtual Agents, 2001.

[9] C. Smith and R. Lazarus., "Emotion and Adaptation," in *Handbook of Personality: theory & research*, Pervin, Ed. NY: Guilford Press, 1990, pp. 609-637.

[10] J. Rickel, S. Marsella, J. Gratch, R. Hill, D. Traum, and W. Swartout, "Toward a New Generation of Virtual Humans for Interactive Experiences," in *IEEE Intelligent Systems*, vol. July/August, 2002, pp. 32-38.

[11] C. Elliott, "The affective reasoner: A process model of emotions in a multi-agent system," Northwestern University Institute for the Learning Sciences, Northwestern, IL, Ph.D Dissertation 32, 1992.

[12] W. S. Neal Reilly, "Believable Social and Emotional Agents," Carnegie Mellon University, Pittsburgh, PA, Ph.D Thesis CMU-CS-96-138, 1996.

[13] M. S. El Nasr, J. Yen, and T. Ioerger, "FLAME: Fuzzy Logic Adaptive Model of Emotions," *Autonomous Agents and Multi-Agent Systems*, vol. 3, pp. 219-257, 2000.

[14] L. Beaudoin, "Goal Processing in Autonomous Agents," University of Birmingham, Ph.D Dissertation CSRP-95-2, 1995.

[15] D. Moffat and N. Frijda, "Where there's a Will there's an agent," presented at Workshop on Agent Theories, Architectures and Languages, 1995.

[16] S. Marsella and J. Gratch, "A Step Toward Irrationality: Using Emotion to Change Belief," presented at First International Joint Conference on Autonomous Agents and Multiagent Systems, Bologna, Italy, 2002.

[17] E. Peacock and P. Wong, "The stress appraisal measure (SAM): A multidimensional approach to cognitive appraisal," *Stress Medicine*, vol. 6, pp. 227-236, 1990.

[18] R. Lazarus, *Emotion and Adaptation*. NY: Oxford University Press, 1991.

[19] C. S. Carver, M. F. Scheier, and J. K. Weintraub, "Assessing coping strategies: a theoretically based approach," *Journal of Personality Psychology*, vol. 56, pp. 267-283, 1989.

[20] J. Blythe, "Decision Theoretic Planning," in *AI Magazine*, vol. 20(2), 1999, pp. 37-54.

[21] M. Bratman, "What is intention?," in *Intentions in Communication*, P. Cohen, J. Morgan, and M. Pollack, Eds. Cambridge, MA: MIT Press, 1990.

[22] B. Grosz and S. Kraus, "Collaborative Plans for Complex Group Action," *Artificial Intelligence*, v. 86, 1996.

[23] P. Costa, M. Somerfield, and R. McCrae, "Personality and Coping: A Reconceptualization," in *Handbook of Coping*, M. Zeidner and N. Endler, Eds.: John Wiley and Sons, Inc., 1996.

[24] D. Chapman, "Planning for conjunctive goals," *Artificial Intelligence*, vol. 32, pp. 333-377, 1987.

[25] G. Clore, N. Schwartz, and M. Conway, "Affect as information," in *Handbook of affect and social cognition*, J. P. Forgas, Ed., 1994, pp. 121-144.

[26] A. A. Rizzo, U. Neumann, R. Enciso, D. Fidaleo, and J. Y. Noh, "Performance-Driven Facial Animation: Basic Research on Human Judgments of Emotional State in Facial Avitars," *CyberPsychology and Behavior*, vol. 4, pp. 471-487, 2001.

[27] W. L. Johnson, S. Narayanan, R. Whitney, R. Das, M. Bulut, and C. LaBore, "Limited Domain Synthesis of Expressive Military Speech for Animated Characters," presented at 7th International Conference on Spoken Language Processing, Denver, CO, 2002.