# Fear: Appraisal of danger as anticipation of harm

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**Abstract**

In this paper we present a novel approach to a grounded synthesis of emotional appraisal, based on a multicausal model of the appraisal process. We investigate the functional nature of emotion by implementing a robotic model in a predator/prey scenario which is able to discriminate and anticipate outcomes through emotional appraisal. The robots evolve to react in apparently emotional ways, showing how the functionality of emotion can emerge naturally. We demonstrate through this implementation the value of emotion appraisal as a form of anticipation. This supports the view that emotional behavior can often be seen as an effective alternative to rational cognition. Our effort here is to build a model that can be simultaneously seen as belonging to both NCS and more classical theorizing based on cognitions and representations, understandable both mechanically and subjectively from a human standpoint.

## Introduction

The functional nature of emotions has motivated different studies in the synthetic approach to cognition (as in Artificial Intelligence (AI), robotics and Artificial Life (AL)). For an AI approach emotion is of extreme interest, as it can be seen as one of the key elements bridging the gap between mere reactive behavior in simple machines toward richer, yet flexible and to a high degree inarticulate interaction with the environment. Development studies show that emotions resulting from adaptational pressures mobilize perceptual and cognitive development (Izard et al., 1984; Bridges, 1932). Neuro-physiological research shows that emotional processes are essential constituents of almost all types of adaptation within the social and natural environment (Damasio, 1994). Phenomenological existential theories defend that emotion brings a mode of appearance of the situation; therefore, by means of the emotions we gain 'information' about the 'external' world, as if it was another 'sense' (Heidegger 1927, Sartre (1971)).

For *perceptual theories of emotion*, the origin of emotions is not a symbolic manipulation of our knowledge of the world, but just the opposite: emotion is the origin of much of our cognitive operations (Sousa (1987), Rorty (1980). There is no obvious "place" for an appraisal "representation" and that is deliberate (Pfeifer & Scheier, 1999). Nevertheless emotions are directed toward objects, events or situations, that when experienced, consciously or not, are learnt about. In computational terms, emotions are relevant for intelligence in order to retrieve an adequate (relevant to the agent's *concerns*) "picture" of the world, which includes cognitions of subject concerning categories. The representational theory of mind (Charland, 1997) claims that emotions are a representational system that may operate independently of the cognitive system, complementing the representational function required for full cognitive abilities. Emotion provides much information, even before local perceptions begin to be organized, towards a full cognition of human adults.

The notion of representation used here, literally meaning re-presentation, can be defined here as a "time-dependent state in which a particular pattern of neural activation that reflects, for instance, some event in the world is re-presented to the nervous system in the absence of the input that specified that event" (Spencer and Schöner 2003, pp 392–412). The representational nature of emotion reveals a connection with concern-relevant situations; the absence of input that specifies that event refers to the inherent perceptive and anticipative content of the emotion.

We are not aiming to produce a literal implementation of any cognitive theory of emotion, by translation, symbol-for-symbol. We want to show how certain concepts can dissolve into the fabric of a model, and later be made to re-emerge by (re-)construction, avoiding the common complaint that top-heavy cognitive models appear not just unwieldy, but unrealistic; and may fall prey to criticisms such as the "symbol grounding problem" (Harnad 1987). In this sense we are placing the notion of feeling within the dynamic relationship between physiological states and environmental conditions.

Feeling involves precognitive experience and apprehension. The hypothesis is that emotion, rather than being the end product of a rational process based on local perception, provides the ability to sense the situation as a whole, at the level of agent/environment relationship (Dewey 1958). In this sense we can distinguish between local sensation and global feeling of the situation. The fact that this information is fast, often reactive, and reliable, accounts for the role of emotion in coping potential.

In this sense we may distinguish between objective knowledge, which aims at inherent features of the objects of the world, and the knowledge that emerges from emotional experience (hot cognitions) (Zajonc, 1980). As an emotion occurs when some concern-relevant factors are at stake, and emotion provides a state of action readiness, hot cognition can be considered affordance related information: "... the dominant factors of evaluation, potency and activity that keep appearing certainly have a response-like character, reflecting the ways we can react to meaningful events rather than the ways we can receive them" (Osgood, 1962). The readiness for action associated with emotions reveal the nature of emotion as enactive representation (Aylwin, S 1985). The representational nature of emotion is therefore defined by the actual behaviors and tendencies underlying emotion. The coping potential of emotion and the precognitive nature of emotion cannot be dissociated. Our aim is therefore to produce a synthesis of a process from which coping potential and cognition of the environment is involved.

## A Perceptual theory of fear

In this section we apply the perceptual perspective in order to investigate the role of fear as the anticipation of harm. We need to question what knowledge is available through the experience of fear. What do we come to know as we experience fear? For this purpose we will attend to a classic distinction in emotion theory (Frijda 1986, Lazarus 1991) between primary appraisal and secondary appraisal. The primary process from which emerges the experience of fear is known as primary appraisal of fear. The knowledge inherent to primary appraisal will be shown as sub-symbolic and subjective. The secondary appraisal process results in the generation of meaning structures that may involve degrees of objective knowledge.

### Primary appraisal

We will investigate that in the face of which class of situations we appraise fear. We first need to recognize that the relationship is a dynamical one. The process of primary appraisal of fear emerges within the dynamics of agent/ environment interaction. These dynamics include physiological processes that are the source of the action readiness of the agent. Knowing that an agent is in fear is sufficient to infer some readiness and tendency in the action. This tendency can be clearly associated to the need to maintain some kind of relationship with the environment.

Therefore, something happens in the relationship that triggers a response; and the response is such that modifies the relationship. From this perspective, we observe:

1. A dynamic relationship in which the agent's concern for safety is at stake
2. A class of states internal to the agent (physiological) in which activation is:
    a. causally linked (effect) to these sort of situations
    b. causally linked (cause) of behavior dynamics towards maintaining a concern-safe relationship.

This preliminary analysis is necessary to answer the question: what is the class that is cognated through the experience of primary appraisal? What is the cognitive structure of that in the face of which we experience fear? Fearful is the situation that is appraised as potentially incompatible with some of our concerns. The fearful can be understood as equivalent to *danger*. Note that in this use of the word danger is not an objective class of situations, as danger is only a potential class, and not a factual class. Nothing is dangerous *per se*, but in interaction. In this interaction we appraise this danger, and that is much dependant on each of us.

In this discussion we are recognizing a primary fact: danger, the cognition involved in appraisal responds to the particular characteristics of the relationship rather than on objective measures of the danger. In this process we do not recognize an inherent feature of the situation (independently of the agent's concerns). But this knowledge is not just about internal states with no reference to the external world. When an agent experiences fear, something that refers to the agent and world as a whole is known.

### Secondary Appraisal

The primary appraisal process is the beginning, not the end, of the emotional experience. We may be able to articulate our experience in the appraisal process, identifying features of world and the self as inherent to what is really happening. This is not a cold articulation added to the feeling of fear, but shapes and modifies our experience. This process, which relies on primary appraisal, is therefore called secondary appraisal. It involves judgment, and therefore may be truthful, mistaken or misguided. This accounts for the fact that sometimes we do not know well why we have a certain emotion, or we are mistaken even in the emotion we ascribe to our experience.

Through secondary appraisal, which involves our cognitive abilities, we may, for instance, identify *where* the danger is, identify what harm is anticipated; even find out the most accurate probabilities of different harms. Harm is not a fuzzy concept. We may define positively a class of states in an agent that are required for coping with the environment. Harm is a cold cognition that emerges in secondary appraisal in reference to fear. Fear is a dynamic process that involves an anticipation of harm. The emotion process as a whole also motivates the action tendencies to resolve or cope with the potentially harmful situation. We can therefore say that the secondary appraisal involved in fear is equivalent to the anticipation of harm.

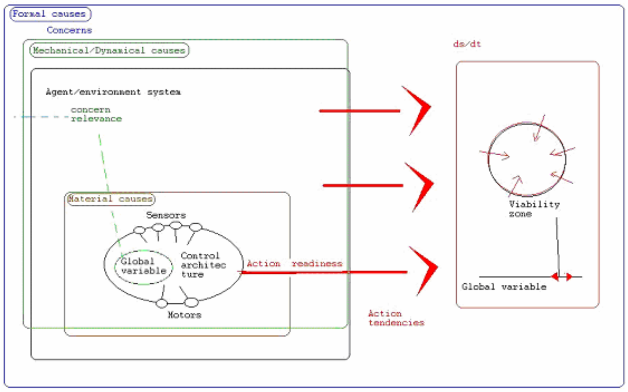


Figure 1. Multicausal representation of Dasein architecture

## A sketch of the DASEIN architecture

We will try to show how, through creating an emotional agent, we can produce the anticipation of harm through the appraisal process. This work is based upon the DASEIN[1] architecture (Dynamic Appraisal System in Embodied INteraction1). This architecture has two foundations: rich causality and dynamical interaction. Figure 1 represents the relevant causal phenomena involved in the appraisal process.

Rich causality means that the range of causal connections allowed in the system is not reduced to mechanical causation. In recent research, the term *emergence* is used indistinct to account for factual causal relationships that cannot be fully explained attending only to mechanical causation. Often, emergent phenomena are taken to lack any causal role. Rich causality nevertheless recognizes different types of causation operating at different spheres - not independently, but as part of a whole. These different forms of causation are not competing realities, but laws that have a different form. Emergent phenomena may present distinct causal roles. Aristotelian science of causation, for example, distinguishes efficient causation, similar to the actual mechanical causation, from final, formal and material.

Our dynamical model is based upon three dimensions: physiological, cognitive and behavioral. Following the new cognitive science paradigm, cognition and behavior are emergent phenomena, causally related to states of a physiological embodiment. Emotional behavior is a form of relational behavior, one that aims at establishing, disrupting or maintaining a certain relationship with some aspects of the environment (Frijda 1986). It is therefore a dynamic negotiation between agent and environment. From the perceptual view, emotions are forms of hot cognition as they re-present environmental condition. In order to clarify the model, we will ask two questions: in response to which environmental conditions do physiological changes occur and what effect do these changes have on the behavior of the system.

In order to identify the functional role of emotion we may look at the phenomena observed in emotion. Philips et al have identified the following phenomena (Phillips et al 2003)

1. appraisal and identification of the emotional significance of the stimulus;
2. production of a specific affective state in response to the stimulus, including autonomic, neuroendocrine, and somatomotor (facial, gestural, vocal, behavioral) responses, as well as conscious emotional feeling
3. the regulation of the affective state and emotional behavior,

Physiological states occur in concern-relevant situations. Concerns are those features that make an agent the type of agent it is, that is, that define this agent as an autonomous entity (Frijda 1986). In this sense, they do not require to be specified in the design process[2]. In order to appraise a concern relevant situation, the system does only need to attend to its own functioning. Physiological changes are autonomic responses to concern-relevant situations. A combination of physiological states determines a state of action readiness (Frijda 1986), often shared by a number of emotions. Action readiness is a form of goal orientation at a general level, but it does not determine the direction of emotional responses (Schachter and Singer 1962). This is negotiated in dynamic interaction with the environment, and the resulting phenomenon is called action tendency.

We can therefore find some emergent phenomena in the appraisal process, such as physiological states,

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1 Dasein means in German "being there", and it is used by Heidegger to refer to the essential constitution of human beings, of which emotional tonality (Befinderheit) is an essential constituent.

2 Hofstader presents the example of a computer network which only function with a limited number of users. Number of users will therefore be a concern of the system.

concerns, action readiness and action tendency. We are now concerned with the implementation of DASEIN in the evolution of neural control systems for situated robots. In order to understand and use in design the relationship between these emergent phenomena we will use the concept of *collective variable*. A collective variable is one that allows tracking of overall agent/environment characteristics, such as emergent phenomena of the collective system (Clark 1997). Collective variables offer a way integrating emergent phenomena in the causal system. We nevertheless favor the name *global variable* because collective suggest that is because of the complexity of the system that we cannot fully explain the overall behavior in mechanical terms.

We argued that physiological reactions, with their representational and enactive character, occur in response to a certain class of events, concern relevant events. There is therefore a relationship between physiological states and overall features of the interaction which allows us to think of physiological states as global variables. Physiological states may be sufficient for the appraisal process to emerge. The minimal conditions in the relationship between internal and overall states for the emergence of the appraisal process emerges is the activation of a global variable that relates to some concern-relevant situations and provokes a change in action readiness. As physiological states are part of the control system, they may be sufficient to produce significantly different behavioral processes. It is in this change that the appraisal process is observed.

Our methodology will consist in simulating the representational character of physiological reactions, insofar as they allow us to track concern-relevance as an emergent feature of the interaction, and they shape behavior. To achieve this dual relationship in terms of the controller architecture, our simple approach will consist in adding an input node to the neural controller: this input node will compute a global variable of the interactive dynamics, that is, a variable that tracks some overall concern relevant property. This input node is similar to a sensor, but whilst the sensor is activated by local states of the environment in relation to the agent, the activation of the new input node is related to the emergence of global features.

In this sense, we need to think of this neuron as a perceptual unit, rather than a purely internal unit. This is the main difference between this type of variable and internal units or short-term memory. This difference is not essential – we may evolve an architecture with an internal unit and later observe that the activation of this neuron does reflect the overall dynamics, and could be considered a global variable. It is through this observation that we would necessarily identify this process as "emotion" rather than "memory" or "cognition". Whether this global variable has been computed, or emerges in evolution, makes no difference to the emotional nature of the system.

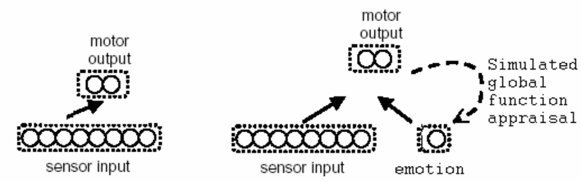



Figure 2. Simple feedforward architecture.
Rigth. DASEIN, incorporating global variable unit

## Experimental setup

In the second part of this paper we illustrate the previous discussion with the implementation of a simulated Khepera robot (Mondada et al, 1993)), using a realistic simulator (Evorobot, see Nolfi and Floreano 2000), capable of appraising dangerous situations. This experiment is framed in the situated cognitive science paradigm, using evolutionary techniques to evolve neuro-controllers. The robot is controlled by a neural network whose connection weights between nodes are obtained through evolution.

We are considering a Khepera robot (prey) situated in the following environment:

- A square space about 6 times larger than the robot's sensory range
- A Khepera robot, that we will call predator.
- A cylindrical stationary object, three times smaller than the robot, that we will call target.

In information processing terms, its behavior needs to distinguish between three different objects, but the static readings from sensors are very similar for wall, target and predator. The prey robot sensory system consists of 8 infrared sensors, with 6 sensors distributed evenly around the front and 2 sensors at the back. From this sensory distribution emerges an interesting fact: static readings of all sensors, at any given moment in time, will not produce enough data to discriminate between different situations in relation to the environment structure: whether a wall, small object or robot is being sensed.

This constitutes a type-2 problem (Clark 1997), a problem in which the agent needs to anticipate concern relevance in the presence of ambiguous stimuli. The aim is to design the robot for the emergence of dynamic patterns that are intrinsically different for the three situations. For the implementation of DASEIN, it is essential that we are capable of defining a proper global variable that would help the robot distinguish between the predator, the walls and the target. The variable would thus be sufficient for tracking the overall concerns.

## Fitness function, concerns and global variable unit

The evolutionary process is determined by the underlying architecture of the neural network (as connections are static throughout evolution) and a fitness function that determines the selection of offspring. The fitness function operates by letting agents interact with the environment and producing an evaluation of the behavior of the agent. The use of predator/prey names is justified by the fitness function of both robots. The prey robot is awarded fitness each life cycle and at the end of the interaction if the prey is alive. If the predator touches the preys, the predator will be awarded a maximum value, while the prey is penalized as the interaction is stopped. An area surrounding the target defines a safe area against predators, in which contact does not affect the life process and fitness increases though staying in the safe area. Prey robots will be selected when they are capable of staying as long as possible close to the target whilst avoiding contact with the predator outside the safe area. Remaining close to the target is in fact the best strategy to maximize fitness.

The choice of fitness function determines the actual concerns of the system. The concerns for this experiment are: a concern for the prey to stay away from the predator and stay close to the target; and the concern for the predator to catch the prey. A prey with high fitness should be able to avoid the predator outside the safe area, find the target and remain close. With this fitness function we expect to develop robots for which the proximity of the predator and/ or target is a concern relevant situation.

The first step in the design process is to identify a potential global variable of the interaction between the robot and the world, and then define the node to compute the variable. Our rationale is based on the observation of behavior evolved from simple feedforward architectures. We have observed that when the prey escapes a predator, it normally keeps it at a sensor range distance. It also normally "controls" this distance by escaping backwards, keeping one or two sensors at the distance mentioned. The prey normally does not keep at a constant distance from static objects, but bounces backwards and forward. The activation of such sensor[s] will have a high value for an extended period of time when the prey is escaping, and highs and lows when the prey is near the target. In order to exploit this regularity, we may multiply the activation of each sensor by the activation of the same sensor in the previous time step. The value of this product will be higher in the presence of a predator, as the chasing produces a continuous activation.

We have therefore considered a global variable as the function of the addition of such products. In order to maintain the time dynamics, the previous activations of the global variable will also affect the current activation. The function proposed is the following:

$$E1= 0.6\ (E0 + (S0*S1)/2)$$

E1 represents the value of this function at a given moment in time, whilst E0 represents the value at the cycle before. S0 and S1 represent the value of the sensors at the present and earlier cycle. (S0*S1)/2 will be high when the predator is chasing the prey and low when the prey is near the target.

Neural firing patterns in emotion are tightly cohere in time and are inter-correlated in intensity (Tomkins 1962). In order to stabilize the emotional reactivity we will use of a differential function, in which the value in the previous cycle is added to the current value, using a corrective constant, 0.6.

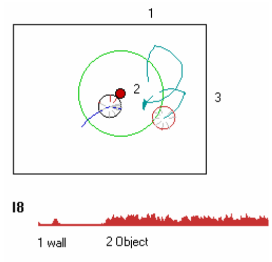
The choice of this corrective constant springs from a trial and error process. We assigned this function, with different corrective constant, to the activation of a unit that is added to the control system of the prey. We evolved this architecture, which we expect to contain a unit whose activation tracks the overall concern relevance of the situation. We evolved the individuals and observed the behavior and the relationship of concern-relevant situations to the value of the global variable. If the behavior was not interesting and/ or the added unit did not compute a global variable, we modified the constants. The choice we made produced interesting behaviors which can be tracked by the activation of the global variable.

## Results

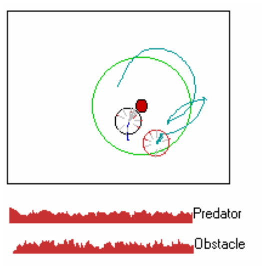
In this section we explain the results of this experiment, evaluating the emergence of emotional behavior and the anticipation of harm through an appropriate appraisal of danger. The experiment rests on whether the neural architecture has evolved so as to make effective use of the global variable. We will demonstrate this is the case by analyzing a set of behaviors.

In the following interactions we can observe how the global variable (I8) allows us to track overall features. In figure a) the predator has crashed against the target, and the prey only interacts with the target object and the wall. It interaction b) the prey is chased by the predator, and we can observe a high activation of the global variable. In interaction c) we can observe a different sensory input for a static predator (crashed against the target) and a static target object (activation taken from a different interaction).

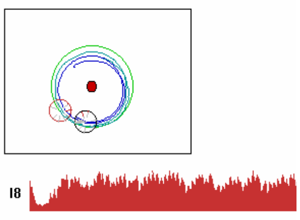
In interaction d, richer than the others, we can observe a variety of activation values for the global variable in response to different classes of situations. The prey first finds the target, but the predator, whose trajectory is represented as a blue line, approaches (point 1). As we see in the internal log, the activation is very high at point 1.



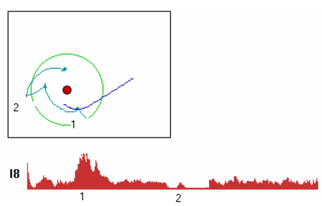

Interaction a.




Interaction b



Interaction c.




Interaction d

The prey nevertheless escapes and the predator crashes into the target. This gives time to the prey to come to the other side of the target. After 1, the activation decreases to the pattern of a target, but the presence of the predator makes the prey avoid the target. It goes out of the homing area to encounter a wall (point 2); it then turns back to the target which it senses normally. The flat areas between the wall (2), and the recognition of the target (past and future), represent the movement of the prey between target and wall, therefore with no activation of the internal neuron. Note that some of the sensors will be activated, since the distance between wall and target is very small. The global neuron is nevertheless able to have a flat value since no sensor is going to be activated for more than one period of time (except of course when close to the wall or target)

## Implementing secondary appraisal as anticipation of harm

We have observed how from the primary appraisal process emerges a change in action-readiness through the activation of a global variable. We have been dealing so far with the appraisal of fear and joy. Now we aim to establish a relationship between the appraisal of fear and the anticipation of harm. We can say this is the case if there is an experience of the presence of an entity of a negative character. This is an example of the situational meaning structure, a structure contains that sufficient information to draw conclusions on objective aspects of the world. (Frijda 1986).

In order to evaluate whether the system of dynamic appraisal is capable of anticipating harm, we have developed a secondary appraisal system that articulates the activation experienced into a situational meaning structure. Our aim is therefore to generate a secondary appraisal system that is able to anticipate harm, that is, that is able to discriminate between the target object and the predator. We will apply Frijda's decomposition of situational structure into a number of components. The basic ones are: presence/absence and positive/negative valence. Valence is a core component, that is, it is required valence for the experience of emotion. "Events, objects, and situations may posses positive or negative valence; that I, they may posses intrinsic attractiveness or aversiveness" (Frijda 1986, p.207). Presence/absence (context components) and valence form the basic componential division of emotional situations (Arnold 1960, Roseman). Each combination of these results in a meaning component profiles.

| Valence<br>Presence | Positive | Negative |
|---|---|---|
| Present | Contentment, enjoyment | Suffering |
| Absent | Desire | Contentment, safety |

Table 1. Table of situational meaning structures for simple robots.

Secondary appraisal is a form of categorization that is fully grounded in the agent's interaction with the world, the agent's concerns and action tendencies. The appraisal of context components must therefore be grounded in sensory-motor co-ordination. The global variable embodied in the system's network as well motor outputs will form the somatic feedback. From an observation of the interaction explained above, we have established the following thresholds, which we will call markers, as they bare some relationship to the Damasio's concept of somatic marker (Damasio 1994).

| | | |
|---|---|---|
| if (energy < 0.135)<br>**absence** | if (energy * average motion) < K<br>**positive valence;** | if (energy < 1.0)<br>**modifiable ;** |
| if (energy > 0.175)<br>**presence** | if (energy * average motion) > K<br>**positive valence;** | if (energy > 1.2 )<br>**non-modifiable;** |

Table 2. Thresholds for secondary appraisal process

The presence marker depends on the value of the global variable, and it justified because walls, predators and objects result in distinct values. The valence parameter is a core component of emotion, and distinguishes the attractiveness or aversiveness of entities and agents, that is, target has a positive valence while the predator has a negative valence. We have considered the average motion of the robot in combination with the global variable. When the robot is being chased by the predator, which should result in a negative value, the average speed is high, while next to the target it is low. The product of the relative speed and the global variable allows us to discriminate between presence of the predator (negative value), and target (positive value). When neither target nor predators are present, the action tendency of the prey is navigating the environment to find the target, which agrees with the positive valence. Note that when there the prey crashed within the target area, the motors do not respond, the average movement is 0 and therefore the valence is positive. Situational meaning structures and meaning profiles. The identification of two context parameters allows the generation of 4 possible meaning profiles. Each profile will define the nature of an emotion, although not all possible emotions will make sense in the context of this particular agent. In other words, and this applies to both artificial and human emotions, typical emotions are subject to componential analysis, but not all possible component combinations are actual emotions. In our case, we have ignored the structure absence of negative value (joy/relief) because of the limitations of the robot. We have adapted Frijda's table of profiles of emotions, taking into account only the components appraised in the system.

| | Presence | Absence | Positive Value | Negative Value |
|---|---|---|---|---|
| Joy | X | | X | |
| Desire | | X | X | |
| Fear | X | | | X |

Table 3. Simplified table of meaning component profiles for typical emotions (Adapted from Frijda 1986).

The profiles for emotions are generated by combining the components. For Frijda, fear is "uncertain expectation of the presence of negative character, but which event is modifiable". This is the case when the prey is chased by the predator (escape). In a similar way, the situational meaning profiles or diverse emotions are construed. Desire can be considered the absence of an entity of positive value (explore), while joy is the presence of positive value (approach). If presence of an entity of positive or negative valence is appraised as non-modifiable, it will result in either love (unmodifiable approach) or distress (unmodifiable avoidance). Emotions over a period of time are often mixtures of such profiles. We can observe that next to a predator the structures reported often mix joy and fear. In the interactions with the target, it is often combined joy with desire. These mixed emotions make sense if we observe real behavior. In achieving something dangerous, the adventurous experiences a mixture of fear and joy for overcoming the danger. When we are very hungry, we do not experience a satisfaction of our desire but it comes and goes.

## Evaluation

The experiment reported uses a dimensional analysis of situational meaning structures to synthesize a secondary appraisal system. The system could be described as one that takes in disorganized external stimuli, and integrates information over time in order to produce internal states from which action tendencies spring. The generation of action tendencies is related to the role of the global variable as an input to the control system. On top of the primary appraisal system, we have implemented a secondary appraisal system that appraises a situational meaning structure, that is, a higher level structure based on internal and motor states that makes sense of the overall response pattern. Two components are continuously identified: presence/ absence, and positive/negative, which together constitute different appraisals. Since each situational meaning structure is above all informative about the situation, we could say that the secondary appraisal carries a categorizing task.

We can establish a relation between objective features of the world and appraisals. The target object can be considered as the natural object of joy (presence of positive value), while the predator is the natural object of fear (presence of negative value). Desire (absence of positive) should sign the absence of any concern-relevant entity (for example it should be indifferent to walls). Patterns of sensory stimuli are therefore transformed into a representation of the situation that relate to objective features of the environment.

The relational themes appraised are "hot cognitions" or "subjective" perceptual classes, since they are logically dependent of the agent's aims and situation. A way to validate the synthetic appraisal is to consider it as a form of signal detection. In our case we can consider the secondary appraisal system as a signal detection system whose target signal detection corresponds to the presence of predator (fear, panic), the target (joy) and none of them (desire). We have considered the predator and target to be present when their distance is less than 20mm, and we have recorded emotional states over 1000s of interactions. The following table represents the total results.

| | **Both** | **Predator** | **Target** | **None** |
|---|---|---|---|---|
| Fear | 61.94% | 73.34% | 3.45% | 5.12% |
| Joy | 36.01% | 24.35% | 87.70% | 2.75% |
| Desire | 2.06% | 2.30% | 8.85% | 92.13% |

This analysis reveals high precision in anticipating environmental concern relevance. The probability, given a particular emotion, that the environmental conditions fit the meaning structure, ranges between 78% chance that the predator will be present if fear is experienced, and 70% that there is no relevant stimuli when desire is experienced.

| | Both | Predator | Target | None |
|---|---|---|---|---|
| **Fear** | 16.67% | 77.84% | 3.83% | 1.67% |
| **Joy** | 7.25% | 19.33% | 72.76% | 0.67% |
| **Desire** | 1.29% | 5.70% | 22.92% | 70.09% |

Figure 3 represents such distribution of emotional reactions (blue for joy, red for fear and green for desire), across a two dimensional representation of the position of the prey in the environment, in which the Y-axis represents the distance between the prey and predator, and the X-axis the distance between prey and target. In a single graph we can see how the system consistently classifies environmental sources of stimuli.

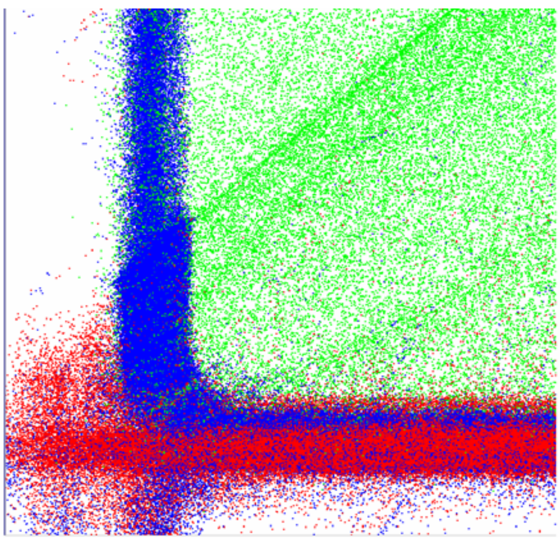


Figure 3. Emotions experienced at concrete relative distances from predator and target object.

## Conclusion

Perceptual theories of emotion are of enormous interest for AI insofar they recognize in emotion a functional role, bridging the gap between inarticulate reactions and cognitive representations. In the case of fear, we can say that appraisal of danger implicitly involves an inarticulate anticipation of harm. In order to synthesize a functional theory of emotion, we have presented an approach that takes into account a variety of causal phenomena involved in the appraisal process. We have implemented the DASEIN model of dynamic appraisal in a robotic agent, an experiment that resulted in the generation of emotional behavior and the ability of the robot to anticipate potential harms and benefits of the situation when no static reading in the sensors provides the means for such discrimination (type-2 problem). We can therefore conclude that the emotions can aid the synthesis of anticipatory cognitive systems, through founding possible categorizations on dynamic appraisal.

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