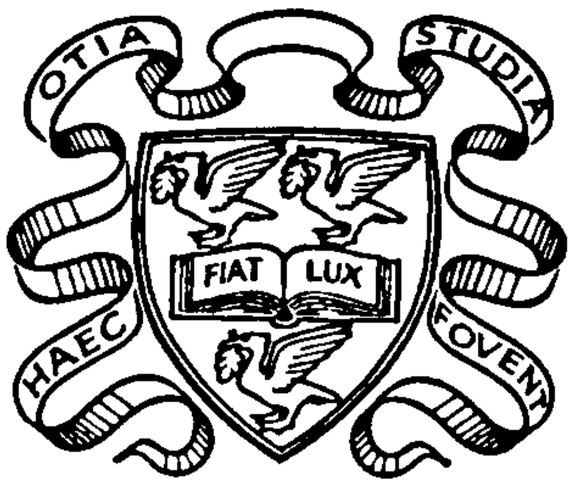
The Emoter: A Model that Employs Emotional Behaviour in the Management of Limited Resources.

Thesis submitted in accordance with the requirements
of the University of Liverpool for
the degree of Doctor in Philosophy
by Shaun Allen.

September, 1994



This one is for:

* My parents without whom ...

* Dr. T. J. M. Bench-Capon whose continuous enthusiasm and supervision requires more than a simple acknowledgment.

* K. H. & A. D. because I promised that it would be.

Contents

List of Figures

List of Tables

LIST OF TABLES

Chapter 1

Introduction

1.1 Research Aims

This thesis describes research aimed at the development of a system, termed the *Emoter*, which will exhibit emotional behaviour and use that behaviour to resolve conflicts in a multi-agent environment. The concept of emotional behaviour will be taken from a theoretical model which describes emotion. Such a system has been designed to aid the explanation of emotional behaviour and to model groups of agents where emotions may influence their plans and resolve conflicts.

1.2 Motivations

Research in artificial intelligence (AI) has for many years focussed on the problem of a single intelligent agent operating in the absence of other intelligent entities. It is only in the last decade that a distributed artificial intelligence (DAI) community has developed to address multi-agent activity. Early researchers adopted a basic assumption of benevolent agents where agents possess common or non-conflicting goals (e.g. Lesser & Corkill, 1983; Georgeff, 1984).

Recently, DAI researchers have acknowledged ideas that have been firmly

embedded in the social psychology circles of research since Coser (1956) and Simmel (1955). That is,

> 'conflict management and conflict resolution are considered to play an important and positive role in cooperation and the maintenance of social stability.' (Galliers, 1988, p. 1)

This research was motivated firstly by a belief that intelligent machines will inevitably be faced with the conflict situations naturally imposed by a constantly changing and unpredictable environment. In addition, such agents will have their own set of desires and goals, and will not necessarily help another agent with information or with actions.

Secondly, there is the belief that thirty five years of conflict studies in social psychology are relevant to the current development of computational models of multi-agent interaction, e.g. Galliers (1988) and Rosenschein (1985). Emotions, although common in the real life management and resolution of conflicts, and consequently a part of the social psychology literature, have been ignored by DAI research. This is natural considering the apparent lack of realistic emotional models. Recently however, interest in the field of motivation and emotion has produced computational theories of emotion which although reside at a preliminary stage to future implementations, nevertheless offer a chance to explore the merits of emotional behaviour for multi-agent activity.

The final motivation for this research is the belief that emotions are far from being irrational; emotions serve an extremely rational function that may be exploited by Artificial Intelligence for resolving conflicts between agents and enhancing their ability to survive in an unpredictable environment.

1.3 Original Contribution

Two overlapping themes provide the original contribution for the research. These are:

- Improvements to the computational model of emotions.
- Employing the model of emotions to manage and resolve conflicts.

The former reflects adaptations to the cognitive orientated theory suggested by Frijda (1986). Many of these improvements address a number of problems with the ACRES implementation of Frijda's theory (Swagerman, 1987) that were identified by Moffat et al. (1993). The problem of 'hasty' or volatile emotions is tackled using an attentional filter that dampens emotional shift in all but extreme events. Feedback during the processing of emotional events to the attention filter provides an explanation of emotional moods. Also, Frijda's misleading linear diagram (ref. p.454) of the emotion theory is replaced using a blackboard architecture.

The resulting model places an emphasis on the expressive aspect of emotions without dwelling on introspective reports. Unlike previous implementations, this model employs action readiness in a major role. Such an emphasis allows the exploitation of emotions to manage and resolve conflicts. A 'society' of computer agents, as modelled in this thesis, use emotions to manipulate the mental states of each other. Emotions are also used in the preparation of actual overt (or cognitive) response, under conditions that such response is felt to need extra resources or adjustments.

Finally, the effectiveness of employing emotion in these conflict management and resolution roles, and ultimately as a survival technique, are discussed.

1.4 Theoretical Background

The research described here is an extension of the computational model ACRES by Swagerman (1987). The properties of the resulting model of emotions owe much to the theories of Frijda (1986), Sloman (1987) and other motivation and emotion theorists, such as Bower and Cohen (1982). Aspects of the work of Oatley and Johnson-Laird (1987) form the grounding upon which the proposed theory of emotions is incorporated into multi-agent interaction.

Background to the social psychology of conflict was provided by numerous sources, notably Porter and Taplin (1987), Sycara (1988) and Deutsch (1971).

1.5 Methodology and Testing

The methodology has been to create a computational model of the theory, and then implement that model, in the language C++, on a simple domain which is at once tractable and rich enough to contain the range of behaviour necessary to show emotion. The implementation of multiple agents provides results to gauge the import of emotional behaviour for the domain. Such results depend on the agents having believable emotional behaviour, and as such offer a test of the validity of the theory employed.

The emphasis of the research programme is both the development of a realistic emotional model and the influence that such a model has upon conflict scenarios. The specification and description of the model offer valuable tools for the understanding of emotion. Combined with the implementation, a rigourous base according to which the various paths of reasoning necessary to manage and resolve conflict can be traced and tested.

To this end, there are two stages of testing:

- The ascription of emotional behaviour.

- Analysis of the import of emotional behaviour for conflict resolution.

Incremental improvement of the theory has occurred via the retrospective analysis of these results.

1.6 Disclaimer

It should be noted that there is no claim that the thesis describes a computer system that is definitively emotional. Whether a computer system can be said to have real emotions or even to experience emotions, is controversial. The author will not express an opinion on this philosophical point. The model shows behaviour that answers the functional description of emotional behaviour, that is to say, it satisfies general properties of emotional systems and matches accepted design specifications provided by various theorists on the emotions. The justification of the model lies in the validity of Frijda's theory as implemented by Swagerman (1987); in development by Raccuglia (1992); in analysis by Moffat et al. (1993); and through a comparison of properties between the model's processes and our concept of real emotional processes. It should be noted that the emotional behaviour expressed is appropriate for the computer agents of the restricted domain and it is not intended that conclusions be drawn which relate to human emotions in all domains of real life. Therefore terminology like *emotion*, *affect*, or *feel* should be read as if in quotation marks.

1.7 Thesis Outline

Chapter 2 comprises a literature review that reflects the theoretical background and developments of both emotion and conflict in multi-agent scenarios. It provides terminology and concepts for both areas as a preliminary to explaining the computational model developed with this research.

Chapter 3 describes Frijda's theory and the adjustments this research adopted. The chapter concerns the top level discussion of the proposed model. A comparison with related work is made.

Chapter 4 places the computational model in the context of a domain and reveals the architecture of an agent in the system, thereby placing the computational model in perspective.

In Chapter 5, the actual model of emotion is broken down into a format of description that follows a typical emotion event.

An evaluation is then performed on the implementation in Chapter 6. This provides a number of conclusions that are used in Chapter 7 for a critical discussion of the system; its limitations; the roles it takes in conflict; and how the system may be exploited to address new directions of research.

Chapter 2

Literature Review

2.1 Introduction

The aim of this chapter is to show the problems inherent in studying emotion and conflict resolution. It should be noted at this stage that the avenue of research is aimed at cognitive human emotions. The field of emotion includes non-human, e.g. animal, emotions but these are not examined in detail due to time constraints. This chapter will examine both emotion and conflict resolution by reviewing definitions and theories. Then, by discussing the applications of this research to Artificial Intelligence the current position as regards computation can be shown. By the end of this chapter the reader will gain an insight into the phenomena of emotions and conflict resolution along with an understanding of relevant concepts and terminology.

The literature on the emotions and conflict resolution covers many disciplines, e.g. psychology, sociology, physiology and artificial intelligence. It consists of decades of research and as such, this chapter can only hope to provide the reader with the information necessary to understand the domain broadly. In-depth information will focus on recent developments with relevance to computer implementation. In addition, this chapter will afford the reader an 'up-date' on the

current research in the field.

2.2 Approaches to Modelling Emotion

2.2.1 What is an Emotion?

Naturally, any study begins with subject definitions. With both human emotion and non-human emotion, there is no general consensus on the exact definition of emotion. For example, some scientists and laymen consider "hunger" an emotion, others do not (Frijda, 1986). The difficulties inherent in defining emotions include:

- The lack of a single criterion, or even a group of criteria, for their identification.
- The complexity and lack of knowledge on anatomical and physiological mechanisms involved.
- Problems due to the lack of a unified terminology.

Read (1993b) insists the current terminology regarding emotion is

> 'too vague, and burdened with acquired meaning.' It needs to be replaced with terminology that 'emerges from a putatively complete theory of the conceptual space of mechanisms and behaviours, spanning several functional levels, (e.g.: neural, behavioural and computational.)'

When words such as feeling and affect are found in this thesis, it will be made clear whose usage is being followed. Hopefully this will avoid problems the reader may encounter when making comparisons between various theories on emotion. For the most part, the term emotion will be used broadly. In this way, the reader

is encouraged to build a general concept of emotion that reflects its every day usage.

Consider the following definitions:

> 'An emotion may be defined as a patterned bodily reaction of either destruction, reproduction, incorporation, orientation, protection, rejection, integration, or exploration or some combination of these, which is brought about by a stimulus.' (Plutchik, 1962)

> 'It is my basic assumption that the labels one attaches to a bodily state, how one describes his feelings, are a joint function of ...cognitive factors and of a state of physiological arousal.' (Schachter, 1970)

> 'I am aware of no evidence for the existence of a special condition called "emotion" which follows different principles of action from other conditions of the organism.' (Duffy, 1941)

Despite the problems of labelling a phenomenon emotional, many researchers consider human emotions to have two aspects:

- The state of individual experience or feelings. This state may be analysed and reported through introspection. The experiential state requires the individual judgement of a situation which depends on sensory inputs, past experience, neurophysiological mechanisms, mental attitudes and other aspects.
- The expressive or behavioural aspect of emotions. This affects mainly the motor system, e.g. gestures; the autonomic system, e.g. respiration; and the endocrine glands, e.g. adrenals. Other effects can be recorded for intracerebral changes such as thermal and electrical activity.

In addition, there are considered to be general properties that characterise emotional processes. These are:

1. **Lack of Voluntary Control**

   - An external stimulus is necessary for the initiation of emotional reactions which cannot be voluntarily created. We cannot turn on emotions whenever we want to although we can obtain a similar effect by say remembering past emotional events.
   - Interpretation of the stimuli that results in emotional behaviour is involuntary. For instance, an exciting thought is interpreted without our consent. We cannot control the way it is interpreted to make a sad response.
   - Emotional responses are involuntary and difficult to repress. For instance, if we are embarrassed, we cannot control the flushing of our face and we find it difficult to repress.

2. **Positive and Negative Reinforcement.**

   Emotional acts involve personal feelings which may be either pleasant or unpleasant. This condition of conscious options is termed the affective process. It orients behaviour towards or away from the stimulus and therefore repetition of the experience as well. Lilly (1960) terms these two behavioural mechanisms as the start and stop systems.

3. **Motivation.**

   The affective process obviously directs behavioural performance, thus motivating the individual to approach or avoid an emotional situation.

4. **Modifications of Sensory Interpretation and Responsive State.**

   During the time that an emotion affects an individual and until that emotion disappears, the interpretation of sensory inputs is shaded by the emotional

state, e.g. a joke is not amusing when a friend dies.

5. **Necessity of Understanding Sensory Input.**
   Insulting words may shock us and produce anger, but only if we understand their meaning. The same words in an unknown language may not seem insulting.

6. **Emotional Contagiousness.**
   Observing emotions in other individuals especially seeing our own emotion reflected in another individual reinforces our personal emotional experience.

7. **Feedback.**
   Feedback tends to prolong and facilitate the pattern of emotional response. The feedback mechanism allows the magnification of sensory perceptions and allows the facilitation of the establishment of conditioning.

8. **Nonlinearity of the Stimulus-Response Relation.**
   The quantitative and qualitative nature of emotional responses often depend more on individual characteristics than magnitude or pattern of the stimulus. However, environmental factors may influence through reinforcing, inhibiting or modifying behavioural patterns.

9. **Influences upon the planned behaviour.**
   According to our emotional state a behavioural plan is selected from our repertoire. Different emotional states influence our planned behaviour: either a new plan altogether or a slight alteration to the same plan.

It is worth noting that according to Meyer (1933) it is not possible to draw a line between emotional and non-emotional reactions. Similarly, Duffy (1941) states

> 'Emotion has no distinguishing characteristics. It represents merely an extreme manifestation of characteristics found in some degree in all responses.'

Hilgard (1962) suggests there is a continuity among emotional states and that there is a slow transition with varying degrees in the quality and quantity of the manifestations. Although there is no clear distinction between emotional and non-emotional activities there is a zone of contact that represents integration of the two. This principle of zone boundaries also applies to the limits between different emotions: several of them overlap and mix with each other. Thus, emotions may blend with each other, and also with non-emotional phenomena.

It should be obvious that the question 'what is an emotion?' is difficult to answer. For this reason a working definition is now provided and an accurate definition at the end of the chapter.

Kleinginna and Kleinginna (1981) categorised hundreds of definitions on emotion, and concluded by trying to encapsulate everything into one.

'Emotion is a complex set of interactions among subjective and objective factors, mediated by neural/hormonal systems, which can (a) give rise to affective experiences such as feelings of arousal, pleasure/displeasure; (b) generate cognitive processes such as emotionally relevant perceptual effects, appraisals, labelling processes; (c) activate widespread physiological adjustments to the arousing conditions; and (d) lead to behaviour that is often, but not always, expressive , goal directed, and adaptive.'

The problem with this definition is that it is too vague and embraces too many possibilities. As a working definition however, it gives an idea of the term 'emotion', an insight into the research already performed and an idea of the research still needed.

2.2.2 Historical Development

There are a great number of theories on the emotions. Each attempts to give a description of that which we feel every day, which we read of and associate with in literature. The subject of the emotions has entertained and plagued researchers for centuries. Historically, the rationalist philosophy of the emotions began with Plato and Aristotle, but Descartes provided a greater discussion in 'Passions de l'ame.' His view of emotions, or passions, was as a basic determinant of action – they intervene between stimulus and response to be less rational than it otherwise would have been. It should be noted at this stage that this view is a key notion when applying emotions to conflict resolution: emotions present an explanation of behaviour that cannot be obtained by simple goal directed considerations alone.

As Strongman (1987) notes, the next significant discussion of emotion was from Darwin in 1872. He laid emphasis on overt action as the biologically significant aspect of emotion. Environmental stimuli provide the causative elements for the action. In addition, his theory of evolution expressed the continuity of emotion between man and animals. It is therefore valid to research the emotions of animals and apply the information to man.

Shortly after this, James (1884) provided what is generally regarded as the first psychological theory of emotion. This theory is amongst five historically significant theories. Each will be presented as a brief synopsis since the aim of this section is to show the wide ranging theories on emotion.

The James-Lange Theory.

The grouping of the authors for this theory is confusing since Lange (1885) did not agree with James (1884) one hundred percent. The main exponent of the theory was James but it was also presented by Lange in a separate report. The gist of the theory is shown below

> 'the bodily changes follow directly the PERCEPTION of the existing fact, and that our feeling of the same changes as they occur IS the emotion' (James, 1884, p.189; capitals his)

The theory hypothesises that emotional behaviour leads to emotional feeling. It rests on the belief that visceral discharges associated with an environmental situation lead to the emotion. The argument that he put forward was heavily based on introspection. James gives an example of the theory by suggesting we do not cry because we feel sorry - 'we feel sorry because we cry' (James, 1890)

The Cannon-Bard Theory.

Although the theory came from Cannon (1927;1931;1932) much of the experimental work came from Bard (1929;1934;1950). Cannon offered this theory as an alternative after repeated criticism of James. He argued that visceral reactions are too slow to account for the arousal of emotions and that

> 'the peculiar quality of the emotion is added to simple sensation when the thalamic processes are aroused' (Cannon, 1927 p.119)

Thus when the thalmus discharges, we experience the emotion almost simultaneously with occurring bodily changes.

W. McDougall

McDougall (1928) believed that behaviour stems from approaching or avoiding stimuli. He proposed that the two feelings of pleasure and pain modify all goal-directed behaviour. The emotion theory begins with an assumption that goals become more specific with the evolution of man. Similarly, goal-directed behaviour becomes more specialised. Instincts are central to McDougall's explanation for all thoughts and actions. Such instincts depend on perception suggesting perception triggers emotion. For example, an individual may perceive a mortal threat

thereby invoking a basic survival instinct to flee or feel fear. The emotion theory presented was not specific as to bodily responses or cognition aspects.

J.W.Papez.

Like Cannon, Papez (1937) offered a neurophysiological basis for his theory. Although Papez quoted Bard's 1929 results to show a link between hypothalmus and emotional expression, he viewed the cortex as an essential aspect of subjective emotional experience. Further, he suggested that emotional expression and experience may be separated from one another in an individual. Strongman (1987) views this as 'a somewhat dated view.'

J.B.Watson.

Watson (1929) presented the first of the behaviourist theories. It is outlined in the following quotation:

> 'An emotion is an hereditary "pattern-reaction" involving profound changes of the bodily mechanism as a whole, but particularly of the visceral and glandular systems.' (Watson, 1929 p.225)

The main contributions he offered to the research on emotions was to place emphasis on behaviour rather than feelings and internal states. He viewed emotions generally as disorganising and offered this as the essential difference between emotional and instinctive reactions. He also proposed that three types of fundamental emotional reactions exist, namely fear, rage and love.

Although these five 'classical' theories look naive, they are important for the foundations of more recent views.

In general, theories can be organised into a broad classification according to the type of approach adopted. The categories are:

- Arousal, motivation or physiological.
- Behavioural.
- Psychoanalytic or experiential.
- Cognitive.

2.2.3 Arousal, Motivation or Physiological Theories

The main point is the acceptance that emotion is merely a part of a continuum, be it arousal, motivation, pleasantness/unpleasantness or behaviour. The implication is that the concept of emotion should be removed from scientific usage.

Duffy (1934; 1941) gives an extreme version by arguing that emotion (and all behaviour) can be broken down into changes in: level of energy, organisation and conscious states. She suggests each of these occurs on a continuum and that it is meaningless to study emotion because it 'has no distinguishing characteristics' (1941). She advocates a study of any response according to its energy level, how well it maintains goal-direction and the environmental situation that it occurs in. Young (1961) and Bindra (1969) also follow the idea of a continuum. Although such views have been overtaken and now appear to be as meaningless as they view emotion, they do point to important links between emotion and motivation, both of which have significance in attempting to account for psychological functioning.

2.2.4 Behavioural Theories

These theories tend to view emotion as dependent on complexities of classical conditioning and the nature of reinforcing stimuli. Most concern only observable behaviour and the environmental conditions which are believed to control it.

Millenson (1967) and Gray (1971) offer good examples in the behavioural tradition. Although it is beyond dispute that aspects of emotion can be conceptualised in a behavioural way, the significance of cognitions and subjective

experiences are ignored. If a full description of the emotions is required, then behavioural theories are left wanting. This is reflected by their recent decline in influence.

2.2.5 Psychoanalytic or Experiential Theories

Theories exemplified in this category are concerned with a conceptual analysis of emotional experience. They investigate aspects of emotional experience that are non-observable. A typical psycho-analytical theory is proposed by Rapaport (1950). He views the temporal sequences of feeling and the emotional expression (see Cannon and James) as detracting from the idea that both are the result of a common variable, namely something unconscious. Thus,

> 'affects regulated from the unconscious are defined as discharge processes of energies of instinctual origin.' (Rapaport, 1950 p.21)

Sartre (1948) also provides a good example, this time from an existential viewpoint. He views emotions as attempts to make a qualitative change in an object, to give that object a new quality without substantively changing it. Thus emotions are transformations made on a world that one cannot deal with. In the case of fear for example, Sartre describes this as consciousness that negates or denies something dangerous which substantively exists in the external world.

Throughout these theories, terms such as 'consciousness' and 'will' are present. As such, the only significant method of investigating their claims is with introspection.

2.2.6 Cognitive Theories

The main idea, whether explicit or implicit, in the cognitive theories is the appraisal of a situation or stimuli. It can be described as a process of cognitive

evaluation. Three authors are highly influential in this field: Schachter, Arnold and Lazarus.

S. Schachter.

Schachter (1959;1964;1970) developed a cognitive/physiological view of emotion. The cognitive appraisal of a stimulus or situation determines the quality of feelings whereas the physiological arousal determines the intensity of feelings. He maintains that physiological arousal is given its direction by our cognition of what brought it about. Three propositions were made:

- If the reasons for physiological arousal cannot be provided then the individual's experience will be labelled and he will react to it in whatever cognitive way he can.
- If the reasons for physiological arousal can be provided the individual will probably use that cognitive account and no others.
- If the individual encounters the same cognition over time the experience will only be termed emotional if he is physiologically aroused.

Schachter's theory of emotion depends on interaction between physiological arousal and cognitive appraisal. The theory mentions very little on how cognitive factors influence emotions.

M. B. Arnold.

Arnold (1960;1968;1970) believes the appraisal of a situation or stimulus is central to an emotional reaction. Through cognitive analysis, she suggests we immediately, possibly involuntarily, evaluate any encounter. This appraisal results in a tendency to approach 'good' evaluations; to avoid 'bad' evaluations; and to ignore anything evaluated as 'indifferent'. The tendency is felt and also apparent in the physiological pattern of reaction. Also important to the theory, are memories of

past emotional experiences. Arnold suggests that affective memories form the basis of appraisal for novel situations. These affective memories combine with aspects of a situation to predict the future results of an emotional encounter. From this a plan of action is developed with various possibilities for coping with the situation - the best one is chosen. Thus Arnold describes a perception; appraisal; feeling; and finally action cycle of emotion.

R. S. Lazarus.

Lazarus (1970;1980;1984) regards individuals as evaluating, with respect to personal significance, each situation they encounter. Thus,

> 'each emotional reaction ... is a function of a particular kind of cognition or appraisal.' (Lazarus et al. 1970, p.218)

The concept of cognitive appraisal is divided into three main areas: primary, secondary and reappraisal. Primary appraisal is

> 'the evaluation of every transaction or encounter for its significance for well-being.' (Lazarus et al. 1980, p.193)

Secondary appraisal is the evaluation of an individuals coping potential for direct action to alter or prevent some aversive event. Reappraisal refers to modifications in primary and secondary appraisal due to changes in the adaptational encounter.

Lazarus stresses that secondary appraisal need not follow primary and that the various components of emotion are experienced as a whole rather than as separate parts.

Emotions are generally viewed as a 'response syndrome' where emotions can be distinguished only through their eliciting conditions, their patterns of response, and how these have changed over time. Thus, emotions cannot be distinguished through their structure.

Further, Lazarus regards the emotional response system as self contained and able to interrupt and change present ongoing behaviour.

It is the cognitive approach that has offered the greatest improvements to the general understanding of emotion. Correspondingly, the upsurge in research following the cognitive approach has practically eclipsed that of the behavioural approaches. Now the majority, if not all, theorists view emotion as intricately and intimately intertwined with cognition. Strongman (1987) reflects this view with

> 'it would be foolish, not to say churlish *not* to discuss cognition when attempting to account for emotion.' (p.42)

2.3 Modelling Emotion in A.I.

To provide a computational model of emotion in Artificial Intelligence (A.I.) the actual steps leading from the stimulus to the phenomena of the emotions must be specified. Figure 2.1 represents an oversimplified account of this *emotion process.*

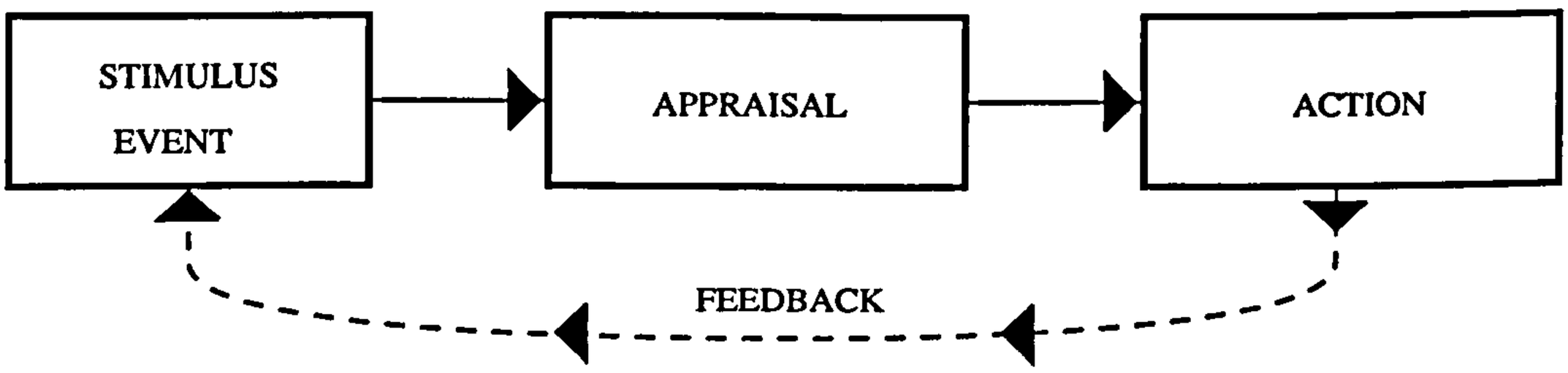


Figure 2.1: Simple Emotion Process

Within the family of cognitive theories, there are a subset known as the Conflict and Evaluation theories of emotions. Conflict theories are founded on the idea that emotions occur when a psychological tendency is stopped or when ongoing action is interrupted. The mental disturbance of this interruption is an emotional experience. Angier (1927) introduced the term in a discussion of Dewey (1894;

1895). Mandler (1984), however, says that Paulhan (1887) first proposed the idea that emotions are based on interruptions. Whatever the beginnings, conflict theories have gripped modern cognitive science. Hebb (1946) and Mandler (1975) are classic examples of the basic postulate. Likewise, Miller et al (1960) and Simon (1967) subscribe to the theory, although they talk more of interruptions to plans and dealing with multiple goals rather than psychological tendencies and smoothly flowing action.

Evaluation theories have a similar basic postulate in that emotions arise with the evaluation or appraisal of stimuli where there is potential conflict with the resulting outcome and the desired outcome. Most derive from Lazarus (1966). Among the more interesting of the family of conflict and evaluation theorists are: Bower & Cohen (1982), Pfeifer & Nicholas (1981), Sloman & Croucher (1981), Toda (1982), Abelson (1983), and Wegman (1985). Each of these theorists suggest a similar information-processing model of emotion. A system with multiple goals and finite resources will require the management of interruptions: that is, when one goal becomes more important/urgent than the ongoing processing of another, a disturbance and therefore an emotional experience occurs. Frijda (1984; 1986) presented a description of the 'emotion process' that shares many essential features with these information-processing models. His model manages 'concerns', which are similar to goals, in an unpredictable environment.

2.3.1 Recent Developments

Recently Sloman (1987), Beaudoin & Sloman (1991; 1993) have argued that emotional disturbances arise with the interference or modification of mental processes by new thoughts or motives. They regard emotions as epiphenomena for systems of motive processing. The theory is one of the conflict and evaluation theories on emotion and is based on Simon's (1967) work and examines Kuhl's (1992) extensive theory of the regulation of motivation as potentially useful. To examine

their theory, Beaudoin and Sloman are developing a prototype model called the 'Nursemaid'.

Perhaps the most computationally advanced model of emotions is that of Frijda and Swagerman (1987) which has been implemented as a program called 'ACRES' (Swagerman, 1987). Although Frijda's research is constantly cited, it is perhaps strange that the model ACRES was ignored as a research tool until Raccuglia (1992) and Moffat et al (1993) provided extensions and an analysis to the model. Moffat is currently developing a new model called 'WILL' which

> 'advances on ACRES in its architecture, its modelling of attention and in its domain independence' (Moffat, 1993)

On a similar vein, Oatley & Johnson-Laird (1987) and Oatley (1992) propose that emotions arise at certain junctures in plans and arouse the whole system to deal with the problem. Oatley (1992) states that

> 'Emotions are a human solution to problems of our simultaneous multiple goals, of our limitations and uncertain knowledge, and of our interactions with others. By contrast, gods and robots have no contradictions among their goals, and have full powers and perfect knowledge of their worlds. There is no need for them to have emotions.' (p411)

Although this viewpoint is accurate for individual robots, 'societies' of robots may have contradictions among their goals, limited resources and insufficient knowledge of competing and/or cooperating enemies and allies. In such a situation, emotions may play an important role since the role of emotions can be *interpersonal* as well as personal.

This short section characterises the direction and interest in modelling emotion in artificial intelligence and the more recent field of 'animats'. Their aim is to design and build a complete autonomous agent. The problem in modelling

emotion is that knowledge of the relation between emotional behaviour and the control structure or architecture is very limited (Pfeifer, 1993).

2.4 Conflict Resolution

Coser (1967) defines conflict as

> 'the struggle over values or claims to status, power and limited resources, where the parties involved attempt to obtain these values and also neutralise, injure or eliminate rivals.'

Social conflict is one of the most ubiquitous of events and as such is a complex, multi-faceted field. There are many approaches to its study, management and cessation at various levels of analysis.

This research will focus on small scale group interaction. It will emphasise a micro-structural approach rather than macro-structural since discussions of class cohesion through conflict, class conflict and revolution would only detract attention from the focus. Thus figures such as Marx, Sorel, and the neo-Machiavellians (Pareto, Mosca, and Michels) will be excluded.

2.4.1 The Nature of Conflict

In the real world people interact constantly. They often bring differing goals to the encounters. The goals may be tangible, such as a limited food supply, or they may be abstract as in freedom or status. Whatever the goals, interaction is the normal state of affairs – rarely is it possible that an individuals' goals can be pursued without interaction.

Interaction can be seen as a continuum of conflict, where the two extremes are 'pure conflict' and 'absence of conflict'. 'Pure' conflict occurs when there is only one winner and any other participant is a loser. In game theory 'pure' conflict

is equivalent to 'zero-sum' and has been researched extensively (Luce and Raiffa, 1957).

In the real world however, pure conflict is extremely rare. Canonical examples usually take war as pure conflict, but in so doing assume simplifications of the conflict. For example, surrender or retreat may be mutually advantageous. Similarly, the absence of conflict is extremely rare. All participants may have identical goals, but conflict will probably occur because of an overlapping of interest. Rosenschein and Genesereth (1985) explain that participants in the case of conflict-free interaction would be mainly concerned with helping each other with the common goals. In real life the participants would probably have separate goals of who would contribute most to the joint solution.

Thus most interactions fall between the extremes of the conflict continuum.

Whether the interactions are multi-international or dyadic, the nature of the conflict will have common general properties.

- At least two units are required be it man against environment or international conflict (Mack and Snyder, 1971).
- Resource limitations must be present otherwise all desires would be catered for and no conflict would arise (Mack and Snyder, 1971).
- There must be interaction between opposing units (Mack and Snyder, 1971).
- Actions to obtain resource limitations must be possible (Kerr, 1954).
- Differing goals and/or beliefs give rise to the conflict (Druckman, 1977; Brehmer, 1977; McClintock, 1977).
- Power is an integral part of conflict. The acquisition or exercise of control on limited resources is termed 'power' (Sheppard, 1954).

'Resource limitations' is a term that covers many aspects. In sociological terms these are 'resource scarcity' and also 'position scarcity'. Combined together, these

aspects cover, for example, the limited supply of objects or state of affairs; the fact that two objects cannot occupy the same position; and the limitation of time and energy.

Galliers (1988) describes conflict as being subjective,

> 'conflict of goals or conflict of beliefs exist between one agent and another, when the agents' beliefs or goals with respect to the same proposition are believed by the one agent to be in opposition, and this agent is also committed to a goal to change the other's belief or goal.
>
> Alternatively, there may be a mutual belief about the difference in belief or goal between the participating agents, in which case, conflict exists if either or both also has a committed goal to change the other's belief or goal.' (p.123)

Such a definition contains the properties described above but also emphasises that conflict can be subtle as well as explosive.

2.4.2 The Functions of Conflict

Conflict has strong negative connotations. It often produces strong negative emotions; is often stressful; constantly interferes with the communication between the parties involved; and diverts attention and needed energies away from major tasks. Besides such obvious disadvantages, conflict also encourages group leaders to tend towards authoritarian rather than participative styles of leadership. Consequently, the working environment deteriorates when groups are in conflict (Fodor, 1976). In addition negative stereotyping is common in conflict situations. Participants view opposing agents in increasingly unfavourable terms.

Finally, on the negative side of conflict, group members tend away from viewing the opponents position with any form of merit. As a result, it becomes increasingly difficult to see the other's perspective and thus it is harder to develop

an effective resolution of the conflict (Blake and Mouton, 1984).

Although conflict is often only seen with negative connotations, it has under some conditions a positive side. Simmel, Coser, Dahrendorf and Gluckman have analysed conflict as having a positive, functional value for group structures. The functions of conflict, according to Porter and Taplin (1987) who cite Coser and Simmel are to:

- Establish unity and cohesion.
- Produce stabilising and integrative elements
- Ascertain the relative strength of antagonistic interests within the structure.
- Constitute mechanisms for maintenance and/or readjustment of power balance.
- Produce associations and coalitions.
- Help reduce social isolation and unite individuals.
- Maintain boundary lines between new associations/coalitions.
- Act as a 'safety-valve' to reduce frustration and aggression.
- Produce situations for consensus.

Conflict brings problems that have been ignored into consideration again; it encourages the consideration of new ideas and new approaches (Coser, 1956); and it encourages the monitoring of opponents actions. Each of these effects may increase the motivation and performance of agents involved in the conflict, but only when that conflict is carefully managed and rationality is still present.

Thus the management of conflict is an extremely important area of research especially since Dahrendorf (1958a) states

> 'Not the presence, but the absence of conflict is surprising and abnormal, and we have good reason to be suspicious if we find a society or social organisation that displays no evidence of conflict.' (p.127)

2.4.3 Methods of Conflict Resolution

The term 'conflict resolution' describes the management and control of conflict situations. Each method of conflict resolution attempts to end the conflict and instill a period of 'peace' for parties concerned.

Most research into this area stems from labour negotiations, international relations, and the areas of law and judicial decision (for example, Meynaud & Schroeder, 1961).

There are ten major means of conflict resolution. The methods are as follows and will be described in subsequent sub-sections.

1. Avoidance
2. Conquest
3. Education and Contact
4. Spontaneous Remission
5. Direct Negotiations
6. Mediation
7. Arbitration
8. Judicial Decision
9. Induction of Super-ordinate Goals
10. Escalative Intervention

Avoidance

Simmel describes this process as the 'disappearance' of one or both parties. It requires an end to contact between parties. One or both parties simply avoid the conflict situation thereby ensuring no present conflict evolves. Whether this completely ends the conflict or merely postpones it until a future event is a moot

point. Boulding (1962) however, gives a fine example. If a dispute occurs during bargaining, to avoid the conflict, one then seeks another bargainer.

Conquest

Boulding defines conquest as a method

> 'by which one of the parties is, in effect, removed to infinity, or removed from the scene, leaving the victor in sole possession of the field.' (p.309)

Simmel terms this 'zero-sum' method 'victory'. Coser similarly describes the process as a victor dealing a 'death blow'. Each researcher implies that both the victor and the vanquished make a contribution to the final solution (Coser, 1961; Simmel, 1964, p.114) Among Porter and Taplin's many examples that differentiate between 'Avoidance' and 'Conquest' they provide an explanation of marriage.

- Couples who do not get along, divorce. (*Avoidance*)
- Couples who do not get along, shoot at each other and one is killed. (*Conquest*)

Education and Contact

Most examples of this method come from interracial conflict. When the parties concerned are educated, commonalities are presented that often reduce conflict. Similarly contact will often disperse negative propaganda and confirm the positive educational elements. Unfortunately, this method is constantly regarded as a solution to many conflicts where it is not appropriate. Education may emphasise elements of difference and contact may exacerbate existing tensions.

Spontaneous Remission

Although by its very nature, this method cannot be forced onto a conflict situation, it is still a means for the cessation of conflict. In medicine, this method may result in a disease vanishing overnight, leaving the doctor with no rational explanation as to the underlying causes. Porter and Taplin (1987) again provide fine examples by suggesting actors in a conflict may

> 'tire themselves out which then leads to withdrawal from the field of conflict (avoidance)' (p.23)

or

> 'It may also result from nonverbal communication which states both parties agree spontaneously to terminate conflict with little or no loss of face or honor.' (p.23)

Direct Negotiations

Direct negotiation is a dyadic state where the two parties pursue communication to resolve differences. It is a form of compromise with many tactics to create a solution. This method of conflict resolution is by far the most common strategy and is often termed bargaining. The process involves both parties exchanging offers, counter-offers and concessions in an attempt to reach a settlement. If the process is successful both parties have an acceptable solution. It is possible that under such circumstances there is also enhanced understanding and improved relations between the two parties. The alternative is costly deadlock and intensified conflict (Lewicki & Litterer, 1985; Lewicki, 1986).

The outcome of negotiations is strongly affected by the specific tactics adopted on each side. Many aim at reducing opponent's aspirations.

Thus parties attempt to convince opponents that they have little or no chance of achieving their goals and should consider accepting less substantial offers. A

common tactic is the 'big lie' technique. (Chertkoff & Baird, 1971)

This procedure involves for example, one party claiming their economic break-even point is much lower than it really is or that it has other potential clients and will withdraw from current negotiations if its proposals are not accepted.

Another technique for reducing aspirations is that of extreme initial offers (Chertkoff & Conley, 1967). Such offers put strong pressure on opponents to make large concessions.

Perhaps the most important factor affecting the outcome of negotiations is the parties' orientation towards them. Huber et al. (1987) suggest that when negotiations focus on the potential benefits rather than potential losses or costs, the nature and course of the actual process is facilitated.

Similarly, Pruitt et al. (1983) point out that negotiations can be viewed as distributive, or 'win-lose' situations where gains on one side are linked to losses on the other. Alternatively, negotiations can be viewed as integrative agreements, or 'win-win' situations where the interests of both parties are not necessarily incompatible and potential gains can be maximised for all. Integrative agreements reduce contentious tactics such as threats, 'unyielding positions' and they allow the exchange of accurate information, and the enhancement of relations.

Pruitt et al. (1983) offer five types of integrative agreements:

- *Broadening the Pie* – available resources are broadened so that both parties can obtain their major goals.
- *Non-specific Compensation* – the party that does not achieve its major goal is compensated on an unrelated issue.
- *Log-rolling* – each party allows concessions in exchange for higher value concessions in other areas.
- *Cost Cutting* – the party that does not achieve its major goal has its costs reduced or eliminated.

- *Bridging* – neither party achieves its major goal but a satisfying alternative option is developed.

Mediation

When negotiations reach an impasse, the aid of a third party is needed. By definition the third party must not be directly involved in the conflict. Mediation is the process whereby disputants reach a solution with the aid of a guide. The guide or mediator has no formal powers to impose an agreement on both sides but instead, clarify issues, suggests recommendations for compromise, and in general facilitates communication between the two disputants (Carnevale & Conlon, 1988). Mediators often use a combination of techniques to accomplish their role as guide. Two common methods that provide less active intervention are:

- *Initiation* – here the third party acts as a middleman through which communication flows. This conflict resolution technique is basically a dyadic relationship, yet the mediator is essential for communication. For example, the role of a match-maker is to initiate the contact of man and woman for marriage.
- *Inquiry/investigation* – the third party discovers the underlying causes of the conflict and as such educates the combatants in the hope of a settlement. In labour negotiations the third party takes the form of a 'fact-finding' committee.

Arbitration

An arbitrator performs many of the same functions as a mediator. He guides, initiates and directs the resolution of conflict process. In addition to these functions, an arbitrator can pass judgement. Simmel (1964) notes:

> 'as long as the third (party) properly operates as a mediator, the final termination of the conflict is exclusively in the hands of the *parties themselves.* But when they choose an arbitrator, they relinquish this final decision' (p.151. Author's emphasis)

In theory this quotation is not entirely correct since the final decision may take the form of a strong *recommendation.* In reality, the personal stature and expertise of the arbitrator often makes it difficult to reject such a recommendation.

Arbitration can therefore take many forms depending on whether an agreement is recommended or imposed. *Voluntary arbitration* allows the parties to reject an agreement whereas *binding arbitration* is a decision made in advance by the parties to accept the impositions of the arbitrator's terms of agreement.

Judicial Decision

Although arbitration and judicial decision both involve the third party imposing judgement, judicial decision does not usually involve preliminary guidance to resolution. Judicial decision has a greater coercive power and is often termed 'law'. It is a government's final method of conflict resolution for criminals. A policeman, as opposed to a court of law, holds the dichotomous roles of mediator and arbitrator.

The Introduction of Super-ordinate Goals

Fiske & Taylor (1984) noted combatants in general perceive the world in terms of 'us' and 'them'. This magnifies differences between the parties and also increases the disparagement of 'enemies' and outsiders. Through the induction of super-ordinate goals the parties of a conflict will focus on common aims which reduce the barriers of communication, coordination and agreement. Thus, the 'us' and 'them' attitude, and its associated problems are reduced.

A typical example is the induction of growing competition from foreign companies. Faced with such a common goal, companies temporarily join forces to turn back the wave of foreign imports that threaten their joint livelihood.

Escalative Interventions

In some forms of conflict, intensification can lead to resolution (Van de Vliert, 1984; 1990). This new approach to the cessation of conflict has emerged from the following central postulate. Intensification brings matters to a head thereby clarifying the underlying causes of friction, and increasing motivation towards integrative solutions. By pushing conflicts into the open, the focus of the parties attention is adjusted so that the main priority is resolution.

In the context of marriage guidance, escalative intervention provides a favourable trade-off between controlled temporary intensification of conflict and its effective long-term management (Van De Vliert, 1990).

2.5 Conflict and Cooperation in A.I.

Distributed artificial intelligence (DAI) is concerned with the problems of interacting intelligent agents. The first research in DAI focussed on agents cooperatively achieving goals without acknowledging conflict. Agents were presumed to have compatible goals and help one another. This was mainly due to their designer's fiat of built-in 'agent benevolence'.

In many cases agents are assumed to be working on the same overall problem (e.g. Lesser & Corkill, 1983). Alternatively, Georgeff (1983; 1984) has agents with potentially distinct goals. Nevertheless, he does not deal with truly conflicting plans, he assures non-interference among distinct agents' plans by identifying and protecting critical regions within those plans. Besides the attitude of agent benevolence, two other solutions are typical of early DAI: in the event of a conflict,

agents would work around it as an immovable obstacle (e.g. Sussman, 1975; Hammond, 1986) or capitulate and adopt the other's goal (e.g. Doran, 1985).

Research into DAI agents that acknowledge conflict is a new field. According to Rosenschein (1985) it is a decade old.

> 'Until now ... work has focussed on how agents can cooperatively achieve their goals when there are no conflicts of interest ...' (p.3)

2.5.1 Recent Developments

Rosenschein's work (Rosenschein, 1985; Rosenschein & Genesereth, 1985) explains the ubiquity of conflict in interactions and the need for systems/multi-agents that are flexible enough to reason about action when conflict is present.

One solution to the conflict of multi-agents is the master-slave relationship (Rosenschein, 1982). This solution is equivalent to binding-arbitration or judicial decision. A third party simply decides for the agents involved. The assumption is that communication exists between slave and master and that the agents will perform the actions asked of them. The advantages of control being exercised by a single authority are clear. Global considerations can be easily translated into pertinent actions. Similarly there is no trouble in achieving global coherence.

The problems of centralised control include bottlenecks at the central authority and slow reaction times.

When agents have control over their own actions, and have their own goals, then they will follow their own interests. Autonomous agents might possibly reject decisions from central authorities. It is also clear that central authorities may not be present in a conflict situation.

Another solution to agents' conflict resolution is the introduction of a mediator. Cawsey et al. (1992) describe an information retrieval intermediary that guides a user in deciding on appropriate literature searches. This form of conflict resolution is an inquiry/investigation mediator role.

Sycara (1988) has produced the PERSUADER program which

> 'acting as a labor mediator enters in negotiation with each of the parties ... proposing and modifying compromises and utilities until a final agreement is reached.' (p246)

Direct negotiation does not require third party intervention and as such is an appropriate solution to the resolution of conflict in a 'society' of autonomous agents. Galliers (1988; 1992) proposed a system for resolving conflicts with direct negotiation. The theoretical framework describes cooperative systems which use dialogue to resolve differences. This is an extension of the speech act theory of Cohen & Levesque (1987) and Perrault (1987).

The theory was implemented as a computer model which provided feedback to develop the framework further (Cawsey et al., 1993). The claimed result is a framework for fully autonomous agents that do not automatically believe what they are told by other agents, nor automatically adopt other agents' recognised goals.

> 'The agents *choose* what to believe and how to act' (p.131)

The trait for current developments in the area of conflict and cooperation in AI is towards autonomous agents resolving their own problems without the need of third party intervention.

2.6 Employing Emotional Behaviour as a Technique

Any method of conflict resolution attempts to bring about a cessation to conflict. This can be through conquest where the parties employ action aimed at 'death-blows'. Alternatively, more subtle attempts such as changing the other's mind

can be employed. Whatever the method of resolution, the conflict will involve a struggle over values or limited resources.

The connection of emotions to the area of conflict resolution is not trivial. Frijda (1986) reports the emotional system can be said

> 'to serve the furthering and defence of the agents interests.' (p.371)

Also, emotions

> 'serve the useful functions of watching, guarding and satisfying the individuals' concerns and realigning action toward satisfaction when disturbed.' (p.371)

Emotional behaviour manages conflicts of interest in various ways. It is the belief of the Social Sciences that the effective management of conflicts is usually achieved through contact and communication (e.g. Porter & Taplin, 1987; Deutsch, 1971).

Oatley & Johnson-Laird (1987) have argued that emotions in an individual communicate to others indicating a readiness for certain kinds of action or interaction. Similarly Frijda (1986) states

> 'What they [emotions] all do, though, is reflect and "express" what the individual is concerned with.' (p.478)

Such a communication channel is typical of preliminary stages of conflict resolution. A dialogue is set up to express and aid claims to limited resources. Subsequent stages of conflict resolution either involve committed action or recommendations.

Oatley (1992) states emotions

> 'communicate to others, tending to induce in them states similar to or complementary to our own, and thus prompting continuations or transitions in those with whom we interact.' (p.68)

Such theories of emotion are functionalist viewing emotion as useful for the preparation or selection of appropriate action. It appears emotions provide, or at least attempt to provide a promising approach for realising important interests in a continually changing environment.

2.7 Conclusion

The relevance of this chapter has been to show the traits for the areas of emotion and conflict resolution. The current trend in the theories of emotion is towards 'cognition'. In the area of artificial intelligence it is the Conflict and Evaluation theories that are leading the way. Within this subfield, Frijda, Sloman and Oatley are the current research 'giants'. Frijda's theory is perhaps the most computationally advanced with Swagerman's ACRES implementation. Therefore, Frijda's theory forms the background for the model of emotion described in this thesis. Frijda's theory is described and analysed in the next chapter.

In the area of conflict and cooperation in AI, the current trend is towards methods that do not involve third party intervention. An autonomous agent should be able to work out the problems of conflict and cooperation on its own. Thus, research is tending towards direct negotiations (e.g. Galliers)

Although using emotional behaviour to control conflict situations has similarities to direct negotiations it is not intended to replace Galliers work on belief revision. In fact, it is hoped this research will complement that of belief revision.

Chapter 3

Theoretical Analysis

3.1 Introduction

This chapter will describe and analyse Frijda's (1986) theory which has provided the framework for perhaps the most computationally advanced model of emotion, i.e. the ACRES model (Swagerman, 1987). First a summary of the theory is presented then an analysis of the requirements for emotional models is presented. This analysis views suggestions from Frijda (1986), Swagerman (1987), Moffat et al. (1993) and Beaudoin & Sloman (1993). Using the requirements analysis, problems of the ACRES model of Frijda's theory of emotions are addressed to show essential changes that should be incorporated in future models. Such a discussion constitutes a top-level description of the model of emotions employed by this research – these same improvements are explained in greater detail in Chapter 5.

Finally similar recent models/theories, most notably *Will* and the *Nursemaid*, are compared to the model presented.

3.2 Summary of Frijda's Theory of Emotions

Frijda (1982;1986;1987) belongs to the group of Conflict theorists that hold the basic postulate that emotions occur when a psychological tendency is stopped or when ongoing action is interrupted. He regards emotions as the manifestations of a concern satisfaction system. Concerns are described as dispositions that the individual brings to the situation. They develop through experience. Swagerman (1987) describes concerns as

> 'equivalent to the notions of "major goal" or "motive", as these are used in the analysis of behaviour.' (p.8)

He explains favouring the use of the term with

> 'it [the term] carries fewer connotations of striving and behaviour instigation than "goal" or "motive" ...(and) refers to the dispositions that, when appropriate circumstances arise (opportunities, wants, threats) give rise to goals and actual motivations.' (p.8)

Frijda (1986) believes emotion and action are intimately intertwined. The readiness or unreadiness for action shows in expression and is experienced in emotional feeling. Emotional phenomena are necessary consequences of optimal concern realisation with a system that has multiple concerns and limited resources. Frijda describes his 'emotion process' in terms of an information processing model (see Figure 3.1).

The emotion process is the sequence of steps leading from the stimuli to the phenomena with the sequence of steps being under the influence of various side conditions. Frijda's model shares similar characteristics with other models. Namely:

- Abelson (1983).
- Toda (1982).

- Sloman and Croucher (1981).
- Pfeifer and Nicholas (1981).
- Wegman (1985).
- Bower and Cohen (1982).

These authors hold the same basic postulate that emotional phenomena are necessary consequences for a system with multiple concerns and limited resources.

3.2.1 Frijda's Emotion Process Architecture

There are three main areas of the process (see Figure 3.1): the core process; the regulation line containing processes that influence the core process; and the inputs and side conditions. Each will be described in the following sections.

The Core Process.

Stages 1→5 are the stimulus processing and stages 6 & 7 the generation of responses.

1. **Analyser:** aspects of the stimulus event, whether real or through imaginary thought, are received. The *Analyser* codes the event in terms of known event types and what they imply with respect to cause and consequence.
2. **Comparator:** here the stimulus event is appraised with regard to the individual's concerns. Concerns are the standards that are laid down in the system and exist within the system prior to a call for action: for example, freedom from pain, presence of a given person, unhampered achievement of a goal one is pursuing. Outputs of the *Comparator* are the four relevance signals: pleasure, pain, wonder or desire. Alternatively the process can exit if the event is irrelevant.

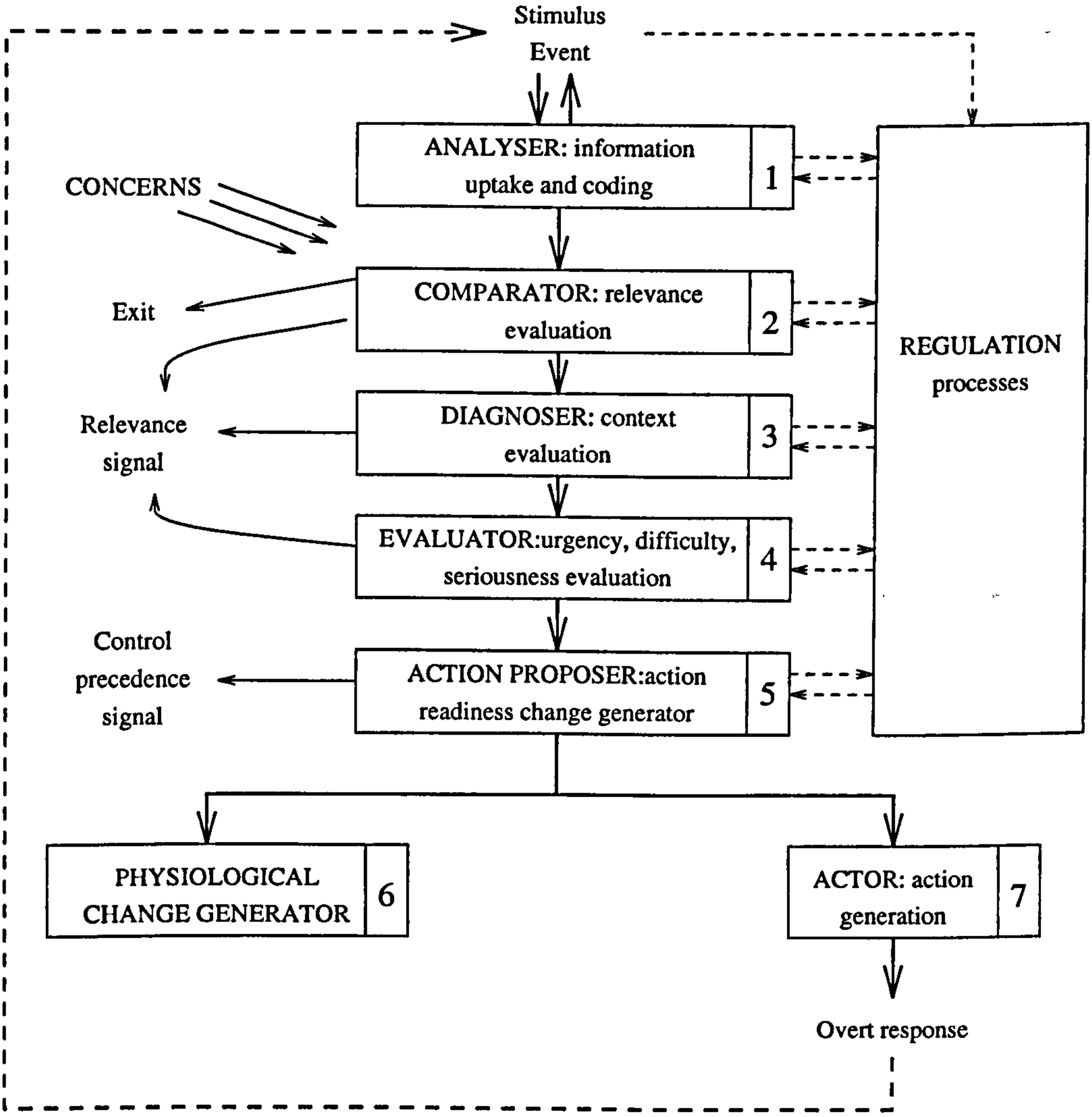


Figure 3.1: Frijda's Emotion Process Architecture
(taken from Frijda, 1986, p.454)

3. **Diagnoser:** the situation is now appraised in terms of what the individual can or cannot do about it. This presents action possibilities or the impossibility of coping with the situation. The output of this process is information on how difficult, urgent, or serious events are.

4. **Evaluator:** information from the previous process is evaluated on the basis of previous experience. They combine to present a 'control precedence signal' for dealing with the current event: that is, they bring about present action interruption if necessary or provide distraction from present action.

5. **Action Proposer:** the information gathered is used to generate a plan of action. The 'action readiness' mode is generated: that is, the level of alertness, the interestedness and eagerness for interaction.

6. **Physiological Change Generator:** physiological change is effected according to the action readiness mode.

7. **Actor:** action, whether overt or cognitive, is selected according to the action readiness mode.

Inputs and Side Conditions

The two major inputs for the process are aspects of the stimulus events and the concerns of the system. The stimulus events should be thought of as transactions. They are not true events since they are continuous over time; are elicited by the subject involved; imposed upon him by others; and are affected by other stimuli. Concerns as described earlier, are dispositions that the individual brings to the process. They are connected with the action readiness mode: that is, the level of alertness, the interestedness and eagerness for interaction. Further inputs and side conditions include: coding categories for stimulus events; context coding categories and inference rules to deduce implications. In addition, the stimulus events are inputs to the regulatory processes.

Regulation

Every stage of the core process is subject to intervention from various sources including voluntary self-control. External stimuli influence the core process to prevent emotion in the light of new evidence. Similarly, the core processes influence the regulation by announcing that a response is planned or actually underway. It is worth noting at this stage that the processing is not linear, i.e. not sequential. Information uptake and accompanying relevance evaluation are continuous. The 'action control precedence' can interrupt other processes and block access to action control for other stimuli and other goals. Also, information uptake is guided by information already processed and parts of the process may be interchanged for different events.

3.3 Approach For Improving Computational Models

Research in AI is constantly attacked with announcements that the computational approach to the study of the mind is a failure.[1] Splinter groups purport to rival symbolic AI (for example, artificial life models, connectionism and genetic algorithms). Hubert Dreyfus, the arch-critic of AI, has compared AI with reaching for the moon by climbing trees. Yet progress *is* being made in AI research.

> 'We have already learnt a great deal about the nature of the problems, and why some tempting mechanisms don't work and why others are better' (Sloman, 1993, p.9)

Current AI tools and techniques may lack the power to achieve their long term objectives, but relentless experimentation through critical implementation is at least a positive method to discover essential requirements for successive models.

[1] For a discussion of refutations of the 'Strong AI' thesis see Sloman, 1992.

Therefore, this research adopts a design-based approach. That is, an analysis of requirements, high level design specification, implementation details, followed by analysis and an exploration of alternatives. Research advances in a cycle of implementation, analysis and feedback to the design model.

The model of emotion presented through this research provides an improvement on Swagerman's (1987) model ACRES – a computational implementation of Frijda's (1986) theory. The improved model will be constantly termed 'Emoter' to reduce confusion. Information for the design of the Emoter has developed from many sources. Perhaps the most significant is Frijda's original theory. Although ACRES claims to provide an implementation of Frijda's theory, only selected aspects are included. This is probably due to its focus on two primary aims:

1. Minimal design specifications for an emotional model.

2. The exploration of one interesting area – naming its own emotions.

The Emoter will address insights gained from Frijda's original theory, that are supported by recent research. It should be noted at this stage that Frijda's (1986) book, 'Emotions' is a 'solid' reference book – possibly even essential to researchers of emotions. Unfortunately,

> 'It is difficult to find one's way through the text ... the multitude of facts does not make it easy to separate the main points from the side issues' (Terwogt, 1990)

One major difference from ACRES, is that the Emoter explores emotional expression in detail. That is through simulated physical action and physiology rather than ACRES' hardwired natural language responses. The Emoter does not address the provision of a model's ability to name its own emotions. Such a specification is admitted as being essential to any comprehensive model of human emotions, but its exclusion from the Emoter will not detract from the model being termed emotional. The justification for this assumption stems from the fact

that labelling an emotion can be notoriously inaccurate, whether it is through introspection or third person ascription (e.g. Kenny, 1963).[2]

Similarly, further design specifications for a comprehensive emotional model are not included in the Emoter. Acceptance is noted so that the design can accommodate such features at a later date without major architectural revision. The reason for excluding certain aspects lies with the quantity of work involved and the fact that certain simplifications will still allow the model to perform emotionally. For example, course grain parallel processing is not implemented, yet the design architecture acknowledges it by modularising and providing information on the level to which parallel processing could occur.

The next section outlines design specifications for the Emoter, bringing together ideas recently reiterated in three sources: Swagerman (1987); Moffat et al. (1993); and Beaudoin & Sloman (1993). These requirements/specifications have been held by the authors for many years and are still regarded as valid (e.g. Beaudoin & Sloman, 1993 still hold Sloman & Croucher's 1981 requirements to be valid). The specifications that this present research will not adhere to are surrounded by ▷ and ◁.

3.4 Design Specifications For The System

In Swagerman's development of ACRES, a concern realisation system based on Frijda's theory (see Swagerman, 1987), he proposes seven design specifications.

1. The provision of methods of detecting objects that provide satisfaction or cause harm.

2. The ability to act on this information.

3. The ability to monitor its own endeavours.

---

[2]A discussion of the problems surrounding the labelling of emotions can be found in section 7.2.1.

4. The provision of a repertoire of appropriate actions and the ability to construct action sequences or plans.

5. The provision of pre-programmed actions for major contingencies or emergencies.

6. The provision of a stock of social signals.

7. The provision of flexible goal priority ordering and for interrupting the processing of one goal for another.

Although each of these specifications is acknowledged as important and necessary, the list is not exhaustive. This is reflected by Moffat et al. (1993). In their 'Analysis of a Model of Emotions' they list 14 requirements. In addition to Swagerman's specifications they include:

8. Appropriate tasking that is not just emotional. A system is necessary that performs some other task and emotions 'incidentally'.

9. The provision of an internal logging of the emotions the system goes through.

10. Modification of actions according to the emotional state. For example, a neutral action such as closing the door would be modified under anger to slamming the door.

11. Some concerns should be more important than others to help decide which goals to pursue in case of conflict – conflict occurs through multiple needs.

12. When the system is satisfying a low-priority concern it should not apply as much effort or consume as many resources as when a high-priority concern is threatened.

13. The ability to perceive the urgency of situations.

14. Emotional behaviour should have appropriate intensity levels that are variable and appropriate to a situation.

Beaudoin & Sloman (1993) also provide additions to the list of specifications.

15. Multiple independent sources of motivation or concern will operate asynchronously as triggered by stimulus events.
16. ▷ Its mental processing is parallel, for instance controlling a physical action while monitoring the environment.◁
17. Concerns should be dynamic.
18. ▷ Provision of time constraints on concerns.◁

Even this list is not exhaustive, but many of the major issues on emotion are addressed. The model presented through this thesis will employ aspects found to work in previous models and address problems uncovered by an analysis of these models. This research will address in particular a number of major areas uncovered by this extended list of requirements. The next section outlines the major areas that are addressed.

3.5 Major Improvements Offered By The Emoter.

Four major areas of improvement to Frijda's (1986) theory, and in particular, the ACRES model (Swagerman, 1987) are addressed. These are:

1. **Non-linearity.**

   Although Frijda (1986) suggested the emotion process has at least a course-grained parallel configuration, he offered no practical solution as to its architecture. Instead, Frijda provided the misleading linear diagram shown

in figure 3.1. This research provides a revised parallel architecture through the use of the blackboard structure (Erman et al., 1980).

2. **Attention filter and thresholds.**
   Selection methods are introduced to reduce the amount of information to be processed during the emotion process. These selection methods along with variable threshold levels constitute a control for the focus of attention in the agent. In addition, this improvement provides a control for any inconsistencies between the system's concerns which reduces problems associated with belief revision (e.g. Galliers, 1988). The variable threshold levels allow degrees of categorisation to be represented. For example, the system can recognise the difference between minor and mortal threats and therefore offer an appropriate intention for action, be it overt or cognitive.

3. **Threshold feedback.**
   A major problem of the ACRES model (Swagerman, 1987) is that of 'hasty' or volatile emotions (Moffat et al., 1993). Negative feedback to the variable threshold levels that govern concerns provides regulation for such extreme emotion swings.

4. **Action readiness.**
   The intensity of an emotion and physiological activity are addressed through this improvement. Neither of these aspects were represented in the ACRES model, but are central to the Emoter's role in conflict resolution. Indeed, these two aspects will be shown as crucial for any emotional system (see Section 3.9 for evidence).

The problems will be discussed in the following sections and a detailed description of a solution presented. It should be noted that the summary of Frijda's theory presented earlier now provides the framework in which the problems are discussed.

3.6 Non-linearity

Frijda's (1986) misleading linear diagram is shown in figure 3.1. The diagram imposes a belief on the reader that processing follows a linear pattern: a discrete event is picked up by the *Analyser*, is evaluated and an action results. Unfortunately it is insufficient to describe the emotion process as a linear configuration (see figure 3.2): It has been mentioned that the stimulus event is continuous over

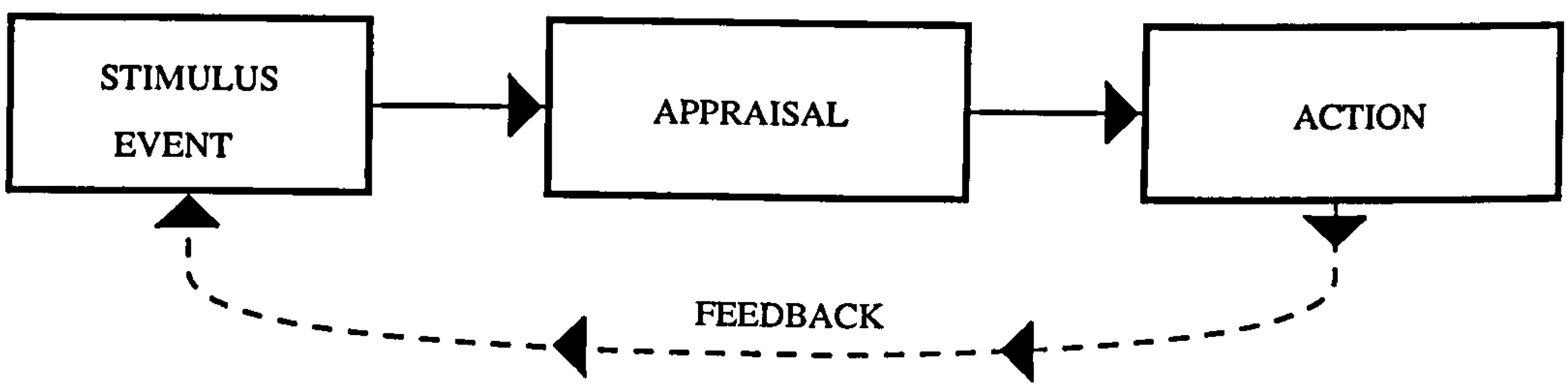


Figure 3.2: Linear Configuration

time – it is not discrete. Lazarus & Folkman (1984) explain that which actually elicits a given emotion may have been sought as well as encountered. Further it also develops in such a way that it becomes relevant and loses its relevance, varies in urgency and in quality. This implies moment to moment scanning of the environment even while other information is appraised. Thus information from the *Analyser* may halt the processing of information or impress an urgency for action.

Dispositions, or concerns, are an essential part of the emotion process so there must be some method of detecting objects or events that interact with concerns. This concern match/mismatch evaluation should be a continuous operation since the stimulus event is changing from moment to moment.

Similarly other aspects of the core process involve feedback and provide continuous information that influences all aspects of the emotion process. For example, if the evaluation/appraisal determine that a particular action should be performed but the action 'process' cannot perform that action then feedback will

occur and a new action proposed by the appraisal.

All this requires a general overall monitoring of the emotion process, of its elicitation, its course and its results. Monitoring needs central integration of all relevant information coming from different sources and moments.

Such monitoring by centrally integrated information is provided by the 'black-board structure' (Erman et al., 1980). It is sensible to leave the details of this adjustment to the emotion process until an understanding of the blackboard structure is made.

3.6.1 The Blackboard Structure

The structure is suitable for interpretations that develop as multiple knowledge sources contribute their advice opportunistically and asynchronously so that interpretations gain support from the various sources. The partial interpretations produced by knowledge sources are called hypothesis elements. Typically, the input to a knowledge source is the output of another knowledge source. For example, a stimulus event might have to be identified cognitively by one expert before its emotional significance can be appraised by other experts. Several competing hypotheses may be under consideration simultaneously. However, attention eventually focusses on that hypothesis for which the evidence is greatest; the alternative hypotheses slowly fade from the blackboard.

The blackboard control structure can be described as 3 steps:

- Update the To-Do-Set.
- Schedule a pending knowledge source activation record (KSAR).
- Execute the scheduled KSAR.

The 'To-Do-Set' refers to feasible actions, identifying all KSARs eligible for execution on each problem solving cycle. The Knowledge Source Activation Record (KSAR) is similar to an item on a task agenda. It represents a unique triggering of

a particular knowledge source by a particular blackboard event. When a KSAR is chosen by the scheduling mechanism, its knowledge source's action executes in the context of its triggering information, typically producing new blackboard events. The scheduling mechanism determines which of several KSARs competing to execute their actions are used and in what order they are used. Criteria for the scheduler's decisions could be knowledge source reliability, triggering information credibility, or expected value of the knowledge source's actions.

So in step 1, the scheduler identifies a set of permissible computations as the set of pending KSARs. In step 2, the scheduler selects the next computation by selecting one of the pending KSARs. In step 3, it executes the next computation, a knowledge source action, which ordinarily has the computational power of a program of production rules.

3.6.2 An example – The Blackboard Structure as Used by Bower & Cohen, 1982

In Bower & Cohen's model of emotion, two main knowledge sources are applied to the blackboard: cognitive interpretation knowledge and emotional interpretation knowledge. The other knowledge sources are: importance and unexpectedness knowledge, and interaction knowledge. The model of emotion is vague as to the specific rules in the knowledge sources, but provides detailed information on how the blackboard changes with the knowledge sources. Obviously, Bower & Cohen have made generalisations as to the methods of applying knowledge and as such the model of emotion can only offer a general architecture. The input output descriptions of the four knowledge sources employed by Bower & Cohen are shown in table 3.1. The changes to the state of the blackboard in general follows the cycle of events shown in figure 3.3.

Rules	Input	Output
Cognitive Interpretation (CI)	Sensory stimuli, or RHS of CI rules	Symbolic representation of external environment.
Emotional Interpretation (EI)	RHS of CI rules	Adjustment of current emotion.
Importance and Unexpectedness	RHS of CI rules	Adjustment to intensity of an emotion.
Interaction	RHS of EI and RHS of CI rules	Adjustments among emotions, adjustments to intensities of emotions.

Table 3.1: The Four Knowledge Sources of Bower & Cohen's Paper
(Taken from Table 13.3, p.311)

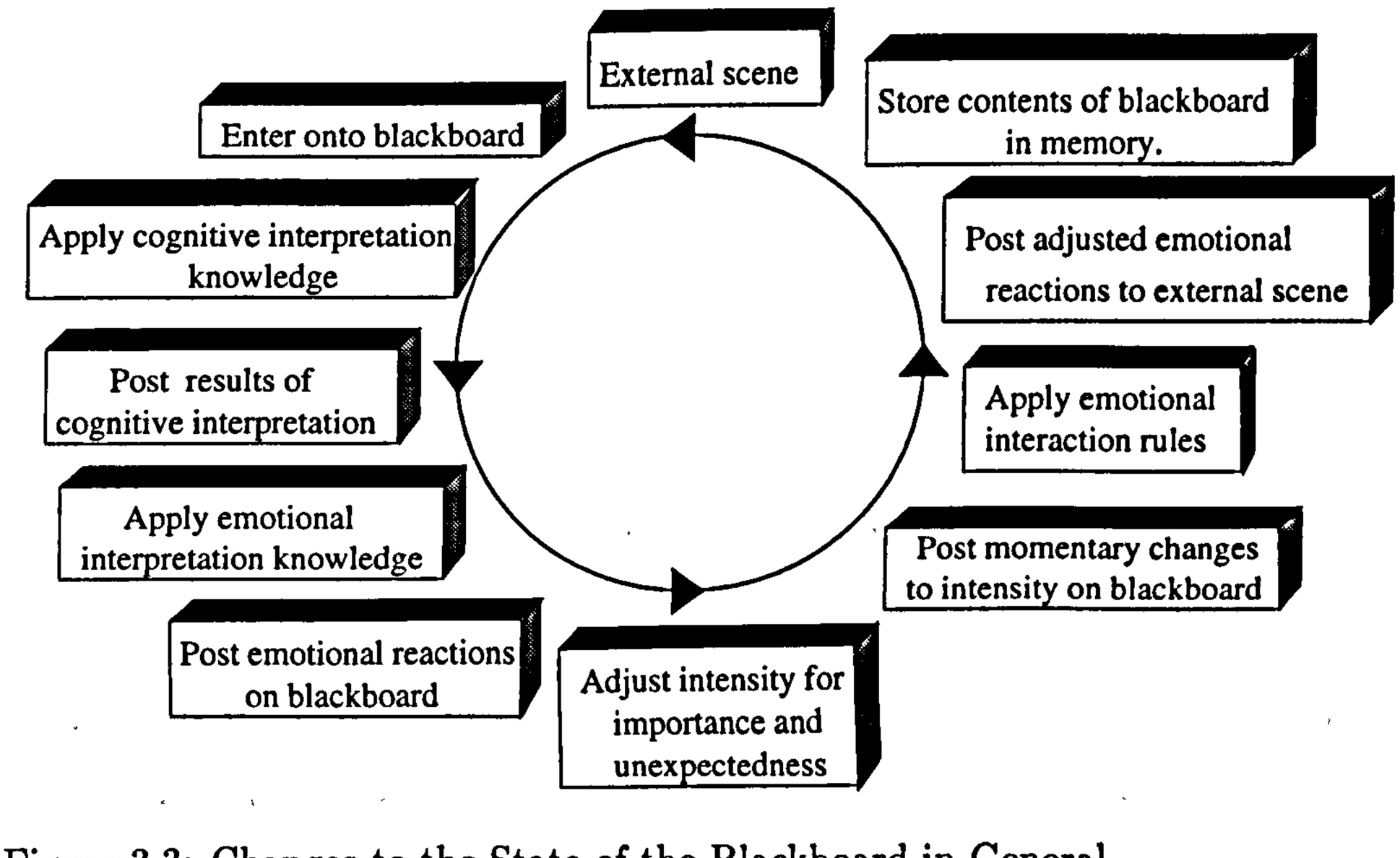


Figure 3.3: Changes to the State of the Blackboard in General
(Adapted from figure 13.9, p.311)

An example, showing a typical emotional event follows.

A student living just off Ullet Road in Liverpool was mugged on his way home from a night on the 'Town' last week. This week in a similar spot at around the same time of day, another student hears footsteps behind her.

Initially, she thinks she is going to be attacked, experiences fear, and considers running. Then however, she hears a small child say 'Daddy, slow down please', infers the footsteps and small voice are a father and daughter hurrying home, then feels intense relief. Figure 3.4 shows the state of the student's blackboard after hearing the footsteps.

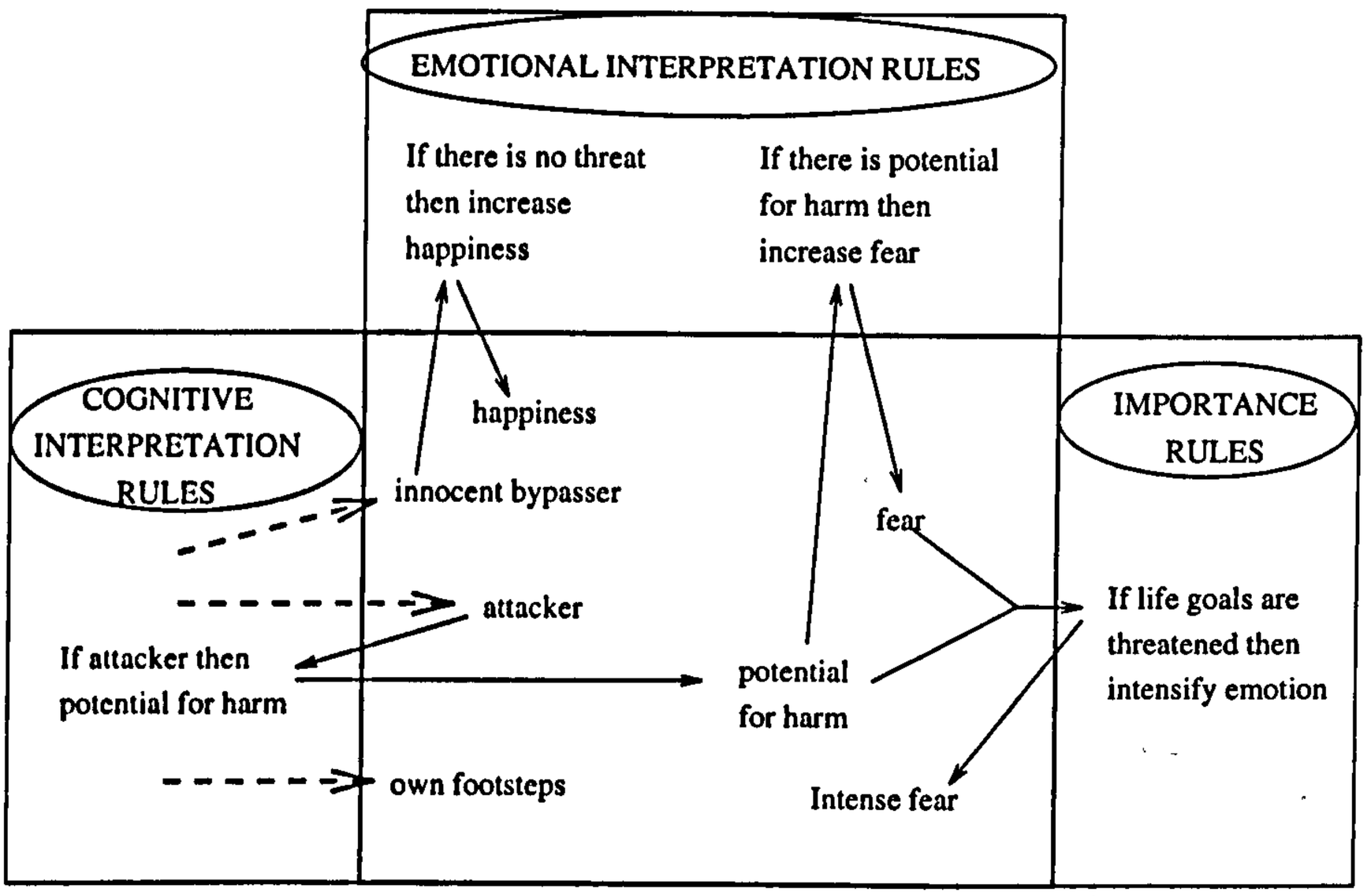


Figure 3.4: Example Using the Blackboard Structure

Cognitive interpretation knowledge provide several possible explanations – an attacker, a mugger, an innocent by-passer, own footsteps – and emotional interpretation knowledge assigns an initial interpretation to each. Some hypotheses have only a fleeting life. The 'own footsteps' is quickly discarded when there is no match between limb movement and sound. That leaves two competing hypotheses on the blackboard. Since events last week had a certain emotional

significance and there are similarities between this event and that one the dominating hypotheses is that of an attacker/mugger. Even though one is favoured both hypothesis elements remain on the blackboard until new information, in this case the voice, is provided.

The example reflects Bower & Cohen's theory of emotion, although only three knowledge sources are used instead of the four suggested by the authors. By comparison Frijda's model relates cognitive interpretation to the *Analyser* and the *Evaluator* (see fig 3.1). It breaks emotional interpretation into the remainder of the main process.

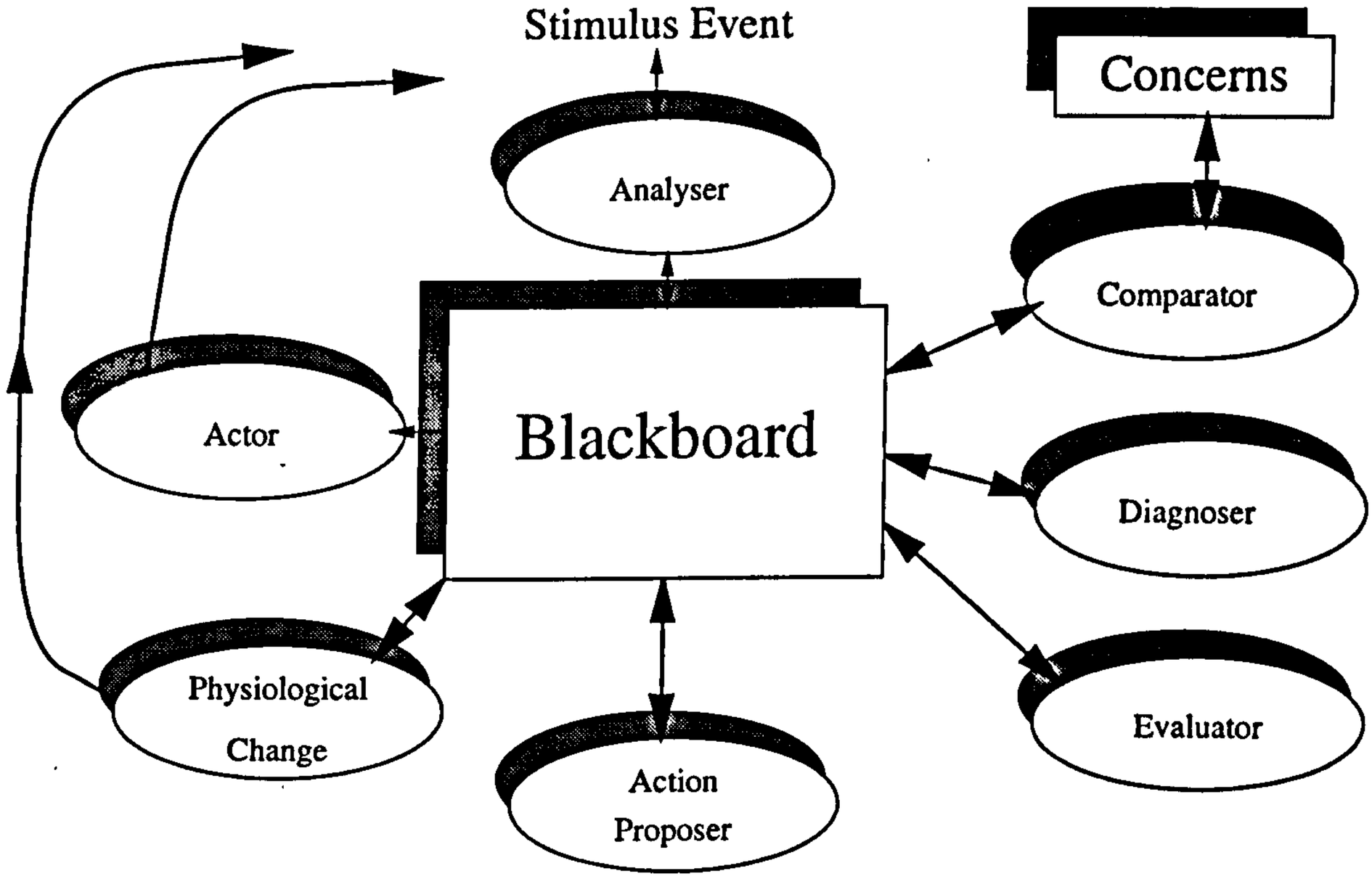


Figure 3.5: Revised Emotion Process Architecture

In Frijda's emotion process, stimulus events and concerns meet at the *Comparator* where stimulus events are compared to the satisfaction conditions of concerns. These mismatch/match result in relevance signals that alert the action system, they also notify the *Analyser* if further processing is required. They activate the *Diagnoser* and direct its search by using their context properties to

decide what actions are and are not possible. The *Analyser* simply codes the event in terms of implications and consequences. It can also actively seek information from the stimulus. The *Diagnoser* processes information to provide an appraisal profile. This profile determines what the system can or cannot do about the situation, how difficult, urgent or serious events are. The output could be described as situational meaning structure. Information from the *Comparator* and the *Diagnoser* combine to create a final relevance signal for the action system. This is arrived at through the *Evaluator*. The last aspect of the emotion process is the action system which selects an appropriate plan of action.

In general the various processes can be regarded as a set of rules that are triggered using threshold values/rules. These define which degree of mismatch/match constitutes relevance or irrelevance, urgency, difficulty, or seriousness.

By relating the emotion process to the blackboard structure the individual processes as defined by Frijda can be thought of as knowledge sources that use and contribute hypothesis elements to the blackboard. The concept of regulation may also be thought of as a knowledge source. The concept of action control precedence and action readiness mode could be integrated into the various knowledge sources with explicit representations posted on the blackboard. Frijda suggests a 'table of correspondences' between situational meaning structures and action readiness modes, physiological changes included.

Figure 3.5 represents the revised architecture.

3.7 Attention Filter and Thresholds

The need for an attention filter is obvious when one considers the amount of information there is in an environment. If an agent has multiple concerns, then the amount of relevant information is high. To reduce the quantity to be processed there must be selection methods. Such selection methods are termed attention

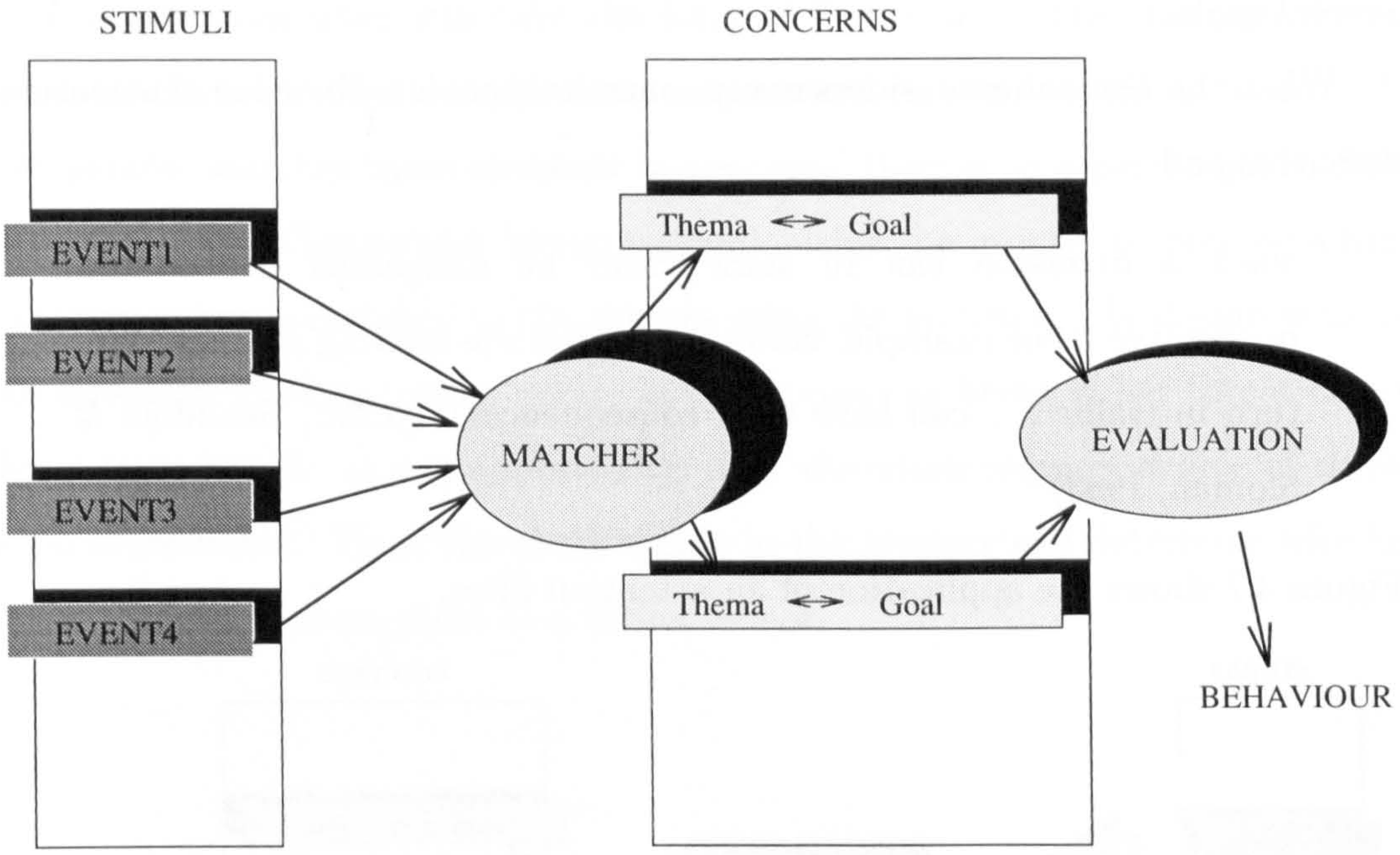


Figure 3.6: Without an Attention Filter

filters.

Filters reduce drains on processing power since they reduce the number of concerns that simultaneously exist in different states of processing (e.g. Georgeff & Lansky, 1987). This can be seen by considering the current model of emotion without an attention filter. In figure 3.5, events from the environment or generated in thought are both affected by and affecting the *Analyser*. Elements from the events that are deemed relevant to the system are continuously posted on the blackboard. The *Comparator* then checks each of the concerns against the elements posted by the *Analyser* (see figure 3.6). Once match/mismatch is obtained the systems intention for action is stated. This is achieved by using Schank & Abelson's (1977) themas to define concerns. The themas represent preconditions or triggers for action and should be regarded as dormant demons. The themas are connected to high level goals thereby representing the system's intentions for action. It should be noted that one stimulus event may trigger the posting of

several goals.

When the *Evaluator* considers many concerns there is a diversion of attentional resources and

> 'such a diversion can in some cases be dangerous or counter-productive. (For example, being diverted while making a tricky right turn in traffic ... can have fatal consequences)' (p.232, Beaudoin & Sloman, 1993)

Figure 3.7 shows the application of an attention filter.

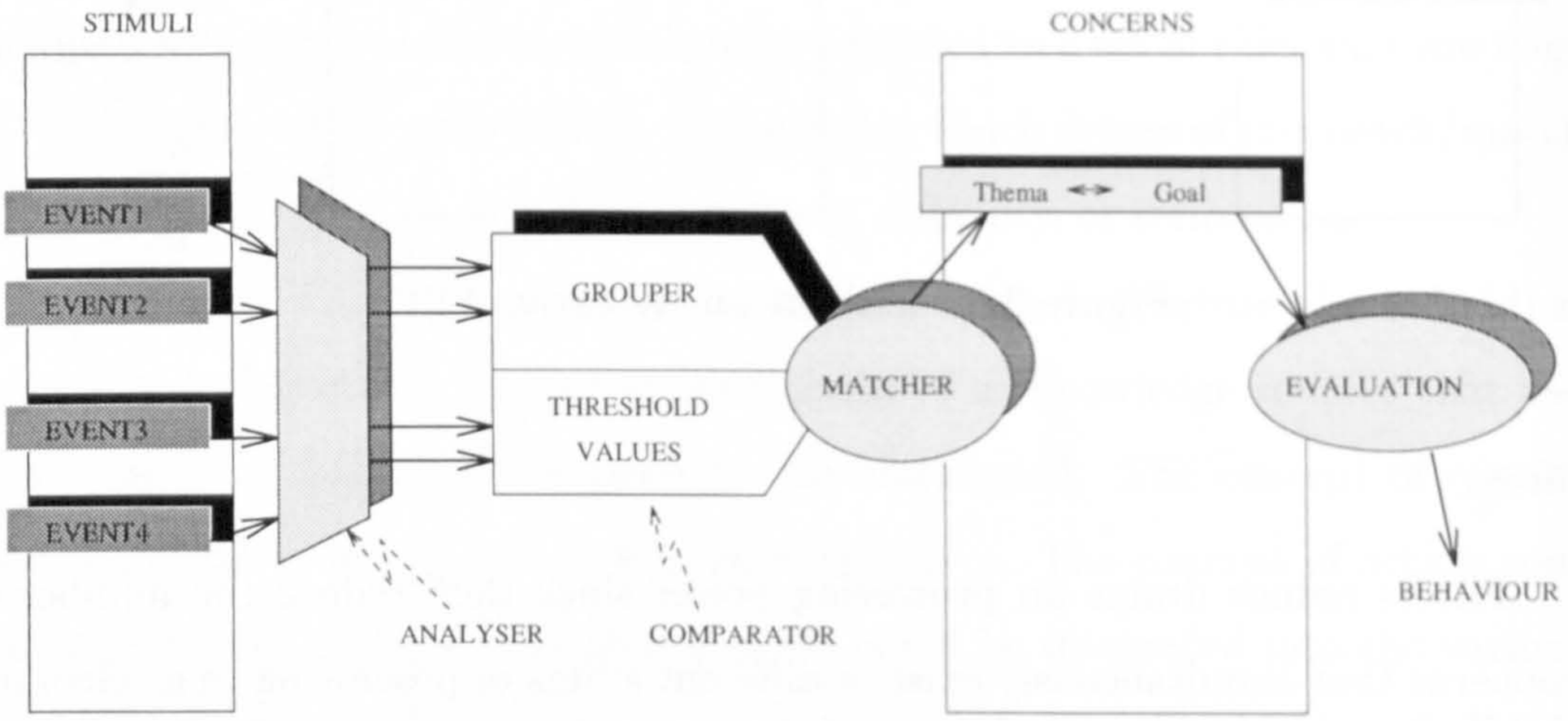


Figure 3.7: With an Attention Filter

The attention filter contains threshold values at which concerns are triggered. In comparing a concern's preconditions to actual stimuli, the match is not simply boolean. Fuzzy matching reflects real life situations, e.g. degree of threat or opportunity. Also threshold values determine what degree, of say threat, the system recognises. This use of threshold values is not new and is documented elsewhere (e.g. Frijda, 1986; Sloman, 1993a). New theory lies in the fact that varying such values controls the focus of attention. For example, if threshold values for all themas except one are increased to a level impossible to achieve then the agent has a fixed focus.

The attention filter will take the form of figure 3.7. The *Analyser* selects elements from the environment that are deemed relevant to the system. The *Comparator* matches these elements to concerns' themas to generate goals. Subprocesses of the *Comparator*, group elements using the *grouper* to provide a high level event that is matched to the themas using the *matcher*. The design without the attention filter generates events in the *grouper* as being either threat or not threat, opportunity or not opportunity. The alteration requires degree of threat to be represented. Thus, threshold values in the *grouper* will determine whether a minor threat is recognised as a threat or not.

Further, by using such threshold values to direct attention, the problem of concern consistency is addressed. Previous systems have imposed consistency on their database of concerns or beliefs, e.g. Galliers (1988). In real life, however, such inconsistencies do appear. For example, a person may have the concerns of *sticking to a diet* and *eating a cream cake* at the same time. The choice between the two conflicting concerns is resolved partly through focus of attention. *Sticking to a diet* has long term benefits, whereas *eating a cream cake* has immediate short term benefits. Depending on the focus of attention being short or long term benefits, the themas threshold values will only allow a particular concern to be processed. It is accepted that focussing may allow two inconsistent concerns to be processed at the same time. In such a case a method of resolving such inconsistencies would be required that probably relies on benefits from the attached goals. An ideal method would combine both goals to select a set of actions to optimise benefits to the agent. Such resolution of inconsistent concerns is beyond the scope of this research.

3.8 Threshold Feedback

In Moffat et al.'s (1993) analysis of ACRES (the implementation of Frijda's theory) the major problem of 'hasty' or volatile emotions was identified. That is, ACRES would experience extreme emotion swings. This problem is constantly cited within cognitive science – the modelling of physiology is often ignored or limited thereby providing no smooth flow from one emotion into another.

One solution is self regulation,[3] or feedback from the agent itself. With feedback to the attention filter, attention shift and therefore emotion shift is harder. That is to say, once attention is fixed on a concern only similar or relevant concerns will be triggered. This is achieved by increasing or decreasing threshold levels that trigger concerns. The feedback will occur after evaluation. The corresponding thema will be sent back to the *Comparator's grouper* process which will adjust threshold values with respect to the thema.

In deciding which threshold levels to change and the intensity of that change, certain information must be available. Grouping categories for the concerns will allow a number of concerns to be changed simultaneously and a physiological value will provide the intensity of change. The grouping categories already exist within the design model whereas modelling physiological functions has yet to be explained. The following section provides this description while embracing the main area of interest for this research.

[3]This idea of self regulation may be of interest as a determinant of fixation *vs.* displacement of mental energy. That is, an aspect affecting what makes some people stick to unfulfilled wishes and intrusive thoughts, whereas others are able to disengage from such contexts. This problem was identified by Freud (1938) as crucial for the understanding of all psychological disorders.

3.9 Action Readiness

Although Frijda believes emotions are part of a system for realising concerns, he also regards the term 'action readiness' as central to the theory. The term stems from Arnold's (1960) 'action tendencies'. 'Action tendencies' are simply the internal tendencies that exist prior to expressive behaviour. Such tendencies may result in executed behaviour or be suppressed. According to Frijda it is

> 'clear that "action tendencies" and "emotion" are one and the same thing' (p.71)

and that the inner experience of emotion is

> 'to a large extent awareness of action tendency – of desire to strike or to be with' (p.71)

Frijda continues his argument by pointing out this definition of emotion is valid for only some emotions and that all emotions can be explained by expanding the definition of action tendency. By renaming 'action tendency' with 'action readiness' and including unreadiness for action in the term, his version of Arnold's theory becomes:

> 'Emotions, then can be defined as modes of relational action readiness, either in the form of tendencies to establish, maintain, or disrupt a relationship with the environment or in the form of mode of relational readiness as such.' (p.71)

Action readiness modes are therefore the *level* of alertness, the interestedness and eagerness for action. Emphasis is placed on the 'level' since in Frijda's linking of different emotions to different action readiness modes (p.72), the intensity of the emotion is reflected in the intensity of the action readiness mode.

Action readiness is basically the attitude an agent has towards a situation – whether to maintain, disrupt or establish that situation and the level to which

it desires that relationship. This action readiness attitude correlates with the strength of expressive behaviour shown, physiological activity included. The action readiness mode stems from the concerns of the system and develops through evaluation to provide information for action processes and physiological change generators. It begins as a simple disrupt, maintain or establish attitude, gains an intensity value and eventually directs adjustments to the decided action and physiological activity. The intensity value may be a null-intensity (c.f. 'relational null state' in Frijda's terminology), corresponding to the inhibition of an emotion.

To incorporate action readiness modes into the Emoter, two questions must be answered:

- What factors influence the intensity of an emotion?
- How can physiological activity be modelled?

3.9.1 Factors Influencing the Intensity of an Emotion

There are four main factors influencing the intensity of an emotion. Ranked in the order of their relative influence, these are:

1. The importance of a concern.
2. The amount of match/mismatch between a concern and stimuli.
3. The number of action options available.
4. The mood or emotional inertia of the agent.

With the first factor, Frijda (1984, p.4) and Toda (1982, p.134) state the intensity of an emotion depends mainly on the importance of the emotional activity in relation to the survival or welfare of an individual. A concern that deals with emergency responses would demand extra resources from the physiological system that a low importance concern such as a slight social signal would need.

Thus, importance dictates the level of response from the action system, physiology included. For example, large wild cats place incredible temporary demands on their physiological systems when chasing food, this is at the expense of tissue repair and similar essential long-term concerns.

With the second factor, De Spinoza (1969, p.266) states an emotion's intensity correlates with the number of simultaneously cooperating causes evoking that emotion. If a threat is barely accepted as such the response will be correspondingly slight whereas a threat that is without doubt, will increase emotional intensity. The third factor stems from Frijda's (1986) view of controllability. Given fewer options for action and the effort required to develop those options the intensity of an emotion increases.

Lastly, the intensity of an emotion is influenced by the current emotional mood. If the agent is experiencing intense happiness it will not swing immediately to intense rage but tend toward anger. Thus the intensity of an emotion has an influence upon the agent by increasing or decreasing an intensity profile. The profile then influences physiological activity and planned action.

Swagerman's implementation, ACRES, combines concerns with action readiness modes thereby removing the concept of an intensity profile. Swagerman comments on this with

> 'In the names he [ACRES] gives to his experience this difference in intensity does not find expression.' (p.87)

Also ACRES has a very limited physiological system: a bleeping noise and a flashing green light, each of which functions more as a social signal than anything corresponding to a physiological system. A physiological system provides amongst other aspects a form of emotional inertia which ACRES does not possess. ACRES consequently suffers from extreme mood swings, conflicting emotional responses and predictable responses; the stimulus-response map is extremely rigid and does

not depend on the emotional mood of the agent. Clearly, action readiness modes for emotional intensity profiles and a physiological system for emotional inertia are required in the Emoter.

3.9.2 Modelling Physiological Activity

It is the view of many theorists (see Literature Review, Sec. 2.2.4 → 2.2.6) that physiological response is an essential part of any model of the emotions. However, there is a similarity between physiological response patterns in different emotions and in conditions such as hunger or cold (Cannon, 1927). Similarly, physiological actions may be unconnected with emotion: increased heart rate occurs after prolonged exercise.

It seems clear that some physiological responses may be emotional and some not. Physiological response is nevertheless a necessary and functional part of emotion as well as being indicative of the emotion. Cannon (1927) regards physiological response as being functional for preparation of active, energy-requiring response. Similarly, Frijda (1986) suggests autonomous response

> 'is part of action readiness change at some stage of actual execution or preparation of actual overt (or cognitive) response, under conditions that such response is felt to need extra resources or adjustments.' (p.124)

IIe concludes with

> 'physiological response, autonomic arousal included, is part of action readiness mode.' (p.124)

Now, modelling physiology in a computer can be approached from two angles: actual or simulated. It is possible to view a physiological system as analogous to the computer at the hardware level (e.g speed of processing). The alternative

simulated approach would appear more reasonable since aspects of the simulated physiology can be connected to the actual physiology of future applications (e.g. autonomous land vehicles).

In the simulated approach, physiological activity can be modelled by employing a profile of specific physiological responses along with relevant energy/intensity levels. This profile is described further in the next chapter.

Action readiness has a direct influence on the intensity and attitude of physiological activity and planned behaviour. In addition, action readiness is an essential part of the Emoter's feedback to the attention filter. The action readiness mode, mainly the intensity profile, directs the amount of change to the threshold levels in that filter. Thus, physiological activity and action readiness modes provide emotional inertia for the agent.

Action readiness mode is essentially the means by which an agent prepares himself for conflict situations or even cooperative opportunities. Preparation is a major part of resolving conflicts. Thus, during a situation where an emotion occurs, agents adjust their attitudes and physiological responses to best suit the situation. Such an emotional situation has, according to Conflict theorists (see Literature Review, Sec 2.3), the characteristics of either a match or mismatch to the agent's plans of action. Oatley (1992) suggests emotions occur when an agent's plans are reinforced by stimuli, as in the case of love, or when an agent's plans have to be changed because of stimuli (e.g. frustration).

Emotions are one of the methods by which individuals prepare for conflict and cooperation situations. In particular, the intensity of physiological response and the adjustments to planned behaviour by emotions ensure an agent has essential resources for conflict resolution or continued cooperation.

3.10 Comparison With Other Work

In the past five years there have been a number of models that have attempted to provide a fuller explanation of the emotions than was given by Swagerman's implementation of Frijda's theory. These recent models have progressed from the theoretical stage into a design that is aimed at implementation. The whole field of research into 'Motivation and Emotion' is fraught with disagreement as to the best approach for studying emotion and its underlying architectures. Approaches vary from top-down (i.e. trying to use requirements to induce the underlying designs, e.g. Beaudoin & Sloman, 1993) to bottom-up (i.e. exploring primitive mechanisms, what they offer and seeing how they can be made more complex, e.g. Pfeifer, 1993; Brooks, 1991). Approaches range from broad and shallow to narrow and deep implementations. This comparison of the Emoter with other work will only consider top-down approaches. It will outline the simplifications such models have adopted and contrast common areas of research and their alternative approaches.

3.10.1 The Nursemaid

Beaudoin & Sloman (1991) outlined proposals for a University of Birmingham research group to study emotion. Their approach is one of progressive sophistication of scenarios and emotion architectures. The initial scenario involves a simulated nursemaid with the task of looking after a collection of robot 'babies' in a 2-D simulated world (Beaudoin & Sloman, 1993). Beginning with a broad but shallow prototype designed with the top-down approach, the group is studying separate fragments of an agent and emotion in general. The hope is that eventually, a complete autonomous agent can be arrived at.

A central aspect of the group's work is the representation and processing of motivators (c.f. concerns). A motivator has a richer structure than a goal and

consists of ten provisional fields.

1. A proposition *P*.
2. A motivational attitude to *P*.
3. A belief about *P*.
4. An importance value.
5. An urgency descriptor.
6. An insistence value.
7. A plan or set of plans.
8. A commitment status.
9. Management information
10. A dynamic state such as 'plan aborted' or 'being considered'.

In a comparison with the Emoter presented in this research, a motivator collects information from various parts of the processing. For example, in the Emoter, the *8) commitment status* is implicit in the triggering of the concerns. The only field that is not represented in the Emoter is that of *3) A belief about* P. The provision of belief representation and their necessary revision is an important aspect of any complete agent. However, the Emoter simplifies this provision by allowing beliefs to be implicit in the concerns of the system.

The Emoter has two extra aspects that Beaudoin & Sloman have not included in their prototype model: a representation of intensity and a form of physiology. In the Birmingham group's research, threshold filters are mentioned,

> 'the role of the filter is to prevent insufficiently insistent motivators from disrupting the management process. Motivators whose insistence are less than the filter's threshold are ignored.' (p.235)

but detail is missing from their processing or from the 'filter updater' that is mentioned. The other fragments under the focus of research are 'Learning' (Shing, 1993), 'Terminology' (Read, 1993b) and an evolutionary perspective of emotion (Read, 1992).

An interesting area mentioned by Sloman in Workshops (WAUME93; AISB-93) is the necessity for 'execute anytime plans' which allows plans that are in the process of expansion and refinement to be executed whenever needed. After all, in real life, individuals can rarely afford the necessary time to perfect plans for action; action must sometimes begin even while a plan is being formulated. Unfortunately, like much of the Birmingham group's research, details are missing because the prototype model is at such an early stage of implementation.

3.10.2 Will

Will purports to advance on ACRES in its architecture and domain independence (Moffat, 1993). It employs a blackboard area with several modules accessing and modifying the blackboard apparently in parallel. Such an adjustment is a natural progression of ACRES architecture and it is perhaps reassuring that another researcher has independently arrived at the same conclusion (see Allen, 1993). A further improvement was proposed in Moffat et al.'s (1993) 'Analysis of a Model of Emotion'. One of the main problems of ACRES was its extreme mood swings caused by a lack of anything corresponding to autonomic arousal or other physiology in humans. Such physiology gives the emotions and moods a certain inertia. Raccuglia (1992) suggested that this inertia could be supplied by a recurrent neural network. Moffat et al. however opt for increasing the memory of ACRES so that the recent past, e.g. goals, can influence the system's state to provide inertia. This is an interesting cognitive area and avoids the philosophical problems of computer physiology.

Will resides at a preliminary stage, with elementary planning, anticipation

and concerns. According to Moffat,

> 'Will is a symbolic, but minimalist system, doing as much with as little as possible.'

In a comparison with Sloman's motivators, Moffat explains

> 'Will has goals, beliefs, memories, expectations and intentions without needing to label them as such' (Moffat, 1993)

3.10.3 Affective Reasoner – A.R.

The A.R. (Elliott, 1992) is a computer simulation that reasons about emotions in a multi-agent system. The A.R. is designed around the hypothesis that there are twenty-four distinct categories of emotion each based on a different set of eliciting conditions (c.f. Ortony et al., 1988). Elliott & Siegle (1993) proposed an extension to the A.R. by addressing the intensity of an emotion. Unfortunately, Elliott's work is simply a matter of matching categories of conditions to emotion concepts such as 'hate' or 'love' to pronounce the emotional state of the system. As such it mainly offers the ability of naming emotions to the Emoter. An interesting aspect of Elliott & Siegle's work that is of relevance to this research are the factors influencing the intensity of an emotion. They categorise three groups of factors influencing intensity:

1. Stimulation-event variables.

2. Stable disposition variables.

3. Mood-relevant variables.

The first factor refers to 'objective' features of the world such as the loudness of a noise or the brightness of a light. The second factor refers to the bias of an agent toward interpreting a stimuli one way or another, e.g. approach or avoid.

The variables are slow to change and are usually uni-directional. The third factor refers to how a current mood influences the degree of emotional intensity.

The Emoter takes into account the second and third categories, whereas the first finds no representation at all. This is possibly a direction for future improvements to the Emoter.

3.11 Conclusion

This chapter has described improvements to the model ACRES, an implementation of Frijda's (1986) theory by Swagerman (1987). It achieved this by first providing a summary of Frijda's theory, then describing the top-down approach to designing the Emoter presented. Specifications were outlined and simplifications noted. Four major areas relating to improvements in the model ACRES were tackled. These were:

- Non-linearity.
- Attention filter and thresholds.
- Threshold feedback.
- Action readiness.

In tackling the non-linearity of Frijda's theory, the blackboard structure was incorporated into the Emoter. The attention filter and thresholds control dynamic attentional focussing which reduces the computational drains of processing many concerns. It also allows a degree of threat, opportunity and such like to be represented. Threshold feedback provided emotional inertia for the Emoter representing the stability of attentional focussing and consequently stable emotions. This 'hastiness', or extreme mood swings, was identified as a major problem of ACRES.

Finally action readiness was addressed. Action readiness modes account for the intensity of emotion which is unsatisfactorily covered in the ACRES model. Action readiness directs adjustments to the intensity of emotional expression. By including such an aspect in the Emoter two further areas of research were explained: factors influencing emotional intensity and the physiological response system that is needed to express emotions and their intensity.

The chapter ends with a comparison between the Emoter and other work.

Chapter 4

The World and Agent Behaviour

4.1 Introduction

Chapter 3 expressed the need for embedding a theory of emotions into a general action system. Similarly a suitable domain for this action system must be selected. This chapter describes these two aspects along with the benefits and restrictions they provide. The domain of the blocks world is chosen for an implementation of the emotional theory. In this implementation the action system is analogous to a human hand with the ability of both detecting events and simple movement. Finally, the positioning of the emotional theory into an agent's general action system is provided.

It should be noted that the term *Emoter* that was used to describe the emotional model employed by this research is now expanded. *Emoter* now denotes an agent in the blocks world domain, i.e. the action system. To distinguish between various agents the practise of adding both a fore-name suffix or adjective prefix will be adopted. Thus *Emoter Fred*, *Emoter George* and *Defensive Emoter* or *Altruistic Emoter* denote agents.

4.2 The Environment

When the task of implementing human-like functions arises, scientific progress is usually achieved by making key simplifications. A common simplification is that of the environment and the agents' interface with the environment (sensors and the ability to act). This is termed the 'micro-world' approach.

A common micro-world in the field of artificial intelligence is the blocks world. At its simplest, this involves a small number of objects that can be stacked together to form patterns. The behaviour of an agent in the blocks world offers an insight into the intelligent activity of a child playing with 'building brick' toys. This child's game, like any other game is an emotional affair. For example, frustration will arise when blocks don't fit together, happiness when a pattern is completed. Consequently, the blocks world is a well known research environment rich enough to support emotional behaviour by the Emoter.

Figure 4.1 represents the blocks world domain for this research's implementation of the emotional theory. Two agents compete/cooperate to form the blocks into set patterns – the prescribed tasks the agents are trying to achieve may be different or the same. The term 'prescribed task' denotes the pattern(s) an agent tries to achieve.

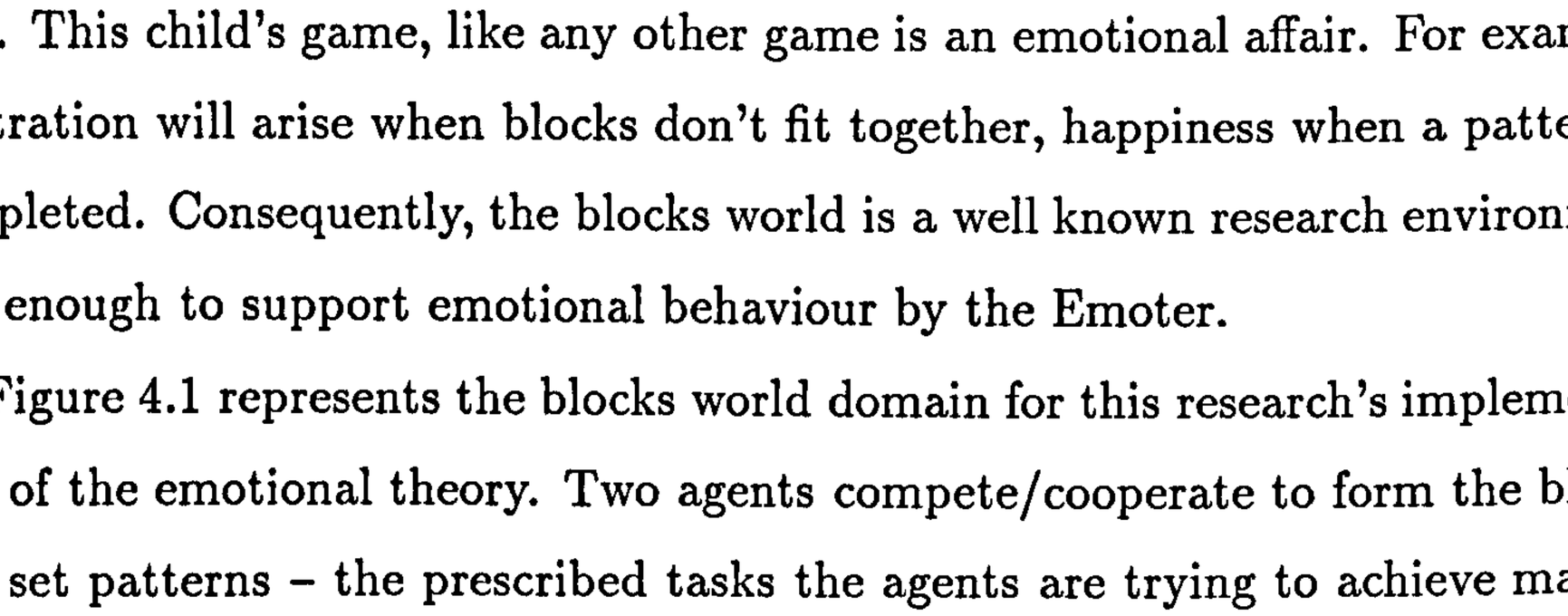


Figure 4.1: The Blocks World

4.2.1 Domain Characteristics

Blocks

Eight similar blocks are arranged on a table. Each has an identification and may be stacked on any other providing the bottom block is supported by the table. A stack of eight blocks is allowed.

Agents

The two agents in the world may move themselves, grasp a block or release a block. Thus, an agent may move a block by positioning itself above that block, grasping it, then moving to the required position and releasing it. The three moves allowed in the blocks world are:

- *move to x, y* – the agent moves to position x, y.
- *pick up* – the agent grasps whatever is beneath it.
- *put down* – the agent drops whatever it is grasping.

Restrictions

Physical restrictions apply to the world such that two objects, be it agents or blocks, cannot occupy the same position. An agent can only grasp the top block of any stack but may compete in a contest of strength with another agent for possession of a block. In such an event, the agent with the greatest strength of grasp will gain the block. Agents do not have the ability to pick up other agents. Once a block is released from an agent's grasp, gravity will dictate the block moves down towards the table. If another block is in the way then the released block will be stacked on that block. Lastly, an agent that has a block dropped on it will be crushed and die.

World Boundaries

The blocks world has physical boundaries of ten positional horizontal units and ten positional vertical units. A positional unit denotes the space that either a block or an agent may occupy. Thus, figure 4.2 shows all horizontal positional units filled and figure 4.3 all vertical positional units filled.

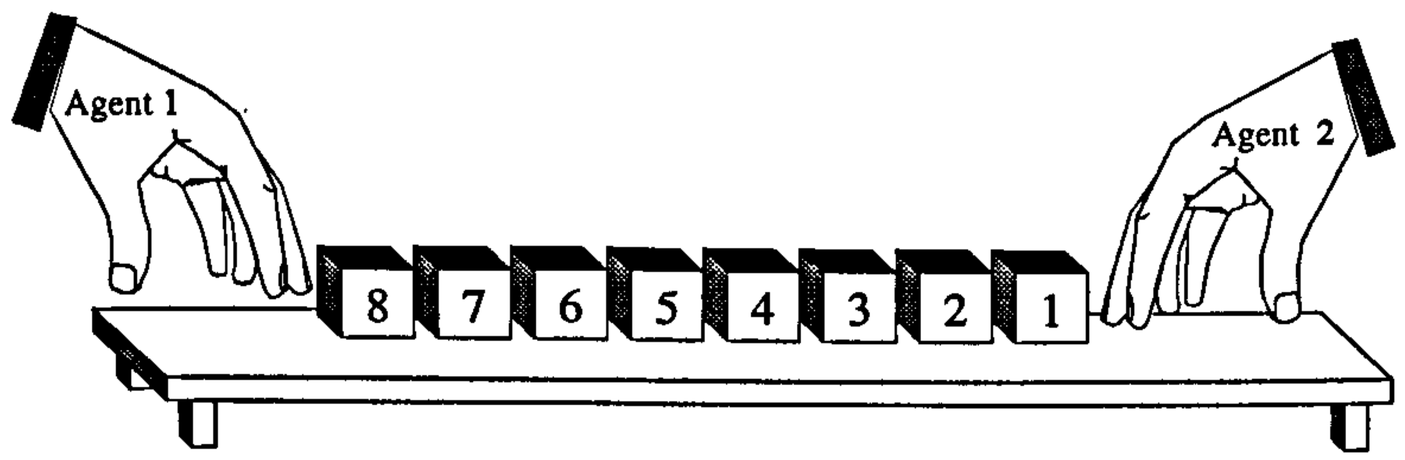


Figure 4.2: The Blocks World's Horizontal Boundary

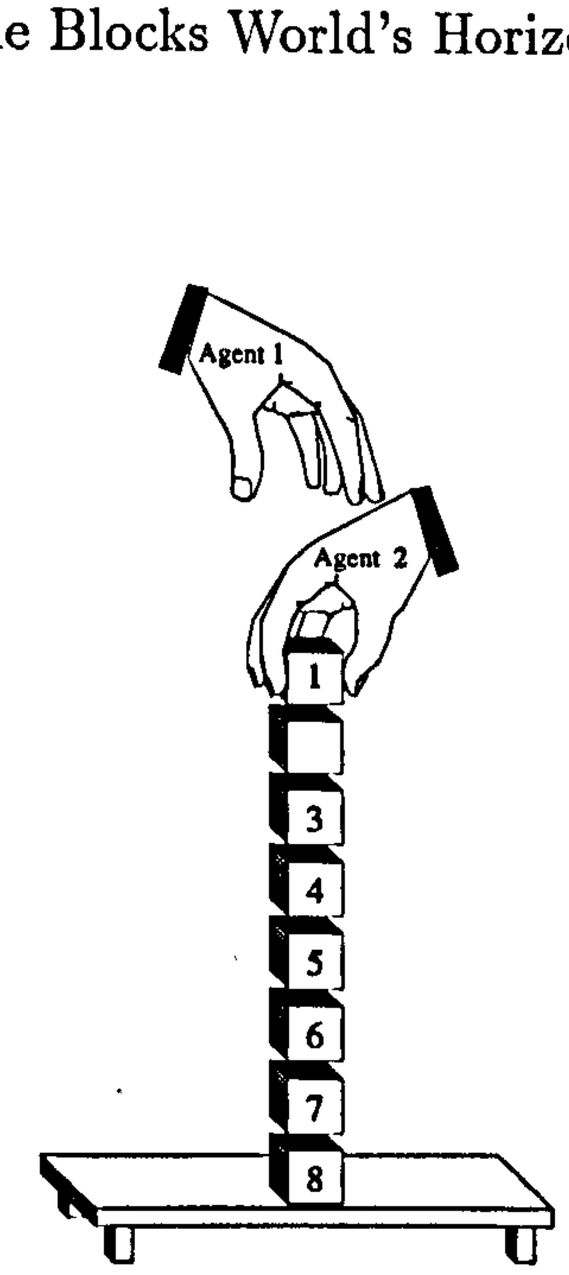


Figure 4.3: The Blocks World's Vertical Boundary

4.3 Agent Interaction

4.3.1 Sensory Inputs

Two types of environmental interaction are defined: detection and action. With detection or sensory inputs the main problem is in striking a balance between overwhelming any agent with too much information and relating enough information to make intelligent decisions about the world, e.g. predicting opponents actions or defining threats. The Emoters in the blocks world only require simple sensors to allow emotional behaviour.

An Emoter should be aware of:

1. The position of individual blocks.
2. The position of agents including itself.
3. Whether or not an action is successful.
4. Whether or not it is grasping a block.
5. The successful completion of its prescribed task.
6. Whether or not an agent, including itself is crushed by a block.

Further aspects can relate to emotional activity and are important in the context of the Emoter's physiology. In particular:

7. Awareness of the speed characteristics of agents, including itself.
8. Awareness of the amount an agent is trembling, including itself.

An ideal agent would be aware of:

9. Other agents' prescribed tasks.
10. Other agents' emotional states.
11. Other agents' intended actions.

12. Other agents' grasping strengths.

Including this degree of awareness into the agent's detection abilities makes the environment too predictable. Thus, only two types of sensory inputs exist for the Emoter: Omni-directional sight and self-awareness. Omni directional sight satisfies points 1) → 8), whereas self-awareness points 2), 4), and 6) → 8).

The sight sense was selected because of the distinction drawn by Sherrington (1906) between consummatory and precurrent functions. Therefore, sight allows

> 'detection and reaction at a distance to environmental events which would otherwise receive no response. Thus food is grasped by a primitive organism only after physical contact, while an animal with vision will see and pursue food from a distance.' (Broadbent, 1971, p.17)

Similarly, emotional responses become more interesting with detection and reaction at a distance. If primitive organisms experience emotion then the response would only be similar to hunger, i.e. a simple drive. The Emoter, however, aims to experience more than the moot emotion of simple hunger.

The omni-directional aspect to the sight sense is necessary in the study of attention since a focus of attention is only possible if there is a broad vision capability.

Self-awareness of action is equally important to gauge progress in the environment. Being aware of actions, their success and physiological limitations such as one's speed of movement is essential in deciding on future actions.

The Emoter extracts elements of information from the environment through omni-directional sight and self-awareness. In emotional behaviour the detection abilities of an agent are influenced by a further factor: that is, variability in the effectiveness of extracting information.

Consider the influence of happiness and sadness on one's vision. In happiness, interest in the causative event increases. There is an action tendency of approach

and pupillary response increases. The amount of information entering the eye increases. In sadness, however, the converse is true: the amount of information entering the eye decreases. Depression is a clear extreme where an agent detaches himself from the environment and reduces the amount of detected information to a minimum.

Thus the effectiveness of the senses of the Emoter should be capable of variation.

4.3.2 Physiology

Any movement function of the agent is physiological. However there must be a distinction between physiology and action. The simple mapping of physiology onto non-goal directed behaviour is inadequate. Five groups of physiological response can be distinguished:

- Autonomic responses involving changes in functioning of the smooth muscles and other internal organs.
- Changes in hormone secretions.
- Changes in neural responses, e.g. such as those reflected in EEG readings.
- Changes in the chemical composition of body fluids.
- Muscle tension and overt movement.

Since not even futuristic robots (designed to be physically similar to a human at a gross level of description) let alone our Emoters will possess muscles or body fluids, mappings must be made that reflect the functionality of human physiological responses.

Functionality

Consider the 'emergency reaction' produced by the body on encountering a potential threat. The key points of this reaction as reported by Read (1993a), are:

- Blood is channelled to the head from the extremities to aid cognitive processing (Frijda, 1986).
- The sympathetic nervous system acts in conjunction with adrenalin secretion from the adrenal medulla to produce body readiness (Gray, 1971).
- This reaction is present in anxiety states and panic attacks (Clark, 1986).
- Energy is mobilised prior to physical action. Although this takes time and must be performed in advance if possible, the time taken to perform an action is greatly reduced.
- The stroke volume is increased, both rate and strength, to pump more oxygen around the body. The spleen contracts to release stored red blood cells to carry oxygen around the body. The amount of stored sugar in the liver is reduced for muscle use. Blood pressure increases. Respiration rate increases. Sweating occurs (thought to aid skin resilience to damage). Muscle tension increases in readiness for action.

The mental architecture of the human has evolved to make the best use of the body in situations like the above. The physiological responses are controlled in such a way that the body is prepared for action, e.g. the level of physiological arousal is raised. The human body, like a futuristic robot, has many demands on its resources of limited energy and time. In an emergency reaction for the body, essential long-term functions that facilitate growth, reproduction, and allow the body to fight infection and prevent exhaustion are temporarily switched off. A futuristic robot similarly has long term functions. For instance, the self diagnosis of faults or integrating new information into its internal world model: all of which

take time. The Emoter, however, is predisposed towards 'bodily' behaviour which makes human mappings of physiology onto computer functions simpler. Table 4.1 summarises a set of mappings with the human functions taken from Delgado (1973).

Actual motor movements such as a kick or punch are not included in the mappings because a robot's equivalent of motor movement is obvious. Facial expressions are a combination of the above mappings along with jaw and eye movement. Facial expressions are assumed irrelevant to the computer agents.

The main physiological response mappings that are relevant to the Emoter are:

- Speed of the agent.
- Grasping strength of the agent.
- Ability to detect both objects and self-awareness.
- Movement latency.
- Trembling or shaking of the agent.

These five basic responses provide the physiological profile for the Emoter.

4.4 Conflicts

Since the aim of this research is to show that emotional behaviour provides an effective management tool for conflict situations, the nature of conflicts in this specific domain must be outlined.

As in most multi-agent environments, conflict will arise over limited resources. In the blocks world, this translates into attaining a block, positioning that block in a precise location or moving an agent to a specific location.

Two agents may have separate tasks that involve totally different blocks but still encounter conflict. For example, consider figure 4.4. Here two agents Fred

Human	Computer
Heart rate	Change in the speed of response or action.
Blood pressure and blood flow distribution	Change in energy for different parts of the agent.
Respiration	Change in overall energy of agent.
Electrodermal activity and sweating	Change in friction attribute for movement or grasping of objects.
Pupillary response	Change in ability to detect movement in the world.
Trembling	Trembling or shaking of various parts.
Temporal stability	Change in magnitude of response over time.
Response latency	Response latency.
Recovery rate	Recovery rate.
Muscle tension and tremor	Change in speed of response for agents parts.

Table 4.1: Mapping Examples For Physiological Response

and Bill have the separate tasks of stacking block 1 on block 2 and block 3 on block 4 respectively.

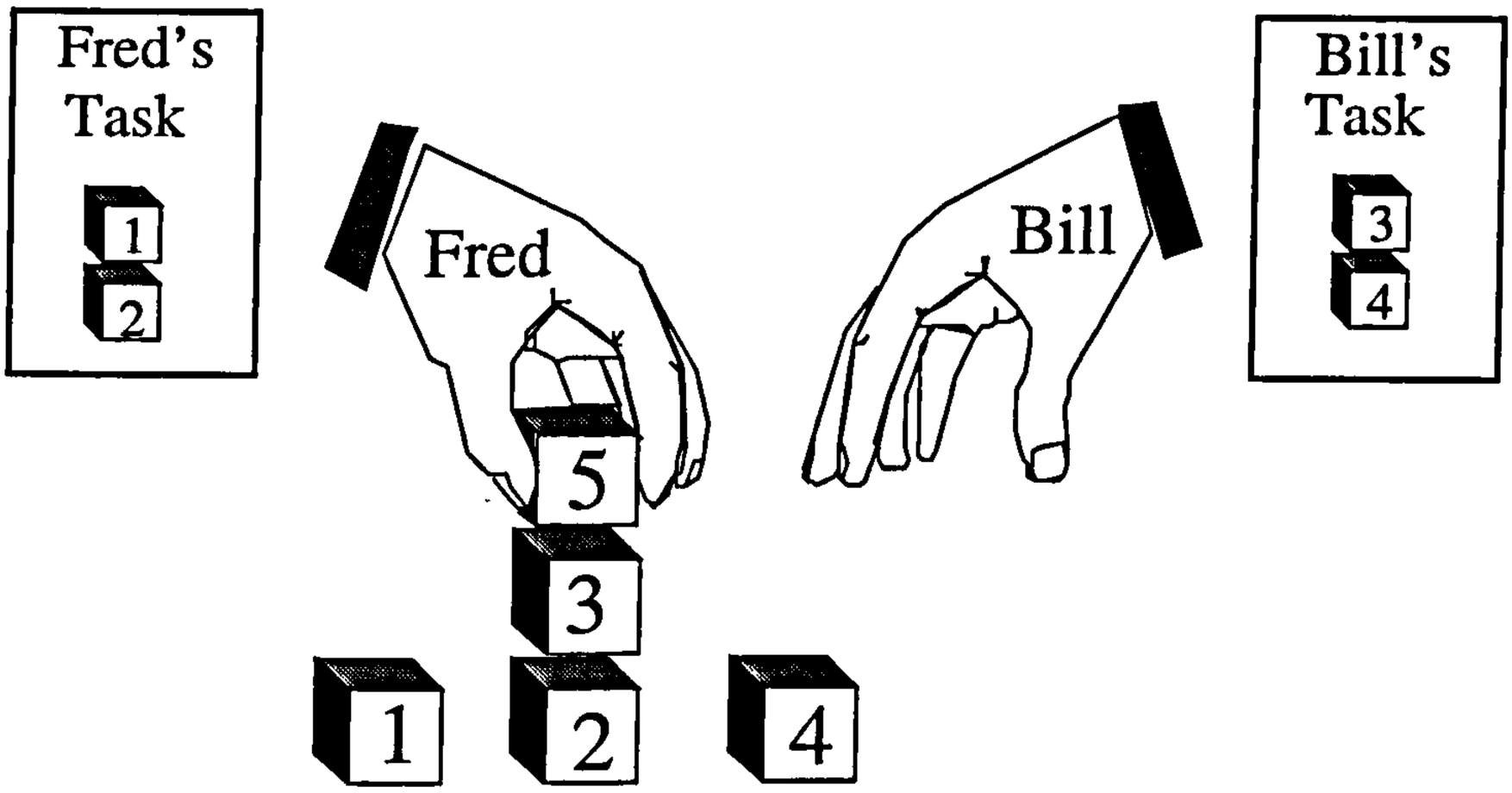


Figure 4.4: An Example of an Unintentional Conflict

Clearly blocks 5 and 3 must be removed for agent Fred to achieve his task, similarly block 5 must be removed in agent Bill's plan of action. Conflict may occur because both agents wish to remove block 5.

Further unintentional conflict situations develop as the game continues. For example, in removing block 5 agent Fred may cover block 4 when discarding it, thereby hindering agent Bill.

In general, however, interesting conflict situations occur where two agents compete for a resource that, if the agents do not possess emotional behaviour, would create a deadlock. Resolution in such an event, if possible, would need to be arbitrarily decided.

With the Emoter, resolution would occur using emotional behaviour. On encountering a conflict, the Emoter will adopt an emotional attitude that at once provides preparation for the conflict, i.e. raising arousal levels, and offers opportunities that an agent concerned only with the prescribed task will never have. For example, in anger, the Emoter may kill the other agent involved in the

conflict, and/or gain extra speed and strength (c.f. adrenalin rushes that occur in a 'fight or flight' situation). Alternatively, disrupting the other agent's task blocks may be sufficient. In all cases, the Emoter avoids the deadlock that must be arbitrarily resolved.

4.5 Agent Architecture

Figure 4.5 represents the various levels of embedding for the Emoter and its world.

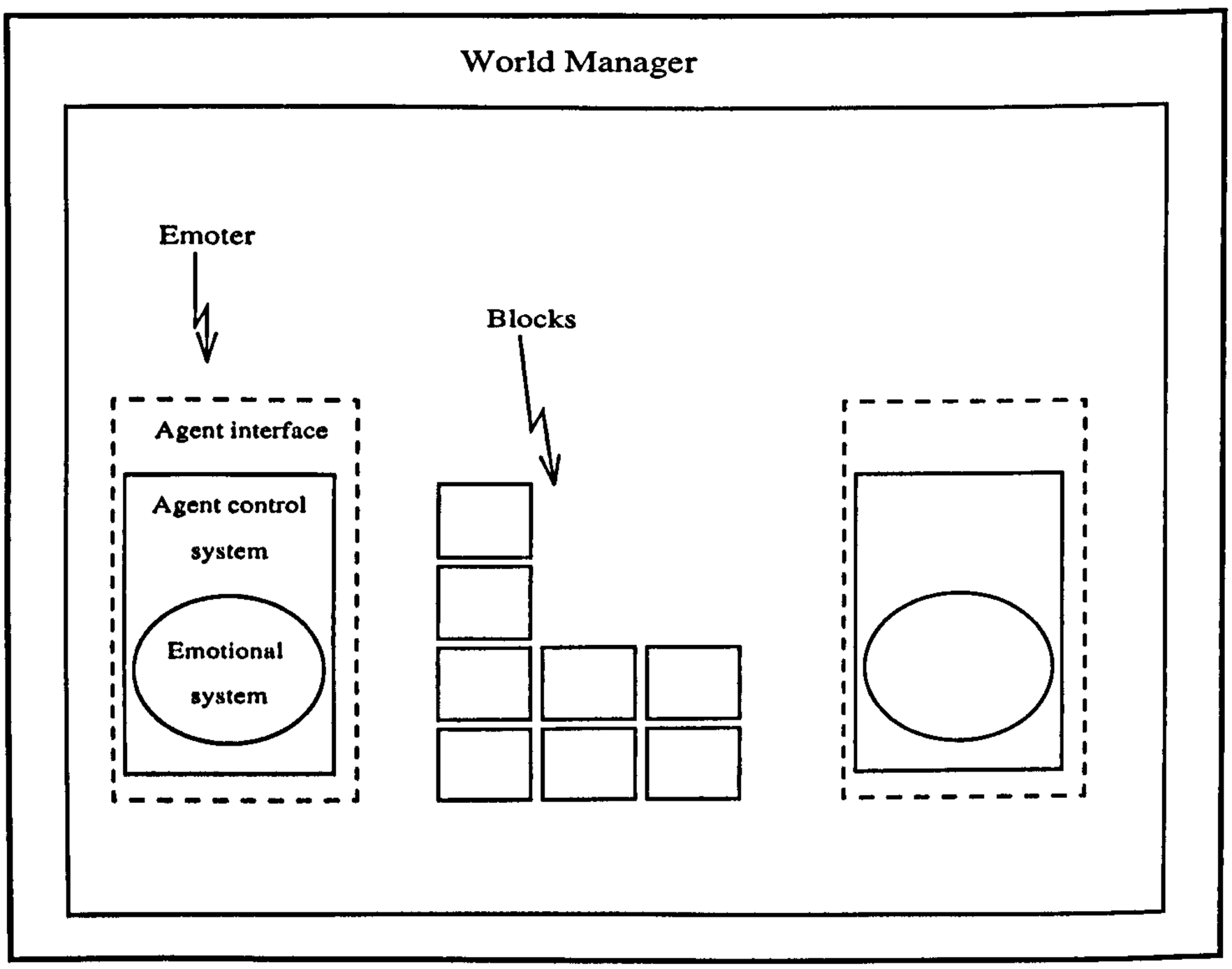


Figure 4.5: Various Levels of the Emoter and its World

- The world manager controls the movement of blocks and agents in the world.
- The agent interface controls information entering and leaving the agent. On deciding a move the agent interface passes the proposed action to the world

manager for execution.

- The agent control system controls the meta-management of evaluation processes employed by the emotional system described in the next chapter.

4.6 Conclusion

The relevance of this chapter has been to describe the blocks world domain in which the Emoter system is implemented. This micro-world along with the interaction of agents within it constitutes a rich enough environment for the occurrence of emotional behaviour and various complex conflict scenarios. The Emoter is described as analogous to a human hand with detection abilities. The specific moves the Emoter can make in the world are:

- *Move to x, y* – the agent moves to position x, y.
- *Pick up* – the agent grasps whatever is beneath it.
- *Put down* – the agent drops whatever it is grasping.

Besides these moves, the Emoter has a physiological profile of:

- Speed of the agent.
- Grasping strength of the agent.
- Ability to detect both objects and self-awareness.
- Movement latency.
- Trembling or shaking of agent.

The methods of detection employed by the Emoter are two-fold: omni-directional sight and self-awareness.

Finally, the projected methods in which the Emoter resolves conflicts along with its component physiological behaviour was shown

Chapter 5

The Emotion Process

5.1 Introduction

This chapter describes the model of emotion that is at the heart of the Emoter system. With respect to the domain and its C++ implementation, a clear understanding of the model, its restrictions and benefits are afforded the reader. C++ was chosen as the computer language for this implementation because of its suitability for object orientated designs.

The layout of this chapter (see figure 5.1) follows a typical emotional event, through its conception to the resulting action, be it overt or cognitive. This is accomplished by employing section levels to describe the component processes suggested by Frijda (1986). Thus, at a gross level of description, the *Analyser* detects stimuli, the *Comparator* matches the stimuli to concerns and the *Diagnoser* filters triggered concerns that can be realised and develops the concerns into possible goals. The *Evaluator* decides whether the ongoing processing and/or execution of a goal should be interrupted and if so the new dominant goal. The *Action Proposer* then develops a plan of action and suggests a move. This section also deals with physiological change. Finally threshold feedback or focus of attention is explained. The section levels or processes also correspond to C++ classes

in the implementation. For example, the *Analyser* is implemented as a C++ class with a set of interface functions that may be requested to update information on a central blackboard. An overview of the implementation is provided at the end of the chapter.

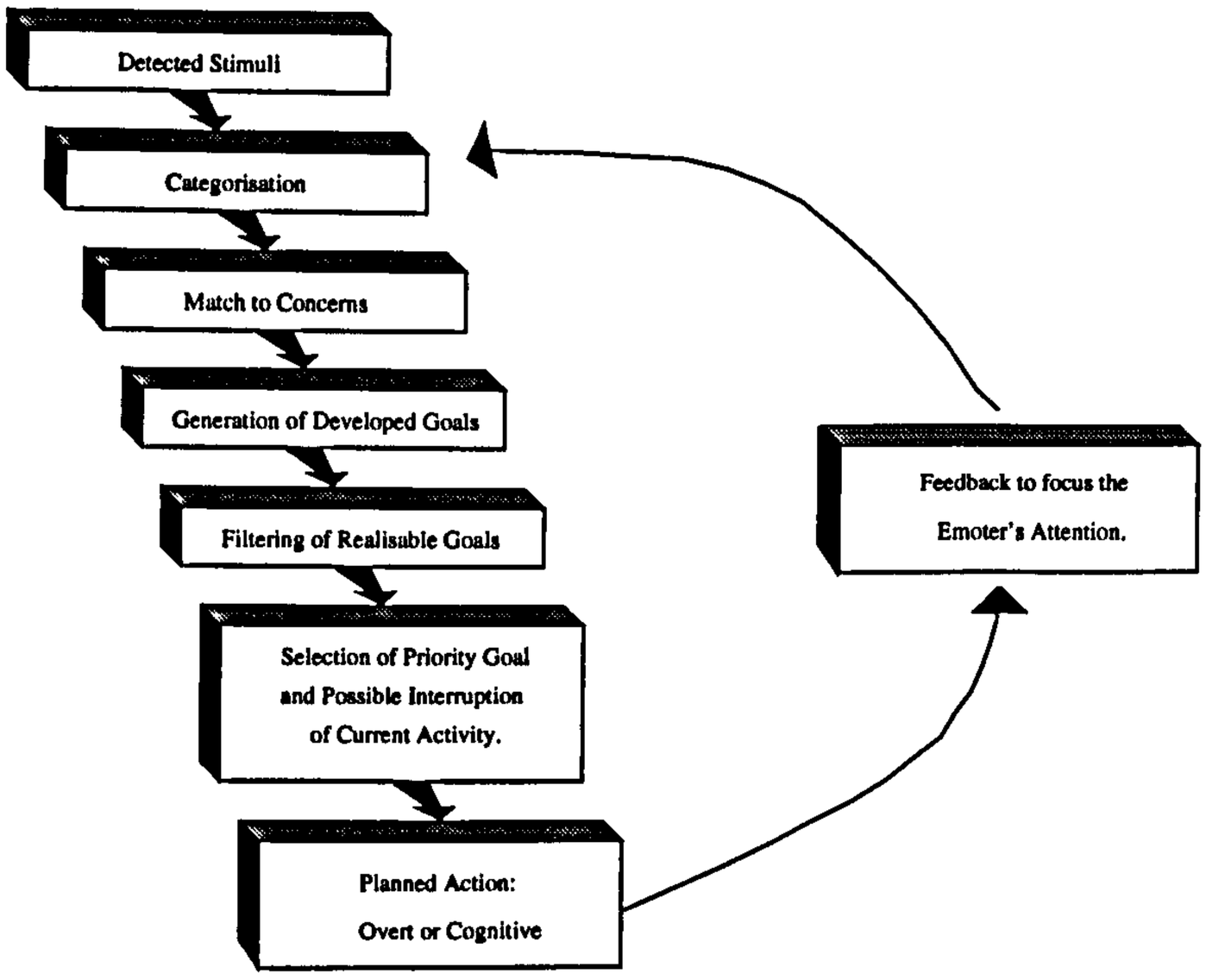


Figure 5.1: A Typical Emotional Event.

5.2 Scheduling the Processes

Figure 5.2 represents the emotional model as a general architecture. The processes, described in the following sections, are derived from Frijda's (1986) model. This model dictates the modularisation of such processes since each is intended to operate in parallel with each other. Thus information on the central blackboard indicates whether a process should be executed. In its intended parallel operation, the processes will be evaluating concerns whilst information is currently upgraded. The *Action Proposer* will be working on one goal whilst the *Diagnoser* will be continuously developing new goals. The *Evaluator* will indicate

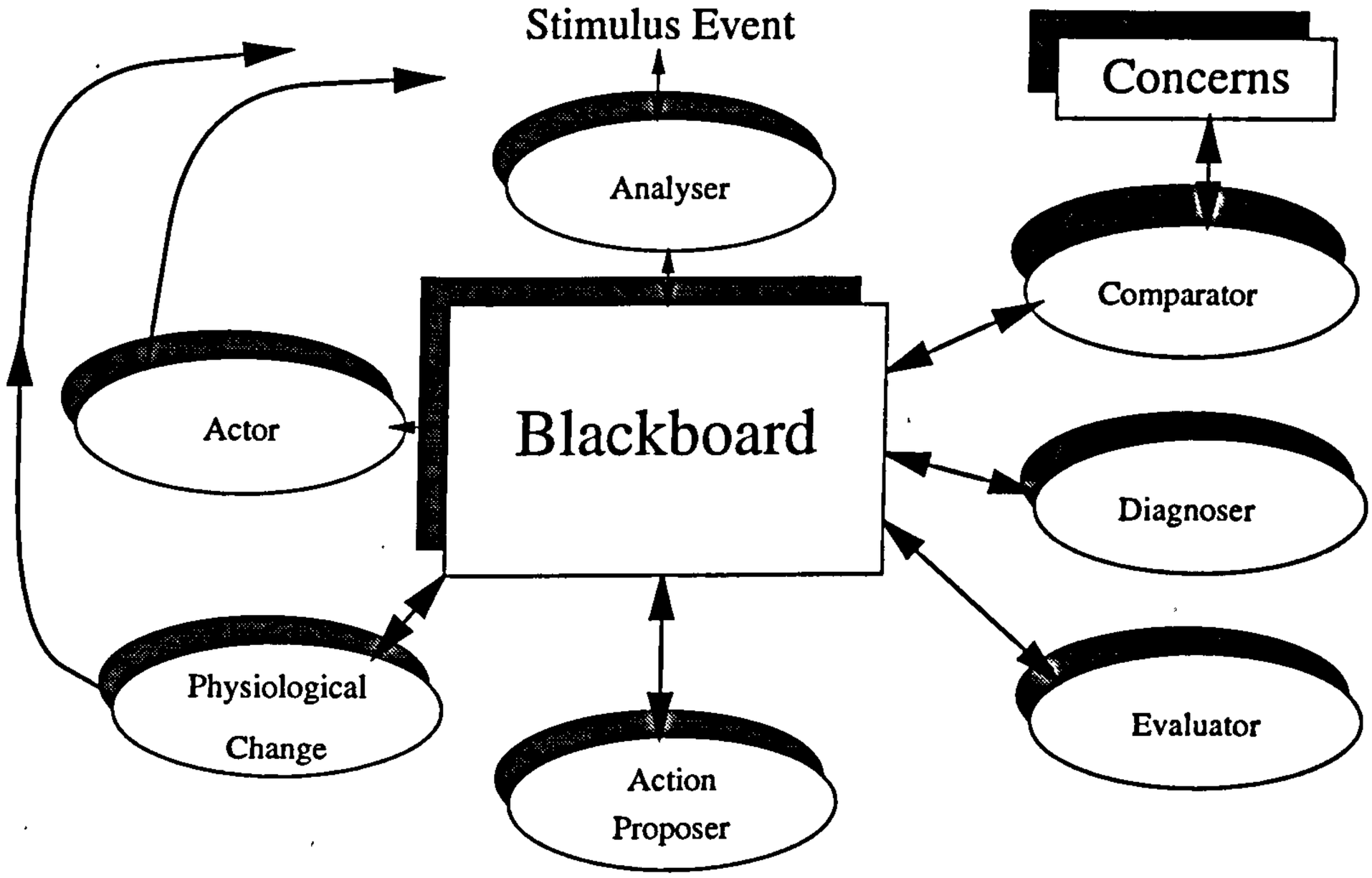


Figure 5.2: Emotion Process Architecture

if the *Action Proposer* should abandon planning the current goal in favour of a new one. Each process should be regarded as a separate module whose action is governed by the current information posted on the blackboard. In the implementation, however, scheduling of processes is linear or sequential. This does not detract from the underlying parallel organisation, but simply eases implementation. It is accepted that some problems associated with this simplification are not addressed. In particular the 'execute anytime' planning proposed by Sloman (1993) cannot be realised. However, most actions in the blocks world involve a plan of action that is continuously revised and involves many individual moves. The result of employing a world manager that gets a move from both agents and then applies those moves means that the environment is not constantly changing whilst processing is underway. Such an arrangement allows this C++ implementation to be simplified without affecting the emotional model. The organisation of modules, e.g. the *Comparator*, corresponds to C++ classes which are exe-

cuted when specific information is present on the blackboard. Thus, although the world manager dictates a sequential activation of modules, future implementations may use this organisation of the modules to provide the connectionism stated in specification 16 of section 3.4.

5.3 The Analyser

Events from the blocks world or generated in thought are both affected by and affect the *Analyser*. Elements from the events that are deemed relevant to the Emoter are posted on the blackboard.

The *Analyser* controls inputs from the environment to the emotion process. In the Emoter, this involves monitoring the personal characteristics of the other agents, i.e. its speed, amount of trembling, what it is grasping and its position. Such monitoring is achieved by requesting each agent to provide information on itself. For example, the C++ function call `fred.look( access, speed )` will request that the agent 'fred' returns his current speed. The access parameter refers to the requesting agent's sight sense. Unfortunately, the reliability of this information decreases with the Emoter's sight sense, which means that only reliable new information will be posted on the blackboard. Besides the personal characteristics of other agents, the *Analyser* can be requested to perform further functions. One major function that occurs when the Emoter receives a prescribed pattern is the identification of individual blocks in that pattern, and of the stacks of blocks needed to complete that pattern. In essence, the exact nature of the prescribed pattern. The *Analyser* also identifies through C++ class functions:

- Any blocks moved by other agents or involved with another agents' moves.
- Thoughts such as a continuously repeated action or whether a move was blocked by the actions of another agent.

- Information relating to the Emoter's personal characteristics.

Further occasionally requested functions of the *Analyser* are:

- Identifying a mortal threat, e.g. another agent that is positioned directly above the Emoter while grasping a block. Clearly this represents a potential threat of being crushed. This particular event in the blocks world is termed an 'emergency' event.

- Identifying blocks that are beneath other blocks.

- Identifying blocks that are immediately available to be picked up.

Table 5.2 shows a number of stimulus events that the *Analyser* can identify.

5.3.1 The Reliability of Information and the Omni-directional Sight Sense

Each of the *Analyser's* functions outlined earlier returns information to the blackboard or other evaluation processes, but the reliability of the information is dependent on the sight sense to detect such information. Thus, if the Emoter has 'withdrawn' from the environment, as in the case of depression, it may not recognise a mortal threat or even identify immediately available blocks.

The information from the environment is filtered through the mask of the sight sense; causing accurate, corrupted or null information.

A value associated with the sight sense indicates one of the effectiveness levels described in table 5.1.

5.4 The Comparator

The *Comparator* checks each of the Emoter's concerns against the elements posted by the *Analyser*. In theory, Frijda suggests this checking is parallel for each

Level	Label	Related Information
0	Telepathic	Can read others intended action and task.
1	Aware	Accurate information on everything except the above.
2	Reduced awareness	Cannot read the other's sight sense.
3 & 4	Low vision	Cannot gauge the others strength of grasp or remember the other's previous move.
5	Poor vision	Cannot see what the other agent is grasping or which move the agent made. The amount of trembling by the other agent is corrupted.
6→9	Poor vision	The other agents speed and the positions of objects are corrupted to a varying degree.
10	Blind	No information except on personal characteristics.

Table 5.1: Information Obtained From the Sight Sense

concern. In practise however, the concerns have an importance value attached and are checked in that order. Swagerman (1987) cites Schank & Abelson's (1977) themas for defining concerns. The themas represent preconditions for action and should be regarded as dormant demons. General concepts are required for the themas that could allow fuzzy matching (Rosch (1978), Kosko (1988) for example). In this implementation, five general concepts are used. These are: threat, opportunity, boredom, stability, and neutral. Stimulus events directly map onto these general concepts along with a degree of match. For example, if all the blocks required by an agent are uncovered and available to be picked up then that agent will have a general concept of *opportunity-for-self* with a match of 100%. If, however, only one of the five blocks required by the agent is available then a match of 20% occurs. The C++ implementation refers to a list of stimulus events and their related rules for determining a degree of match when categorising general concepts. Such an approach provides an explicit path of reasoning from stimulus to the triggered concern and high level intended goal. This is at the expense of labelling unaccounted stimulus events as neutral. Once a degree of

Stimulus Events
Block above self
My task block in his grasp
His task block under own
Own task block available
Own task block not available
Own goal repetition
His speed critically low
Own speed critically high
Own information intake low
Intended move prevented

Table 5.2: Examples of Typical Stimulus Events

match/mismatch is obtained, dynamic threshold values allow the Emoter to select an intention for action. This is achieved through the coupling of themas to goals. It should be noted that one stimulus event may trigger the posting of several goals.

Firstly, the *Comparator* translates information on the success of previous tasks, on events generated in thought and the new information posted by the *Analyser* into general categories. Table 5.2 represents typical stimulus events whereas Table 5.3 shows the format of a general category. The general category comprises of a concept, the intentionality of that concept, e.g. whether a threat is towards oneself or another, and a degree to which the concept matches the event. Thus, another agent that is grasping a block and is positioned above the Emoter will be categorised as a 100% threat whereas another agent picking up one of the blocks required by the Emoter will be categorised as less of a threat.

Secondly, the *Comparator* matches the categorised events with the Emoter's concerns. Table 5.4 indicates the structure of a concern.

The example shown indicates that when a 'threat to self' event occurs a comparison will be made with the concern shown. If the stimulus event is categorised

Concept	Intentionality	Degree
Threat	self	100%
Opportunity	other	20%
Neutral	none	50%
Goal boredom	self	30%
Stability	self	90%

Table 5.3: Examples of Categorised Events

Structure Element	Example	Comment
Triggering thema i.e. a categorised event	Threat to self	There is a threat to the Emoter
Goal concept	Mortal threat to self	An emergency reaction goal
Relational intention towards the goal	Disrupt	Intention is to stop the event's consequences
Threshold that triggers the goal concept	60%	Makes sure an emergency reaction is not produced with a minor threat
Importance ranking	1	The most important concern of the Emoter

Table 5.4: The Format of a Concern

as a 'threat to self' of over 60% then the concern will be triggered. The blackboard will then be notified of the corresponding goal concept, the relational intention, the importance of the event, and the amount of match/mismatch between the category and the goal concept. In the above situation, the goal of disrupting a 'mortal threat to self' is posted along with an indication that this is the most important event that could occur. Also a value representing the degree of confidence that the event has taken place is posted, i.e. the amount of match/mismatch between the category and the goal concept.

The output from the *Comparator* is a set of high level goals ranked in order of importance and reliability, such that goals are initially ranked in order of importance. Goals with equivalent importance are further ranked according to their reliability. Each represents an intention for action that the Emoter would pursue if possible.

5.5 Diagnoser

The *Diagnoser* decides whether the goals can be realised. It makes this decision by taking each of the triggered concerns and their associated goals in order of their importance and reliability. It then develops the goals into more specific plans of action. These plans of action are filtered to remove unrealisable actions. However knowledge of available actions must be known before this is possible. It does not infer a detailed plan of action rather a degree of similarity between known plans of action and the current goal (see Rich (1988), Sec 8.1 for example).

This is achieved by matching the developed goal against preconditions of known plans of action and their resulting effects in the environment. If a match is successful then the developed goal is posted. In the Emoter a concern's goal can be attempted in many ways, but only a few may be suitable to the situation. The *Diagnoser* simply filters out the unachievable goal concepts and suggests practi-

cable solutions to the remaining goals. This is accomplished by developing the goal concept into a set of theoretical actions that have known preconditions and a resulting influence upon the environment. Should a discrepancy occur between the preconditions and the current environmental situation then the theoretical action is rejected. The *Analyser* provides the necessary information about the environment to aid this decision. Output from the *Diagnoser* is a set of theoretically achievable goal concepts each with a number of possible solutions.

For example, maintaining a threat for the other agent may be achieved by putting one of the Emoter's own blocks on his, by moving above the other agent with a block, i.e. intending to kill the other agent, or by removing part of his pattern of blocks.

5.6 Evaluator

The task of the *Evaluator* is to decide whether or not to interrupt ongoing action and/or appraisal to process the new goal. This is achieved on a number of levels. If the *Diagnoser* has not contributed evidence to the blackboard about the goal and the *Comparator* indicates the goal is of a sufficiently higher-level than the ongoing goals then interruption will occur. This is the case for emergency situations, e.g. a mortal threat. However, in most cases the situation does not justify immediate interruption, and the *Evaluator* will wait for information from the *Diagnoser*.

At first sight, the *Evaluator* would simply sort through the set of new goals for the most important compare this with the importance of the ongoing action/appraisal and choose the most important. However, other factors influence the decision. Firstly, the amount of processing or stage of execution of a goal. Secondly, the relative difference in importance values and their respective reliability. The urgency of a goal. Lastly, the energy required to achieve the goal.

Each factor contributes to the decision. Three important exceptions exist to the general operation of the *Evaluator*: encountering an emergency situation, encountering a goal to relieve boredom or a goal to tackle a move that is continuously blocked.

5.6.1 Encountering an Emergency Situation.

An emergency goal should be regarded as a hard-wired reaction which bypasses planning with a specific response. Thus, a quick reaction of moving out of the way is required. While processing the list of developed goals, if an emergency goal is encountered, processing stops and the emergency reaction executed.

5.6.2 Encountering a Goal to Relieve Boredom

If after processing the whole list, the *Evaluator* decides that this goal should interrupt current processing/action then the next most important goal in the list is selected. Such an occurrence may involve a goal of lower importance interrupting present activity. For example, given 3 developed goals, listed in priority order, to process:

1. 'Establish variety in goal'.

2. The current goal.

3. A different goal.

The *Evaluator* will select the 3rd most important goal to interrupt the current goal.

5.6.3 Encountering a Goal to Tackle a Move that is Continuously Blocked

If this goal is deemed important enough to interrupt present activity then processing follows a number of directions. Firstly, if there are various methods of achieving the high level goal currently being executed then one of these alternative developed goals is selected. Secondly, if no alternative developed goals exist for achieving the current goal a high level goal of reduced importance is selected. Finally if these two directions are not successful a developed goal of 'recuperate' is selected. These combined directions allow an Emoter, that cannot resolve conflict through adjusting its physiological profile, to select another approach to the situation. Should the circumstance arise where no alternative approaches are possible, the Emoter will withdraw from the environment to recuperate energy.

5.7 Action Proposer

There are two aspects to the *Action Proposer*:

- Effect physiological change
- Propose a specific move.

In the Literature Review [Sec 2.2.2], the ordering of these two aspects constituted a major discussion point as does the awareness of physiological behaviour.

The James-Lange theory suggests physiological change occurs before an action or emotion is decided. In the parallel architecture of the Emoter, physiological change may trigger the generation of new goals before a specific move is suggested, thereby allowing the abandonment of the goal before a specific action is proposed. Thus physiological change will influence the specific move proposed.

The Cannon-Bard theory however states both appear almost simultaneously. With this in mind, both aspects are grouped together into a single process showing

the linearity rather than a parallel execution.

Also physiological behaviour is effected faster than the gross moves of overt behaviour. The ordering in the Emoter reflects this attitude by allowing physiology to influence the final specific move but not to change the underlying concern.

Each aspect is described separately below.

5.7.1 Effect Physiological Change

Given the current goal for execution, a change is applied to the Emoter's physiological profile. The amount of change is a calculation representing the influence of four factors:

α The importance of the concern triggering the goal where α is inversely proportional to importance, i.e. $\alpha = 1$ represents the most important concern.

β The amount of match/mismatch between the categorised event and the concern where $\beta = 1$ represents a 100% match and $\beta = 0$ represents a 0% match.

γ The number of developed goal options to achieve the high level goal – γ is an integer.

ϵ Whether the goal is an interruption to present activity or not – ϵ is boolean.

The basis of the model is that these factors should be combined into a composite equation representing relative weightings where α has a greater overall effect than β and β a greater effect than α. Since the amount of change is calculated as :

$$\frac{3}{\alpha} + 2\beta + \frac{1}{\gamma}$$

where α, β and γ refer to the factors listed above. The result of this calculation is in the range

$$0 \leq result \leq 6$$

Considering the 0→10 range of values in the physiological profile, the degree of change can be an extremely significant 60%.

The fourth factor, ϵ, that has an influence on the amount of change addresses the fact that physiological change dissipates over time. Thus as a goal is continuously executed, 10% of the physiological change will be lost. After ten moves the agent will have the same physiological profile it had before adopting the current goal for execution.

The amount of change, whether it is from factors $\alpha \rightarrow \gamma$ or factor ϵ, is arbitrarily high. The figures of 60% change in the total range and the 10% dissipation per goal over time are chosen to be high to emphasise the influence of emotional behaviour in conflict situations.

Given the amount of change that should occur, the actual direction of change must be decided. For example, whether the speed should be increased, decreased or remain the same.

The Emoter makes this decision by matching the current high level goal to known high level goals and their associated physiological tendencies. From these tendencies the amount of change can be applied in the correct direction or not at all. For example, maintaining an instrumental event will involve no physiological change whereas disrupting a mortal threat will involve increasing sight and speed, decreasing movement inertia, but will have no effect on the grasping strength or the amount of trembling. A comprehensive breakdown of the known high level goals and their associated physiological tendencies can be seen in table 5.5 The information in table 5.5 is compiled from insights gained through the information on functionality and tendencies of human responses provided by Frijda (1986). These insights were then mapped onto the Emoter's physiological profile using information in Chapter 4 (specifically Table 4.1)

High-level Goal	Effect On Physiological Profile				
	Sight	Speed	Strength of grasp	Trembling	Movement inertia
Maintain threat for self	decrease	no change	no change	increase	no change
Establish threat for self	decrease	decrease	decrease	increase	increase
Disrupt threat for self	increase	increase	increase	decrease	decrease
Maintain threat for other	increase	increase	no change	decrease	decrease
Establish threat for other	increase	increase	increase	decrease	decrease
Disrupt threat for other	decrease	decrease	decrease	increase	increase
Maintain opportunity for self	increase	increase	increase	decrease	decrease
Establish opportunity for self	increase	increase	increase	decrease	decrease
Disrupt opportunity for self	decrease	decrease	decrease	increase	increase
Maintain opportunity for other	decrease	decrease	decrease	increase	increase
Establish opportunity for other	increase	increase	no change	no change	increase
Disrupt opportunity for other	increase	increase	increase	decrease	decrease
Maintain self being killed	decrease	no change	no change	increase	no change
Establish self being killed	decrease	decrease	decrease	increase	increase
Disrupt self being killed	increase	increase	increase	decrease	decrease
Maintain variety in goal for self	increase	increase	increase	increase	decrease
Establish variety in goal for self	increase	increase	increase	increase	decrease
Disrupt variety in goal for self	decrease	decrease	decrease	no change	increase
Maintain instrumental action	no change	no change	no change	no change	no change

Table 5.5: Associated Physiological Tendencies

Intended Action	Blocks to avoid
Put down other's block(s)	the blocks involved in other's pattern
Move other's blocks from own blocks	the blocks involved in own pattern
Pickup other's block	the blocks involved in own pattern

Table 5.6: Examples of Blocks to be Avoided in Some Actions

5.7.2 Propose a Specific Move.

The *Action Proposer* develops plans of action depending on the situation.

Firstly, it is advantageous to avoid partial solutions already developed and in general to avoid negating the intended action by the consequences of an action. For example, if an intended goal is to help another agent and the circumstance involves releasing a block from one's own grasp, then the intended action would be negated if that block killed the other agent by falling on it.

In a similar way, some groups of blocks must be avoided for an intended action to have the desired effects. Table 5.6 shows a number of examples.

Once the blocks that must be avoided have been identified there are 5 main planning options. Developed goals may employ simply 1 option or a combination to propose a specific move.

- Emergency move.
- Get a block.
- Drop a block.
- Move into a killing position.
- Continue with the task.

The following subsections describe each of these planning options in detail.

Emergency move

This planning option is extremely basic and corresponds to the 'flight' reaction of humans. With a minimum amount of processing a position to the left or right of the current agent's position is found. If no position move is possible then the agent will not suggest a move.

Get a block

There are a number of stages to this option. Firstly, if the Emoter is currently holding a block that is not the required block then it will suggest dropping that block. This suggestion does not involve simply releasing the block but also finding a position to drop the block (see *Drop a Block* planning option).

If the Emoter is not currently holding a block, then it must find the nearest relevant block. Once this is achieved then the Emoter can either pick up the block, if it is above that block, or move to a position ready to grasp the block. In exceptional cases the Emoter may not be able to move above the relevant block. For example, it may be beneath another block or another agent may be in that position, In such a case the Emoter will take up a position above the other agent or will remove the redundant blocks above the relevant block.

As with all detected information, the reliability depends upon the accuracy of the sight sense.

Drop a block.

This action option determines a 'safe' position in which to drop the currently held block. If the agent is in this position then the block will be dropped. A 'safe' position is determined as one in which the objects that negate the intended action are avoided. Thus, a 'safe' position may be above another agent: a paradox since dropping a block will kill the other agent.

Should a safe position be impossible to find then the block will be dropped at the present location.

Besides simply dropping a block, this action option can be employed to stack what is currently grasped onto a specific block. This is accomplished by specifying that a safe position is above the relevant target block.

Move into a killing position

Both moving above and below an agent are planned using this action option. Once the position above or below is identified and does not violate the world's physical boundaries or involve moving to an occupied location, then the specific move can be proposed.

Continue with the task

Upon executing this action option, an ordered list of the task blocks will have been created by the *Analyser*. Thus given the task of positioning

- block 1 on block 2
- block 2 on block 3
- block 4 on block 5
- block 5 on block 6

The corresponding task list will be:

Here we can see two separate stacks consisting of three blocks in each. The algorithm associated with this action option takes each block of the ordered task list in turn. If there should be a block stacked on it then all redundant blocks are

cleared from it. For example, given a situation like figure 5.3 then the algorithm will clear blocks 2 and 3 to leave 6 uncovered. Once this is achieved, the next

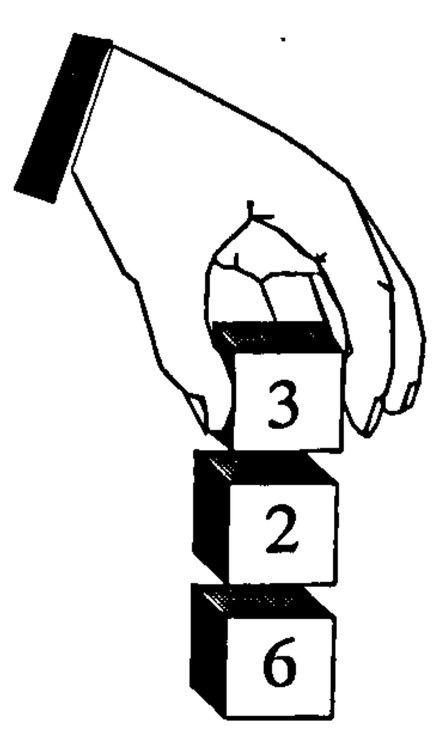


Figure 5.3: An Example.

block in the ordered task list is picked up by using the action option *Pick Up Block*. Then using the *Drop Block* option this block is stacked on the uncovered block.

Such moves are generated until the various task stacks are complete. It should be noted, that upon suggesting a new move to complete the prescribed task, a check is made on the current state of the pattern and appropriate stages of the planning repeated if necessary.

The *Continue With The Task* action option is a simple form of planning which follows an identical method on each execution. Thus given the task of completing two stacks of blocks, the algorithm will always ensure the 1st stack is complete before attempting the second. If during the construction of the second stack, the first is broken up then further actions will abandon the second to reconstruct the first stack.

5.7.3 The Influence of The Physiological Profile on The Proposed Move.

The proposed move is influenced by the physiological profile to a certain degree. If the Emoter's speed is zero then any proposed move cannot occur. Similarly, if the Emoter has difficulty in moving, represented by the movement inertia element, then this will be reflected in the move allowed. For instance, with the highest degree of inertia, the Emoter cannot move, whereas with all other values, the distance the Emoter is allowed to move is proportional to the degree of movement inertia. In addition, the Emoter's grasping strength will influence all specific moves that involve grasping a block, but only to the extent that zero strength indicates such a move is impossible. Naturally, if the Emoter is grasping a block while the strength drops to zero then that block is released.

5.8 Threshold Feedback

Self regulation occurs in the Emoter to provide attention focus and reduced emotional shift. This is achieved by using information on the selected goal that is currently being processed to decrease threshold levels on similar concerns and increase the threshold levels on all others. The information required to make these changes consists of the event category an the amount of physiological change calculated in effecting that physiological change.

The event category is described in table 5.3 and relates to concerns such as those shown in table 5.4

By matching all concerns' themas to the event category, specific concerns' threshold levels can be reduced by a certain amount. This amount is calculated as twice the physiological change amount, which although arbitrary reflects a significant change in threshold levels: a maximum of 12%. Similarly to emphasise

the effects of self regulation in the Emoter the other concerns whose themas do not match the categorised events will have an increased threshold level. However, the amount this time is only the physiological change amount: a maximum of 6%. Clearly repeated application of threshold feedback could result in a threshold level exceeding 100% or falling below 0%. Although such threshold levels could theoretically be useful in ensuring a concern is always triggered with a minor event, or providing a fixed focus, i.e. a concern with a threshold of over 100% cannot be triggered. The intended application of self regulation is to make it more difficult or easier for concerns to be triggered not to remove certain concerns from the process. To this end, a minimum limit of 10% and a maximum limit of 90% is imposed on the concerns' threshold levels.

The actual changing of the threshold levels should take place in the *Comparator* as matches are continuously applied there. Thus in the parallel architecture of the Emoter the intention is that once the amount of change was calculated by the *Action Proposer* and posted on the blackboard the *Comparator* will use this as a signal to make the relevant changes. In the actual implementation, this aspect of the emotion process is executed through an additional process termed *Regulation* to emphasise its importance to the Emoter. Although the *Regulation* process does not correspond exactly to that of Frijda's it embodies at least one aspect of that vague description.

5.9 Overview of the Implementation

The computational implementation uses the various levels of embedding described in section 4.5, which allows multiple instances of the Emoter to be introduced to the blocks world. For the evaluation undertaken in this research, only two instances of the Emoter were used in games. This approach reduces the complexity of interaction between agents. In addition, one of the agents was always

un-emotional (see section 6.3) to act as a 'control'.

The emotion process consists of various subprocesses, e.g. *Analyser*, *Comparator* that correspond to C++ classes in the implementation. The classes each contain a function **start()** to activate them, which is called by a scheduler. The scheduler in this implementation calls each of the class's **start()** functions sequentially. That is, *Analyser, Comparator, Diagnoser, Evaluator, Action Proposer, Physiological Change* and finally *Actor*. Further calls to the class functions occur depending on whether information is required during processing. For example, in determining if a developed goal is realisable, the *Diagnoser* class will place a call to the *Analyser* for information on the state of the world. In general the flow of data is shown by figure 3.5, and although calls between classes occur in the implementation, such information is stored on the blackboard.

5.10 Conclusion

The main purpose of the Chapter *Emotion Process* was to offer an insight into the discrete, deterministic processing of an emotional event using the Emoter model. By describing the model of emotions in terms of the child's game implementation, the reader can associate with the information processing required. In addition, the detailed description clarified the vague improvements to a model of emotions suggested in Chapter 3, *Theoretical Analysis*.

Chapter 6

Evaluation of the System

6.1 Introduction

This chapter describes the criteria that were employed in the evaluation of the Emoter system. The criteria have two aims: to demonstrate that the model exhibits emotional behaviour and to show the influence of this emotional behaviour on conflict situations. An analysis of the influence of emotional behaviour is performed primarily in terms of efficiency. This provides evidence that the emotion process may offer benefits as a control mechanism for computer applications at a reasonable cost, specifically in terms of energy expended, e.g. time taken or processing speed. A discussion of the implications of this evidence is undertaken in Chapter 7.

6.2 Criteria For Evaluation

There are two aims for the evaluation of the model. These are:

- To demonstrate the model exhibits emotional behaviour.
- To show the influence of emotional behaviour on conflict scenarios.

The former stage of evaluation is complex because the emotions experienced by the Emoter are radically different from those experienced by a human. The Emoter has two essential aspects of emotion: physiology that is grossly similar to that of a human, and the overt behaviour that accompanies the physiological changes occurring. It would be ludicrous to suggest an observer can ascribe emotional behaviour from a snapshot of either aspect. In fact, simply ascribing emotional behaviour to the Emoter can only be achieved by providing a complete description of the situation before and after an agent acts. It is only through role playing that an observer can guess a particular emotion the Emoter will experience and its corresponding physiological and overt actions. It should be noted that no analysis of emotional labelling will occur in this research. Simply a question of *'Is the Emoter model emotional?'* is deemed relevant. The reason for this approach is that the work of Frijda (1986), Swagerman (1987), Raccuglia (1992) and Moffat (1993) all point to the acceptance of the underlying theory as a close and effective platform architecture of emotion. More to the point, the pictorial representations offered by the system do not and cannot express the nuances we all associate with particular emotions. Therefore, labelling the Emoter's experiences in human emotional terminology can only instill a sense of inadequacy and estrangement.

Further, this research will not attempt to gather empirical data from the third person ascription of emotional behaviour, instead it will apply a more general argument in ascribing emotional behaviour. To this end, the argument will be presented in the *Critical Discussion of the Model* [Sec 7.2].

The stage of evaluation that shows the influence of emotional behaviour on conflict scenarios is subdivided into two further sections.

- The influence of physiological changes.

- The influence of overt behaviour and physiology combined.

6.2.1 The Influence of Physiological Changes.

The two sections are necessary in the demonstration that emotional behaviour does not require more complex planning than unemotional behaviour. In the *Literature Review* [Sec 2.2.1] it was noted that many behavioural characteristics of emotion are also present in unemotional behaviour. Indeed, the basic postulate of Conflict theories of emotion state the main distinguishing characteristic of emotional behaviour is that a psychological tendency is stopped or ongoing action is interrupted. By allowing emotional and unemotional agents the same planning options and specifically only one mechanism for realising high level goals, the true benefit of emotional action can be seen. Thus, the only difference between an emotional and unemotional agent is that the emotional agent can adjust its physiological profile according to its concerns (see Sec 6.3 for evidence). That is to say, the Emoter can become more aroused or not as the situation dictates. The unemotional agents, on the other hand, perform only simple goal directed behaviour without becoming aroused with environmental stimuli.

Clearly, this section of evaluation does not cover full emotional behaviour. It is accepted that an implementation of the Emoter could misrepresent the influence that emotional behaviour has on conflict scenarios. The reason this may occur is best demonstrated by considering an extreme situation, e.g. an emergency reaction to a mortal threat. In an equivalent human situation, the response may or may not be emotional; the response may be an unemotional reflex action or a 'fight/flight' action. Since an unemotional agent in this research implementation does not possess an unemotional reflex response to a mortal threat there is a possibility that the influence of the Emoter's full emotional behaviour may be misrepresentative. An unemotional reflex response to a mortal threat was not implemented since it is extremely unusual, if actually possible, in the real world. Also, the exclusion of such a response emphasises the influence of emotional behaviour.

6.2.2 The Influence of Overt Behaviour and Physiology Combined.

Having established the importance of analysing the influence of physiological change alone, the fact that emotional behaviour has an influence on planning and overt responses alike must also be established. Therefore, it is assumed that unemotional reflex responses and unanticipated dissimilarities with human behaviour have only a small influence on the resulting behaviour.

The criteria for evaluation in both physiology alone and physiology combined with overt behaviour address two major points. They are, the consequent efficiency for resolving conflicts and the usefulness in the explanation of social interaction.

6.2.3 Efficiency

On the simplest level, the combatant that completes their task first in a conflict scenario represents one measure of efficiency. More important, however, is the ability to cope with conflict and cooperation. For instance, in conflict scenarios where two unemotional agents would become deadlocked and unable to proceed without outside influence, e.g. third party arbitration, what would be the effect of introducing emotional behaviour to one or both of the agents? In such scenarios, the physiology of an agent will influence the amount of expended energy in its overt movement. Thus an analysis of this expended energy may be considered. Finally, the ability of an agent to survive is of primary importance.

These four measures of efficiency can be summarised as:

- Successful combatant.
- Ability to resolve conflicts without third party intervention.
- Expended energy.

- Ability to survive.

6.3 Unemotional and Emotional Agents

The evaluation of the emotional model involves an implementation of two agents – one emotional and one that is unemotional to act as a'control'. The evaluation is performed upon conflict scenarios where two unemotional agents would become deadlocked. The theorem under consideration is that by making an agent emotional the conflict deadlock will be broken. It is assumed that two emotional agents would have at least slight differences in their set of concerns and the threshold levels at which those concerns are triggered, so deadlock between two emotional agents is unlikely. Further, by analysing an emotional agent with a non-emotional agent the analysis of interactions is simplified. The rationale is that this research is not aimed at all forms of emotional interaction but rather the benefits of emotional behaviour as compared with non-emotional behaviour.

Creating an unemotional agent requires a small adjustment to the Emoter. Swagerman's (1987) interpretation of an unemotional action was one in which the triggered concern is of relatively low importance. In the Emoter, the alternative interpretation of an unemotional action is one in which the triggered concern produces an instrumental goal. With such a goal there is no change to arousal levels and similarly no physiological change. Schachter (1959;1964;1970) states that if the individual encounters the same cognition over time the experience will only be termed emotional if that individual is physiologically aroused.

Further, since a completely unemotional agent will not, by definition, suffer interruptions to ongoing action or interruptions to psychological tendencies, the instrumental goal is continuous. Any triggered concern will result in an instrumental action of *continuing with the prescribed task.* This restricts the necessary adjustment to only the concerns of the Emoter. Table 6.1 shows the adjustment.

Importance	Thema		High level goal
1	Mortal threat for self	$\Longrightarrow$	instrumental action.
2	Major threat to self	$\Longrightarrow$	instrumental action.
3	Major opportunity for self	$\Longrightarrow$	instrumental action.
4	Need stability for self	$\Longrightarrow$	instrumental action.
5	Minor threat to self	$\Longrightarrow$	instrumental action.
6	Minor opportunity for self	$\Longrightarrow$	instrumental action.
7	Mortal threat for other	$\Longrightarrow$	instrumental action.
8	Major opportunity for other	$\Longrightarrow$	instrumental action.
9	Minor opportunity for other	$\Longrightarrow$	instrumental action.

Table 6.1: Unemotional Personality

6.4 Conflict Scenarios

Four interesting conflict scenarios are chosen where two unemotional agents would become deadlocked (see Appendix A for the actual moves leading up to the deadlock) after making symmetrically equivalent moves. The areas of conflict address four distinct aspects of conflict that could and do occur in the blocks world. These are:

- Positional conflict to attain a block (see figure 6.1).
- Positional conflict to stack a block on a stable position (see figure 6.2).
- Unintentional conflict occurring by discarding blocks (see figure 6.3).
- Positional conflict to stack a block on an unstable position (see figure 6.4).

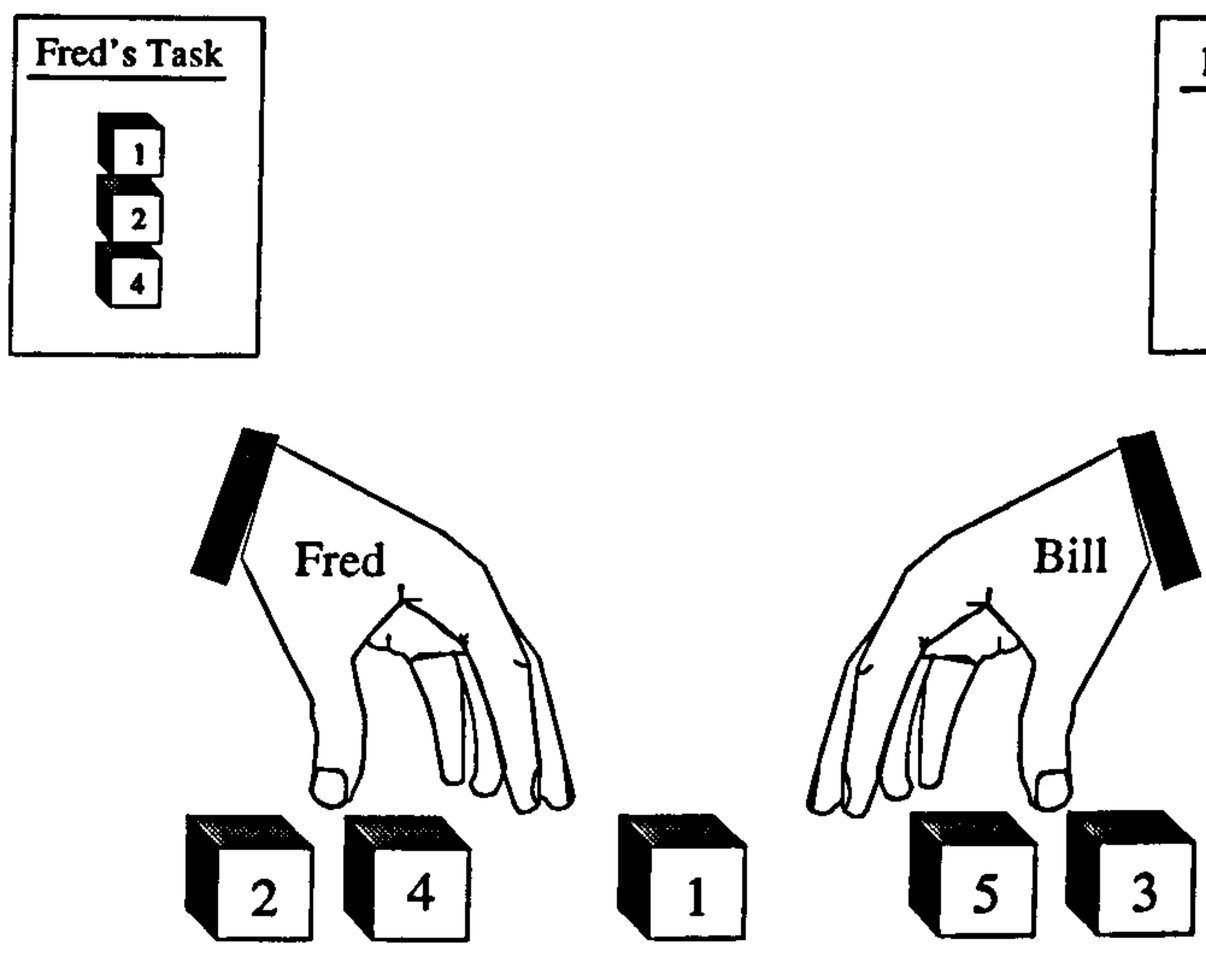


Figure 6.1: Conflict Scenario One.

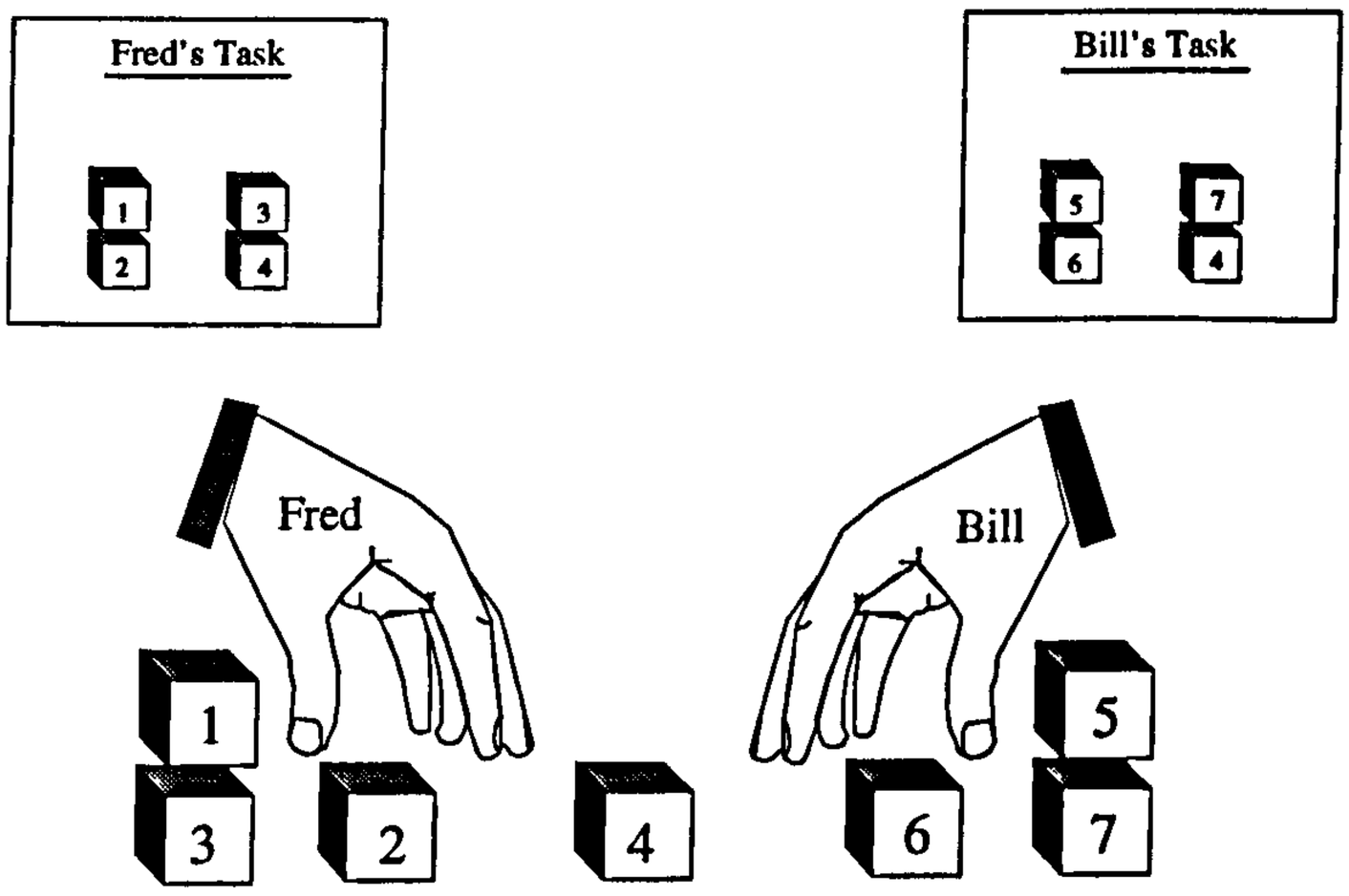


Figure 6.2: Conflict Scenario Two.

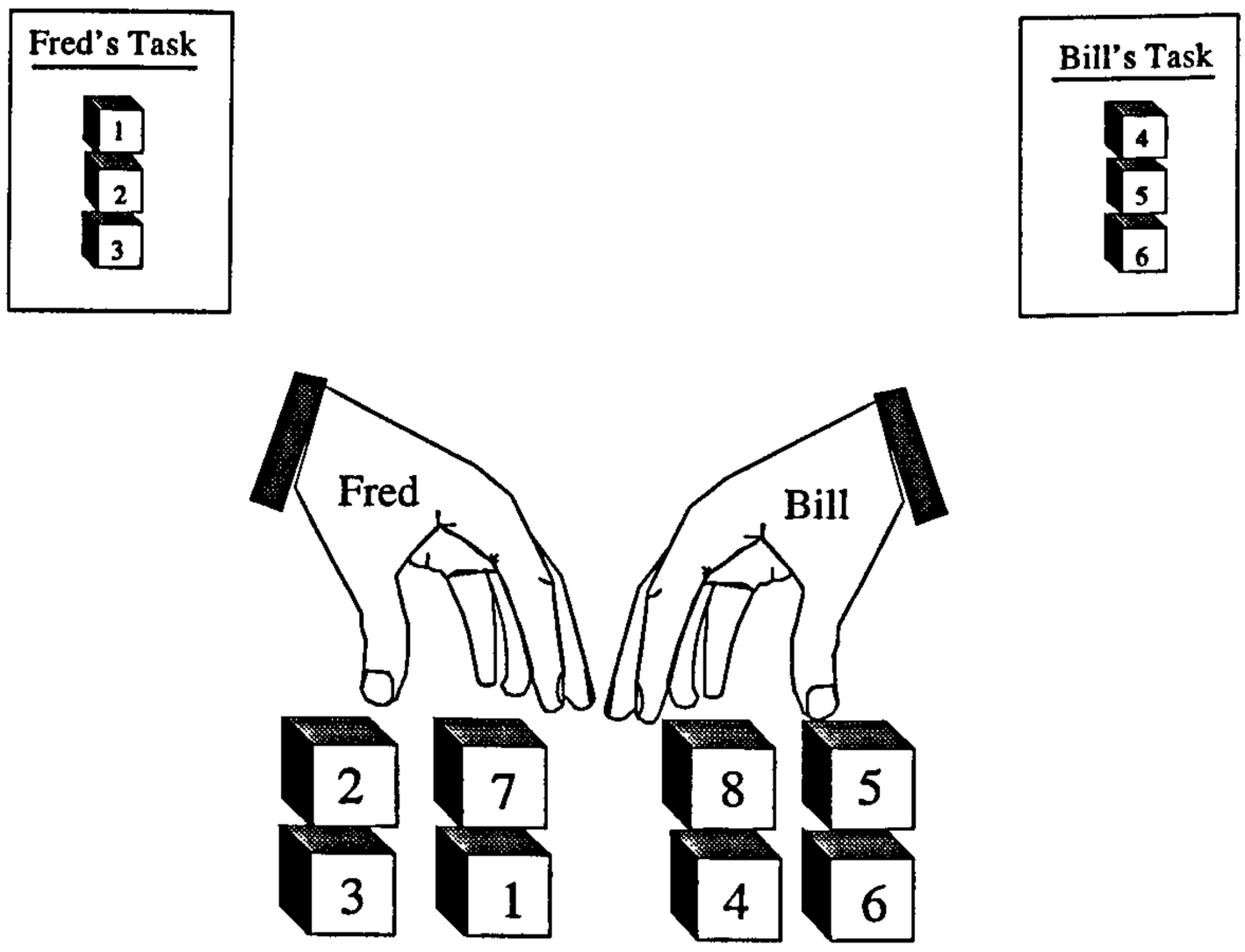


Figure 6.3: Conflict Scenario Three.

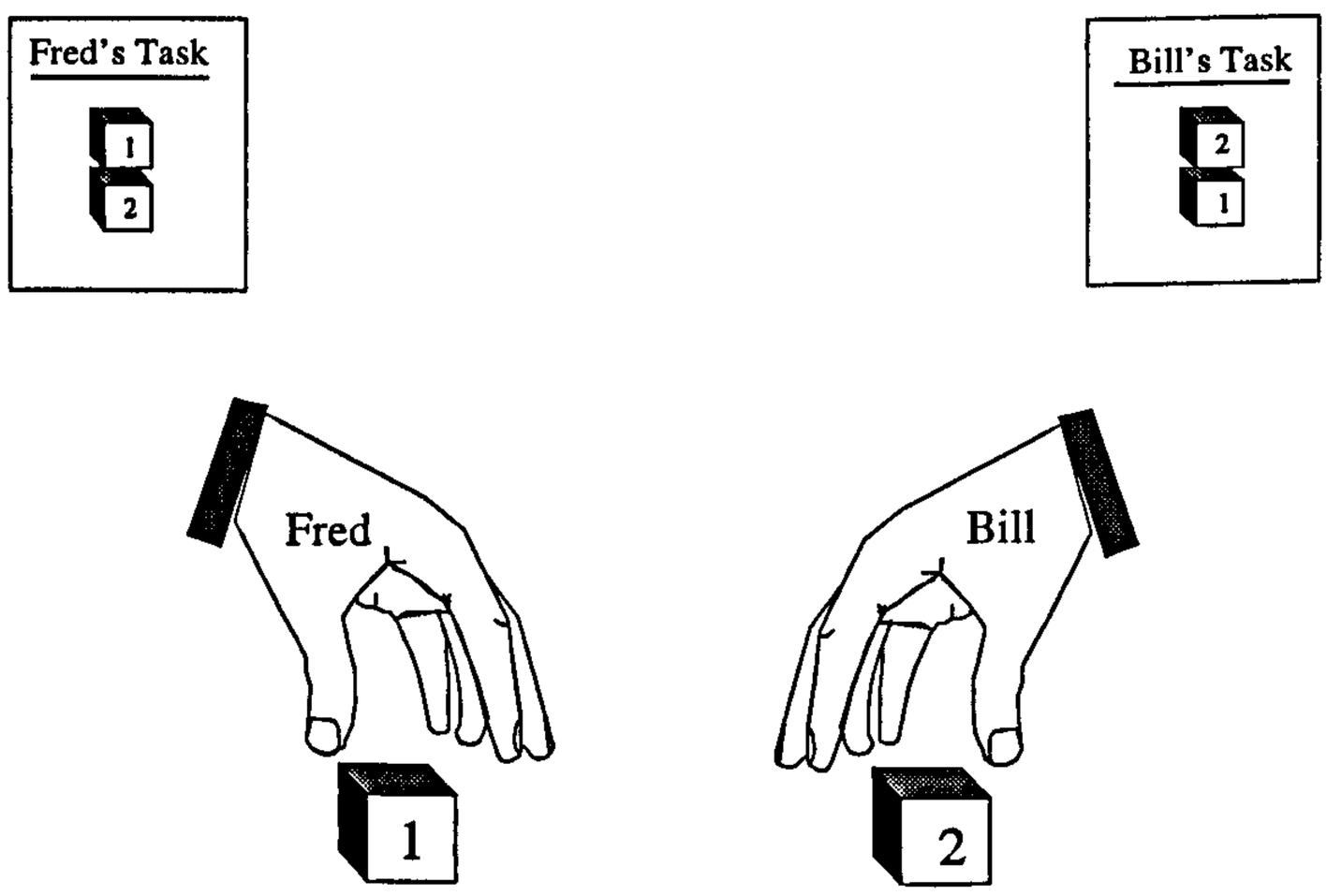


Figure 6.4: Conflict Scenario Four.

6.5 Personality Roles

Along with the unemotional agent which could be described as possessing a personality, be it no personality, five other distinct personalities are presented in the analysis. These are:

Aggressive — threatens other agents whenever possible (see table 6.2).

Altruistic — tries to help other agents whenever possible (see table 6.3).

Defensive — only reacts to threats (see table 6.4).

'Normal' — normal competitive attitude (see table 6.5).

Selfish — looks for personal opportunities everywhere (see table 6.6).

Four of these personalities, i.e. Aggressive, Altruistic, Defensive and Selfish, are commonly used in Game Theory because they represent extremes of behaviour. An aggressive profile being the opposite of altruistic, and defensive the opposite of selfish. The 'normal' personality is an attempt to combine both defensive and selfish reactions. The set of concerns that represent each profile are an intuitive interpretation of the personality types.

An Emoter with a particular personality will be identified by adding a prefix of the adjective. Thus, *Aggressive Emoter, Altruistic Emoter, Defensive Emoter, 'Normal' Emoter* and *Selfish Emoter* correspond to the five personalities under consideration.

Each is described in the following tables.

Importance	Thema		High level goal
1	Mortal threat for self	$\Longrightarrow$	establish mortal threat for other
2	Major threat to self	$\Longrightarrow$	establish mortal threat for other
3	Mortal threat for other	$\Longrightarrow$	maintain mortal threat for other
3	Major threat for other	$\Longrightarrow$	maintain major threat for other
4	Major opportunity for other	$\Longrightarrow$	establish major threat for other
5	Minor opportunity for other	$\Longrightarrow$	establish major threat for other
6	Minor threat to self	$\Longrightarrow$	establish major threat for other
7	Major opportunity for self	$\Longrightarrow$	establish major threat for other
8	Minor opportunity for self	$\Longrightarrow$	establish minor threat for other
9	Need stability for self	$\Longrightarrow$	establish minor threat for other
10	Neutral	$\Longrightarrow$	maintain instrumental for self

Table 6.2: Aggressive Personality

Importance	Thema		High level goal
1	Mortal threat for other	$\Longrightarrow$	disrupt mortal threat for other
1	Major threat for other	$\Longrightarrow$	disrupt major threat for other
2	Minor threat for other	$\Longrightarrow$	disrupt minor threat for other
2	Major opportunity for other	$\Longrightarrow$	maintain major opportunity for other
3	Major opportunity for self	$\Longrightarrow$	establish major opportunity for other
4	Minor opportunity for self	$\Longrightarrow$	establish minor opportunity for other
5	Minor opportunity for other	$\Longrightarrow$	maintain minor opportunity for other
6	Minor threat to self	$\Longrightarrow$	maintain minor threat to self
7	Major threat to self	$\Longrightarrow$	maintain major threat to self
8	Need stability for self	$\Longrightarrow$	establish minor opportunity for other
9	Mortal threat for self	$\Longrightarrow$	maintain mortal threat for self
10	Neutral	$\Longrightarrow$	maintain instrumental for self

Table 6.3: Altruistic Personality

Importance	Thema		High level goal
1	Mortal threat for self	$\Longrightarrow$	disrupt mortal threat for self
2	Major threat to self	$\Longrightarrow$	disrupt major threat to self
3	Minor threat to self	$\Longrightarrow$	disrupt minor threat to self
4	Need stability for self	$\Longrightarrow$	maintain stability for self
5	Major opportunity for other	$\Longrightarrow$	instrumental
6	Major opportunity for self	$\Longrightarrow$	instrumental
7	Mortal threat for other	$\Longrightarrow$	instrumental
8	Minor opportunity for other	$\Longrightarrow$	instrumental
9	Minor opportunity for self	$\Longrightarrow$	instrumental
9	Major threat for other	$\Longrightarrow$	instrumental
9	Minor threat for other	$\Longrightarrow$	instrumental
10	Neutral	$\Longrightarrow$	maintain instrumental for self

Table 6.4: Defensive Personality

Importance	Thema		High level goal
1	Mortal threat for self	$\Longrightarrow$	disrupt mortal threat for self
2	Major threat to self	$\Longrightarrow$	disrupt major threat to self
3	Major opportunity for self	$\Longrightarrow$	maintain major opportunity for self
4	Need stability for self	$\Longrightarrow$	maintain stability for self
5	Minor threat to self	$\Longrightarrow$	disrupt minor threat to self
6	Minor opportunity for self	$\Longrightarrow$	maintain minor opportunity for self
7	Mortal threat for other	$\Longrightarrow$	establish major opportunity for self
7	Major threat for other	$\Longrightarrow$	establish major opportunity for self
8	Minor threat for other	$\Longrightarrow$	establish minor opportunity for self
8	Major opportunity for other	$\Longrightarrow$	disrupt major opportunity for other
9	Minor opportunity for other	$\Longrightarrow$	establish minor opportunity for self
10	Neutral	$\Longrightarrow$	maintain instrumental for self

Table 6.5: 'Normal' Personality

Importance	Thema		High level goal
1	Mortal threat for self	$\Longrightarrow$	disrupt mortal threat for self
2	Major opportunity for self	$\Longrightarrow$	maintain major opportunity for self
3	Minor opportunity for self	$\Longrightarrow$	maintain major opportunity for self
4	Need stability for self	$\Longrightarrow$	maintain stability for self
5	Major threat to self	$\Longrightarrow$	establish major opportunity for self
6	Minor threat to self	$\Longrightarrow$	establish major opportunity for self
7	Mortal threat for other	$\Longrightarrow$	establish major opportunity for self
7	Major threat for other	$\Longrightarrow$	establish major opportunity for self
8	Minor threat for other	$\Longrightarrow$	establish minor opportunity for self
8	Major opportunity for other	$\Longrightarrow$	establish major opportunity for self
9	Minor opportunity for other	$\Longrightarrow$	establish major opportunity for self
10	Neutral	$\Longrightarrow$	maintain instrumental for self

Table 6.6: Selfish Personality

6.6 Efficiency Evaluation

As outlined in the *Criteria For Evaluation* [Sec 6.2], two versions of the Emoter's emotionality are examined: the sole influence of physiological profiles and 'full' emotional behaviour. On each of the four criteria under examination both versions of emotionality are presented. It should be noted that Appendix B shows the actual moves of Emoters, with the personalities outlined earlier, competing against an unemotional agent in conflict scenario one. Similarly, Appendix C shows the same agents competing in scenario two. Appendix D shows scenario three and Appendix E scenario four.

6.6.1 Successful Combatant

Charts F.1 → F.8 of Appendix F show a compilation of the time each agent takes in the conflict scenarios until he either dies, is successful in completing his task or becomes involved in a deadlock. Charts F.1 → F.4 represent the effect of physiology alone and charts F.5 → F.8 represent the effect of 'full' emotional behaviour.

Results for Emoters Employing Physiology Alone

Consider charts F.1 → F.4 of Appendix F. Clearly an *Aggressive Emoter, Defensive Emoter, Normal Emoter* or *Selfish Emoter* is the successful combatant in scenarios that involve positional conflict to attain a block (e.g. scenario one) or positional conflict to stack a block on a stable position (e.g. scenario two). Similarly, although the *Altruistic Emoter* resolves both these conflicts he is never successful in completing the prescribed task first.

With the exception of the *Altruistic Emoter* in scenario three, Emoters with physiology alone cannot resolve scenarios that involve unintentional conflict occurring by discarding blocks (e.g. scenario three) or positional conflict to stack a

block on an unstable position (e.g. scenario four).

Results for Emoters Employing 'Full' Emotional behaviour

Consider charts F.5 → F.8 in Appendix F. An *Aggressive Emoter, Defensive Emoter* or *Normal Emoter* is the successful combatant in scenarios that involve positional conflict to attain a block (e.g. scenario one) or positional conflict to stack a block on a stable position (e.g. scenario two). However, to resolve scenarios that involve unintentional conflict occurring by discarding blocks (e.g. scenario three) or positional conflict to stack a block on an unstable position (e.g. scenario four), the Emoters must capitulate and allow the non-emotional combatant to complete his prescribed task first. Similarly, in resolving all conflicts, the *Altruistic Emoter* is never successful in completing the prescribed task first. The *Selfish Emoter* dies in his attempt to successfully resolve the positional conflict to stack a block on a stable position (e.g. scenario two). He cannot resolve an unintentional conflict occurring by discarding blocks (e.g. scenario three) but successfully resolves a positional conflict to stack a block on an unstable position (e.g. scenario four) by killing the other agent.

6.6.2 The Ability to Cope with Conflict

Again consider charts F.1 → F.8 in Appendix F. Emoters with physiology alone can only cope with scenarios that involve positional conflict to attain a block (e.g. scenario one) or positional conflict to stack a block on a stable position (e.g. scenario two). Emoters with 'full' emotional behaviour on the other hand, can cope with all forms of conflict. The exception being a *Selfish Emoter* attempting to resolve an unintentional conflict that arises from discarded blocks.

It should be noted that the ability to cope with conflict refers to the fact that when Emoters with 'full' emotional behaviour are involved no third party inter-

vention is required. Paradoxically, this may involve the Emoter's with emotional behaviour being crushed or losing the conflict.

6.6.3 Expended Energy

The energy of each move, assuming constant force, is calculated using standard formulae:

$$Energy = Force \times distance$$

and

$$Force = mass \times acceleration$$

Since the Emoter's movement is over unit time in any particular cycle and its speed represents the maximum speed at the end of the move,

$$acceleration \equiv speed\ of\ the\ Emoter$$

Also, the mass of the agent is taken to be unit mass,

$$\Rightarrow Energy = speed\ of\ the\ Emoter \times distance$$

The Emoter's strength is seen as a force,

$$\Rightarrow Energy = strength \times distance$$

And the Emoter's movement inertia value, will influence the formulae by increasing the perceived distance,

$$Energy = speed \times \left(distance + \frac{distance}{inertia} \right) \tag{6.1}$$

$$Energy = strength \times \left(distance + \frac{distance}{inertia} \right) \tag{6.2}$$

It should be noted that the value of inertia that represents the greatest effort to move is '1' and the easiest is '10'. Distance is measured in units in which a block has side one unit and the world has boundaries of ten units horizontally and ten units vertically (see section 4.2.1).

Thus, for calculating the energy used in the four possible moves of an agent:

- **Pick up** — use equation 6.2 with *distance* = 0.5 to signify the block is actually picked up.
- **Put down** — trace energy is used, i.e. 0 energy.
- **Move with a block** — use equation 6.1 and multiply by a factor of 1.5 to account for the additional weight of the block, i.e. the block has mass 0.5.
- **Move** — use equation 6.1.

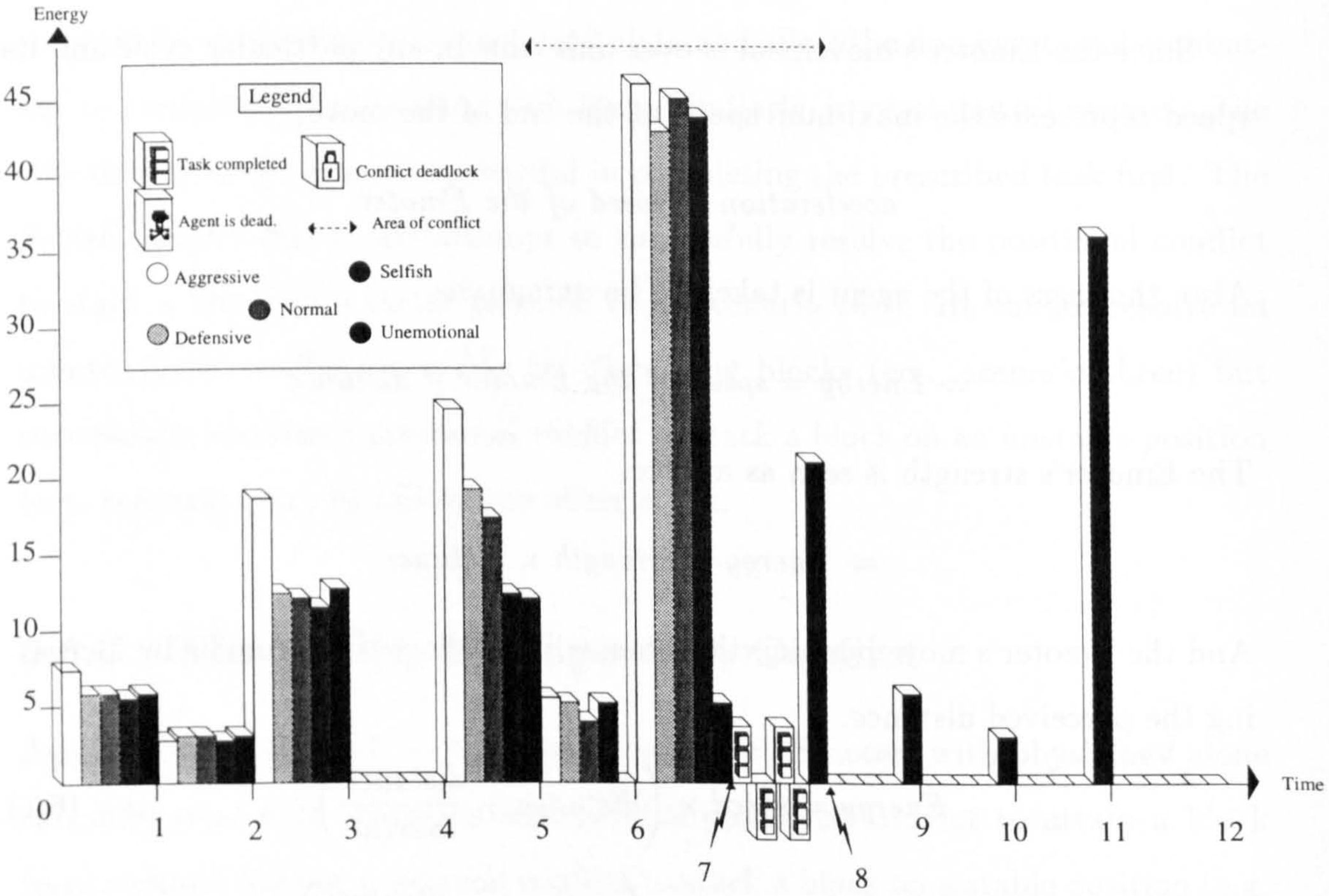


Figure 6.5: Energy Expended on Each Move in Scenario One.

Figure 6.5 describes the changes in expended energy on each move that various Emoters with physiology alone perform in scenario one. Depending on the personality of the Emoter, arousal levels increase to prepare an Emoter for conflict.

Level of Energy Expended	Type of Emoter
Least energy ↑	Altruistic
	Selfish
	Normal
	Defensive
↓ Greatest energy	Aggressive

Table 6.7: Relative Energy Expenditure

Similarly, such arousal levels increase the expended energy of an Emoter. An analysis of efficiency must include a discussion of this expended energy, particularly whether increased energy before a conflict results in a saving of energy over the complete scenario and how different personalities influence the expenditure of energy. Thus charts G.1 → G.8 of Appendix G show the total expended energy for all agents in each of the conflict scenarios. Charts G.1→ G.4 represent the energy expended by agents with physiology alone whereas charts G.5 → G.8 represent the energy expended by agents with 'full' emotional behaviour.

Results on Expenditure of Energy

Emoters with physiology alone expend less energy than non-emotional agents when conflicts are resolved. When 'full' emotional behaviour is utilised, Emoters generally expend more energy to resolve conflicts than non-emotional agents.

The various personalities influence the energy expended by Emoters when resolving conflicts. In a relative analysis of the levels of energy expended, table 6.7 represents a ranking on the influence of various personalities.

6.6.4 Ability To Survive

Consider charts F.1→ F.8 in Appendix F. Agents are crushed by blocks in charts F.5, F.7 and F.8. In scenarios that involve *'Normal'* or *Defensive Emoters* no agents are crushed by falling blocks. With *Aggressive Emoters* the non-emotional combatant is killed in scenario one. The *Selfish Emoter* is crushed in scenario two but crushes his non-emotional combatant in scenario four. The *Altruistic Emoter* is also crushed in scenario four.

Therefore, of all the various personalities examined, the *'Normal', Defensive* and *Aggressive Emoters* have the greatest ability to survive.

6.7 The Influence of Different Personality Roles

The *Efficiency Evaluation* section [Sec 6.6] outlined a number of differences in the results provided by the various Emoter's personality roles. These were:

- *'Normal', Defensive* and *Aggressive Emoters* have the greatest ability to survive.

- An *Altruistic Emoter* expends the least energy in resolving conflicts. *Selfish, Normal & Defensive Emoters* have respectively greater expenditures of energy. An *Aggressive Emoter* expends the greatest energy.

- The *Altruistic Emoter* never completes his prescribed task first in any conflict scenario. *Aggressive, 'Normal'* and *Defensive Emoters* are successful combatants, i.e. they complete their task first, in scenarios one & two, but are not successful in scenarios three & four. The *Selfish Emoter* is only successful in completing his prescribed task in scenario four.

- All Emoters resolve conflicts one → four except the *Selfish Emoter* in scenario three.

These differences emphasise the influence that an agent's concerns have over his behaviour. For instance, an *Altruistic Emoter* is not concerned with disrupting personal threats , he is only concerned with helping his combatant. Therefore, he has a relatively poor ability to survive and is never the successful combatant in conflict situations. An agent's concerns may be categorised into four groups.

1. Reacting to personal opportunities.

2. Reacting to personal threats.

3. Helping a combatant.

4. Harming a combatant.

A reaction implies a change in arousal levels towards an event. Thus a *Defensive Emoter* reacts to personal threats but has instrumental reactions towards other events. *Selfish Emoters* react to personal opportunities. The *'Normal' Emoter* however reacts to both opportunities and threats. An *Altruistic Emoter* only helps the other combatant whereas an *Aggressive Emoter* only harms the other combatant. Such differences are reflected in behaviour patterns to such an extent that:

- Emoters that are concerned with reactions to personal opportunities resolve the conflict in a shorter time period and expend relatively lower levels of energy. However, this is at the cost of successfully completing the task first and their ability to survive.

- Emoters that are concerned with reactions to personal threats have a relatively good ability to survive but expend relatively more energy.

- Emoters that are concerned with helping a combatant, never complete their prescribed task first, have a poor ability to survive but expend the least energy.

- Emoters that are concerned with harming a combatant often complete their task first, have a good ability to survive but expend the most energy.

- Emoters that combine reactions to both personal threats and opportunities often complete their prescribed task first, have a good ability to survive and expend an average amount of energy.

- The difference between Emoters that react to threats but deal with opportunities in either an instrumental, i.e. not aroused, or positive manner is shown in both time taken and energy expended to resolve a conflict situation. The *'Normal' Emoter* reacts positively towards personal opportunities and therefore completes his task faster than the *Defensive Emoter* that reacts instrumentally (see charts F.5 & F.7). Similarly, the *'Normal' Emoter* expends less energy than the *Defensive Emoter* to resolve conflicts (see charts F.1 ... F.4, F.6 ... F.8).

The obvious consequences of these results are that emotions connected with reacting towards a personal threat or continuously trying to harm another combatant leads to a greater ability to survive and a greater success at completing the task first. The disadvantages are that such emotions lead to a greater expenditure of energy and time taken to resolve the conflict.

Reactions to personal opportunities or continuously trying to help another combatant leads to a lower expenditure of energy and time taken to resolve the conflict. The disadvantages are that such emotions lead to a poor ability to survive and less success at completing the task first.

Clearly a combination of both aspects is required to produce an Emoter that uses relatively low amounts of energy to successfully complete a task first in a

short amount of time and has a good ability to survive.

Of the various personality roles represented in this research, the emotions of the *'Normal' Emoter* optimise both aspects to provide benefits of being a successful combatant with a good ability to survive at reasonable costs of energy and time taken.

6.8 Conclusion

This chapter described the evaluation of the Emoter model in terms of its influence on conflict situations and its efficiency with respect to resolving or managing those conflicts. This was achieved by creating four conflict scenarios with two agents competing and/or cooperating to complete prescribed tasks. When two non-emotional agents tackled the conflict scenarios each reached a state of deadlock that could not be resolved without third party intervention. By replacing one of the agents with an Emoter the deadlock was broken. The success of the Emoter and its level of efficiency were dependent on which of the five distinct personality roles that the Emoter adopted. Four specific benefits and costs were analysed. These were: which agent completed the task first, the time taken to resolve the situation, the agent's ability to survive, and the energy expended in resolving the conflict. A discussion of the implications of the results presented in this chapter is undertaken in the following chapter.

Chapter 7

Critical Discussion Of the Model

7.1 Introduction

This chapter provides a critical discussion of the Emoter model, the validity of its emotional behaviour and its value to the field of conflict resolution. The implication of this thesis for emotional systems and the issue of exploiting artificial emotional systems is then discussed. Limitations of the system along with further questions arising from implementing the system are outlined to form the basis of directions for further research.

7.2 Are They Real Emotional Processes?

7.2.1 Why Would Observers Find it Difficult to Ascribe Emotions to the Model?

Chapter six anticipated problems with the third person ascription of emotion. These problems stem from the inherent difficulty we have with identifying distinct qualities of emotional behaviour. That is, identifying differences between emotional and non-emotional behaviour. When one is asked to describe an emo-

tion, for example hate, it is a common practice to associate that emotion with others. Thus, hate *feels* like something else. If the physical characteristics are described, hate loses much of the mysticism behind it and exhibits many characteristics found in unemotional behaviour. Such problems offer an understanding of Duffy's (1941) statement:

> 'Emotion has no distinguishing characteristics. It represents merely an extreme manifestation of characteristics found in some degree in all responses.'

Similarly, Meyer (1933) suggests it is not possible to draw a line between emotional and non-emotional reactions.

> 'Emotion has no distinguishing characteristics. It represents merely an extreme manifestation of characteristics found in some degree in all responses.'

The Emoter not only suffers from the inherent problems of ascribing emotional behaviour, it has to tackle the problem of non-human emotions. One's ascription of the general family of emotions is performed by association with human emotions. Thus, differences in functionality are often ignored. For instance, an animal may appear to smile by showing an expanse of closed teeth, but is actually scared and demonstrating a social signal of 'look how big my teeth are' that should instill a similar emotion on the onlooker. This necessary understanding of the functionality of behaviour is often confused by a human that interprets behaviour by association with his own. The Emoter model's emotions are radically different to those of a human. The minimal physiology profile and overt behaviour of the Emoter do not and cannot express the nuances we all associate with particular emotions.

Another important point, is the difference between third person ascription and introspective reporting on emotion. Consider the common mistake of ascribing

sadness to a person with grit in his eye, or confusing tears of joy with tears of sadness. Rarely, does one person's introspective labelling of an emotion conform *exactly* with the third person ascription of that experience. In fact, even the accuracy of one's introspective labelling of emotion can be debated (Kenny, 1963).

If the ascription of emotional behaviour is in doubt, then how can emotional behaviour be accurately attributed to the model? Another approach lies in a comparison of relevant properties between the Emoter model's processes and our concept of real emotional processes. This approach is a common evaluation practise for top-down designed emotional models (e.g. Moffat et al., 1993; Beaudoin & Sloman, 1993) and makes a number of assumptions. Firstly, not all properties of emotional processes in general need to be present; some can be skipped without the process losing its emotional character (Frijda, 1986, p.461). In addition, some properties of an emotional system are not relevant. For instance, the differences between the medium of a human's emotional process and a computer's emotional process is not relevant. Similarly, we can have an emotion without conscious awareness, so the question of whether the process is a conscious process is assumed irrelevant[1].

7.2.2 Does the Model Satisfy the Specifications of an Emotional System Enumerated in Section 3.4?

The answer to this question will not dwell on evidence of satisfaction, instead table 7.1 shows references to sections of this thesis that describe how the Emoter satisfies a particular property.

Referring to section 3.4, the Emoter clearly satisfies Swagerman's (1987) seven design specifications although point six, i.e. 'the provision of a stock of social signals', is minimally represented through the physiological profile. Moffat et al.'s

[1]For more information on this approach of attributing emotional behaviour see Swagerman (1987), p.81

	Specification	Section Explaining
1	The provision of methods of detecting objects that satisfy or cause harm.	3.7; 4.3.1; 5.3
2	The ability to act on this information.	3.9.2; 5.7
3	The ability to monitor its own endeavours.	4.3.1
4	The provision of a repertoire of appropriate actions and the ability to construct action sequences or plans.	5.7
5	The provision of pre-programmed actions for major contingencies or emergencies.	5.6.1; 5.7.2
6	The provision of a stock of social signals.	4.3.2
7	The provision of flexible goal priority ordering and for interrupting the processing of one goal for another.	5.6
8	Appropriate tasking that is not just emotional. A system is necessary that performs some other task and emotions 'incidentally'.	4.1
9	The provision of an internal logging of the emotions the system goes through.	3.6.1
10	Modification of actions according to the emotional state.	3.9; 5.7.3
11	Some concerns should be more important than others to help decide which goals to pursue in case of conflict – conflict occurs through multiple needs.	5.4; 5.6
12	When the system is satisfying a low-priority concern it should not apply as much effort or consume as many resources as when a high-priority concern is threatened.	5.7.1
13	The ability to perceive the urgency of situations.	5.6
14	Emotional behaviour should have appropriate intensity levels that are variable and appropriate to a situation.	3.9.1
15	Multiple independent sources of motivation or concern will operate asynchronously as triggered by stimulus events.	3.6; 5.2; 5.4
16	Its mental processing is parallel, for instance controlling a physical action while monitoring the environment.	3.6; 5.2
17	Concerns should be dynamic.	3.7; 3.8; 5.8
18	Provision of time constraints on concerns.	×

Table 7.1: Evidence of Satisfaction for Specifications of an Emotional Process

(1993) further seven design specifications are also satisfied, but require additional explanation. 'The provision of an internal logging of the emotions the system goes through' (point nine) is implicitly represented through the blackboard structure in the theory. All relevant information on the emotional experience is logged, thereby providing opportunities for labelling the emotion and association with past experiences. These two aspects are properties that can be incorporated into the Emoter at a later stage. '10) Modification of actions according to the emotional state' and '14) Emotional behaviour should have appropriate intensity levels that are variable and appropriate to a situation' are satisfied by the application of a physiological profile. Point twelve, i.e. 'When the system is satisfying a low-priority concern it should not apply as much effort or consume as many resources as when a high-priority concern is threatened', is reflected by the use of an importance factor when calculating the amount of change to adjust the physiological profile. Beaudoin & Sloman's (1993) additional four specifications are only partially satisfied. Point fifteen, i.e. 'Multiple independent sources of motivation or concern will operate asynchronously as triggered by stimulus events', is implicit in point seven, i.e. 'The provision of flexible goal priority ordering and for interrupting the processing of one goal for another', and is clearly represented. Point sixteen, i.e. 'its mental processing is parallel', however, is not implemented but is accounted for in the Emoter model. Point seventeen, i.e. 'concerns should be dynamic' is partially satisfied through the use of dynamic variable threshold levels that trigger concerns – the exact aspect of concerns that should be dynamic was not mentioned in Beaudoin & Sloman's paper. Finally point eighteen, 'the provision of time constraints on concerns' finds no representation but does not influence the emotionality of the Emoter.

Besides the eighteen design specifications mentioned in section 3.4, the *Literature Review* [Sec 2.2.1] outlined a number of general properties of emotions. Table 7.2 shows the sections of this thesis where a fuller explanation of satisfac-

	Property	Section Explaining
1	Lack of voluntary control.	
(a)	An external stimulus is necessary for the initiation of emotional reactions which cannot be voluntarily created.	4.3.1
(b)	Interpretation of the stimuli that results in emotional behaviour is involuntary.	5.4
(c)	Emotional responses are involuntary and difficult to repress.	5.7
2	Positive and negative reinforcement.	5.4
3	Motivation.	5.4
4	Lasting modifications of sensory interpretation and responsive state.	3.8; 3.9.2
5	Necessary understanding of sensory input.	5.3; 5.4
6	Emotional contagiousness.	×
7	Feedback.	3.8
8	Nonlinearity of the stimulus-response relation.	3.6; 5.2; 5.4
9	Influences on the planned behaviour.	3.9; 5.7.3

Table 7.2: Evidence of Satisfaction for General Properties of an Emotional Process

tion can be found. The property of emotional contagiousness is the only property not adequately reflected in the Emoter model. This is assumed to be a property that emotional systems can skip and still be emotional. The subject of emotional contagiousness is discussed later in section 7.5 *Directions for Future Research.*

The problem with attributing emotional behaviour by comparing relevant properties between the Emoter model's process and our concept of real emotional processes is whether the number of property comparisons is sufficient.

7.2.3 Is the Emoter Really Emotional?

This section has attempted to describe some of the associated problems with ascribing emotional behaviour to the Emoter model.

In so doing, it has dismissed the approach of third person ascription as unreliable – even if the behaviour is ascribed by observers as emotional, the question of whether the model is really emotional still remains. Thus, an alternative approach where accepted design specifications and properties for real emotional processes are compared with the Emoter's process, was undertaken. This revealed no significant discrepancies. Further, the work of many researchers in the field of emotion all point to the acceptance of the underlying theory as a close and effective platform architecture of emotion. These researchers include:

- Frijda (1986)
- Swagerman (1987)
- Oatly (1992)
- Moffat et al. (1993)
- Beaudoin & Sloman (1993)

7.3 The Role of the Model in Conflict Resolution

Chapter 6 provided a number of conclusions about the Emoter. These were:

1. The Emoter aids the resolution of conflicts.
2. Personality roles of the Emoter have attached benefits and costs. These being:

- Ability to cope with conflict.
- Ability to survive.
- Ability to successfully complete the prescribed task first.
- Time taken to resolve the conflict.
- Energy expended in resolving the conflict.

7.3.1 The Emoter Aids the Resolution of Conflicts

On one level the Emoter aids the resolution of conflicts by employing standard techniques.

Avoidance

The *Altruistic Emoter* provides a fine example by occasionally avoiding any form of interference with another combatant. Through this avoidance, the *Altruistic Emoter* fulfils his concerns of helping the other combatant.

Conquest

For example, the *Aggressive Emoter* constantly tries to deal other combatants the 'death blow'. Conversely, the *Altruistic Emoter* seeks martyrdom by encouraging other combatants to deal it a 'death blow'.

Spontaneous Remission

Occasionally agents need to recuperate energy. This can and does lead to new possibilities for resolving the conflict. In effect, such an agent tires himself out and must abstain from the conflict until his energy is recuperated.

Direct Negotiations

The variety in behaviour provided by the Emoter model demonstrates various types of direct negotiations. The *Altruistic Emoter* views conflicts as integrative agreements, or 'win-win' situations where the interests of both parties are not necessarily incompatible and potential gains can be maximised for all – after all, the *Altruistic Emoter* wants other parties to succeed. Conversely, the *Aggressive Emoter* views conflicts as distributive, or 'win-lose' situations where gains on one side are linked to losses on the other.

In general, both parties exchange offers, counter-offers and concessions in an attempt to reach a settlement, i.e. the exchange of threats and opportunities. This is valid for a non emotional agent even if that individual's threat or opportunity is intentional or not. The agents' behaviour shows whether an offer, i.e threat or opportunity, is acceptable or not.

The whole issue of emotions providing direct negotiations where two parties pursue communication to resolve differences can be shown with Oatley's (1992) statement that emotions

> 'communicate to others, tending to induce in them states similar to or complementary to our own, and thus prompting continuations or transitions in those with whom we interact.' (p.68)

In this research implementation the Emoter has control over the negotiations to the extent that it makes an intentional offer of an opportunity or threat. The non-emotional agent simply reacts instrumentally toward that offer indicating whether the offer is acceptable.

Escalative Interventions

Although escalative intervention is usually initiated and controlled by third party intervention, the Emoter's variety of behaviour often intensifies conflicts in order

to resolve them. For example, in disrupting a personal threat, the *Aggressive, Defensive* and *'Normal' Emoters* usually initiate another personally less important conflict, in order to relieve the pressure on the main conflict. This controlled temporary intensification of conflict has been shown, through the figures in Appendices B → E, to provide the effective long-term management of such conflicts

On another level, the Emoter prepares itself for conflict or cooperation by adjusting behaviour to best realise its concerns. These concerns may or may not be aimed at being the successful combatant to first complete a prescribed task, yet the act of adjusting behaviour contributes to the resolution of the conflict.

Any conflict is due to the interests of the parties involved, so the management or resolution of a conflict needs techniques that watch, guard and attempt to satisfy those interests. On an individual basis, emotional systems can be said

> 'to serve the furthering and defence of the agent's interests' (Frijda, 1986, p.371)

Also, emotions

> 'serve the useful functions of watching, guarding and satisfying the individuals' concerns and realigning action toward satisfaction when disturbed.' (Frijda, 1986, p.371)

This is also true of the Emoter which becomes more, or less, aroused and adjusts its behaviour when trying to realise its concerns. Therefore, if the Emoter is concerned with becoming the victor of a conflict situation, the Emoter's process will cause arousal and the modification of behaviour to ensure this occurs. If the concerns of being the victor of a conflict situation are disturbed, the Emoter will have a suitable response to that threat. The concerns are essentially the individual's tactics whereas the emotion system is the strategy for the individual's resolution of a conflict situation.

7.3.2 Personality Roles of the Emoter have Attached Benefits and Costs

The second conclusion from Chapter 6 is that the personality roles of the Emoter have attached benefits and costs. The personality roles of the Emoter are simply sets of concerns that dictate behaviour. As can be seen from the behaviour shown in Appendices B → E, certain personalities express certain types of emotions, for example, behaviour associated with the *Aggressive Emoter* tends to comprise of 'negative' emotions such as anger, hate and aggression. If the Emoter does limit the type of emotions it can express through personalities, then attached benefits and costs also relate to these subsets of emotions. Thus, emotions associated with the Aggressive personality are attached to benefits of completing their prescribed task first, having a good ability to survive but costs of large energy expenditure and a greater time taken to resolve the conflict.

The Emoter model helps in the analysis of behaviour driven by various personalities which, although not a research aim provides interesting questions for future research. It may be that subsets of emotions that are connected with various personalities are appropriate for particular applications. Obvious examples, are that 'battle' robots may need emotions connected with an aggressive personality, and information retrieval interfaces may have emotions connected with an altruistic personality.

Thus, an Emoters' tactics, i.e. specific concerns, have attached benefits and costs as regards conflict resolution. Chapter 6, discovered a balance between Emoters that react to personal threats and opportunities, or continually try to harm and help another combatant, is needed to optimise benefits and costs. The 'normal' personality suggested by this research provides this optimisation.

7.4 Roles For Emotion

As the complexity of computing systems and the necessity of interaction between such systems increases, interest in the field of distributed artificial intelligence (DAI) will continue. Emotions are one aspect of social interaction that offer a new perspective to the field of DAI along with an explanation of personal behaviour.

Frijda (1986) believes emotion and action are intimately intertwined. The readiness or unreadiness for action shows in expression and is experienced in emotional feeling.

The Emoter provides a 'functional analogue' of emotional behaviour, rather than 'emotions as such' – which was shown in Sections 2.2, 2.3 & 7.2 to be an ambiguous property. The functional analogue enables agents to exhibit behaviour not determined by their immediate goals, e.g. the Emoter's prescribed patterns in which blocks must be arranged, but which is rationally explicable by reference to less immediate goals represented by their 'concerns'. and their personality profiles. The Emoters' functional analogue of emotional behaviour intercedes in what would otherwise be simple goal directed behaviour. So just as we could ascribe emotions to people in order to explain non-goal directed behaviour, so too we could ascribe emotions to the Emoter agents to explain variations in their behaviour. This is demonstrated sufficiently by the range of behaviour shown in Appendices B → E, and by the fact that our understanding of the Emoters' behaviour is enhanced by the indicative names given to the various profiles used.

Therefore, the Emoter, enhanced with an accurate model of emotions, might provide a basis for a rationally explicable, self regulating system that could enable us to predict how people we know will behave in given situations.

The lesson for computer systems is that the Emoter with its flexible reasoning about actions when conflict is present, helps manage and resolve that conflict.

Thus, it can be said that just as human emotions are indispensable to a smooth functioning society where different agents pursue different interests in a shared environment, a society of computer agents acting with multiple interests in a shared environment may benefit from a similar conflict management mechanism. Such an aspect suggests it might be possible to employ a control mechanism similar to the human emotion process for any system with multiple agents and multiple interests/goals where conflict was possible. Indeed, Sloman (1993) along with Frijda (1986) believes emotions to be the necessary consequence of a system with multiple interests and limited resources. The Emoter provides a practical sketch of how such a system might work in a beneficial way.

Thus, emotions aid conflict management and provide an explanation of behaviour that cannot be explained through simple goal directed behaviour. Their future roles must take these facts into account along with the communication property associated with emotion. Clearly, roles exist for emotions in research areas that examine and use personal and interpersonal behaviour.

7.5 Directions for Future Research

This section will discuss three areas for future research.

7.5.1 Extensions or Improvements to the Model.

There are two main improvements to the Emoter that are both connected with the interpersonal communication of emotions. Firstly, in section 7.2.2 one property was found lacking in the Emoter – that of emotional contagiousness. If this property was developed then point six of the design specifications would be completely fulfilled, i.e. 'the provision of a stock of social signals.' Similarly, emotional contagiousness would further improve the conflict resolution properties of the Emoter, in particular the interpersonal influence described by Oatley (1992).

That is, emotions

> 'communicate to others, tending to induce in them states similar to or complementary to our own, and thus prompting continuations or transitions in those with whom we interact.' (p.68)

However, this communication property of emotion is fraught with problems: humans, let alone our Emoter, have difficulty in deciphering emotional expression in others which leads to even greater conflict. For example, if we confuse one person's distress as laughter, and then start laughing ourselves, the person in distress will escalate the conflict to anger or rage. Thus, a stock of social signals would be relatively simple to add to the Emoter, but their associated interpretation mechanisms are clearly more difficult. A compromise could be made by creating distinct and unambiguous social signals. This leads to the second main improvement connected with the interpersonal communication of emotions – that of easing the difficulties associated with third person ascription. In section 7.2.1, it was noted that the ascription of emotional behaviour is difficult and often produces unreliable conclusions on behaviour. If a stock of social signals in the form of human facial expressions were added to the Emoter, then observers would be able to invoke the natural tendency of comparing emotional expressions of the Emoter with their own. Again, however, there are problems:

- What mechanisms link action tendencies to facial expressions?
- How would the physiology profile of the Emoter influence the facial expressions?
- Would distinct facial patterns signify distinct emotions?

Clearly these interesting questions, along with others[2], must be answered before such an extension can be added to the Emoter.

---

[2]see Frijda, 1982 for a greater discussion on the problems of ascribing meaning to facial expression.

Another interesting possibility for inter-agent communication lies with the work of Galliers (1988;1992) on belief revision and multi-agent negotiation. Although her agents rely on explicit dialogue information, the advantages for the Emoter in conflict resolution are obvious. That is, Galliers' work would add another conflict resolution technique to the Emoter's repertoire. It may be possible to adopt Cawsey et al.'s (1993) model to provide extensions to the *Analyser* and *Comparator* processes of the Emoter, thereby enhancing the conflict resolution properties and allowing Cawsey et al.'s model of negotiation to experience emotional responses.

Further extensions to the Emoter will improve its performance, but should not drastically alter its behaviour. As such, only vague ideas are suggested:

- Employing connectionism to match stimulus events to categories.
- More sophisticated action planning.
- Time constraints on concerns.
- A broader physiological profile.
- A greater number of overt options rather than the three represented, i.e. *Pick up, Put down,* and *Move to.*

7.5.2 New Domains

Any domain that involves autonomous agents and interpersonal conflict would be suitable for the Emoter's control architecture. Clearly, the stimulus events and the action system would need revising for the new domain, but in general the autonomous agent will still encounter threats, opportunities and blocked moves. It will still need similar concerns to those presented and a control system like that of the Emoter. By applying the Emoter to such new domains, a further investigation into the influence of adding 'emotions' could be determined. It may

be that the epiphenomena associated with more complex behaviour has an adverse influence on the efficiency of resolution. That is, emotions may intensify conflicts and lead to costly deadlock. Such further investigations must be performed before systems similar to the Emoter can be exploited commercially.

Another area, that requires investigation, is that agents with different profiles, and mixtures of profiles could work especially well/badly together. For example, would two *Altruistic Emoters* show the behaviour we would expect, i.e actively helping each other to such an extent that neither agent completes the prescribed task? Similarly, would the aggressiveness of the *Aggressive Emoter* be redundant when applied against the *Altruistic Emoter*?

On a different level, mixtures of profiles could be used by the Emoter in an almost 'schizophrenic' personality such that certain modes of behaviour are applied to different situations – clearly this is not the mental disorder in humans that has the characteristics of asocial behaviour, introversion and loss of touch with one's environment, but implies multi-personalities that are applied to situations as and when it is felt necessary. This activity would be similar to one's playing various roles to achieve particular types of social interaction. For example, contrast a military sergeant major that must motivate 'his men', with the same person in an intimate embrace with his partner. Particular personalities may be appropriate to specific conflict situations, and it may be beneficial for an autonomous agent to adopt various personalities in his life.

7.5.3 Research into Emotions

This subsection points to 'pure' research on emotions that are based on cognitive models. Current research for artificial emotions has mainly focussed on the creation of a 'perfect' model or theory. When computer implementations have been performed, the primary aim has been to use such models for the examinination of those theories and their progressive refinement. This attitude is important

but restricts emotions to an academic niche. Surely, it would be more beneficial for computing systems and the study of emotions if an examination was aimed at the exploitation of emotions. It would be ludicrous to suggest the immediate commercial implementation of an emotional control architecture for present human-computer interfaces, yet if research is aimed at specific application niches then financial as well as personnel resources should be alleviated. Also, such research would help identify the differences between human and computer 'emotions'. It may be that the socially useful emotions for computer agent societies are different from those that have evolved for human societies. If such is the case, then more accurate modelling of human emotions may not improve the systems envisaged by this research.

Other further work could include recognising and reacting to the expression of emotions in computer agents. This emotional contagiousness property could control long term relationships whereby behaviour is informed by past encounters. Such work would form a basis for allowing the Emoter to choose which specific personality role to adopt with particular combatants or allies.

7.6 Conclusion

This chapter has briefly argued that the Emoter exhibits emotional behaviour and aids the resolution of conflicts by employing standard conflict resolution techniques. These techniques are derived from the Emoter becoming more, or less, aroused and the influence this has on its behaviour, be it cognitive or overt. The Emoter essentially resolves conflicts by preparing itself to cope with threats or opportunities. Emotions are the epiphenomena connected with this activity.

A need for more research into the exploitation of artificial emotions was discussed and possible niches for emotional systems shown.

Finally, possible directions for future research included extensions and im-

provements to the Emoter model, domains it could be applied to, and avenues of research that should be investigated.

Chapter 8

Conclusions

8.1 Overview of the Thesis

The organisation of the thesis reflects how the research has progressed. From an understanding of the general areas of both emotion and conflict resolution, trends and promising avenues of interest were identified (i.e Chapter 2). These aspects allowed a working model of emotion, termed the Emoter, to be developed and improved (i.e. Chapter 3). The Emoter was then applied to a domain that is at once tractable and rich enough to support both emotional behaviour and multi-agent conflict (i.e. Chapter 4). An implementation of the Emoter was performed which allowed refinement of the model (i.e. Chapter 5) and a critical evaluation with respect to emotional behaviour and its influence on conflict situations (i.e. Chapter 6). Finally, questions arising from the research provided the theme for the discussions in Chapter 7.

8.2 Summary of Main Conclusions

Chapter 2 explained the traits for the areas of emotion and conflict resolution. The current trend in the theories of emotion is towards 'cognition'. In the area

of artificial intelligence it is the Conflict and Evaluation theories that are leading the way. Within this subfield, Frijda, Sloman and Oatley are the current research 'giants'. Frijda's theory is perhaps the most computationally advanced with Swagerman's ACRES implementation. Therefore, Frijda's theory forms the background for the model of emotion described in this thesis. Frijda's theory is based on the the assumption that emotions occur when a psychological tendency is stopped or when ongoing action is interrupted. Frijda regards emotions as the manifestations of a concern satisfaction system where concerns are described as dispositions that the individual brings to the situation.

In the areas of conflict and cooperation in AI, the current trend is towards methods that do not involve third party intervention. An autonomous agent should be able to work out the problems of conflict and cooperation on its own. Thus, research is tending towards direct negotiations (e.g. Galliers, 1992). The connection of emotions to the area of conflict resolution is not trivial. Any conflict involves a struggle of interests over values or limited resources. According to Frijda (1986) an emotional system can be said

> 'to serve the furthering and defence of the agents interests.' (p.371)

Therefore, an emotional system can be regarded as a technique for the management of conflict situations.

Chapter 3 described improvements to the model ACRES, an implementation of Frijda's (1986) theory by Swagerman (1987). It achieved this by first providing a summary of Frijda's theory, then describing the top-down approach to designing a revised model, i.e the Emoter. Specifications were outlined and simplifications noted. Four major areas relating to improvements in the model ACRES were tackled. These were:

- Non-linearity.
- Attention filter and thresholds.

- Threshold feedback.
- Action readiness.

In tackling the non-linearity of Frijda's theory, the blackboard structure was incorporated into the Emoter. The attention filter and thresholds control dynamic attentional focussing which reduces the computational drains of processing many concerns. They also allow a degree of threat, opportunity and such like to be represented. Threshold feedback provided emotional inertia for the Emoter representing the stability of attentional focussing and consequently stable emotions. This 'hastiness', or extreme mood swings, was identified as a major problem of ACRES.

Finally action readiness was addressed. Action readiness modes account for the intensity of emotion which is unsatisfactorily covered in the ACRES model. Action readiness directs adjustments to the intensity of emotional expression. By including such an aspect in the Emoter two further areas of research were explained: factors influencing emotional intensity and the physiological response system that is needed to express emotions and their intensity. The chapter ends with a comparison between the Emoter and other work.

Chapter 4 described the blocks world domain in which the Emoter system was implemented. This micro-world along with the interaction of agents within it constitutes a rich enough environment for the occurrence of emotional behaviour and various complex conflict scenarios. The Emoter is described as analogous to a human hand with detection abilities. The specific moves the Emoter can make in the world are:

- *Move to x, y* – the agent moves to position x, y.
- *Pick up* – the agent grasps whatever is beneath it.
- *Put down* – the agent drops whatever it is grasping.

Besides these moves, the Emoter has a physiological profile of:

- Speed of the agent.
- Grasping strength of the agent.
- Ability to detect both objects and self-awareness.
- Movement latency.
- Trembling or shaking of agent.

The methods of detection employed by the Emoter are two-fold: omni-directional sight and self-awareness.

Chapter 5 offered an insight into the rational processing of an emotional event using the Emoter model. By describing the model of emotions in terms of the child's game implementation, the reader can associate with the information processing required. In addition, the detailed description clarified the high-level improvements to a model of emotions suggested in Chapter 3.

Chapter 6 described the evaluation of the Emoter Model. The model was analysed in terms of efficiency with respect to conflict management and resolution. This was achieved by creating four conflict scenarios with two agents competing and/or cooperating to complete prescribed tasks. When two non-emotional agents tackled the conflict scenarios each reached a state of deadlock that could not be resolved without third party intervention. Introducing an Emoter to the situation allowed the deadlock to be broken. The success of the Emoter and its level of efficiency were dependent on which of the five distinct personality roles that the Emoter adopted. Four specific benefits and costs were analysed. These were: which agent completed the task first, the time taken to resolve the situation, the agent's ability to survive, and the energy expended in resolving the conflict.

Finally Chapter 7 discussed implications of the conclusions gained from the

evaluation of the Emoter – in particular, the validity of its emotional behaviour, its value to the field of conflict resolution and its possible application to new domains. The implication of this thesis for emotional systems and the issue of exploiting artificial emotional systems was then discussed. Finally, limitations of the system along with further questions arising from implementing the system were outlined to form the basis of directions for further research.

8.3 General Conclusion

As the trend towards autonomous agents continues, the need for control architectures that acknowledge agents have limited resources and will often encounter multi-agent conflict and cooperation increases. Emotions are one such control system. This research has developed and implemented a system that exhibits emotional behaviour and uses that behaviour to resolve conflicts in a simple two-agent environment. An analysis of this behaviour found that there are attached benefits and costs determined by the personality profile adopted.

Although the design was implemented as a two-agent system, it is extensible to multi-agent systems. The effectiveness of such a scale-up is an area of further work.

Bibliography

Abelson, R. B. (1983). "Whatever became of consistency theory?". *Person. Soc. Psychol. Bull.*, 9, 37–54.

Allen, S. (1993). "Employing emotional behaviour to resolve conflicts". In *Workshop on Architectures Underlying Motivation and Emotion (WAUME93).* University of Birmingham: School of Computer Science and Centre for Research in Cognitive Science.

Angier, R. P. (1927). "The conflict theory of emotion". *American Journal of Psychology*, 39, 390–401.

Aristotle (1936). *On the Soul.* London: Loeb Classical Library, Heinemann. Trans. W. S. Hett.

Arnold, M. B. (1960). *Emotion and Personality*, volume I and II. New York: Columbia University Press.

Arnold, M. B. (1968). *The Nature of Emotion: Selected Readings.* Harmondsworth: Penguin Books.

Arnold, M. B. (1970). *Feelings and Emotions: The Loyola Symposium.* Academic Press, New York, London.

Bard, P. (1929). "The central representation of the sympathetic nervous system as indicated by certain physiologic observations". *Arch. Neurol. Psychiat.*, 22, 230–46.

Bard, P. (1934). "Emotion 1. the neurohumoral basis of emotional reactions". In *Handbook of General Experimental Psychology*, volume 22. Worchester, M.A.: Clark University Press.

Bard, P. (1950). "The central representation of the sympathetic nervous system as indicated by certain physiologic observations". In *Feelings and Emotions: The Mooseheart Symposium*, volume 22 (pp. 211–37). New York: McGraw-Hill.

Beaudoin, L. P. & Sloman, A. (1991). *A Proposal For a Study of Motive Processing.* Technical Report 91–6, School of Computer Science, University of Birmingham. Cognitive Science Research Paper.

Beaudoin, L. P. & Sloman, A. (1993). "A study of motive processing and emotion". In *Prospects For Artificial Intelligence: Proceedings of AISB-93* (pp. 229–238).: IOS Press.

Bindra, D. (1969). "A unified interpretation of emotion and motivation". *Ann. New York Acad. Sci.*, 159, 1071–83.

Blake, R. R. & Mouton, J. S. (1984). *Solving Costly Organizational Conflicts.* San Francisco: Jossey Bass.

Boulding, K. (1962). *Conflict and Defense: A General Theory.* New York: Harper and Row.

Bower, G. H. & Cohen, P. R. (1982). "Emotional influences on memory and thinking: Data and theory". In M. S. Clark & S. T. Fiske (Eds.), *Affect*

and Cognition; The seventeenth annual Carnegie symposium on cognition Hillsdale, NJ: Erlbaum.

Brehmer, B. (1977). "Cognitive factors in interpersonal conflict". In D. Druckman (Ed.), *Negotiations: Social-Psychological Perspectives.* London: Sage Publications.

Broadbent, D. E. (1971). *Decision and Stress.* New York: Academic Press.

Brooks, R. A. (1991). "Intelligence without representation". *Aritificial Intelligence*, 47, 139–159.

Cannon, W. B. (1927). "The james-lange theory of emotion: A critical examination and an alternative theory". *Am. J. Psychol.*, 39.

Cannon, W. B. (1931). "Again the james-lange and the thalamic theories of emotions". *Psychol. Rev.*, 38, 281 – 95.

Cannon, W. B. (1932). *The Wisdom of the Body.* Number 38. New York: Norton, 2nd edition.

Carnevale, P. J. D. & Conlon, D. E. (1988). "Time pressure and strategic choice in mediation". *Organizational Behavior and Human Decision Pocesses*, 42, 111–133.

Cawsey, A., Galliers, J., Logan, B., Reece, S., & Jones, K. S. (1993). "Revising beliefs and intentions: a unified framework for agent interaction". In *Prospects For Artificial Intelligence: Proceedings of AISB-93* (pp. 130–139).: IOS Press.

Cawsey, A., Galliers, J. R., Reece, S., & Jones, K. S. (1992). "A comparison of architectures for autonomous multi-agent communication". *Proceeding of the 10th European Conference on Artificial Intelligence*, (pp. 249–251).

Chertkoff, J. M. & Baird, S. L. (1971). "Applicability of the big lie technique and the last clear chance doctrine to bargaining". *Journal of Personality and Social Psychology*, 20, 298–303.

Chertkoff, J. M. & Conley, M. (1967). "Opening offer and frequency of concessions as bergaining strategies". *Journal of Personality and Social Psychology*, 7, 181–185.

Clark, D. M. (1986). "A cognitive approach to panic". *Behavioural Research and Therapy*, 24(4), 461–470.

Cohen, P. & Levesque, H. (1987). *Rational Interaction as the Basis for Communication.* Technical Report 89, Centre for the Study of Language and Information, Stanford University, California.

Coser, L. (1956). *The Function of Social Conflict.* Free Press, Glencoe, Ill.

Coser, L. (1967). *Continuities in the Study of Social Conflict.* New York: The Free Press.

Coser, L. A. (1961). "The termination of conflict". *Journal of Conflict Resolution*, (pp. 347–353).

Dahrendorf, R. (1958a). "Out of utopia: Toward a reorientation of sociological analysis". *American Journal of Sociology*, LXIV, 115–127.

Dahrendorf, R. (1958b). "Toward a theory of social conflict". *The Journal of Conflict Resolution*, II(2).

Dahrendorf, R. (1959). *Class and Class Conflict in Industrial Society.* Stanford: Stanford University Press.

Darwin, C. (1872). *The expression of the emotions in man and the animals.* Chicago: University of Chicago Press. Reprinted 1965.

De Spinoza, B. (1969). *Ethica.* Amsterdam: Wereld- Bibliotheek.

Delgado, J. M. R. (1973). *Intro. to General Psychology.* WM. C. Brown Company, second edition.

Descartes, R. (1911). "Passions de l'ame". In E. L. Haldane & G. R. Ross (Eds.), *The philosophical works of Descartes.* Cambridge: Cambridge University Press. Originally published 1637.

Deutsch, M. (1971). "Conflict and its resolution". In C. G. Smith (Ed.), *Conflict Resolution: Contributions of the Behavioral Sciences.* University of Notre Dame Press.

Dewey, J. (1894). "The theory of emotion. i. emotional attitudes". *psychological Review*, 1, 553–569.

Dewey, J. (1895). "The theory of emotions ii. the significance of emotions". *Psychological Review*, 2, 13–32.

Doran, J. (1985). "The computational approach to knowledge communication and structure in multi-actor systems". *Social Action and Artificial Intelligence.*

Druckman, D. (1977). "Conflict of interest and value dissensus: Two perspectives". In D. Druckman (Ed.), *Negotiations: Social-Psychological Perspectives.* London: Sage Publications.

Duffy, E. (1934). "Emotion: An example of the need for reorientation in psychology". *Psychol. Review*, 41, 184–198.

Duffy, E. (1941). "An explanation of 'emotional' phenomena without the use of the concept 'emotion."'. *J. Gen. Psychol.*, 25, 283–293.

Elliott, C. (1992). *The Affective Reasoner: A Process Model of Emotions in a Multi-agent System.* PhD thesis, The Institute for the Learning Sciences, Northwestern University. Tech. Rep. No. 32.

Elliott, C. & Siegle, G. (1993). "Emotion intensity factors in simulated 'believable agents"'. In *Workshop on Architectures Underlying Motivation and Emotion (WAUME93).* University of Birmingham: School of Computer Science and Centre for Research in Cognitive Science.

Erman, L. D., Hayes-Roth, F., Lesser, V. R., & Reddy, D. R. (1980). "The hearsay-ii speech-understanding system: Integrated knowledge to resolve uncertainty". *Computing Surveys*, 12, 213–253.

Fiske, S. T. & Taylor, S. E. (1984). *Social Cognition.* Reading, MA: Addison-Wesley.

Fodor, E. M. (1976). "Group stress, authoritarian style of control and use of power". *Journal of Applied Psychology*, 61, 313–318.

Freud, S. (1938/1960). *Abrißder Psychanalyse.* Fisher, Frankfurt.

Frijda, N. H. (1982). "The meanings of facial expression". In M. Ritchie-Kye (Ed.), *Nonverbal Communication Today: Current Research* (pp. 103–20). The Hague: Mouton.

Frijda, N. H. (1984). "Toward a model of emotion". In C. D. Spielberger, I. G. Sarason, & P. Defares (Eds.), *Stress and Anxiety.* Washington: Hemisphere. Volume 9, (pp. 3–16).

Frijda, N. H. (1986). *The Emotions, Studies in Emotion and Social Interaction.* Cambridge University Press.

Frijda, N. H. & Swagerman (1987). "Can computers feel? theory and design of a n emotional system". *Cognition and Emotion*, 1.

Galliers, J. R. (1988). *theoretical framework for computer models of cooperative dialogue, acknowledging multi-agent conflict.* PhD thesis, Dept of Psychology, Open University.

Galliers, J. R. (1992). "Autonomous belief revision and communication". In P. Gardenfors (Ed.), *Belief Revision.* Cambridge University Press.

Georgeff, M. (1983). "Communication and interactionin multi-agent planning". *Proceedings of the National Conference on Artificial Intelligence*, (pp. 125–129).

Georgeff, M. (1984). "A theory of action for multi-agent planning". *Proceedings of the National Conference on Artificial Intelligence*, (pp. 121–125).

Georgeff, M. P. & Lansky, A. L. (1987). "Reactive planning". *AAAI-87.*

Gluckman, M. (1966). "The peace in the feud". In L. Coser & B. Rosenberg (Eds.), *Sociological Theory: A Book of Readings.* New York: McMillan Company.

Gray, J. A. (1971a). *The Psychology of Fear and Stress.* London: Weidenfeld and Nicholson.

Gray, J. A. (1971b). *The Psychology of Fear and Stress.* London: Weidenfeld and Nicholson.

Hammond, K. J. (1986). "Chef: A model of case-based planning". *AAAI-86*, (pp. 267–271).

Hebb, D. O. (1946). "Emotion in man and animal: An analysis of the intuitive process of recognition". *Psychological Review*, 53, 88–106.

Hilgard, E. R. (1962). *Introduction to Psychology.* New York: Harcourt, Brace, 3rd edition.

Huber, V. L., Neale, M. A., & Northcraft, G. B. (1987). "Decision bias and personnel selection strategies". *Organizational Behavior and Human Decision Processes*, 40, 136–147.

James, W. (1884). "What is an emotion". *Mind*, 9, 188–205.

James, W. (1890). *The Principles of Psychology.* New York: Holt.

Kenny, A. (1963). *Action, Emotion and Will.* London: Routledge and Kegan Paul.

Kerr, C. (1954). "Industrial conflict and its mediation". *American Journal of Sociology*, LX, 230.

Kleinginna Jr., P. R. & Kleinginna, A. M. (1981). "A categorised list of emotional definitions, with suggestions for a consensual definition". *Motiv. and Emotion.*

Kosko, B. (1988). "Hidden patterns in combined and adaptive knowledge networks". *International Journal of Approximate Reasoning*, 2, 377–393.

Kuhl, J. (1992). "A theory of self-regulation: Action versus state orientation, self-discrimination and some applications". *Applied Psychology: An International Review*, 41(2), 97–129.

Lange, C. G. (1885). *The Emotions.* Baltimore: Williams and Wilkins. English translation 1922.

Lazarus, R. S. (1966). *Psychological Stress and The Coping Process.* New York: McGraw-Hill.

Lazarus, R. S., Averill, J. R., & Opton Jr., E. M. (1970). "Towards a cognitive theory of emotion". In *Feelings and Emotions: The Loyola Symposium* (pp. 207–32). New York and London: Academic Press.

Lazarus, R. S. & Folkman, S. (1984). *Stress, appraisal and coping.* New York: Springer.

Lazarus, R. S., Kanner, R. S., & Folkman, S. (1980). "Emotions: A cognitive-phenomenological analysis". *Emotion: Theory, research and experience*, 1, 189–217.

Lesser, V. R. & Corkill, D. D. (1983). "The use of meta-level control for coordination in a distributed problem solving network". *Proceedings of the 8th International Joint Conference on Artificial Intelligence*, (pp. 748–756).

Lewicki, R. J. (1986). *Research on Negotiation in Organizations*, volume 1. Greenwich, CT: JAI Press.

Lewicki, R. J. & Litterer, J. A. (1985). *Negotiation.* Irwin, IL: Homewood.

Lilly, J. C. (1960). "Learning motivated by subcortical stimulation: The 'start' and 'stop' patterns of behaviour". In *Electrical Studies on the Unanesthetized Brain* (pp. 78–103). New York: Hoeber.

Luce, R. D. & Raiffa, H. (1957). *Games and Decisions.* New York: John Wiley and Sons.

Mack, R. W. & Snyder, R. C. (1971). "The analysis of social conflict – toward an overview and synthesis". In C. G. Smith (Ed.), *Conflict Resolution: Contributions of the Behavioural Sciences.* London: University of Notre Dame Press.

Mandler, G. (1975). *Mind and Emotion.* New York: Wiley.

Mandler, G. (1984). *Mind and body: Psychology of emotions and stress.* New York: Norton.

McClintock, C. G. (1977). "Social motivations in settings of outcome interdependence". In D. Druckman (Ed.), *Negotiations: Social-Psychological Perspectives.* London: Sage Publications.

McDougall, W. (1928). "Emotion and feeling distinguished". In *Feelings and Emotions.* Worcester, MA.: Clark University Press.

Meyer, M. F. (1933). "That whale among the fishes - the theory of emotions". *Psychol. Rev.*, 40, 292 – 300.

Meynaud, J. & Schroeder, B. (1961). "La mediation: Tendances de la recherche et bibliographie (1945-1959)". In *Survey of Research in the Social Science.* Amsterdam: North-Holland Publishing Company.

Millenson, J. R. (1967). *Principles of Behavioural Analysis.* London: Collier-Macmillan.

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). *Plans and the structure of behavior.* New York: Holt, Rinehart and Winston.

Moffat, D. (1993). "Modelling concerned attention – to some affect". In *Workshop on Architectures Underlying Motivation and Emotion (WAUME93).* University of Birmingham: School of Computer Science and Centre for Research in Cognitive Science.

Moffat, D., Frijda, N. H., & Phaf, R. H. (1993). "Analysis of a model of emotions". In *Prospects For Artificial Intelligence: Proceedings of AISB-93* (pp. 219–228).: IOS Press.

Oatley, K. (1992). *Best Laid Schemes.* Cambridge University Press.

Oatley, K. & Johnson-Laird, P. N. (1987). "Towards a cognitive theory of emotions". *Cognition and Emotion*, 1, 29–50.

Ortony, A., Clore, G. L., & Collins, A. (1988). *The Cognitive Structure of Emotions.* Cambridge University Press.

Papez, J. W. (1937). "A proposed mechanism of emotion". *Arch. Neurol. Psychiat.*, 38.

Paulhan, F. (1887). *The laws of feeling.* London: Kegan-Paul, French, Trubner and Co. English Translation 1930.

Perrault, C. R. (1987). *An application of default logic to speech act theory.* Technical Report CSLI 87-90, CLSI, SRI International, California.

Pfeifer, R. (1993). "On the need to study "fungus eaters"". In *Workshop on Architectures Underlying Motivation and Emotion (WAUME93).* University of Birmingham: School of Computer Science and Centre for Research in Cognitive Science.

Pfeifer, R. & Nicholas, D. W. (1981). "Towards computational models of emotion". In *Proc. 7th Int. Conf. Artif. Intell.* (pp. 2369–71).

Plato (1954). "Apology". In *The Last Days Of Socrates.* Harmondsworth: Penguin. Trans. H Tredennick.

Plato (1955). *The Republic.* Harmondsworth: Penguin. Trans. D Lee.

Plutchik, R. (1962). *The Emotions: Facts, Theories and a New Model.* New York.: Random House.

Porter, J. N. & Taplin, R. (1987). *Conflict and Conflict resolution.* University Press of America.

Pruitt, D. G., Carnevale, J. D., Ben-Yoav, O., Nochajski, T. H., & Van-Slyck, M. R. (1983). "Incentives for cooperation in integrative bargaining". In R.

Tietz (Ed.), *Aspiration levels in bargaining and economic decision making.* Berlin: Springer-Verlag.

Raccuglia, R. A. (1992). *A network extension for context in ACRES.* Technical report, Faculty of Psychology, University of Amsterdam. internal report.

Rapaport, D. (1950). *Emotions and Memory.* New York: International Universities Press.

Read, T. (1992). *The Role of Affect in Cognitive Development.* Technical report, School of Computer Science and Centre for Research in Cognitive Science, University of Birmingham. internal report – end of first year report.

Read, T. (1993a). "Systemic design: A methodology for investigating emotional phenomena". Poster at 1993 Australian Joint Conference on AI, Melbourne.

Read, T. (1993b). "The terminological pitfalls of studying emotion". In *Workshop on Architectures Underlying Motivation and Emotion (WAUME93).* University of Birmingham: School of Computer Science and Centre for Research in Cognitive Science.

Rosch, E. (1978). "Principles of categorisation". *Cognition and categorisation.*

Rosenschein, J. S. (1982). "Synchronization of multi-agent plans". *Proceedings of the National Conference on Artificial Intelligence*, (pp. 115–119).

Rosenschein, J. S. (1985). *Rational Interaction: Cooperation Among Intelligent Agents.* PhD thesis, Stanford University, California.

Rosenschein, J. S. & Genesereth, M. R. (1985). "Deals among rational agents". *Proceedings of the 9th International Joint Conference of Artificial Intelligence*, (pp. 91–99).

Sartre, J. (1948). *The Emotions.* New York: Philosophical Library.

Schachter, S. (1959). *The Psychology of Affiliation.* Stamford, California.: Stanford University Press.

Schachter, S. (1964). "The interaction of cognitive and physiological determinants of emotional state". In *Advances in Experimental Social Psychology.* New York.: Academic Press. Volume 1.

Schachter, S. (1970). "The assumption of identity and peripheralist - central ist controversies in motivation and emotion". In M. B. Arnold (Ed.), *Feelings and Emotions: The Loyola Symposium.* Academic Press, New York, London.

Schank, R. & Abelson, R. (1977). *Scripts plans goals and understanding. An inquiry into human knowledge structures.* Hillsdale, N.J.:Lawrence Erlbaum Associates.

Sheppard, H. (1954). "Approaches to conflict in american sociology". *British Journal of Sociology*, V, 324–342.

Sherrington, C. S. *Reflexes as Adapted Reactions.*

Shing, E. (1993). "Computational mechanisms for constraining learning". In *Workshop on Architectures Underlying Motivation and Emotion (WAUME93).* University of Birmingham: School of Computer Science and Centre for Research in Cognitive Science.

Simmel, G. (1955). *Conflict.* Free Press, New York.

Simmel, G. (1964). *Conflict and the Web of Group Affiliations.* New York: The Free Press. Translated by K Wolff and R Bendix.

Simon, H. A. (1967). "Motivational and emotional controls of cognition". In *Models of Thought.* Yale University Press. appearing as a reprint 1979.

Sloman, A. (1987). "Motives, mechanisms and emotions". *Cognition and Emotion*, (1), 217 – 234.

Sloman, A. (1992). "The emperor's real mind: review of roger penrose's 'the emperor's new mind: Concerning computers, minds and the laws of physics". *AI*, 56, 355–396.

Sloman, A. (1993a). "Prolegomena to a theory of communication and affect". In A. Ortony, J. Slack, & O. Stock (Eds.), *Communication from an artificial intelligence perspective: theoretical and applied issues* (pp. 229–260). Heidelberg, Germany: Springer. Also available as CSRP no.194 university of Sussex, U.K.

Sloman, A. (1993b). "Prospects for ai as the general science of intelligence". In *Prospects For Artificial Intelligence: Proceedings of AISB-93*: IOS Press.

Sloman, A. & Croucher, M. (1981). "Why robots will have emotions". In *Proc. 7th Int. Conf. Artif. Intell.* (pp. 197–202).

Strongman, K. T. (1987). *The Psychology of Emotion.* John Wiley and Sons, 3rd edition.

Sussman, G. (1975). *computer model of skill acquisition.* Elsevier, New York.

Swagerman, J. (1987). *The Artificial Concern REalization System ACRES: A computer model that has emotions and can name them.* PhD thesis, Department of Psychology, Amsterdam.

Sycara, K. (1988). "Resolving goal conflicts via negotiation". In *Proc. of the 7th AAAI.*

Terwogt, M. M. (1990). "Book review: Frijda, n h (1986) the emotions: Studies in emotion and interaction". *International Journal of Behavioral Development*, 13(3), 389–391.

Toda, M. (1982). *Man, Robot and Society.* The Hague: Nijhoff.

Van de Vliert, E. (1984). "Conflict: Prevention and escalation". In D. J. D. Drenth, H. Thierry, P. J. Willems, & C. J. Wolff (Eds.), *Handbook of Work and Organizational Psychology.* New York: Wiley.

Van de Vliert, E. (1990). "Escalative intervention in small-group conflicts". *Journal of Applied Behavioural Science.*

Watson, J. B. (1929). *Psychology from the standpoint of a behaviourist.* Philadelphia and London: J. B. Lippincott, 3rd revised edition.

Wegman, C. (1985). *Psychoanalysis and cognitive psychology.* London: Academic Press.

Young, P. T. (1961). *Motivation and Emotion.* New York: Wiley.

Appendix A

DeadLock Scenarios

A.1 Introduction

Appendix A describes pictorially the moves leading to the deadlock in each of the conflict scenarios $1 \rightarrow 4$ that would occur if both agents were unemotional. That is to say, the situation if both agents were only concerned with completing their prescribed tasks.

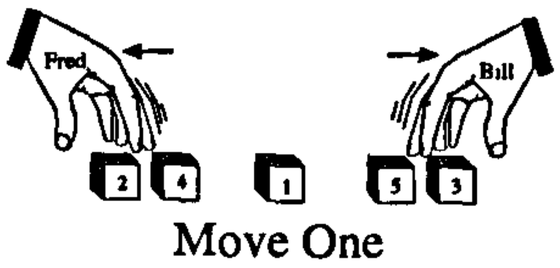
A.2 Conflict Scenario One

In scenario one, both agents compete to acquire block 1, i.e. a positional conflict to attain a block. Since both move the same distance, have the same physiological characteristics and have only one planning option, third party intervention is required to resolve the conflict.

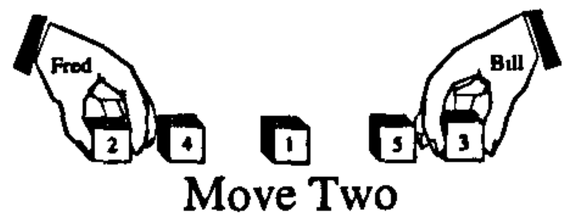
A.3 Conflict Scenario Two

In scenario two, both agents compete to stack the blocks in their grasp on block 4. Third party intervention is again required.

Fred continues with his task
by acquiring block 2.
Bill tries to acquire block 3.



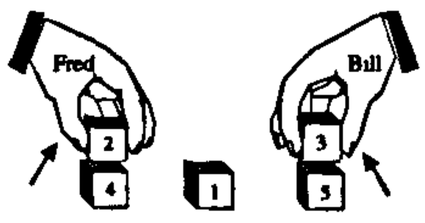
Move One



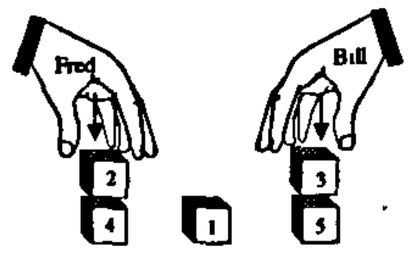
Move Two

Fred acquires block 2.
Bill acquires block 3.

Fred continues with his task
by stacking block 2 on block 4.
Bill tries to stack block 3 on
block 5.



Move Three

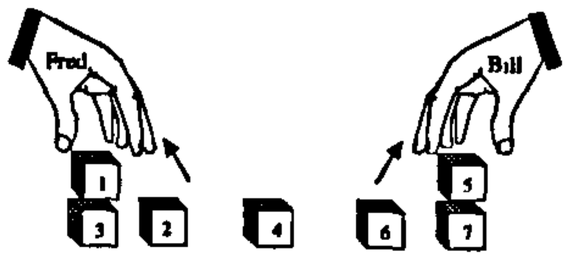


Move Four

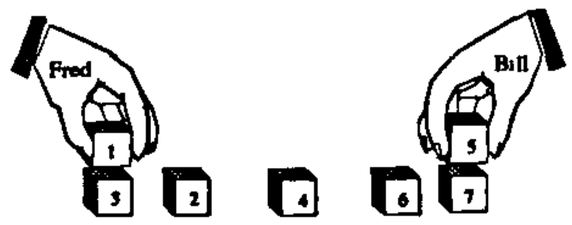
Fred stacks block 2 on block 4.
Bill stacks block 3 on block 5.
Both agents want to acquire
block 1. ****conflict****

Figure A.1: Moves Leading to the Deadlock Position in Scenario One.

Fred continues with his task
by acquiring block 1.
Bill tries to acquire block 5.



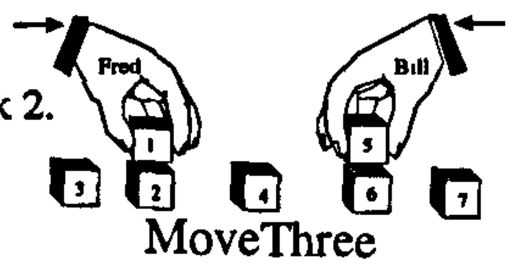
Move One



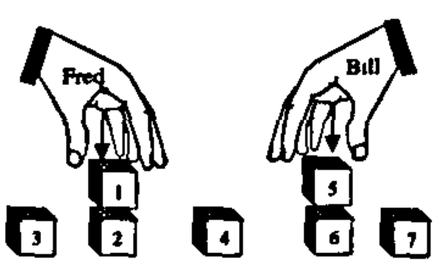
Move Two

Fred acquires block 1.
Bill acquires block 5.

Fred continues with his task
by stacking block 1 on block 2.
Bill tries to stack block 5
on block 6.



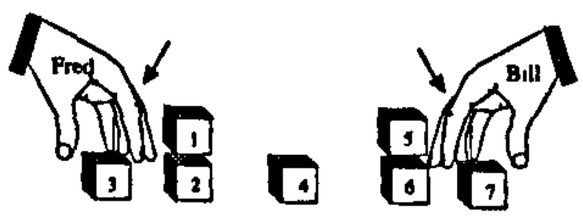
MoveThree



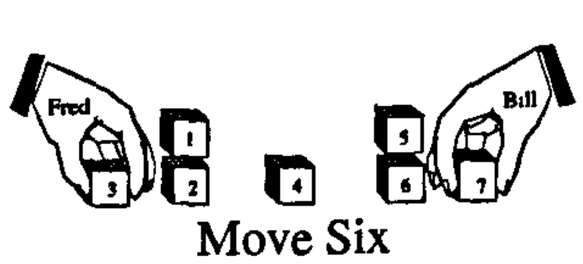
Move Four

Fred stacks block 1 on block 2.
Bill stacks block 5 on block 6.

Fred continues with his task
by acquiring block 3.
Bill tries to acquire block 7.



Move Five



Move Six

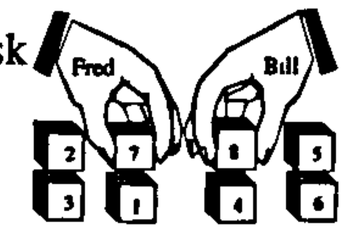
Fred acquires block 3.
Bill acquires block 7.
Both agents want to stack
their blocks on block 4.
****conflict****

Figure A.2: Moves Leading to the Deadlock Position in Scenario Two.

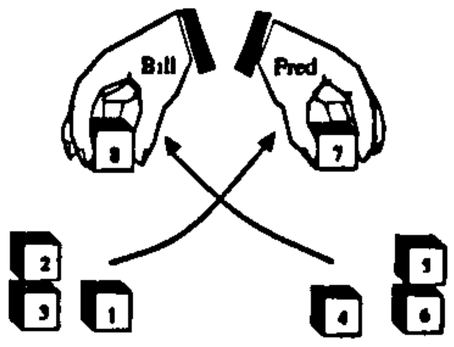
A.4 Conflict Scenario Three

In scenario three, both agents create an unintentional conflict by trying to discard similar blocks. The discarded blocks hinder each agent. Although the two agents do not grind to a stop, they become entangled in an infinite cycle.

Fred continues with his task by removing block 7 from block 1.
Bill attempts to remove block 8 from block 4.



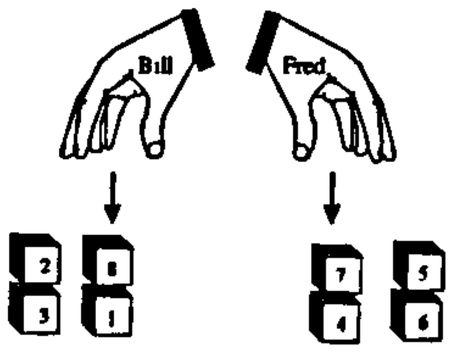
Move One



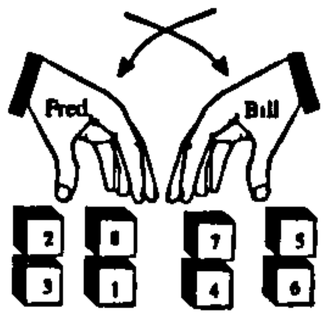
Move Two

Fred has moved block 7
from block 1.
Bill has moved block 8
from block 4.

Fred releases the block
to continue with his task.
Bill also releases the
redundant block to
continue with his task.



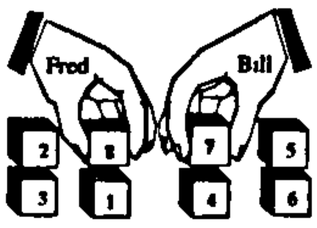
Move Three



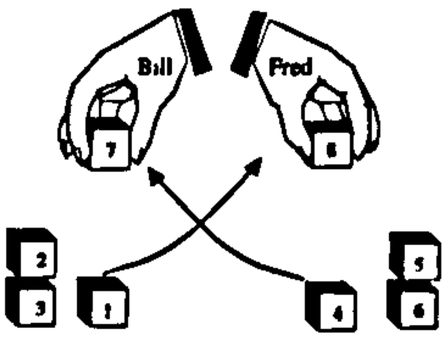
Move Four

Fred now has to remove the block Bill
has dropped and vice-versa.
*****conflict*****

Fred again tries to remove
the block covering block 1.
Bill again tries to remove
the block covering block 4.



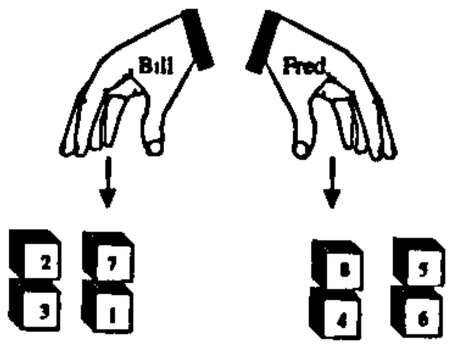
Move Five



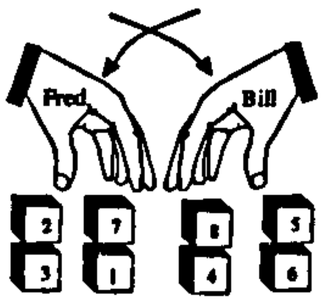
Move Six

Having removed the redundant blocks
both Fred and Bill move into a position
to drop the blocks.

Both Fred and Bill
drop the blocks.



Move Seven



Move Eight

Yet again Fred has to remove the
block that Bill dropped and
vice-versa.
*****conflict*****

Figure A.3: Moves Leading to the Deadlock Position in Scenario Three.

A.5 Conflict Scenario Four

In scenario four both agents attempt to move above each other. This results in a continuous vertical movement that is only halted by the physical boundaries of the world. Consequently, the agents cannot resolve their conflict.

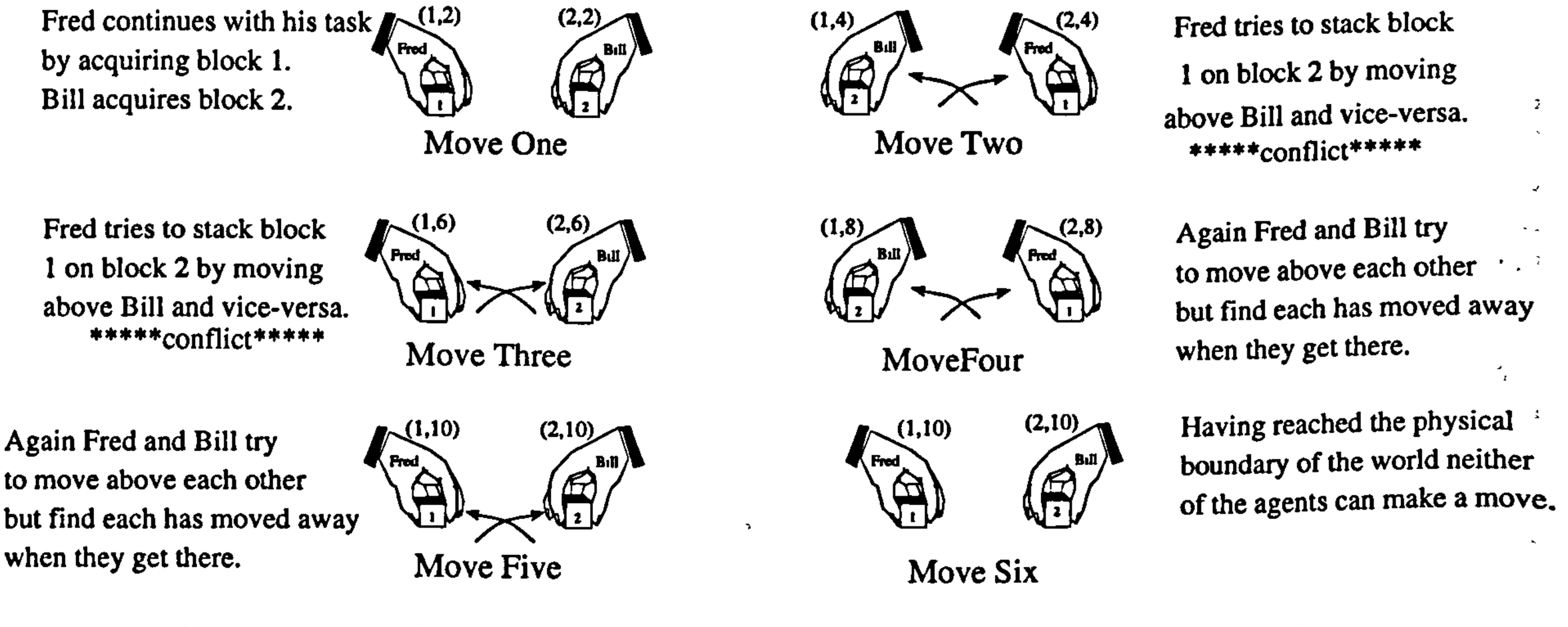


Figure A.4: Moves Leading to the Deadlock Position in Scenario Four.

Appendix B

Conflict Scenario One

B.1 Introduction

This appendix shows the moves various Emoters make in scenario one (see figure B.1) until the Emoter completes his prescribed task, is crushed by a block, or reaches a state of deadlock. Two versions of emotionality are represented. Figures B.2 → B.4 represent moves that Emoters would make utilising physiology alone. Figures B.5 → B.13 represent moves that Emoters would make utilising both physiology and the behaviour derived from multiple goals, i.e. 'full' emotional behaviour.

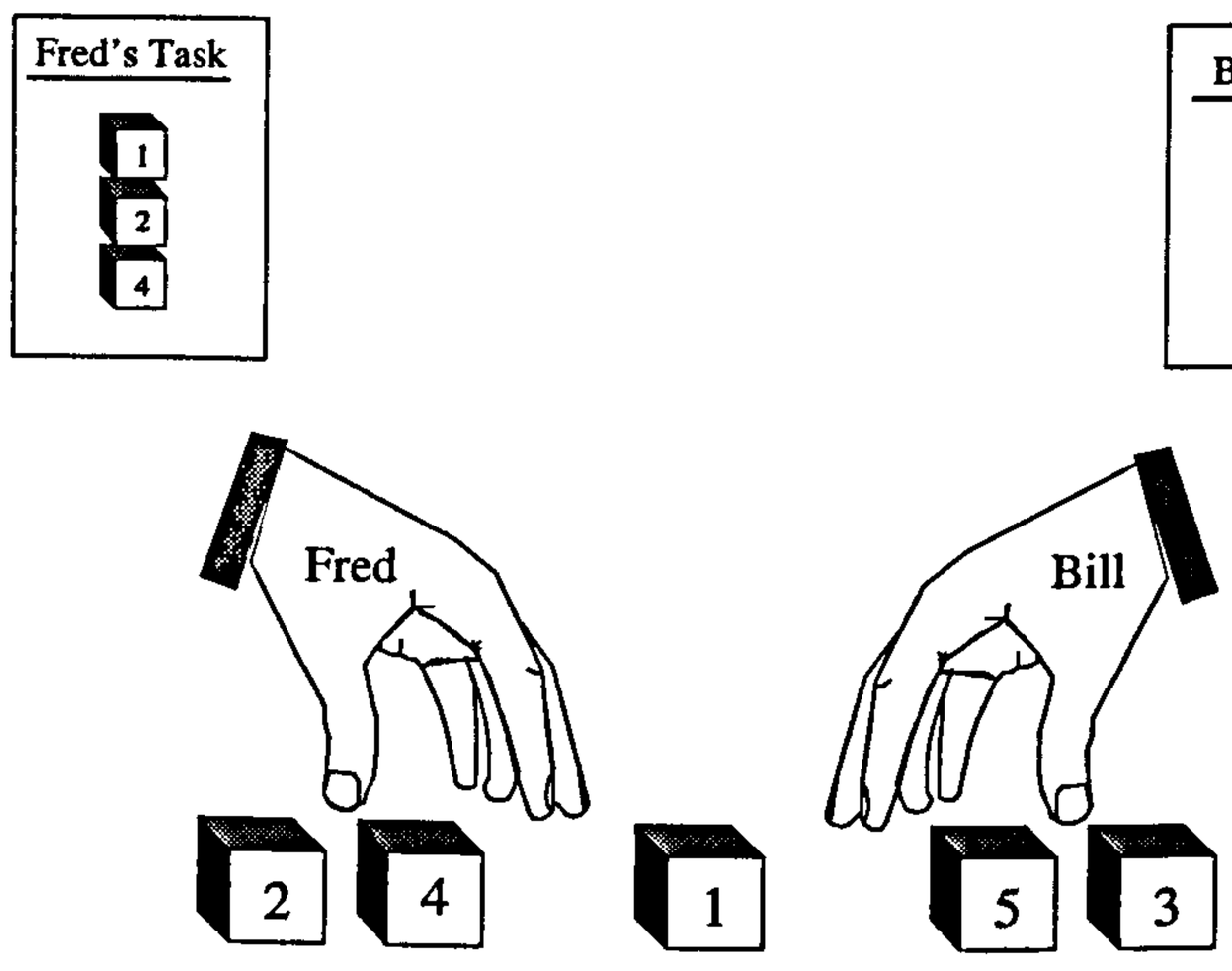
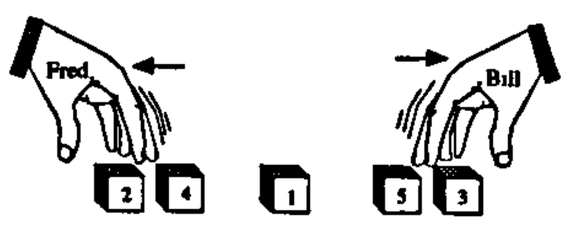


Figure B.1: Conflict Scenario One.

B.2 The Sole Influence of Physiology on the Conflict

The following figures B.2 → B.4 represent the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and only one goal of completing his prescribed task, would perform in conflict scenario one (see figure B.1). With each of the personalities, the Emoter follows a very similar course of action up until the actual conflict. Thus, in scenario one, the Aggressive Emoter, Defensive Emoter, Normal Emoter and Selfish Emoter all follow the course of action shown in figure B.2 whereas the Altruistic Emoter follows the course of action shown in figures B.3 & B.4.

Fred continues with his task by acquiring block 2.
Bill tries to acquire block 3.

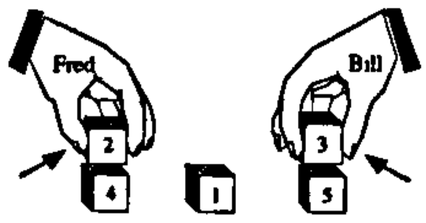


Move One

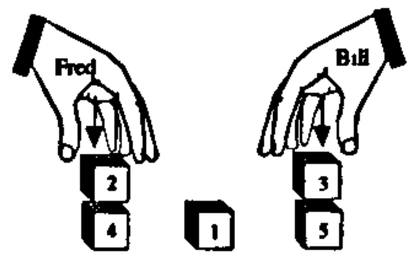
Move Two

Fred acquires block 2.
Bill acquires block 3.

Fred continues with his task by stacking block 2 on block 4.
Bill tries to stack block 3 on block 5.



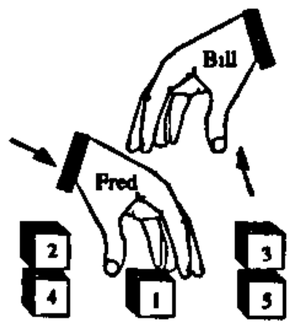
Move Three



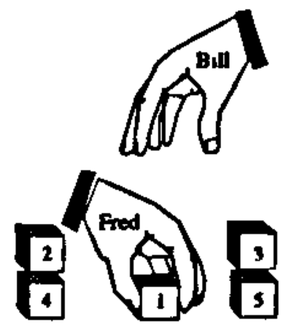
Move Four

Fred stacks block 2 on block 4.
Bill stacks block 3 on block 5.

Fred continues with his task by acquiring block1.
Bill also tries to acquire block 1 but is unsuccessful.
******Conflict******



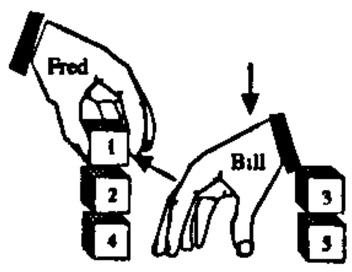
Move Five



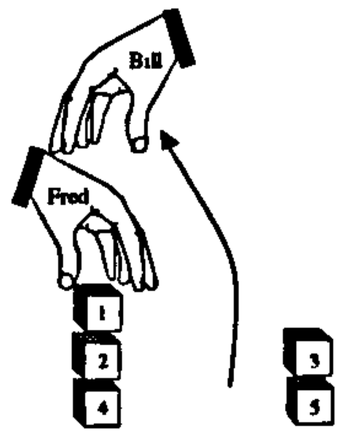
Move Six

Fred acquires block 1.
Bill waits for block 1 to become available.

Fred continues with his task by stacking block 1 on block 2.
Bill tries to acquire block 1 but discovers it has been moved.



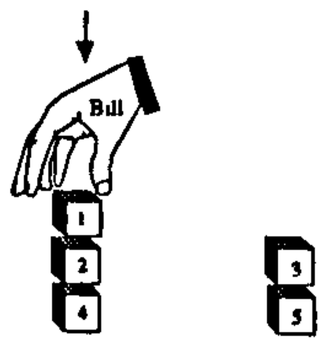
Move Seven



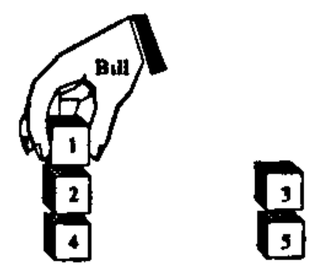
Move Eight

Fred completes his task.
Bill still wants block 1.

Bill can finally acquire block 1.



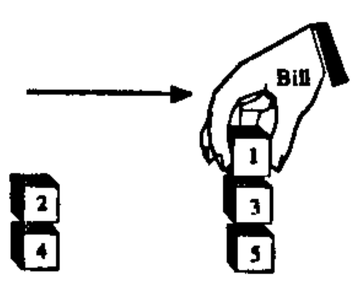
Move Nine



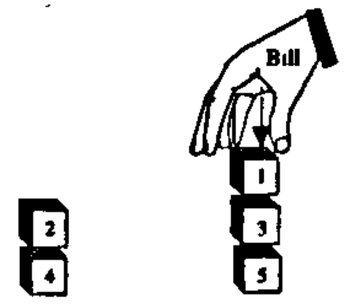
Move Ten

Bill acquires block 1.

Bill continues with his task by stacking block 1 on block 3.



Move Eleven

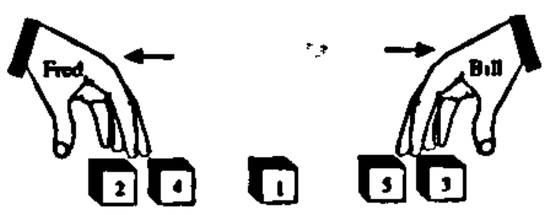


Move Twelve

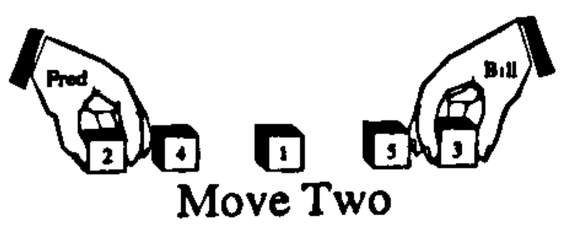
Bill completes his task.

Figure B.2: Fred↦Aggressive, Defensive, Normal or Selfish; Bill↦Unemotional.

Fred continues with his task
by acquiring block 2.
Bill tries to acquire block 3.



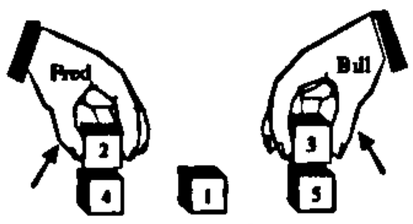
Move One



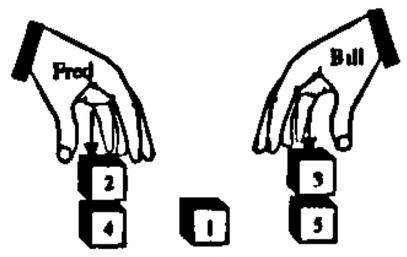
Move Two

Fred acquires block 2.
Bill acquires block 3.

Fred continues with his task
by stacking block 2 on block 4.
Bill tries to stack block 3 on
block 5.



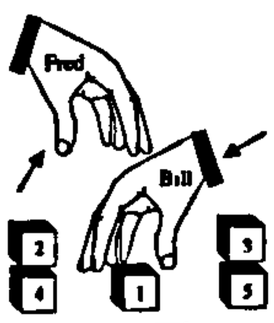
Move Three



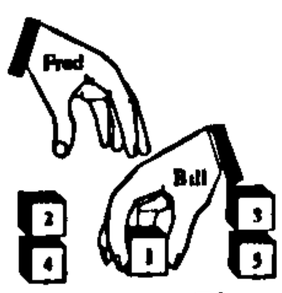
Move Four

Fred stacks block 2 on block 4.
Bill stacks block 3 on block 5.

Fred continues with his task
by trying to acquire block 1.
Bill also tries to acquire block 1.
Bill is successful, Fred is not.
******Conflict******



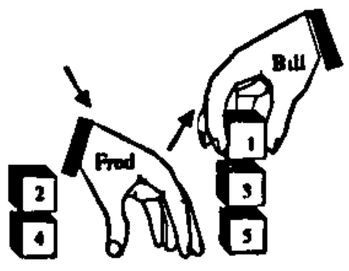
Move Five



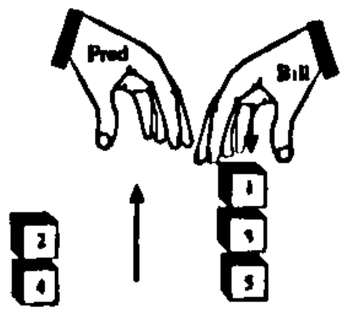
Move Six

Fred waits for block 1 to become
available
Bill acquires block 1.

Bill continues with his task
by stacking block 1 on block 2.
Fred tries to acquire block 1 but
discovers it has been moved.



Move Seven

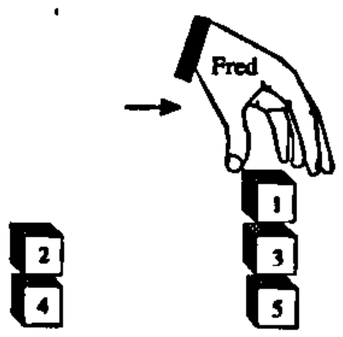


Move Eight

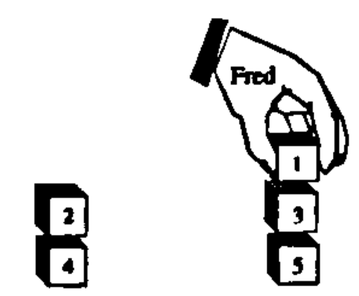
Bill completes his task.
Fred wants block 1 but cannot
move above Bill.

Figure B.3: Part (a): Fred↦Altruistic; Bill↦Unemotional.

Fred can finally acquire block 1.



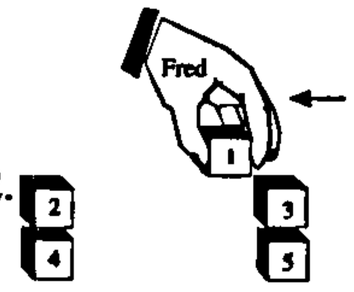
Move Nine



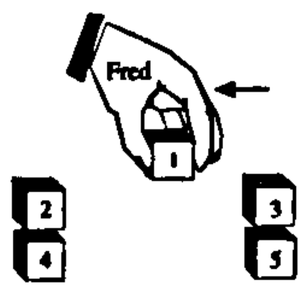
Move Ten

Fred acquires block 1.

Fred continues with his task by stacking block 1 on block 2. Fred can only move 1 unit of distance at a time.



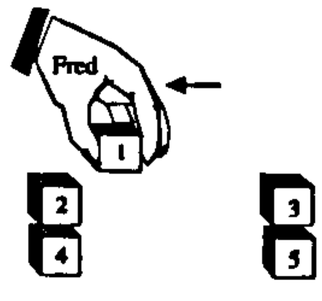
Move Eleven



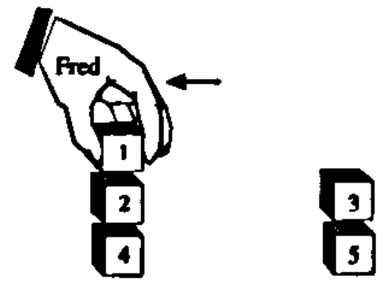
Move Twelve

Fred still tries to stack block 1 on block 2.

Fred still tries to stack block 1 on block 2.



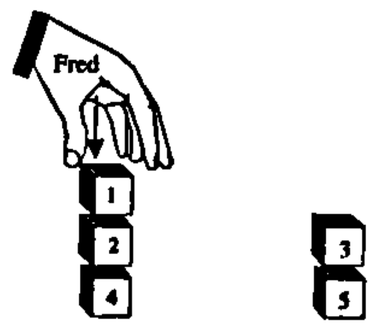
Move Thirteen



Move Fourteen

Fred can finally stack block 1 on block 2.

Fred completes his task.



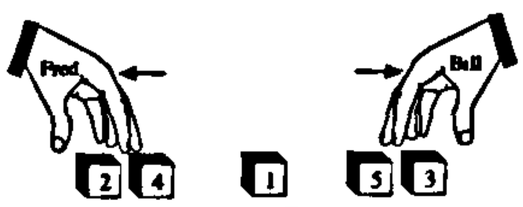
Move Fifteen

Figure B.4: Part (b): Fred↦Altruistic; Bill↦Unemotional.

B.3 'Full' Emotional Behaviour

The following figures B.5 → B.13 represent the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and behaviour deriving from multiple goals and physiology, would perform in conflict scenario one (see figure B.1).

Fred establishes a minor threat to bill by continuing with his task,i.e. stack block 2 on block 4.

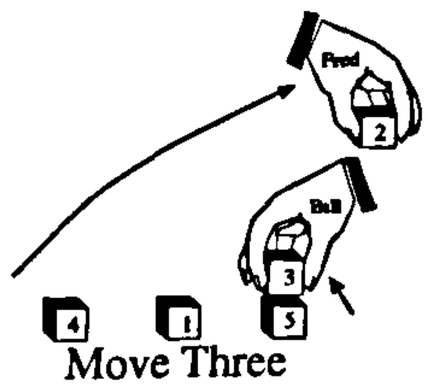


Move One

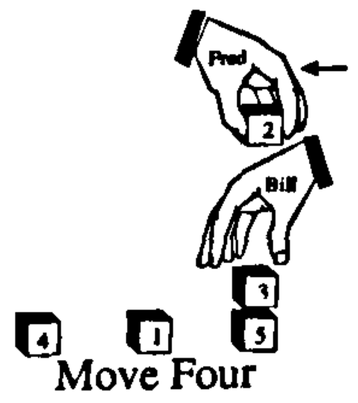
Move Two

Fred continues with this threat while Bill tries to stack block 3 on block 5.

Having identified one of Bill's task blocks, Fred tries to threaten Bill by placing a block on block 3.



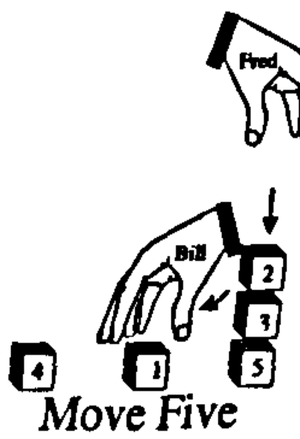
Move Three



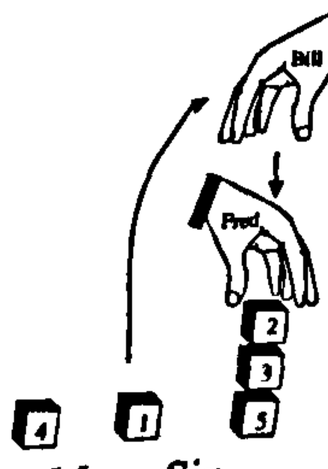
Move Four

Fred continues on this track while Bill has stacked block 3 on block 5.

Fred releases his block to either crush Bill or to cover block 3.



Move Five

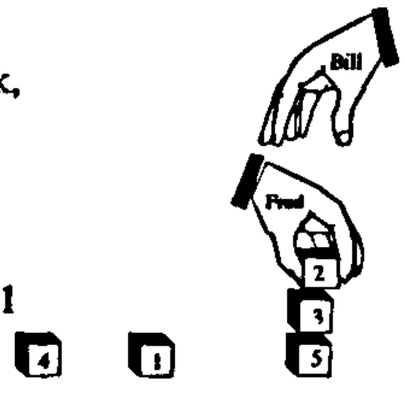


Move Six

Having established a major threat to Bill, Fred decides to maintain this threat by continuing with his task. In the meanwhile Bill must remove block 2 from block 3. Bill tried to move above block 2 but Fred was faster.

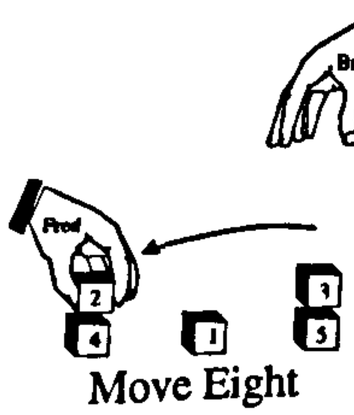
In continuing with his task, Fred tries to stack block 2 on block 4.

Bill has to move block 2 before he can stack block 1 on block 3.



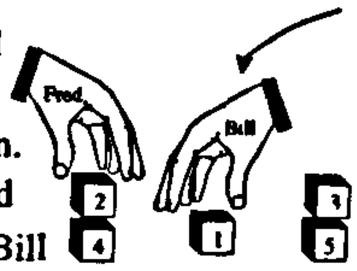
Move Seven

Fred continues with his task of stacking block 2 on block 4.
Bill has just realised that block 2 is now clear of block 3 so he will acquire block 1 again.

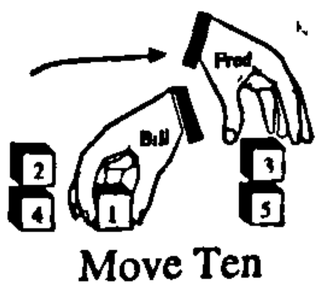


Move Eight

Fred has now reestablished the minor threat to himself by uncovering Bill's pattern. Fred now decides he should establish a major threat to Bill by picking up his block.



Move Nine

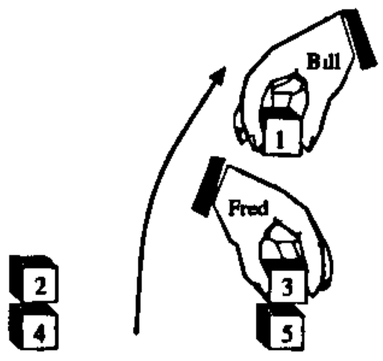


Move Ten

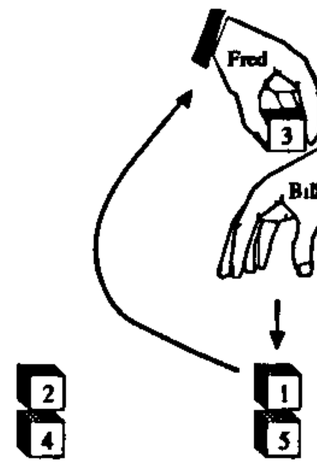
Bill acquires block 1 thereby establishing an unintentional major threat to Fred.

Figure B.5: Part (a): Fred↦Aggressive; Bill↦Unemotional.

Fred continues to threaten Bill by picking up Bill's block 3. Bill tries to stack block 1 on block 3.



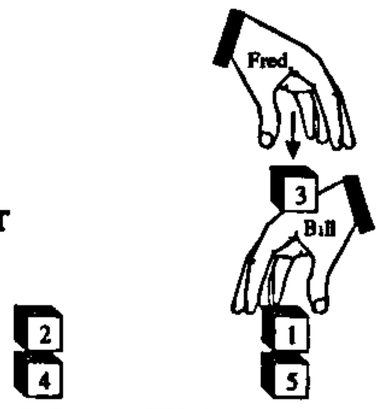
Move Eleven



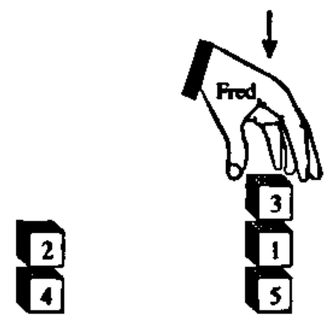
Move Twelve

Fred moves out of the mortal threat in Move Eleven to establish a mortal threat to Bill. Bill hopes to stack block 1 on block 3. Unfortunately Fred moves it before this happens.

Fred maintains the mortal threat to Bill by releasing block 3. Bill tries to uncover block 5 but is crushed by the falling block.
****Bill dies****



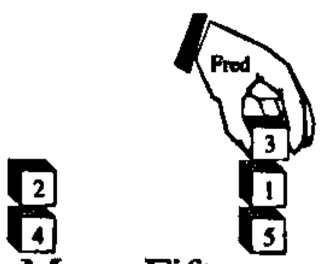
Move Thirteen



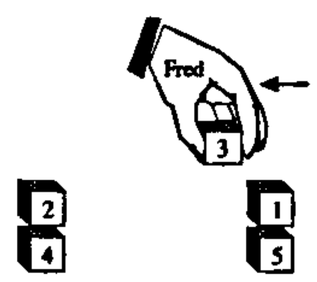
Move Fourteen

Having destroyed his opponant, Fred continues with his task by uncovering block 1.

Fred can now discard block 3.



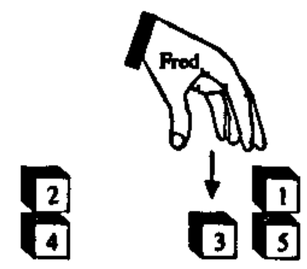
Move Fifteen



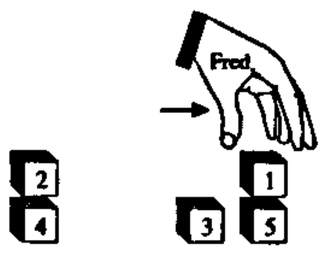
Move Sixteen

Fred finds a safe place to drop block 3.

Fred has uncovered block 1.



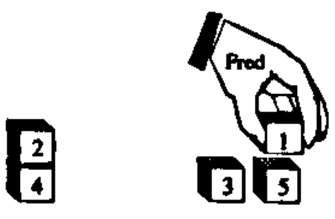
Move Seventeen



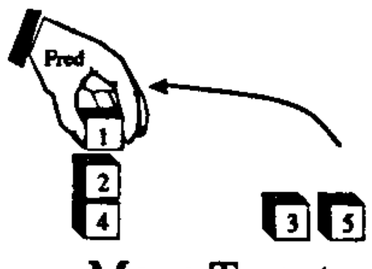
move Eighteen

Fred moves to acquire block 1.

Fred has acquired his last task block.



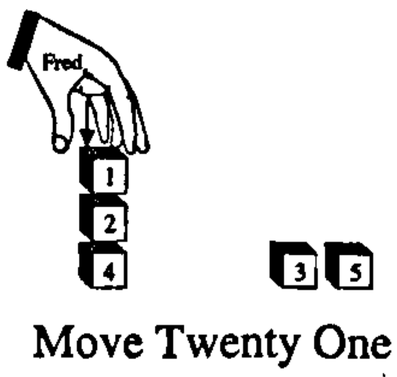
Move Nineteen



Move Twenty

Fred tries to stack block 1 on block 2.

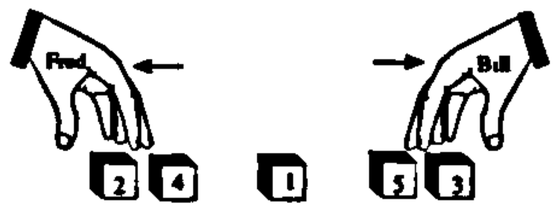
Fred completes his task.



Move Twenty One

Figure B.6: Part (b): Fred↦Aggressive; Bill↦Unemotional.

Fred cannot help Bill until he discovers which blocks are part of Bill's task, so Fred continues with his own task.

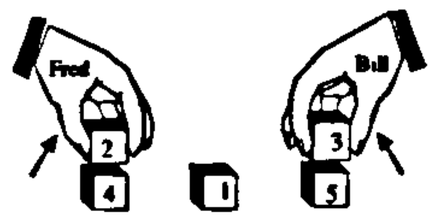


Move One

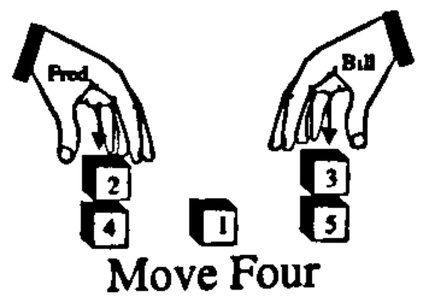
Move Two

Fred tries to stack block 2 on block 4. Bill tries to stack block 3 on block 5.

Fred stacks block 2 on block 4. Bill stacks block 3 on block 5.



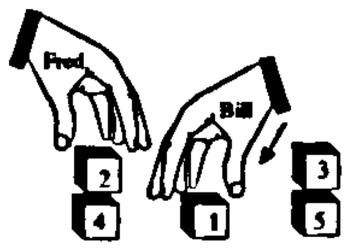
Move Three



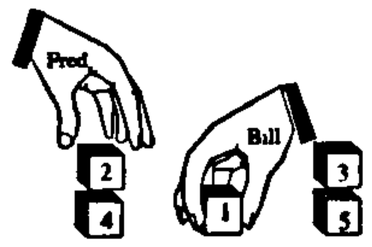
Move Four

Fred stacks block 2 on block 4. Bill stacks block 3 on block 5.

Fred now knows block 3 and block 5 are part of Bill's task so he tries to maintain Bill's opportunity by not moving



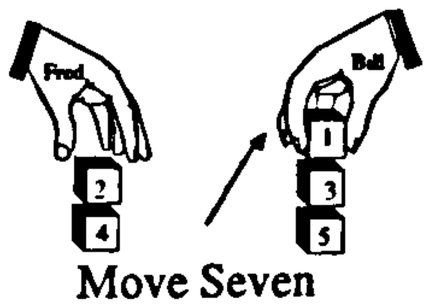
Move Five



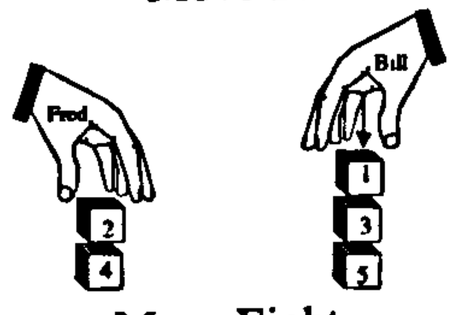
Move Six

Bill continues with his task by acquiring block 1 to stack on block 3.

Fred continues not to interfere with Bill's task.



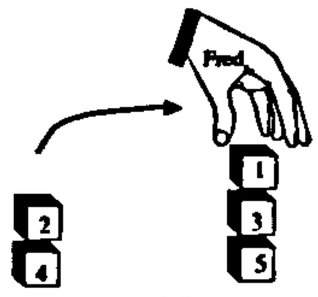
Move Seven



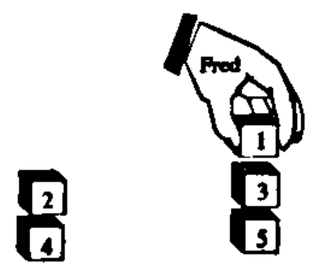
Move Eight

Bill completes his task.

Fred cannot help Bill anymore so he continues with his own task.



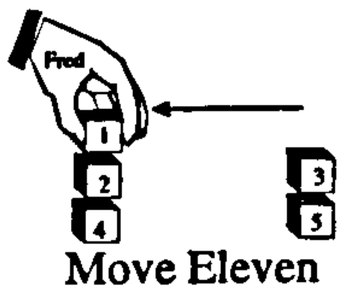
Move Nine



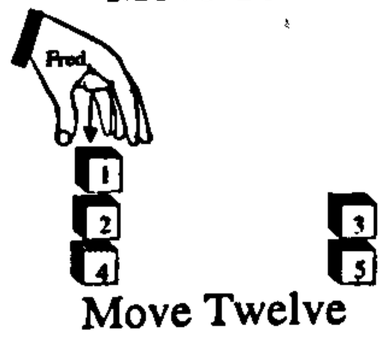
Move Ten

Fred tries to stack block 1 on block 2.

Fred stacks block 1 on block 2



Move Eleven

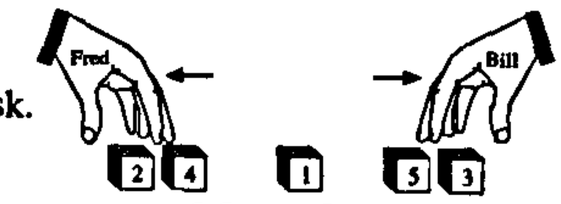


Move Twelve

Fred completes his task.

Figure B.7: Fred↦Altruistic; Bill↦Unemotional.

Fred only reacts to threats, so he continues with his task.

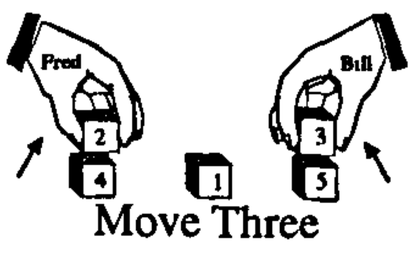


Move One

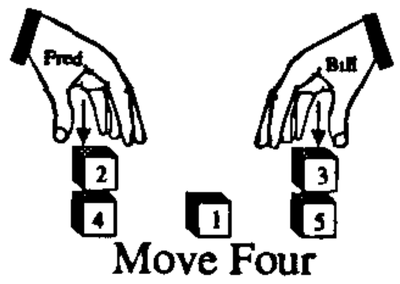
Move Two

Fred wants to stack block 2 on block 4. Bill wants to stack block 3 on block 5.

Fred and Bill both stack their relevant blocks.



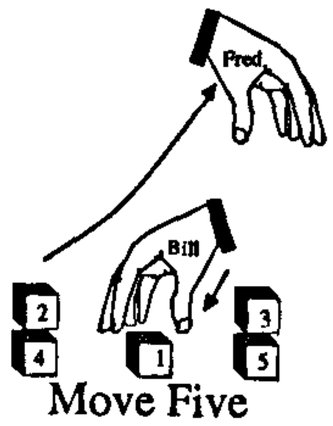
Move Three



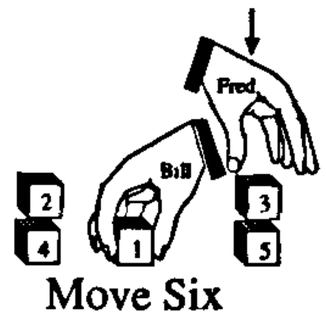
Move Four

Fred now feels threatened since Bill has two blocks stacked together. He decides to disrupt this minor threat by moving above Bill.

Fred moves to where Bill last was but by this time Bill has moved towards his last task block.



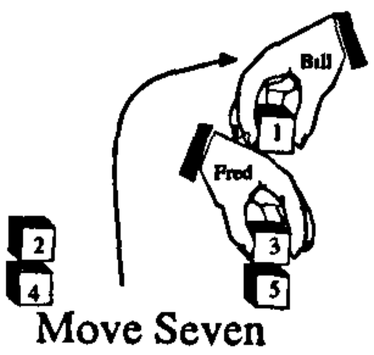
Move Five



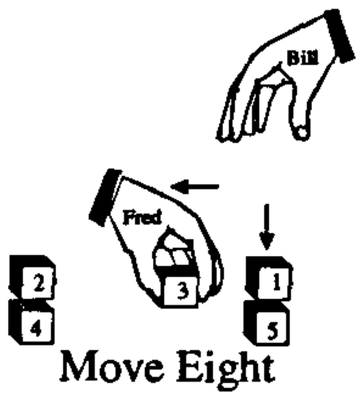
Move Six

Fred tries a different track in disrupting the minor threat. He now wants to pick up Bill's block 3.

Bill wants to stack block 1 on block 3. Fred simply wants to get out from underneath Bill.



Move Seven

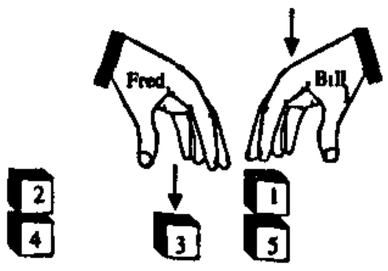


Move Eight

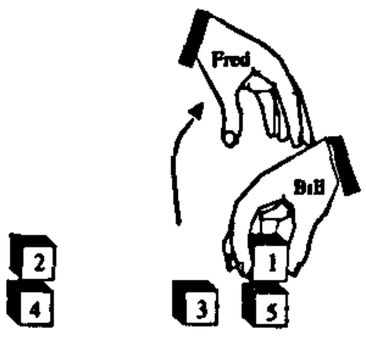
Fred makes an emergency move.

Bill drops his block hoping to stack it on block 3.

Fred has removed the major threat to himself. He now drops Block 3 to continue with his task.



Move Nine

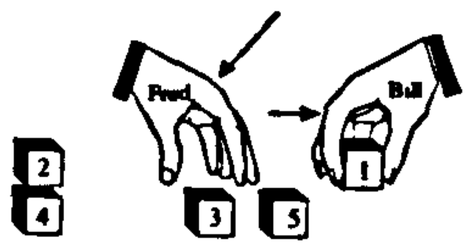


Move Ten

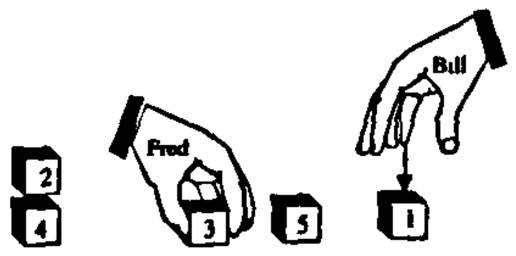
Fred wants block 1 to complete his task . Bill wants to clear the same block from his block 5. Fred has to move above Bill.

Figure B.8: Part (a): Fred↦Defensive; Bill↦Unemotional.

Now that Bill has block 1, Fred tries to disrupt this threat by picking up Bill's block 3.



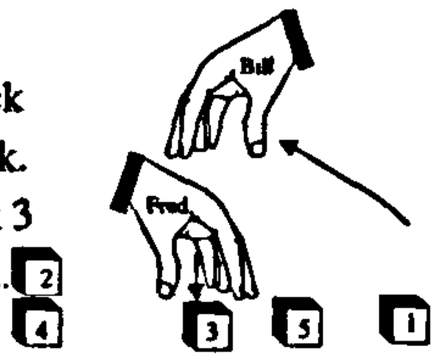
Move Eleven



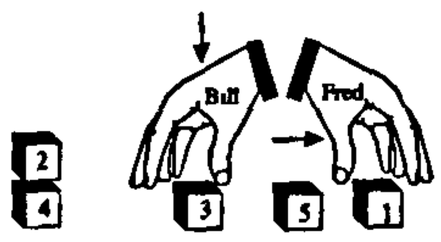
Move Twelve

Bill has succeeded in clearing block 5. Fred is no longer threatened.

Fred decides to drop block 3 to continue with his task. Bill tries to acquire block 3 but must wait above Fred.



Move Thirteen

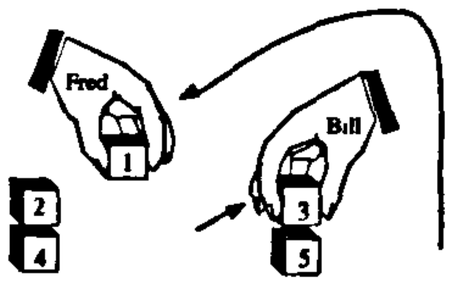


Move Fourteen

Fred can now aquire block 1.
Bill can restack block 3 on block 5.

Fred picks up block 1.
Bill picks up block 3.

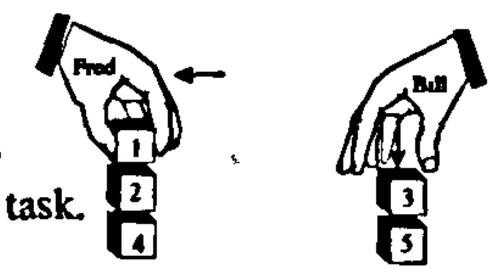
Move Fifteen



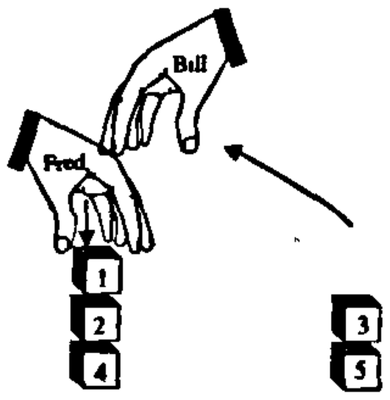
Move Sixteen

Bill moves into a position to stack block 3 on block 5.
Fred tries to move above block 2, but he finds it difficult to move.

Fred finally reaches block 2. Bill now needs block 1 to complete his task.



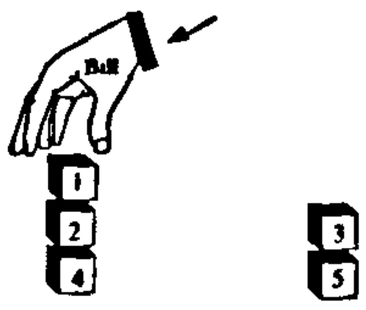
Move Seventeen



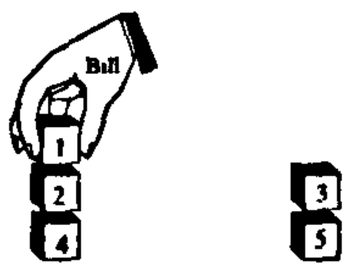
Move Eighteen

Fred completes his task.
Bill waits for block 1.

Bill can now pick up block 1.



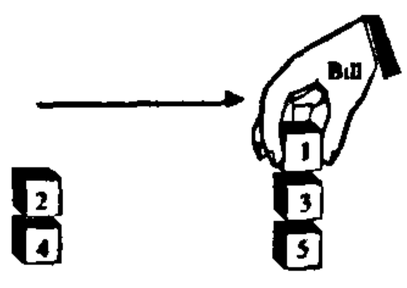
Move Nineteen



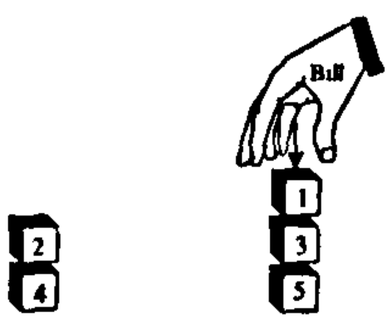
Move Twenty

Bill acquires block 1.

Bill stacks block 1 on block 3



Move Twenty one

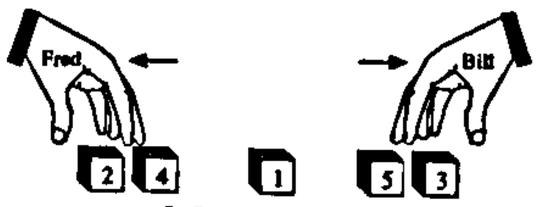


Move Twenty Two

Bill completes his task.

Figure B.9: Part (b): Fred↦Defensive; Bill↦Unemotional.

Fred maintains a minor opportunity by continuing with his task.



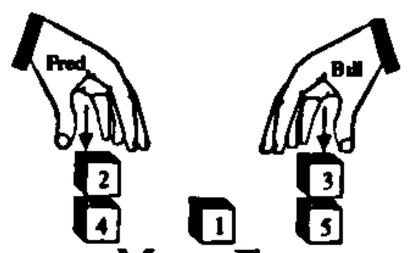
Move One

Move Two

Fred picks up block 2 to stack on block 4. Bill acquires block 3.

Fred stacks block 2 on block 4.
Bill stacks block 3 on block 5.

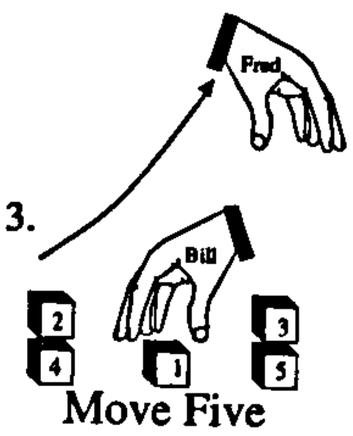
Move Three



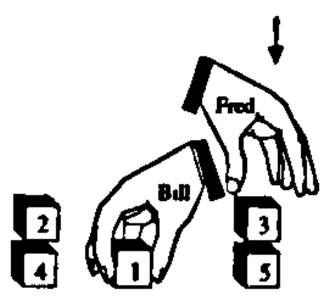
Move Four

Fred is now confronted with a minor threat, i.e. Bill has stacked two blocks. Fred decides to pick up Bill's block 3.

Fred thought he would have to wait above Bill to get block 3.



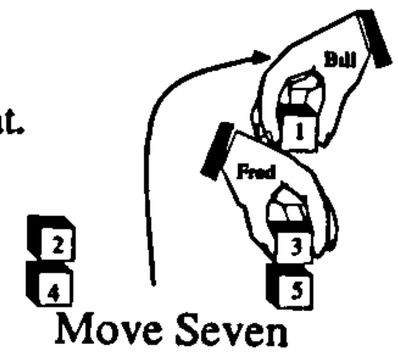
Move Five



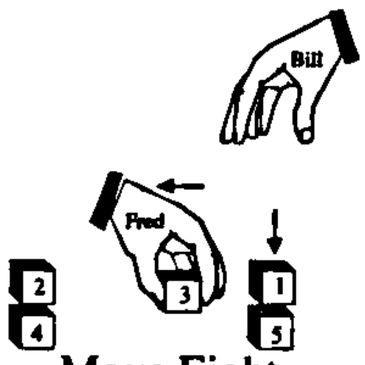
Move Six

Fred can now pick up block 3. Bill places a more serious threat on Fred by picking up his block.

Fred decides that picking up block 3 will reduce the threat.



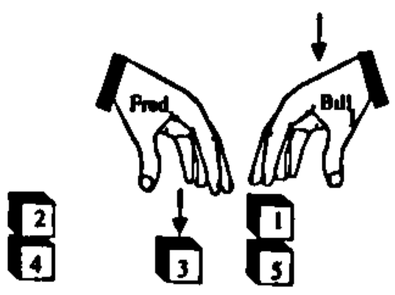
Move Seven



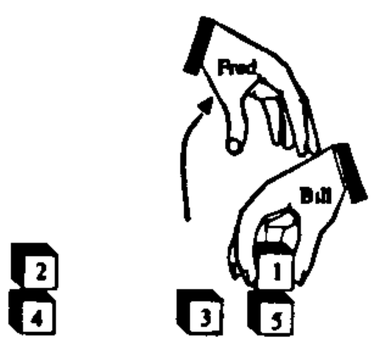
Move Eight

Bill tried to stack block 1 on block 3 but Fred was confronted with a mortal threat and so made an emergency move.

The threat is now removed for Fred so he decides to maintain his opportunity by continuing with his task: he no longer needs block 3.



Move Nine

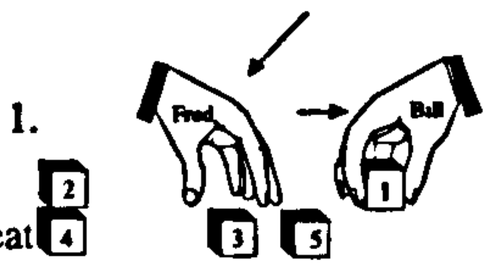


Move Ten

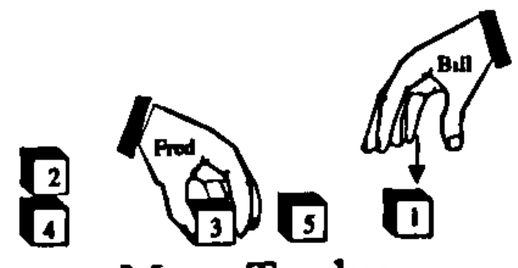
Bill tries to uncover block 5 so that he can restack block 3 on block 5. Fred needs block 1 to continue with his task.

Figure B.10: Part (a): Fred↦Normal; Bill↦Unemotional.

Again Fred is threatened by Bill grasping his block 1. Fred decides to pick up block 3 to disrupt this threat



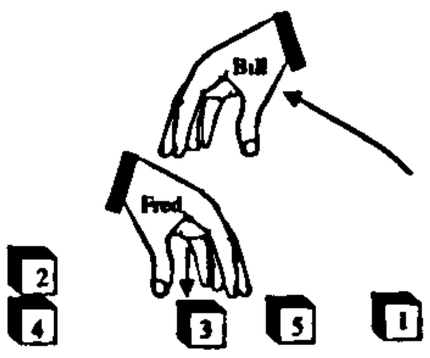
Move Eleven



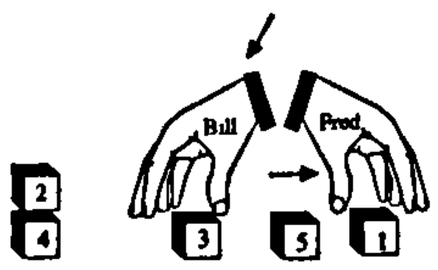
Move Twelve

Bill has finally cleared block 1 from block 5 and unintentionally removed the threat to Fred.

Fred releases block 3 to continue with his task. Bill needs block 3.



Move Thirteen

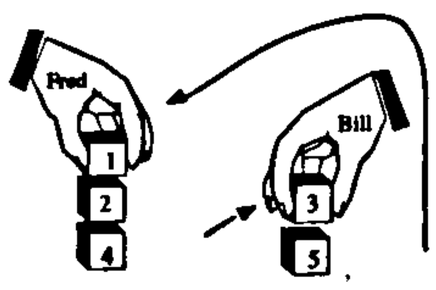


Move Fourteen

Fred can now pick up block 1. Bill can now restack block 3 on block 5.

Fred picks up block 1. Bill picks up block 3

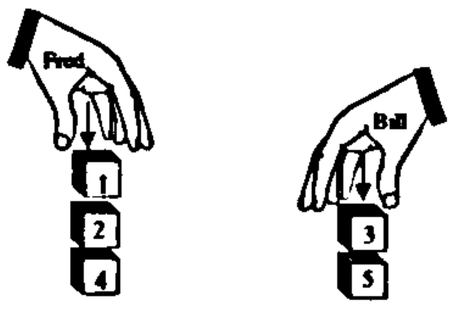
Move Fifteen



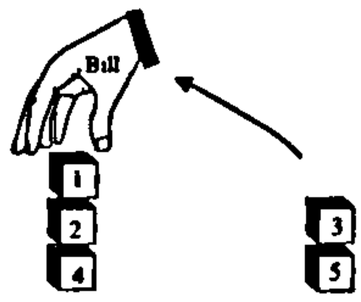
Move Sixteen

Fred tries to stack block 1 on block 2. Bill tries to stack block 3 on block 5.

Fred completes his task. Bill must now get block 1



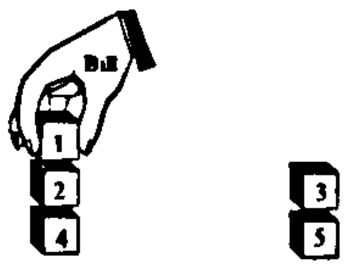
Move Seventeen



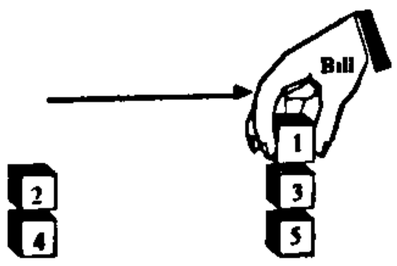
Move Eighteen

Bill moves towards block 1.

Bill acquires block 1



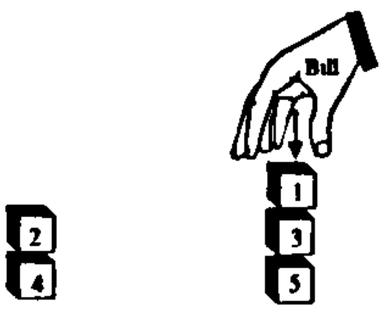
Move Nineteen



Move Twenty

Bill stacks block 1on block 3.

Bill completes his task.



Move Twenty one

Figure B.11: Part (b): Fred↦Normal; Bill↦Unemotional.

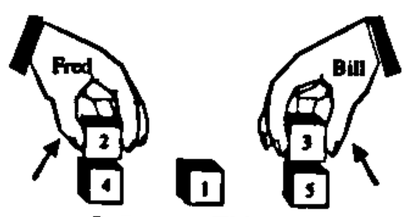
Fred maintains a minor opportunity by continuing with his task, i.e., by acquiring block 2. Bill tries to acquire block 3.

Move One

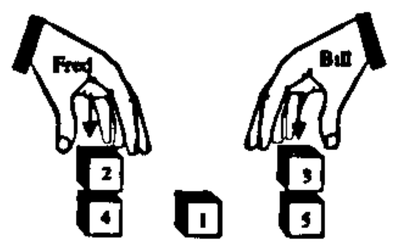
Move Two

Fred acquires block 2.
Bill acquires block 3.

Fred continues with his task by stacking block 2 on block 4. Bill tries to stack block 3 on block 5.



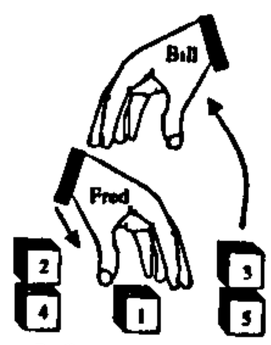
Move Three



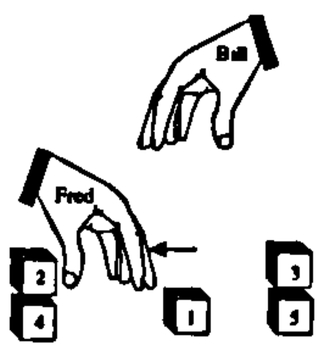
Move Four

Fred stacks block 2 on block 4.
Bill stacks block 3 on block 5.
Even though Fred is now threatened by Bill's stack of blocks, Fred is only concerned with opportunities for himself.

Fred continues with his task by trying to acquire block 1. Bill also tries to acquire block 1. Bill is successful, Fred is not.
******Conflict******



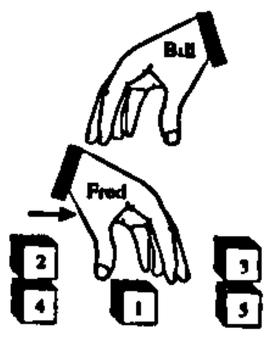
Move Five



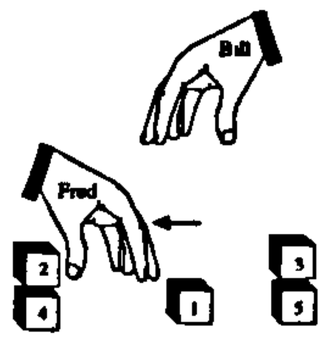
Move Six

Fred is confronted with a mortal threat so he makes an emergency reaction.

Fred establishes a major opportunity for himself by trying to acquire block 1. Bill also tries to acquire block 1. Bill is successful, Fred is not.
******Conflict******



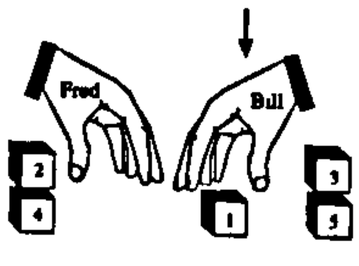
Move Seven



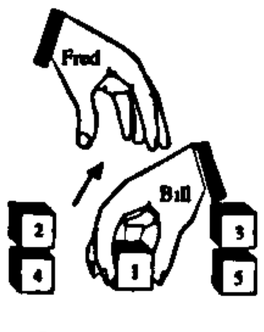
Move Eight

Fred is again confronted with a mortal threat so he makes an emergency reaction.

Fred's move to pick up block 1 is continuously blocked. He has no other option but to recuperate his energy.



Move Nine

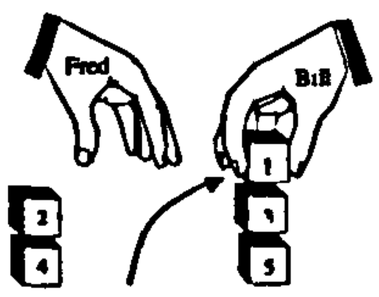


Move Ten

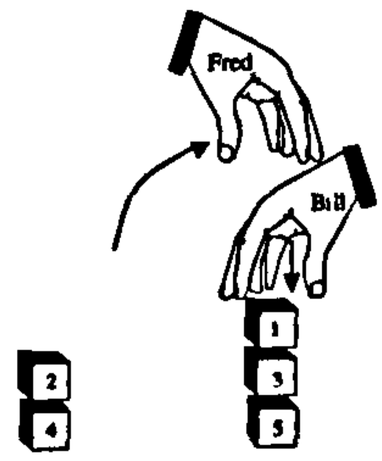
Fred waits for block 1 to become available
Bill acquires block 1.

Figure B.12: Part (a): Fred↦Selfish; Bill↦Unemotional.

Bill continues with his task by stacking block 1 on block 2.
Fred tries to acquire block 1 but discovers it has been moved.



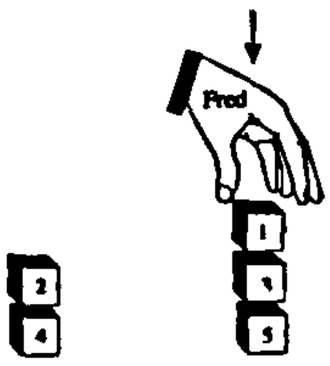
Move Seven



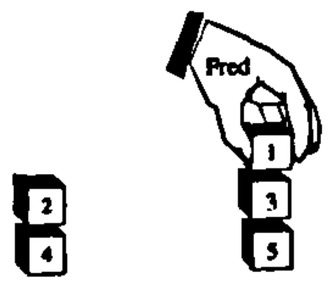
Move Eight

Bill completes his task.
Fred wants block 1 so he moves above Bill.

Fred can finally acquire block 1.



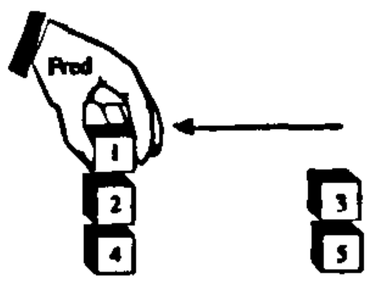
Move Eleven



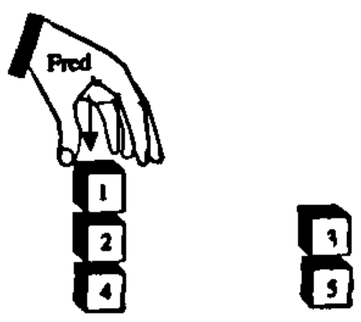
Move Twelve

Fred acquires block 1.

Fred can finally stack block 1 on block 2.



Move Thirteen



Move Fourteen

Fred completes his task.

Figure B.13: Part (b): Fred↦Selfish; Bill↦Unemotional.

Appendix C

Conflict Scenario Two

C.1 Introduction

This appendix shows the moves various Emoters make in scenario two (see figure C.1) until the Emoter completes his prescribed task, is crushed by a block, or reaches a state of deadlock. Two versions of emotionality are represented. Figures C.2 → C.5 represent moves that Emoters would make utilising physiology alone. Figures C.6 → C.15 represent moves that Emoters would make utilising both physiology and the behaviour derived from multiple goals, i.e. 'full' emotional behaviour.

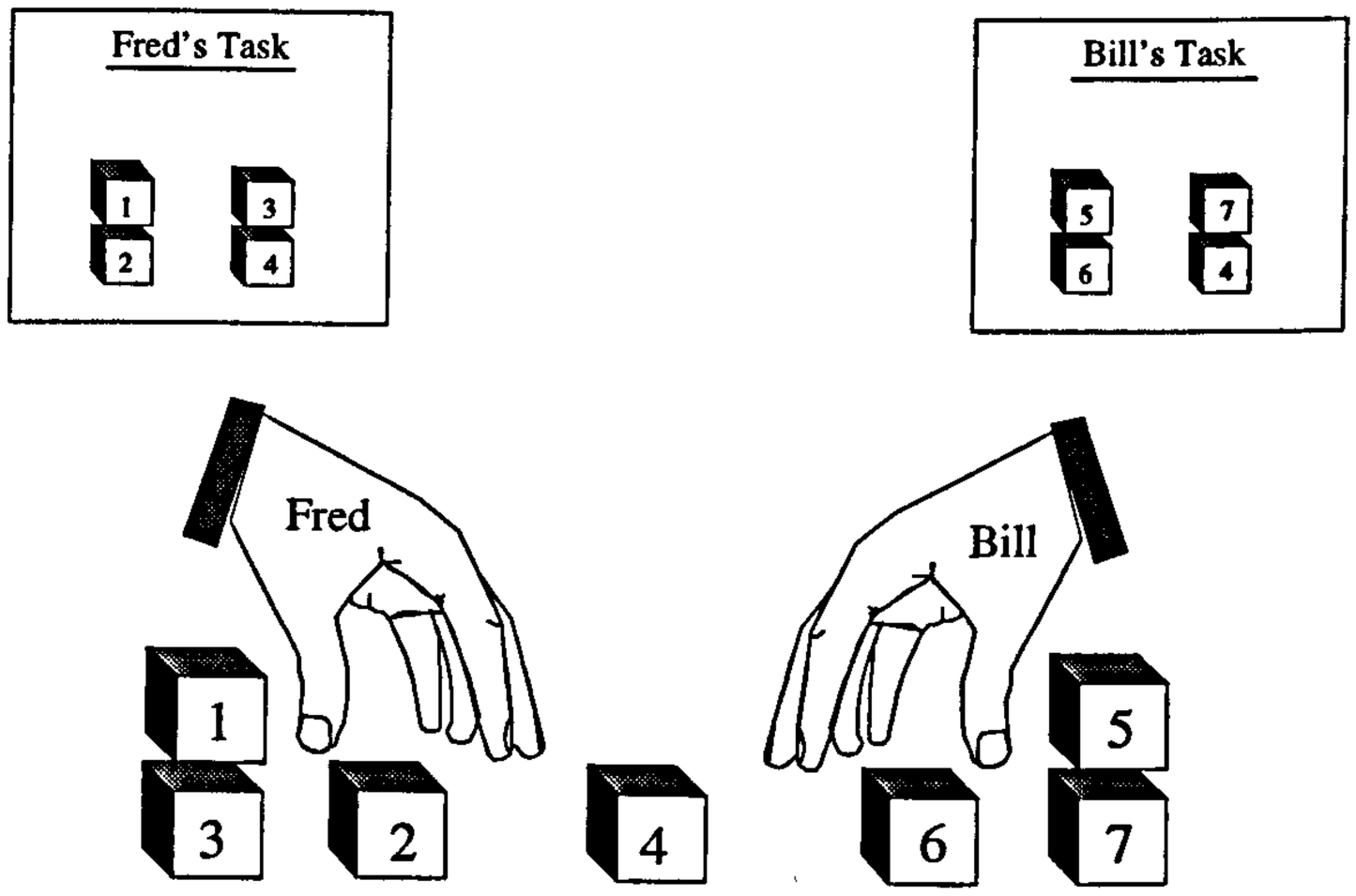
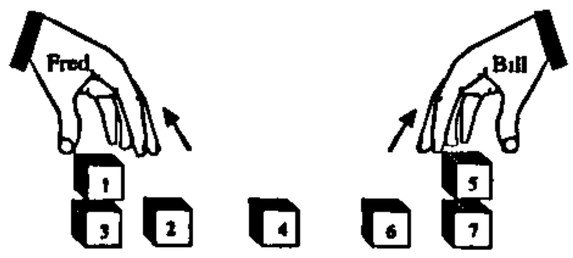


Figure C.1: Conflict Scenario Two.

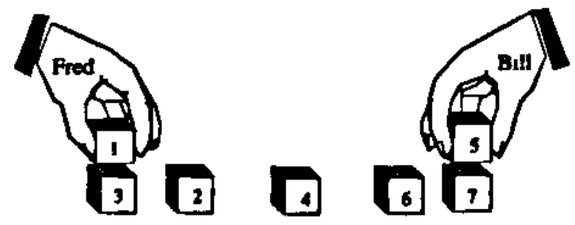
C.2 The Sole Influence of Physiology on the Conflict

The following figures C.2 → C.5 represent the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and only one goal of completing his prescribed task, would perform in conflict scenario two (see figure C.1). With each of the personalities, the Emoter follows a very similar course of action up until the actual conflict. The Aggressive Emoter, Defensive Emoter, Normal Emoter and Selfish Emoter all follow the same course of action, i.e. figures C.2 & C.3 whereas the Altruistic Emoter follows the course of action shown in figures C.4 & C.5.

Fred continues with his task
by acquiring block 1.
Bill tries to acquire block 5.



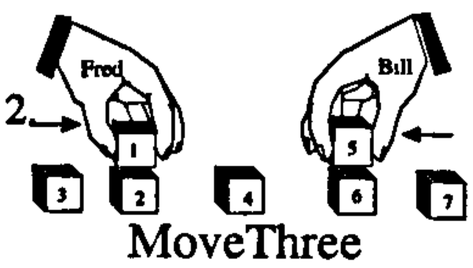
Move One



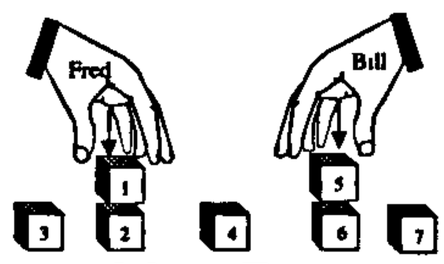
Move Two

Fred acquires block1.
Bill acquires block 5.

Fred continues with his task
by stacking block 1 on block 2.
Bill tries to stack block 5
on block 6.



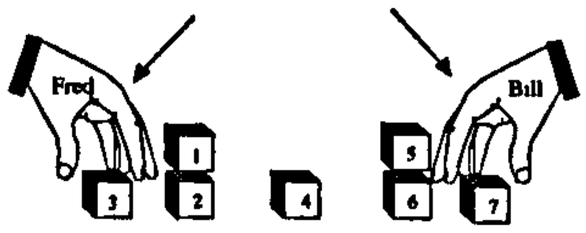
MoveThree



Move Four

Fred stacks block 1 on block 2.
Bill stacks block 5 on block 6.

Fred continues with his task
by acquiring block 3.
Bill tries to acquire block 7.

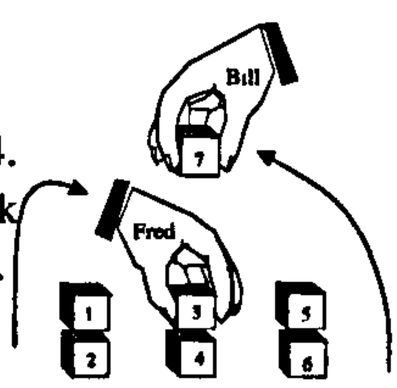


Move Five

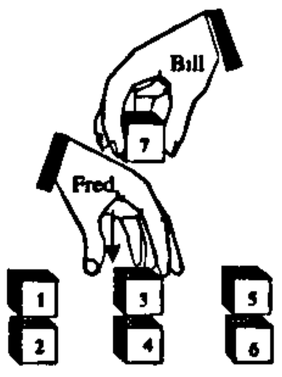
Move Six

Fred acquires block 3.
Bill acquires block 7.

Fred continues with his task
by stacking block 3 on block 4.
Bill also tries to stack his block
on block 4 but is unsuccessful.
******conflict******



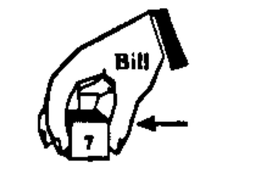
Move Seven



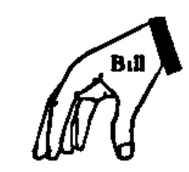
Move Eight

Fred stacks block 3 on block 4.
Fred completes his task.
Bill waits to stack his block on
block 4.

Bill must remove block 3 before
he can stack block 7 on block 4.
Bill puts block 7 to one side.



Move Nine

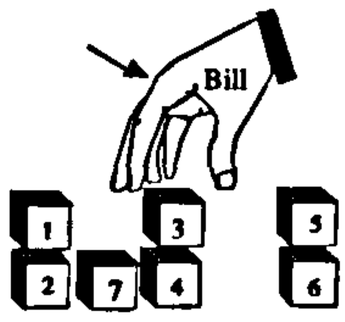


Move Ten

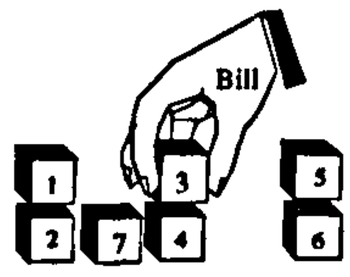
Bill can now remove block 3
from block 4.

Figure C.2: Part (a): Fred↦Aggressive, Defensive, Normal or Selfish; Bill↦Unemotional.

Bill now tries to move block 3 from block 4.



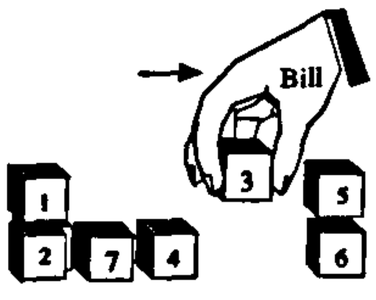
Move Eleven



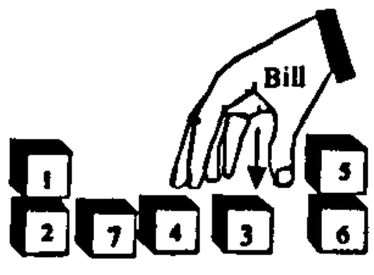
Move Twelve

Bill acquires block 3.

Bill moves block 3 out of the way.



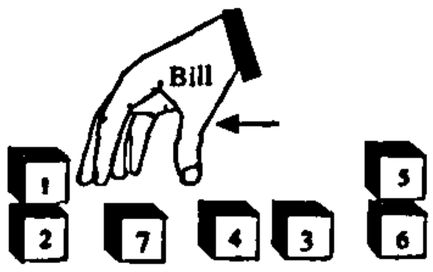
Move Thirteen



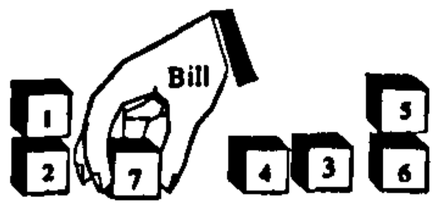
Move Fourteen

Bill has moved block 3 from block 4

Bill can now place block 7 on block 4.



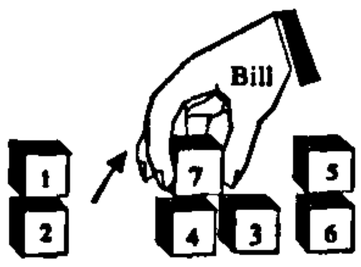
Move Fifteen



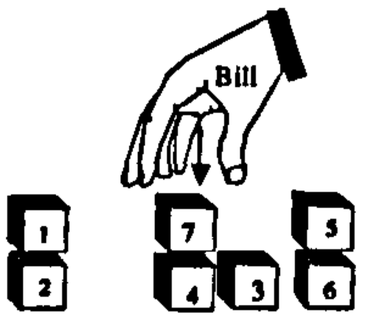
Move Sixteen

Bill acquires block 7

Bill tries to stack block 7 on block 4



Move Seventeen

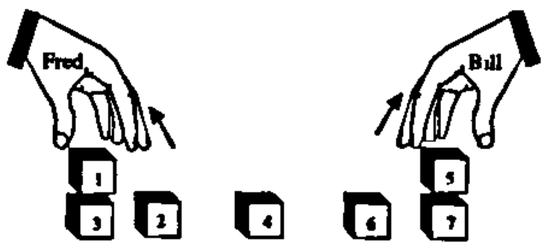


Move Eighteen

Bill completes his task.

Figure C.3: Part (b): Fred↦Aggressive, Defensive, Normal or Selfish; Bill↦Unemotional.

Fred continues with his task
by acquiring block 1.
Bill tries to acquire block 5.

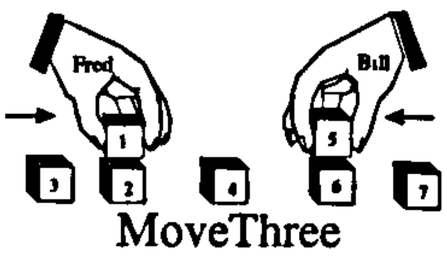


Move One

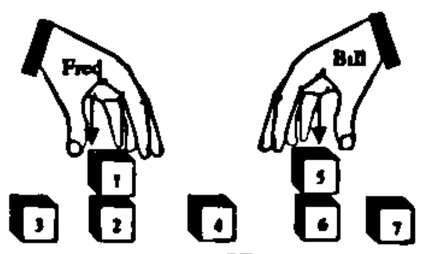
Move Two

Fred acquires block1.
Bill acquires block 5.

Fred continues with his task
by stacking block 1 on block 2.
Bill tries to stack block 5
on block 6.



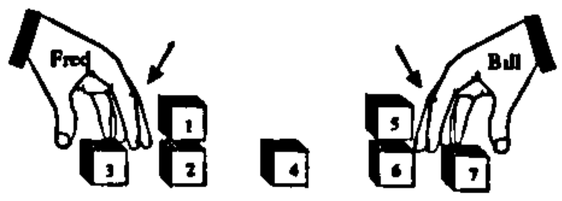
MoveThree



Move Four

Fred stacks block 1 on block 2.
Bill stacks block 5 on block 6.

Fred continues with his task
by acquiring block 3.
Bill tries to acquire block 7.



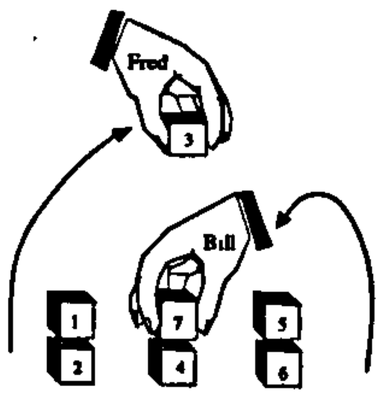
Move Five

Move Six

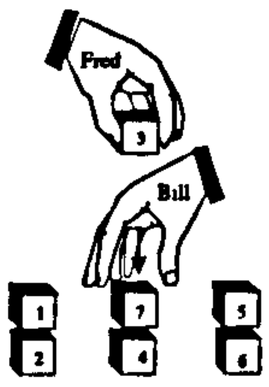
Fred acquires block 3.
Bill acquires block 7.

Fred continues with his task
by stacking block 3 on block 4.
Bill also tries to stack his block
on block 4.
Bill is successful, Fred is not.

******conflict******



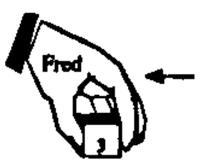
Move Seven



Move Eight

Bill stacks block 7 on block 4.
Bill completes his task.
Fred waits to stack his block
on block 4.

Fred must remove block 7 before
he can stack block 3 on block 4.
Fred puts block 3 to one side.



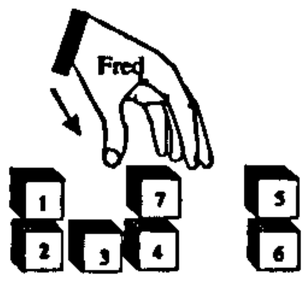
Move Nine

Move Ten

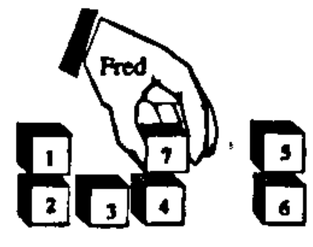
Fred can now remove block 7
from block 4

Figure C.4: Part (a): Fred↦Altruistic; Bill↦Unemotional.

Fred now tries to remove block 7 from block 4.



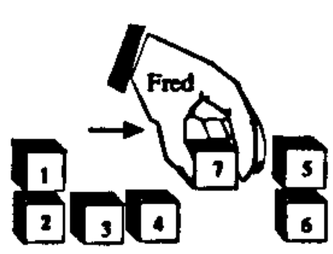
Move Eleven



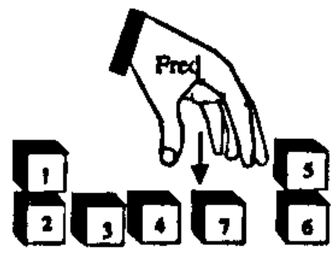
Move Twelve

Fred acquires block 7.

Fred moves block 7 out of the way.



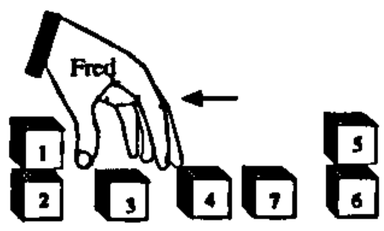
Move Thirteen



Move Fourteen

Fred has removed block 7 from block 4.

Fred can now place block 3 on block 4.

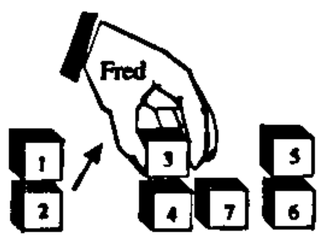


Move Fifteen

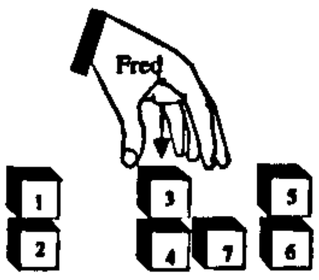
Move Sixteen

Fred acquires block 3.

Fred tries to stack block 3 on block 4.



Move Seventeen



Move Eighteen

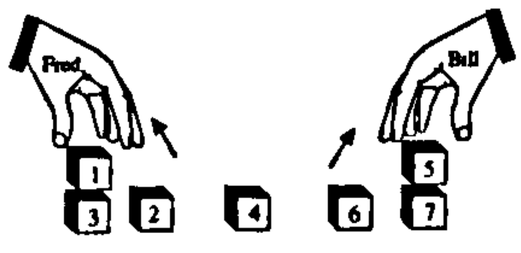
Fred completes his task.

Figure C.5: Part (b): Fred↦Altruistic; Bill↦Unemotional.

C.3 'Full' Emotional Behaviour

The following figures C.6 → C.15 represent the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and behaviour deriving from multiple goals and physiology, would perform in conflict scenario two (see figure C.1).

Fred establishes a minor threat to Bill by continuing with his task, i.e. stack block 1 on block 2.

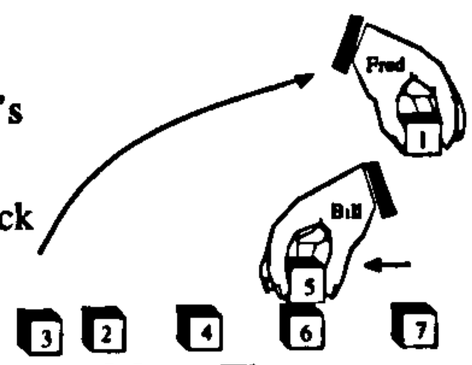


Move One

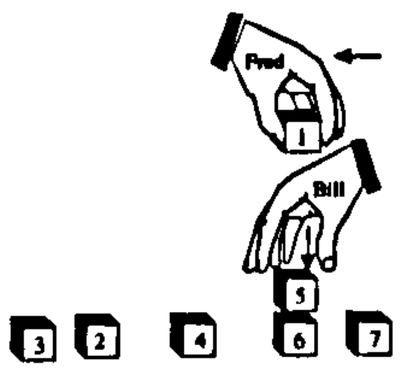
Move Two

Fred continues with this threat while Bill tries to stack block 5 on block 6.

Having identified one of Bill's task blocks, Fred tries to threaten Bill by placing a block on block 5.
Bill moves before Fred can release the block.



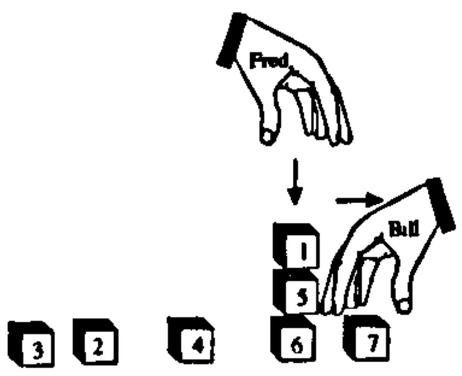
Move Three



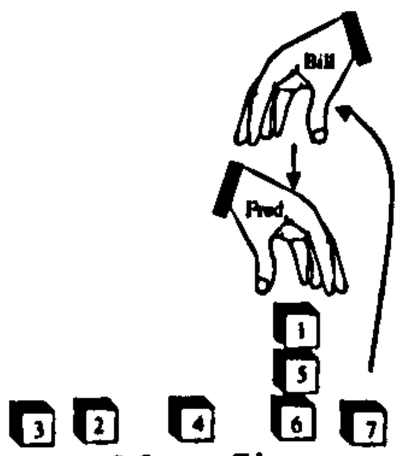
Move Four

Fred continues on this track while Bill has stacked block 5 on block 6.

Fred releases his block to either crush Bill or to cover block 5.
Bill carries on with his task and avoids block 1.



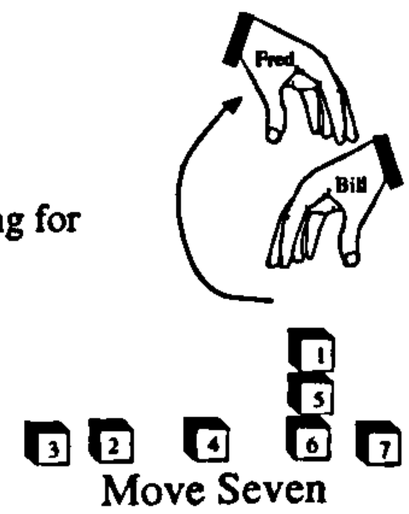
Move Five



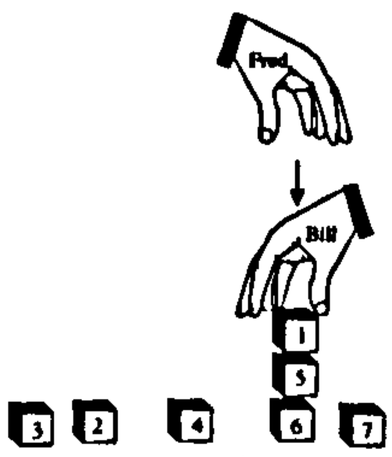
Move Six

Having established a major threat to Bill, Fred decides to maintain this threat by continuing with his task. Bill has to clear block 1 from block 5 as it ruins his pattern. Thus, instead of picking up block 7 as planned he tried to move above block 1 but Fred wants to pick up his task block. Bill fails to move above block 1.

Fred's life is threatened so he moves above Bill hoping to establish a mortal threat. This takes Bill by surprise while he is waiting for access to block 1.



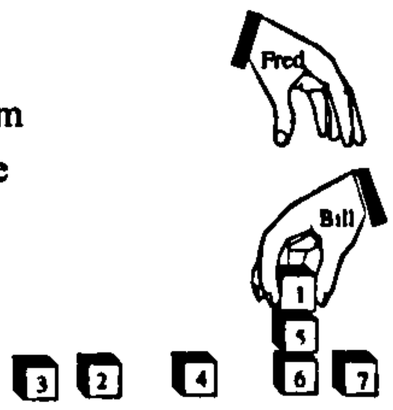
Move Seven



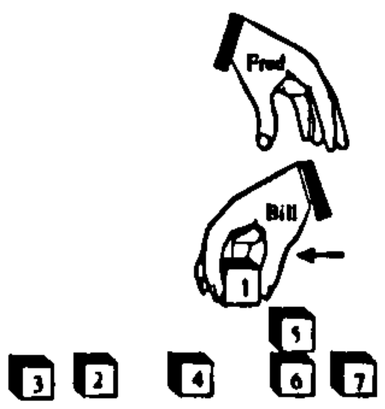
Move Eight

Fred tries to regain his position above block 1 but Bill is closer to the block. Fred has to wait.

Bill must clear block 1 from his pattern of blocks before he can continue.



Move Nine

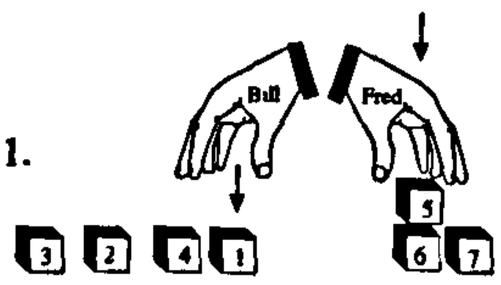


Move Ten

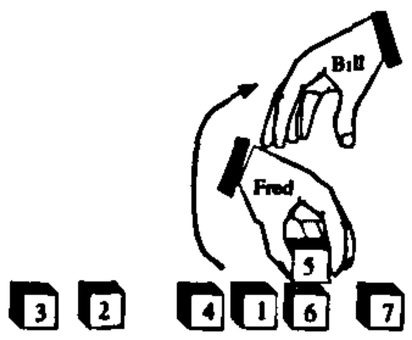
Fred tries to establish a major threat to Bill by picking up one of Bill's blocks. He must wait to gain access to blocks 5 and 6. Bill removes block 1 from his stack of blocks.

Figure C.6: Part (a): Fred↦Aggressive; Bill↦Unemotional.

Fred can now pick up one of Bill's blocks. Bill releases the redundant block 1.



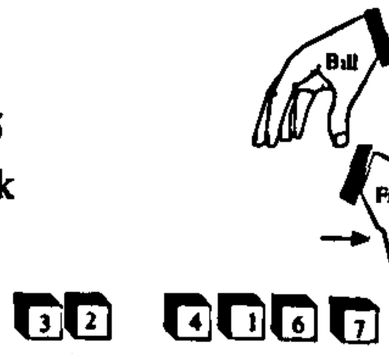
Move Eleven



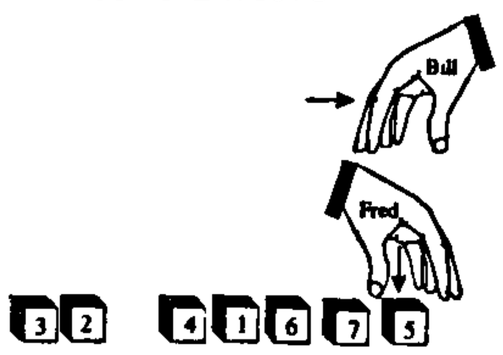
Move Twelve

Bill moves to acquire block 7. Fred threatens Bill by picking up block 5.

Bill moves to restack block 5 on block 6 but finds the block has moved. Fred tries to put Bill's block 5 on the floor.



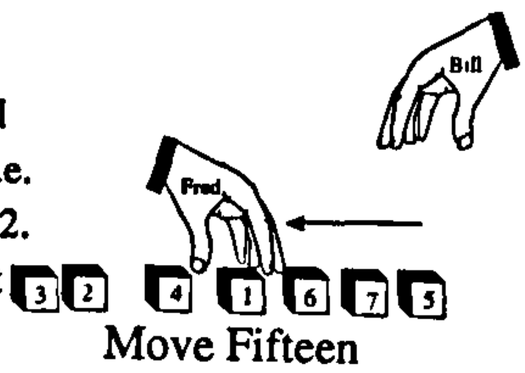
Move Thirteen



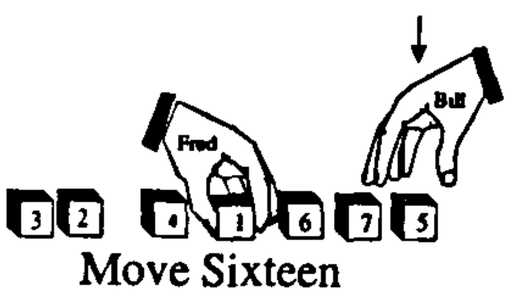
Move Fourteen

Fred drops block 5 on the floor. Bill still needs block 5.

Fred maintains a threat to Bill by continuing with his task, i.e. by stacking block 1 on block 2. Bill has only just realised that block 5 is now available.



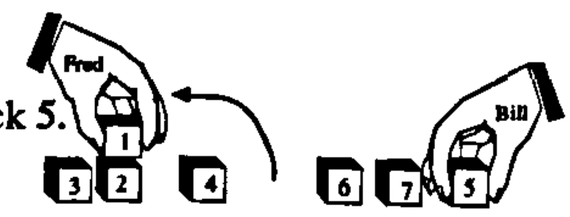
Move Fifteen



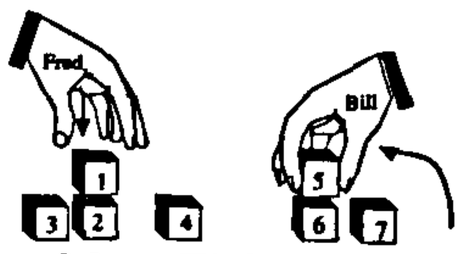
Move Sixteen

Fred acquires block 1. Bill moves to pick up block 5.

Fred stacks block 1 on block 2. Bill acquires block 5.



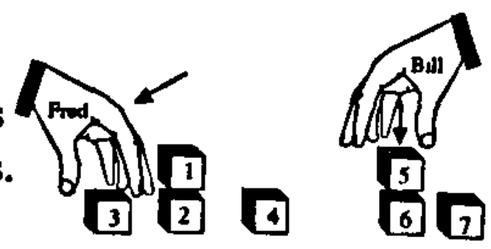
Move Seventeen



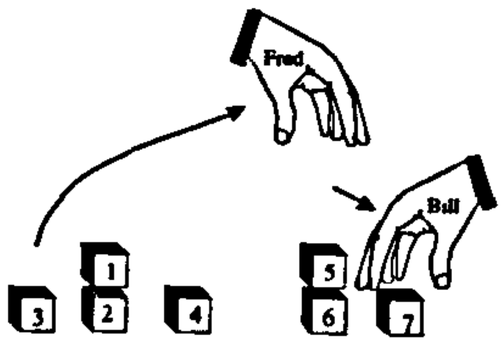
Move Eighteen

Fred has stacked block 1 on block 2. Bill tries to stack block 5 on block 6.

Bill's stack is now a minor threat to Fred, so Fred decides to pick up one of Bill's blocks.



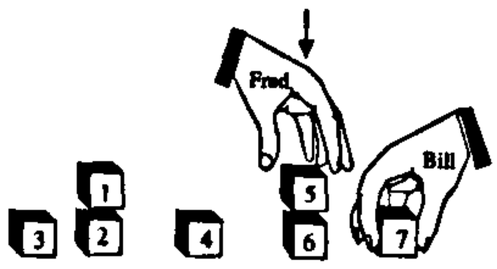
Move Nineteen



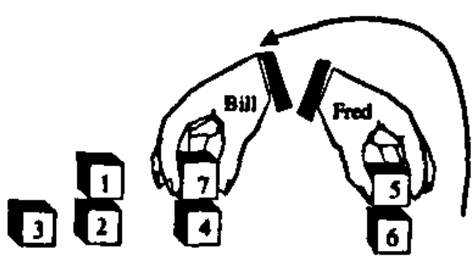
Move Twenty

Fred expects Bill to be above block 5 so he moves above that position. Meanwhile Bill moves to acquire block 7.

Fred can now acquire block 5. Bill acquires block 7.



Move Twenty one

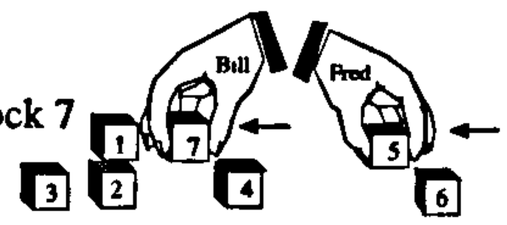


Move Twenty two

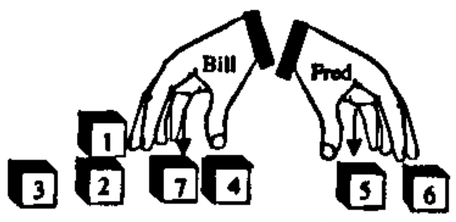
Bill tries to stack block 7 on block 4. Fred picks up Bill's block 5.

Figure C.7: Part (b): Fred↦Aggressive; Bill↦Unemotional.

Fred tries to put block 5 on the floor. Bill abandons block 7 to restack block 5 on block 6.



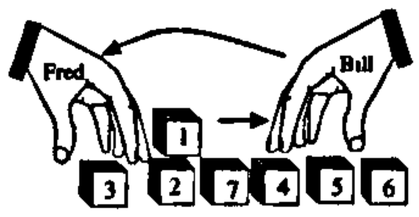
Move Twenty Three



Move Twenty Four

Fred drops block 5 on the floor. Bill has abandoned block 7.

Bill can now restack block 5. Fred maintains a threat to Bill by continuing with his task, i.e. by stacking block 3 on block 4.

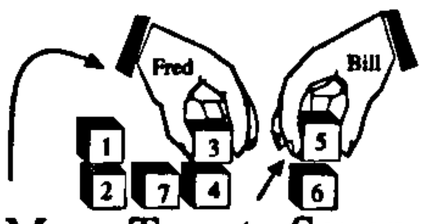


Move Twenty Five

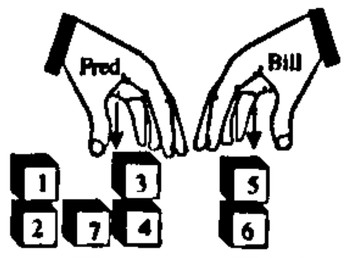
Move Twenty Six

Fred acquires block 3. Bill acquires block 5.

Fred tries to stack block 3 on block 4. Bill tries to restack block 5 on block 6.



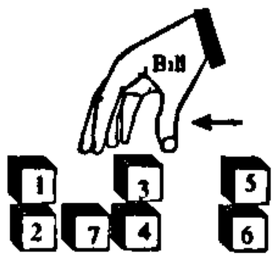
Move Twenty Seven



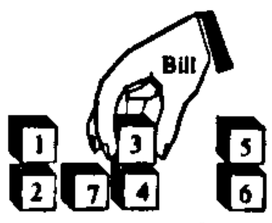
Move Twenty Eight

Fred completes his task. Bill has restacked block 5 on block 6.

Bill must now uncover block 4.



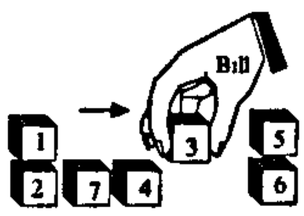
Move Twenty Nine



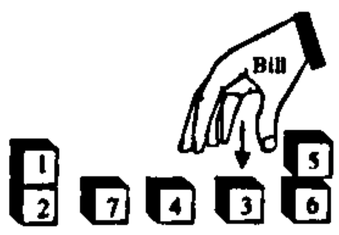
Move Thirty

Bill picks up block 3 to uncover block 4.

Bill moves block 3 to a safe position to discard it.



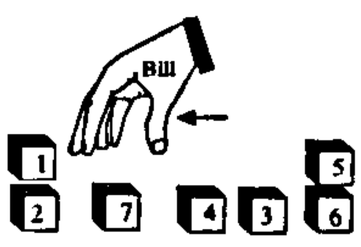
Move Thirty One



Move Thirty Two

Bill discards block 3.

Bill moves to acquire block 7.

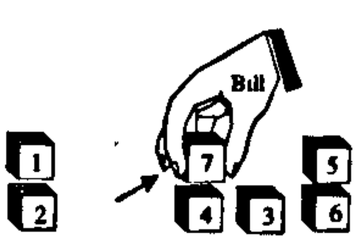


Move Thirty Three

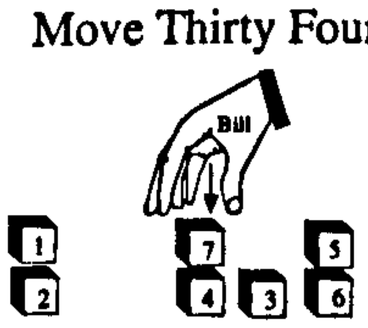
Move Thirty Four

Bill acquires block 7.

Bill tries to stack block 7 on block 4.



Move Thirty Five

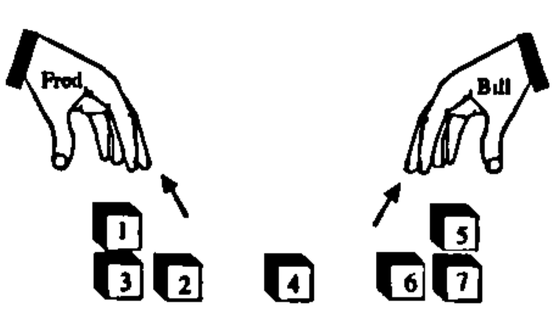


Move Thirty Six

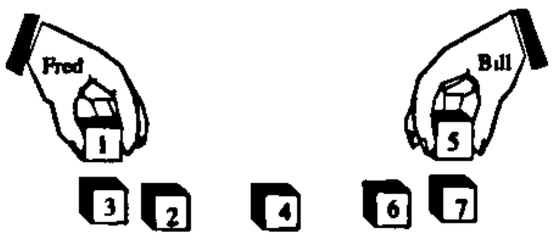
Bill completes his task.

Figure C.8: Part (c): Fred↦Aggressive; Bill↦Unemotional.

Fred cannot help Bill until he discovers which blocks are part of Bill's task, so Fred continues with his own task.



Move One

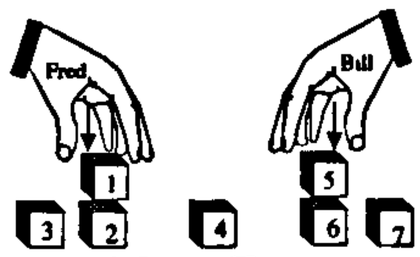


Move Two

Fred acquires block 1 to stack on block 2. Bill acquires block 5 to stack on block 6.

Fred tries to stack block 1 on block 2. Bill tries to stack block 5 on block 6.

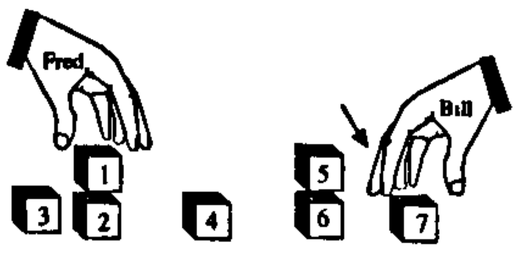
Move Three



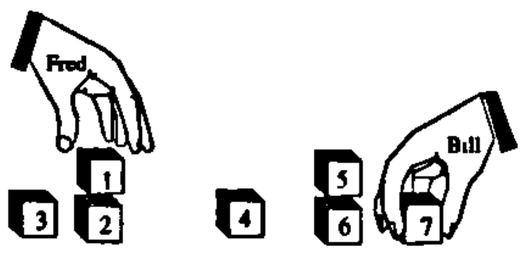
Move Four

Fred stacks block 1 on block 2. Bill stacks block 5 on block 6

Fred now knows block 5 and block 6 are part of Bill's task so he tries to maintain Bill's opportunity by not moving



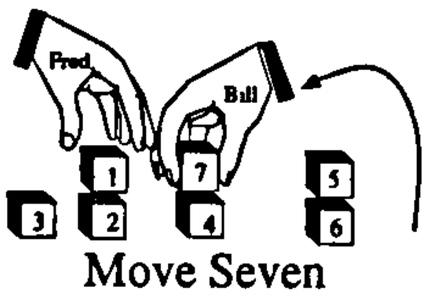
Move Five



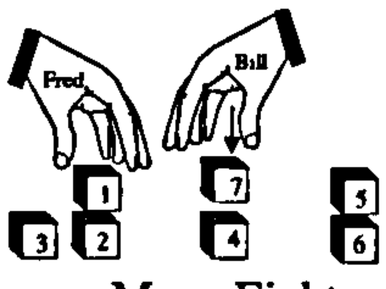
Move Six

Bill continues with his task by acquiring block 7 to stack on block 4.

Fred continues not to interfere with Bill's task.



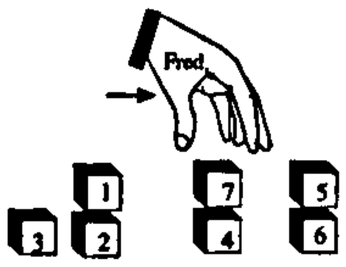
Move Seven



Move Eight

Bill completes his task.

Fred cannot help Bill anymore so he continues with his own task.

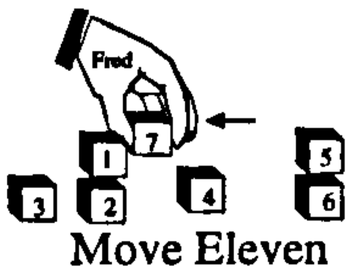


Move Nine

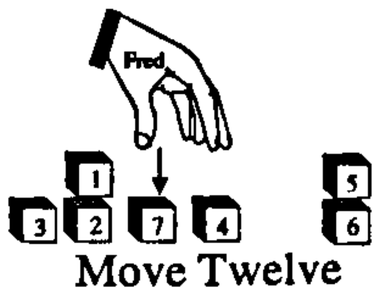
Move Ten

Fred must uncover block 4 so that he can stack block 3 on block 4.

Fred uncovers block 4.



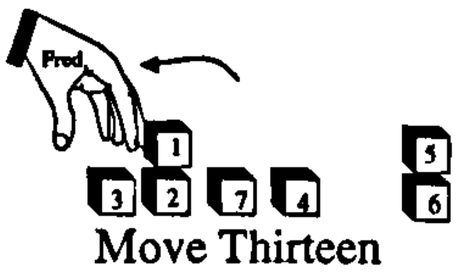
Move Eleven



Move Twelve

Fred discards block 7.

Fred can now stack block 3 on block 4.

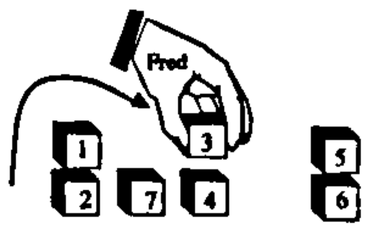


Move Thirteen

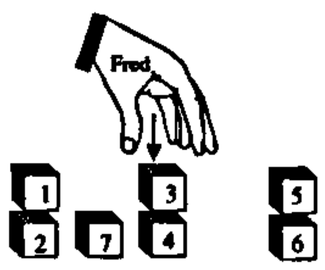
Move Fourteen

Fred acquires block 3.

Fred tries to stack block 3 on block 4.



Move Fifteen

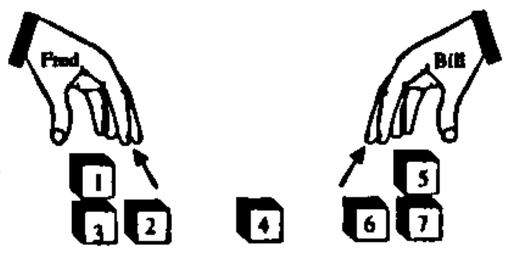


Move Sixteen

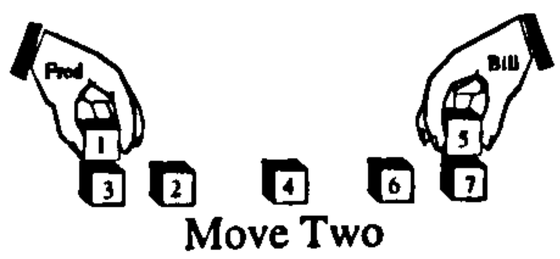
Fred completes his task.

Figure C.9: Fred↦Altruistic; Bill↦Unemotional.

Fred only reacts to threats, so he continues with his task.



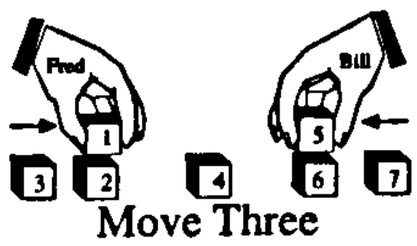
Move One



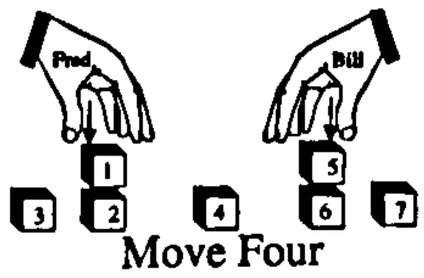
Move Two

Fred wants to stack block 1 on block 2. Bill wants to stack block 5 on block 6.

Fred and Bill both stack their relevant blocks.



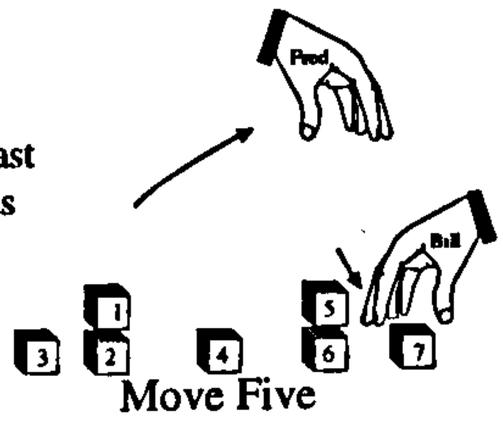
Move Three



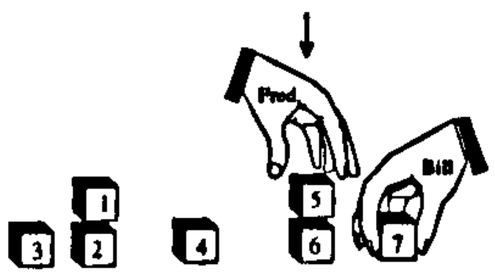
Move Four

Fred now feels threatened since Bill has two blocks stacked together. He decides to disrupt this minor threat by moving above Bill.

Fred moves to where Bill last was but by this time Bill has moved towards his last task block.



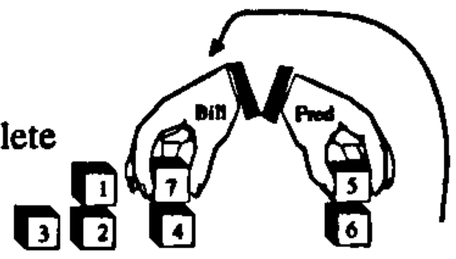
Move Five



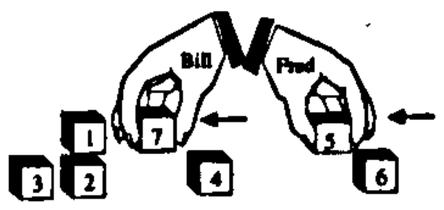
Move Six

Fred tries a different track in disrupting the minor threat. He now wants to pick up Bill's block 5.

Fred picks up Bill's block. Bill was just about to complete his task: now he must abandon block 7 to restack block 5 on block 6.



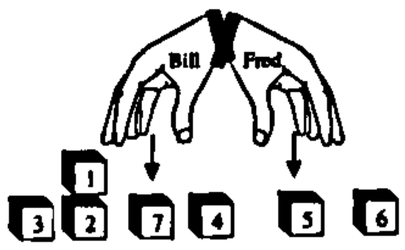
Move Seven



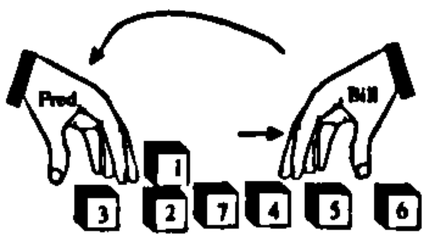
Move Eight

Bill moves to a safe position to abandon block 7.
Fred has stopped the threat to himself.

Fred now drops Block 5 to continue with his task.
Bill abandons block 7.



Move Nine

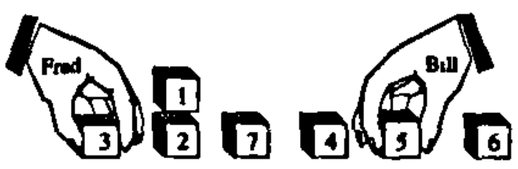


Move Ten

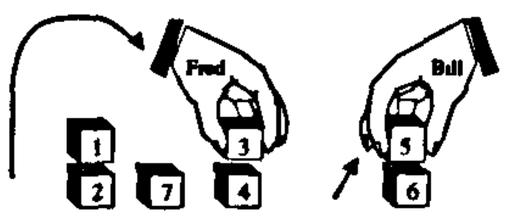
Fred moves to acquire block 3.
Bill can now restack block 5 on block 6.

Figure C.10: Part (a): Fred↦Defensive; Bill↦Unemotional.

Fred continues with his task by acquiring block 3.
Bill tries to acquire block 5.



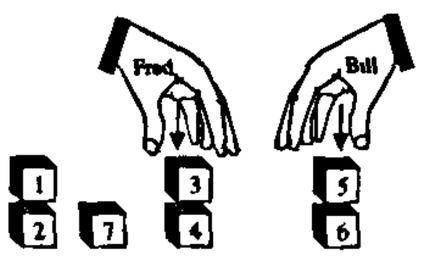
Move Eleven



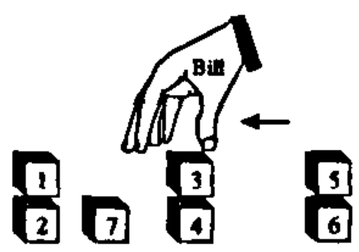
Move Twelve

Fred continues with his task by stacking block 3 on block 4.
Bill tries to stack block 5 on block 6.

Fred completes his task.
Bill stacks block 5 on block 6.



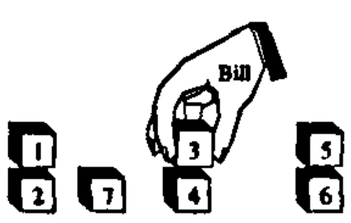
Move Thirteen



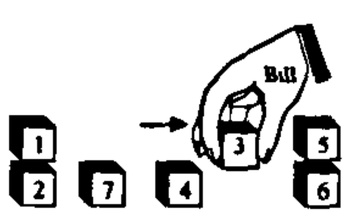
Move Fourteen

Bill must remove block 3 before he can stack block 7 on block 4.

Bill can now remove block 3 from block 4.



Move Fifteen

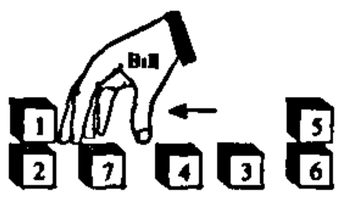


Move Sixteen

Bill moves block 3 out of the way.

Bill has moved block 3 from block 4

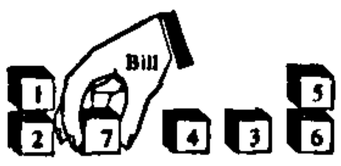
Move Seventeen



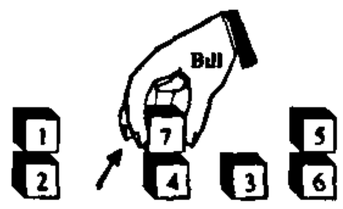
Move Eighteen

Bill can now place block 7 on block 4.

Bill acquires block 7

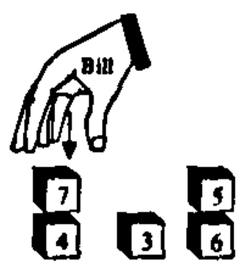


Move Nineteen



Move Twenty

Bill tries to stack block 7 on block 4

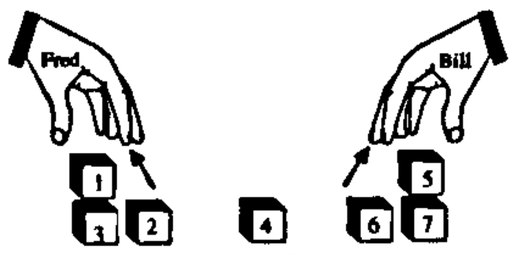


Move Twenty One

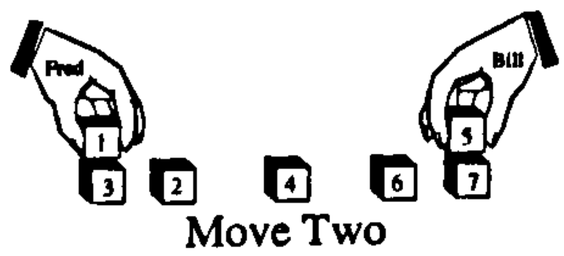
Bill completes his task.

Figure C.11: Part (b): Fred↦Defensive; Bill↦Unemotional.

Fred maintains a minor opportunity by continuing with his task



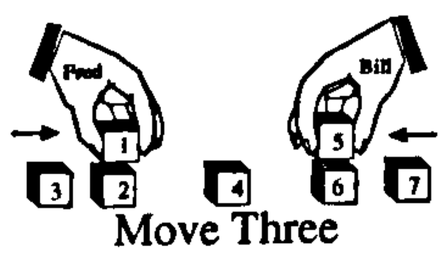
Move One



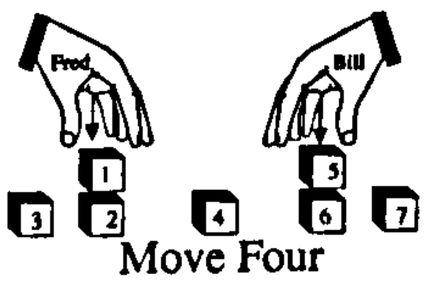
Move Two

Fred wants to stack block 1 on block 2. Bill wants to stack block 5 on block 6.

Fred and Bill both stack their relevant blocks.



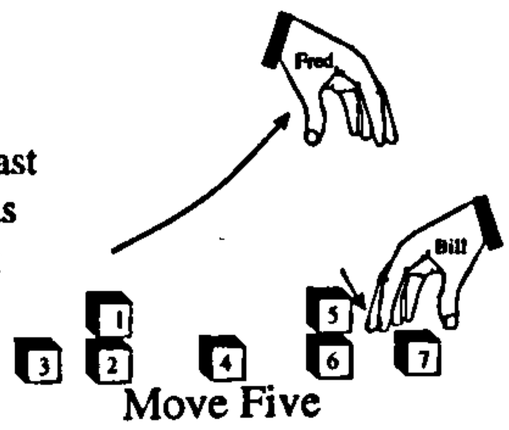
Move Three



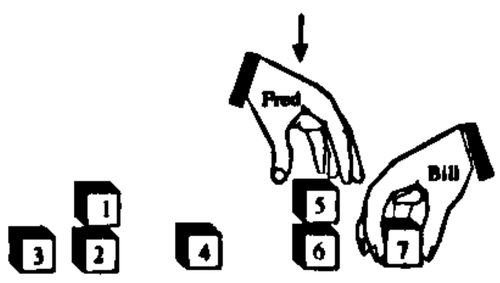
Move Four

Fred now feels threatened since Bill has two blocks stacked together. He decides to disrupt this minor threat by moving above Bill.

Fred moves to where Bill last was but by this time Bill has moved towards his last task block.



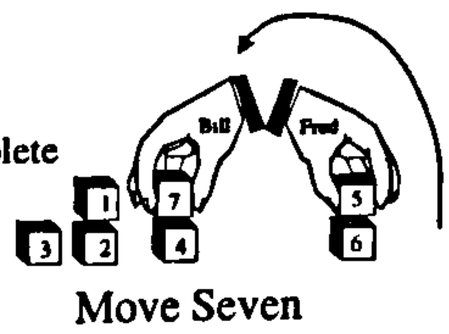
Move Five



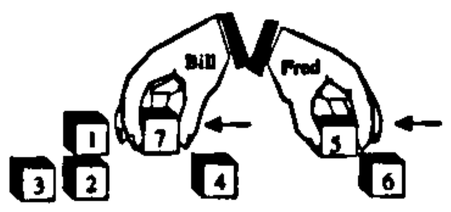
Move Six

Fred tries a different track in disrupting the minor threat. He now wants to pick up Bill's block 5.

Fred picks up Bill's block. Bill was just about to complete his task: now he must abandon block 7 to restack block 5 on block 6.



Move Seven



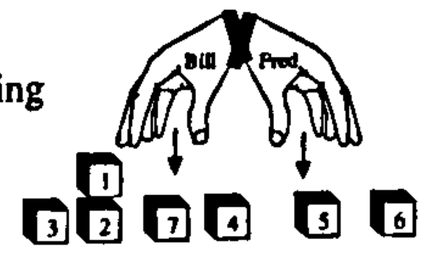
Move Eight

Bill moves to a safe position to abandon block 7.

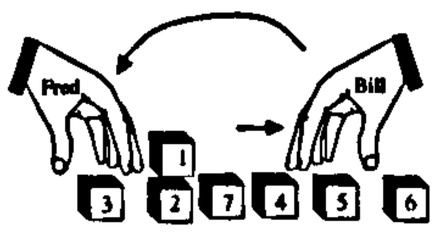
Fred has stopped the threat to himself.

Fred decides to maintain his opportunity by continuing with his task: he no longer needs block 5.

Bill abandons block 7.



Move Nine



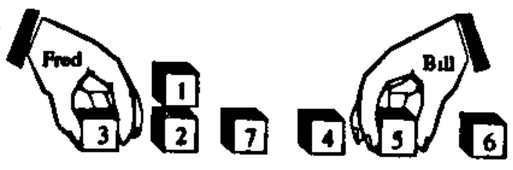
Move Ten

Fred moves to acquire block 3.

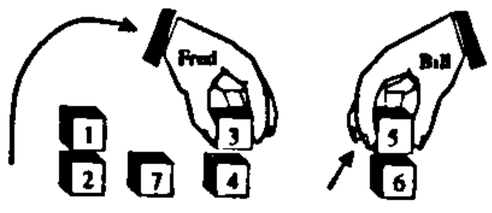
Bill can now restack block 5 on block 6.

Figure C.12: Part (a): Fred↦Normal; Bill↦Unemotional.

Fred continues with his task by acquiring block 3.
Bill tries to acquire block 5.



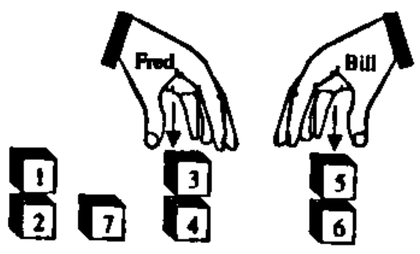
Move Eleven



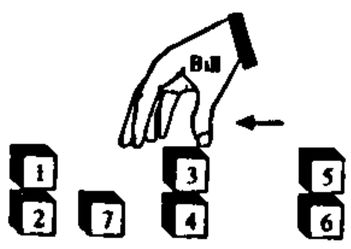
Move Twelve

Fred continues with his task by stacking block 3 on block 4.
Bill tries to stack block 5 on block 6.

Fred completes his task.
Bill stacks block 5 on block 6.



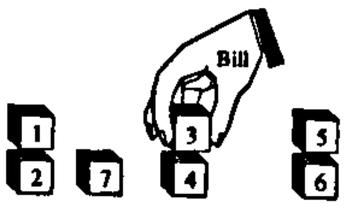
Move Thirteen



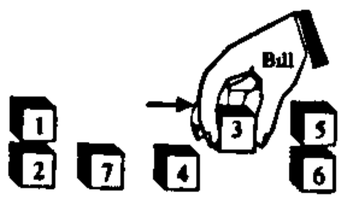
Move Fourteen

Bill must remove block 3 before he can stack block 7on block 4.

Bill can now remove block 3 from block 4.



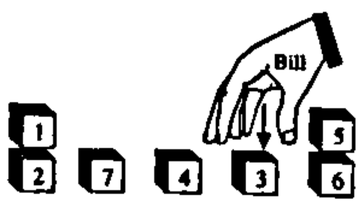
Move Fifteen



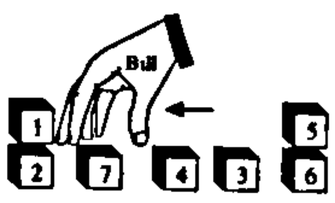
Move Sixteen

Bill moves block 3 out of the way.

Bill has moved block 3 from block 4



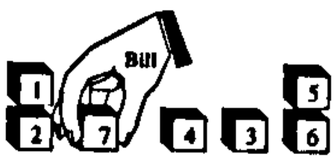
Move Seventeen



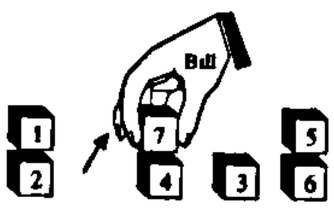
Move Eighteen

Bill can now place block 7 on block 4.

Bill acquires block 7



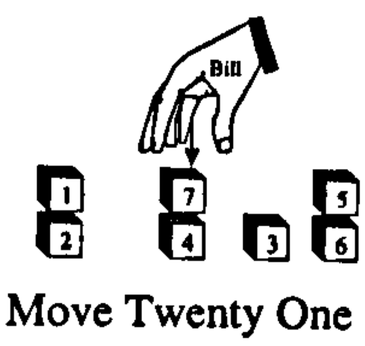
Move Nineteen



Move Twenty

Bill tries to stack block 7 on block 4

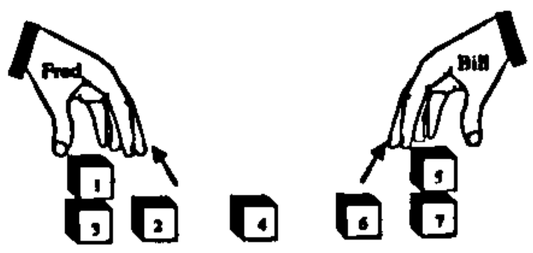
Bill completes his task.



Move Twenty One

Figure C.13: Part (b): Fred↦Normal; Bill↦Unemotional.

Fred actively seeks personal opportunities: he can use block 1 in his task so moves to acquire it. Bill continues with his task by acquiring block 5.

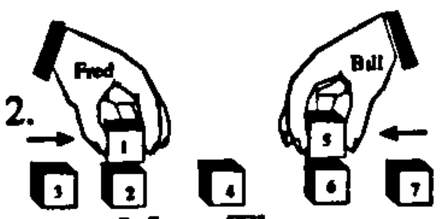


Move One

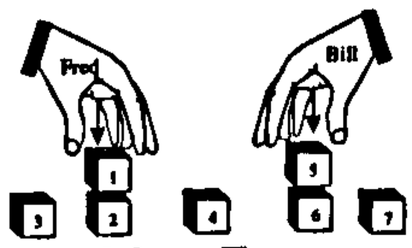
Move Two

Fred acquires block 1.
Bill acquires block 5.

Fred continues with his task by stacking block 1 on block 2.
Bill tries to stack block 5 on block 6.



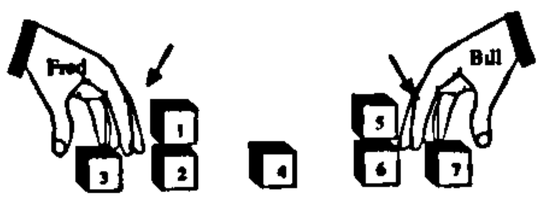
MoveThree



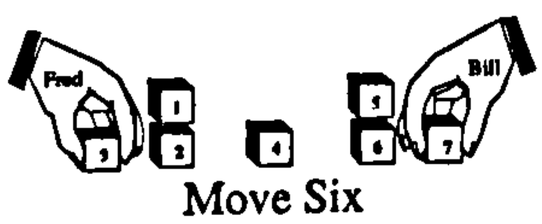
Move Four

Fred stacks block 1 on block 2.
Bill stacks block 5 on block 6.

Fred continues with his task by acquiring block 3.
Bill tries to acquire block 7.



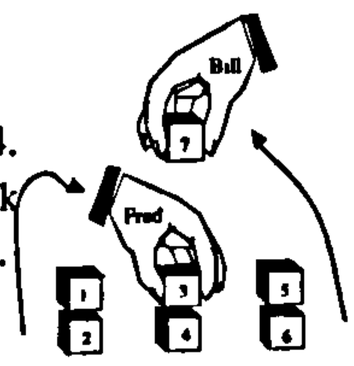
Move Five



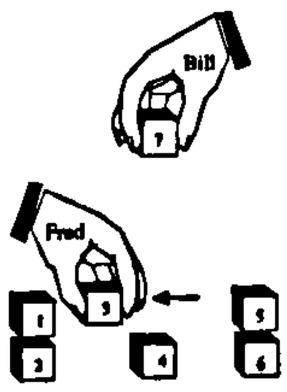
Move Six

Fred acquires block 3.
Bill acquires block 7.

Fred continues with his task by stacking block 3 on block 4.
Bill also tries to stack his block on block 4 but is unsuccessful.
******conflict******



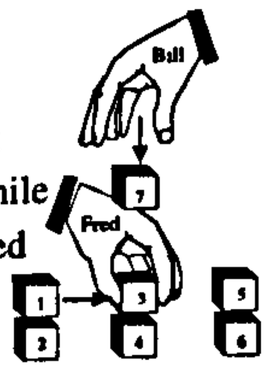
Move Seven



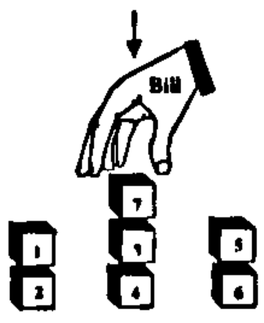
Move Eight

Fred is confronted with a mortal threat so he makes an emergency move.
Bill has just realised he can now stack block 7 on block 4 which he will attempt on the next move.

Fred thinks the mortal threat has past and now seeks to stack his block 3 on block 4. Meanwhile Bill releases his block as planned which crushes Fred.
****Fred dies****



Move Nine

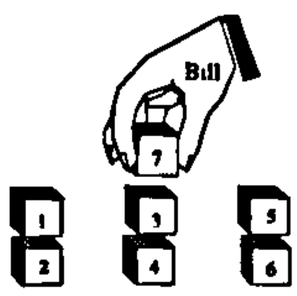


Move Ten

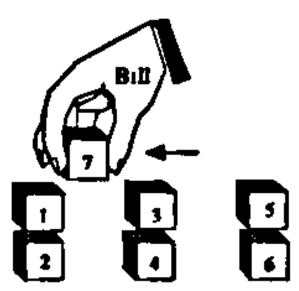
Bill must now remove block 3 from between his block 7 and block 4 to complete his task. He therefore moves to uncover block 3.

Figure C.14: Part (a): Fred↦Selfish; Bill↦Unemotional.

Bill acquires block 7.



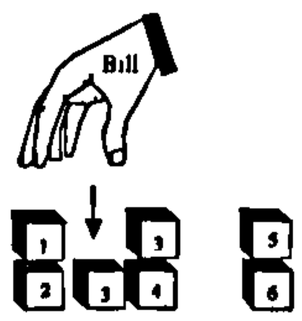
Move Eleven



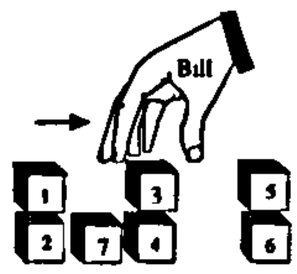
Move Twelve

Bill moves to a safe position so that he can discard block 7.

Bill discards block 7 in a safe position.



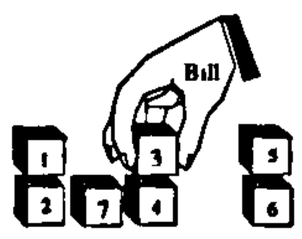
Move Thirteen



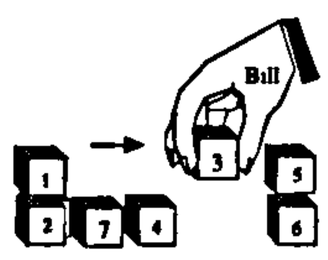
Move Fourteen

Bill now tries to move block 3 from block 4.

Bill acquires block 3.



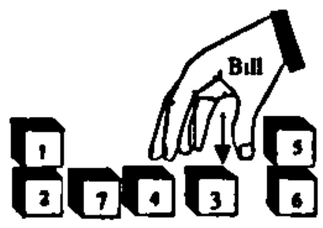
Move Fifteen



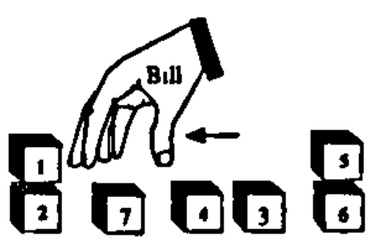
Move Sixteen

Bill moves block 3 out of the way.

Bill has moved block 3 from block 4



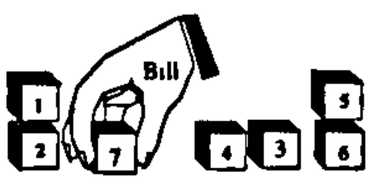
Move Seventeen



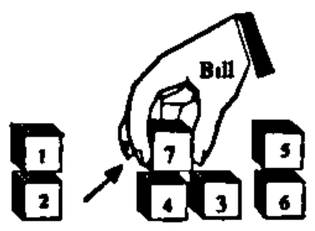
Move Eighteen

Bill can now place block 7 on block 4.

Bill acquires block 7



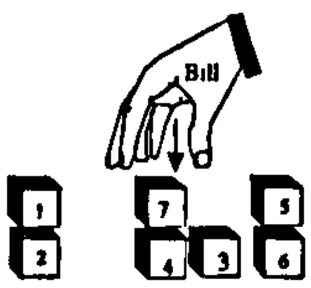
Move Nineteen



Move Twenty

Bill tries to stack block 7 on block 4

Bill completes his task.



Move Twenty One.

Figure C.15: Part (b): Fred↦Selfish; Bill↦Unemotional.

Appendix D

Conflict Scenario Three

D.1 Introduction

This appendix shows the moves various Emoters make in scenario three (see figure D.1) until the Emoter completes his prescribed task, is crushed by a block, or reaches a state of deadlock. Two versions of emotionality are represented. Figures D.2 → D.3 represent moves that Emoters would make utilising physiology alone. Figures D.4 → D.9 represent moves that Emoters would make utilising both physiology and the behaviour derived from multiple goals, i.e. 'full' emotional behaviour.

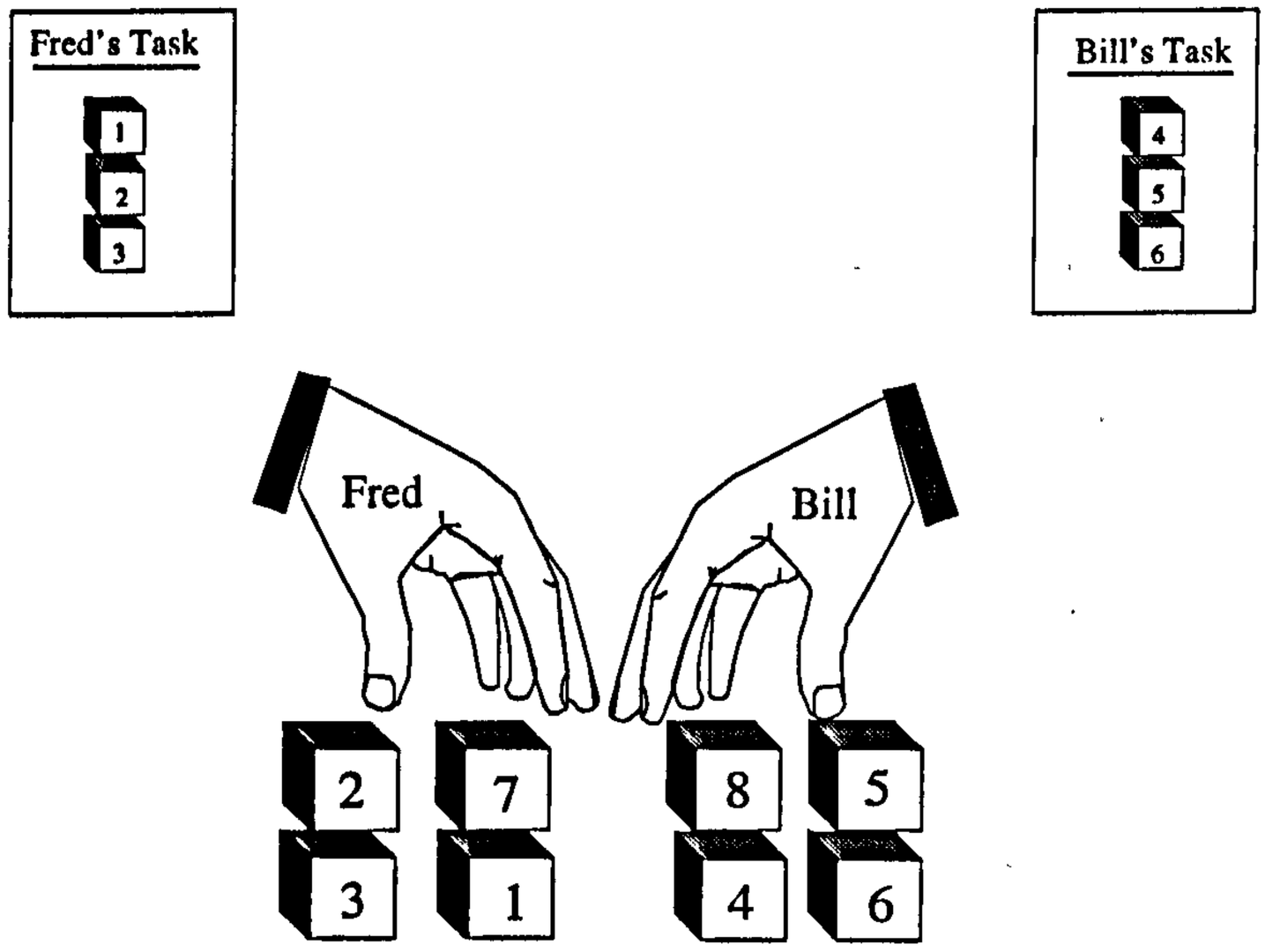


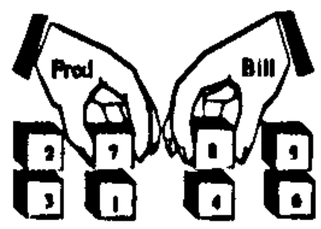
Figure D.1: Conflict Scenario Three.

D.2 The Sole Influence of Physiology on the Conflict

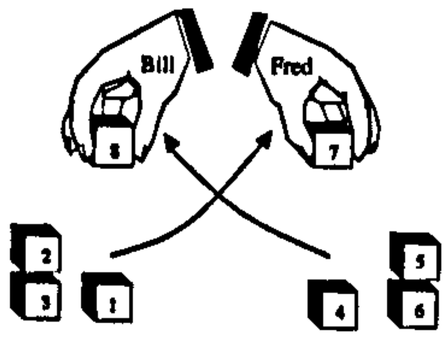
The following figures D.2 → D.3 represent the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and only one goal of completing his prescribed task, would perform in conflict scenario three (see figure D.1). With each of the personalities, the Emoter follows a very similar course of action up until the actual conflict.

In scenario three (ref. D.1), the Aggressive Emoter, Defensive Emoter, Normal Emoter and Selfish Emoter follow the course of action shown in figure D.2 whereas the Altruistic Emoter follows figure D.3 because dropping a block on the unemotional agent Bill would negate the high level goal of helping it. This is an integral aspect of the *continue with task* developed goal

Fred continues with his task by removing block 7 from block 1.
Bill attempts to remove block 8 from block 4.



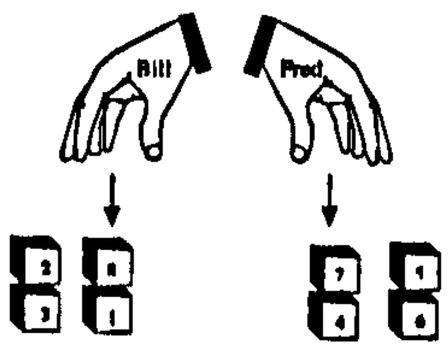
Move One



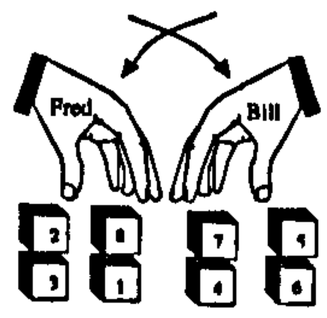
Move Two

Fred has moved block 7 from block 1.
Bill has moved block 8 from block 4.

Fred releases the block to continue with his task.
Bill also releases the redundant block to continue with his task.



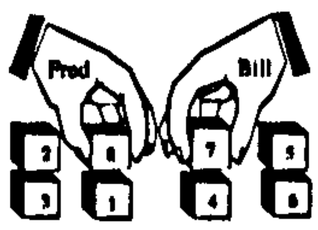
Move Three



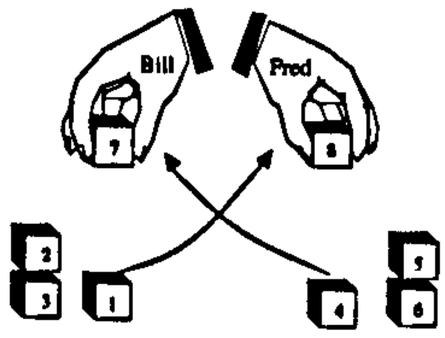
Move Four

Fred now has to remove the block Bill has dropped and vice-versa.
*****conflict*****

Fred again triesto remove the block covering block 1.
Bill again tries to remove the block covering block 4.



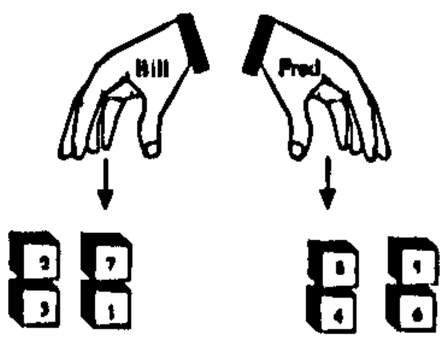
Move Five



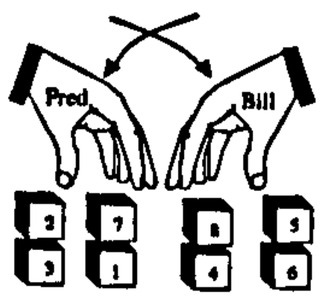
Move Six

Having removed the redundant blocks both Fres and Bill move into a position to drop the blocks.

Both Fred and Bill drop the blocks.



Move Seven

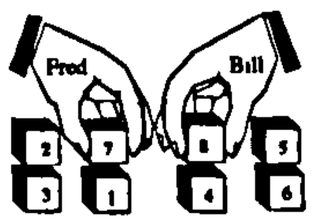


Move Eight

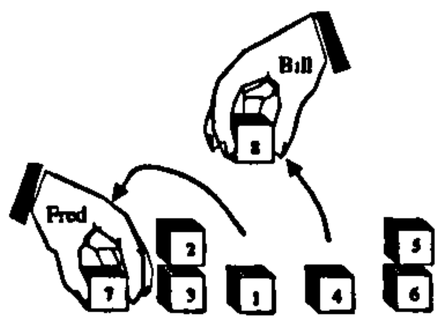
Yet again Fred has to remove the block that Bill dropped and vice-versa.
*****conflict*****

Figure D.2: Fred↦Aggressive, Defensive, Normal or Selfish; Bill↦Unemotional.

Fred continues with his task by removing block 7 from block 1.
Bill attempts to remove block 8 from block 4.



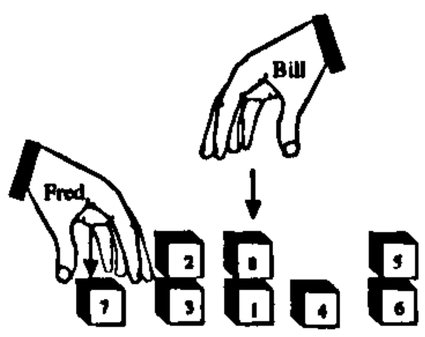
Move One



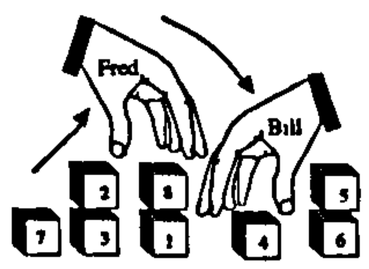
Move Two

Fred has moved block 7 from block 1.
N.B. Fred must avoid moving above Bill.
Bill has moved block 8 from block 4.

Fred releases the block to continue with his task.
Bill also releases the redundant block to continue with his task.



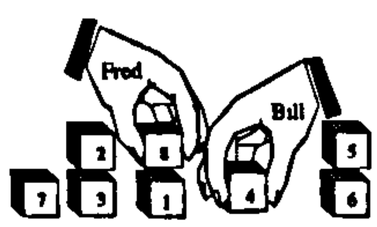
Move Three



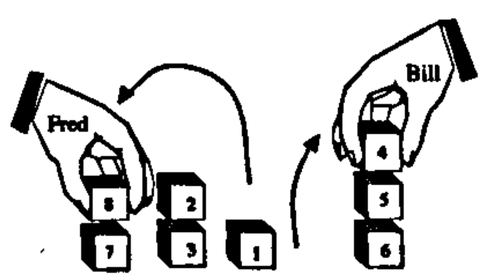
Move Four

Fred again tries to remove the block covering block 1.
Bill continues with his task by stacking block 4 on block 5.

Fred again tries to remove the block covering block 1.
Bill acquires block 4.



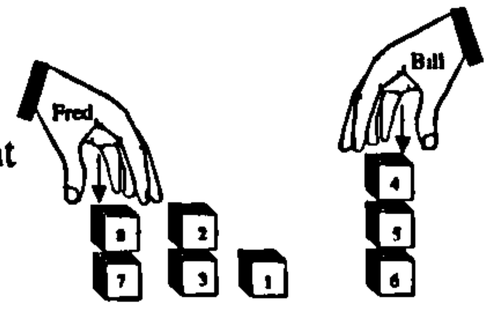
Move Five



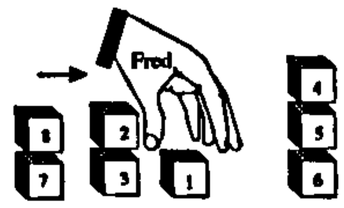
Move Six

Having removed the redundant block Fred moves into a position to drop it.
Bill contines stacking block 4 on block 5.

Fred releases the redundant block.
Bill completes his task.



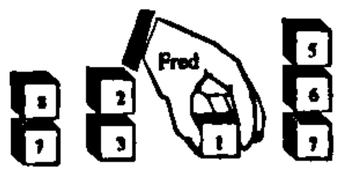
Move Seven



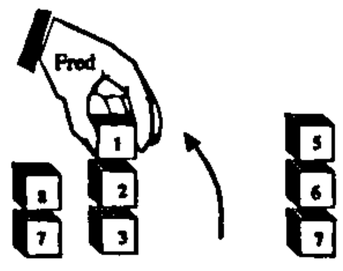
Move Eight

Fred can now continue with his task by acquiring block 1.

Fred acquires block 1.



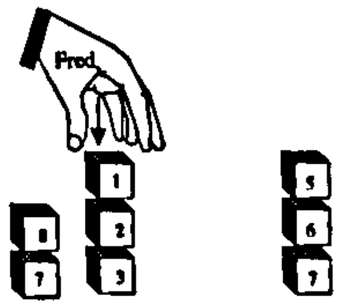
Move Nine



Move Ten

Fred tries to stack block 1 on block 2.

Fred completes his task.



Move Eleven

Figure D.3: Fred↦Altruistic; Bill↦Unemotional.

D.3 'Full' Emotional Behaviour

The following figures D.4 → D.9 represent the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and behaviour deriving from multiple goals and physiology, would perform in conflict scenario three (see figure D.1).

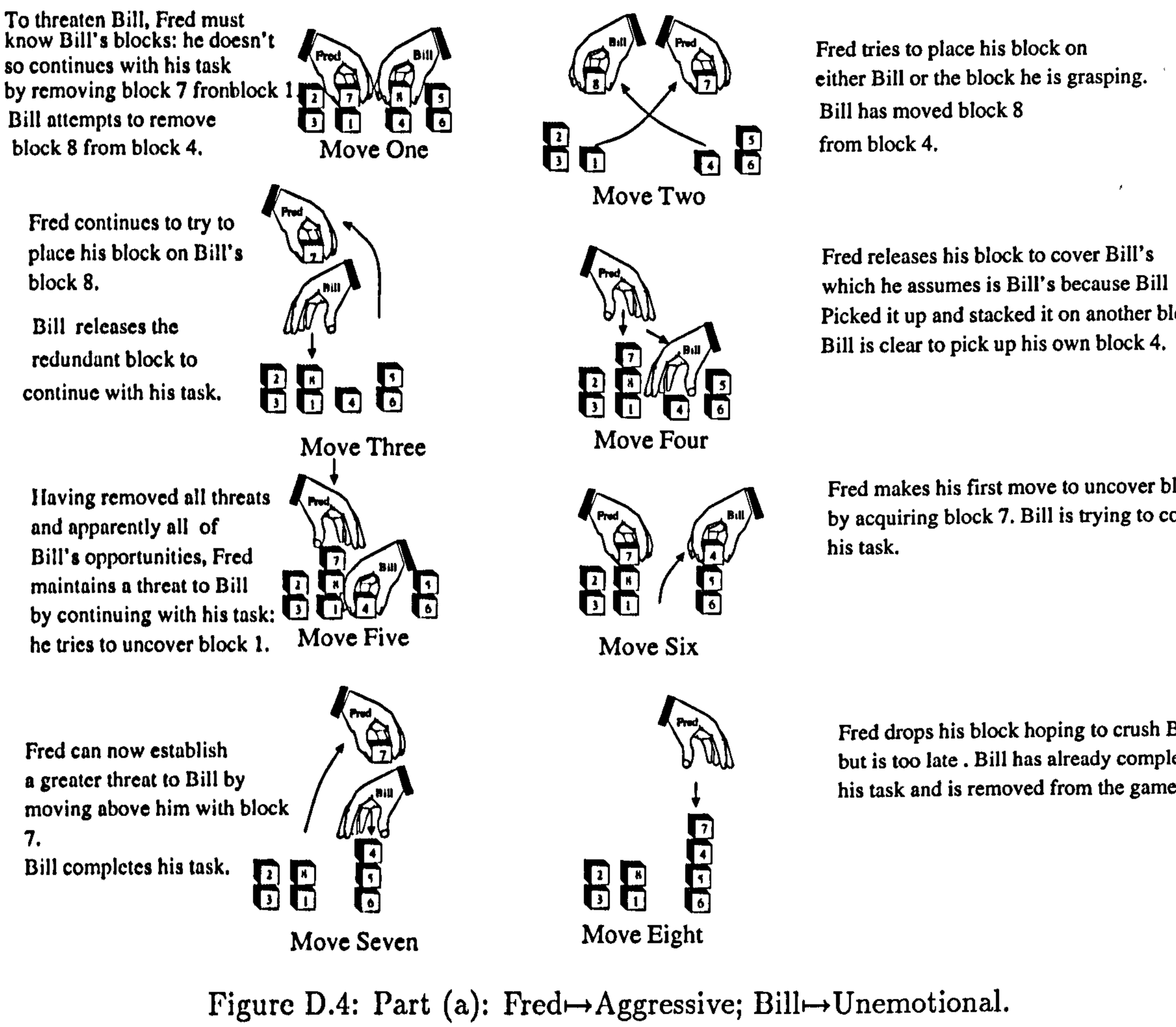
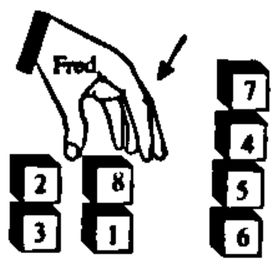
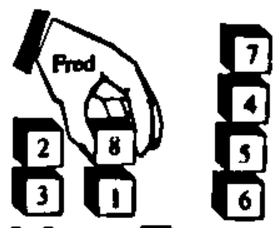


Figure D.4: Part (a): Fred↦Aggressive; Bill↦Unemotional.

Fred cannot threaten Bill anymore so he reverts to an instrumental action of continuing with his task: he uncovers block 1.



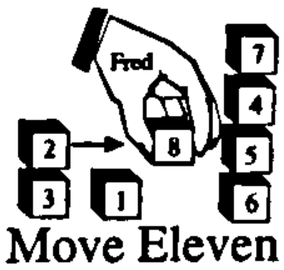
Move Nine



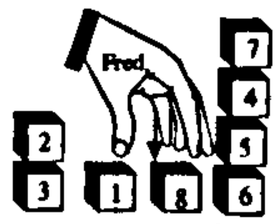
Move Ten

Fred acquires block 8, so that he can uncover block 1.

Fred uncovers block 1.



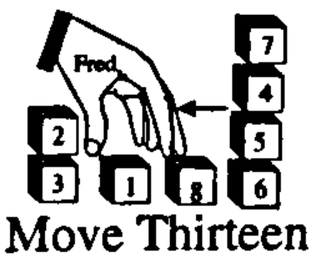
Move Eleven



Move Twelve

Fred discards the redundant block 8.

Fred can now acquire block 1 to stack on block 2.

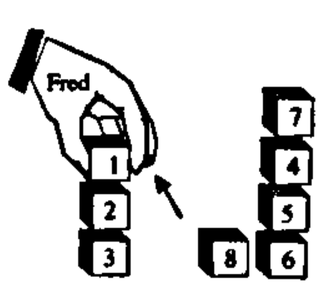


Move Thirteen

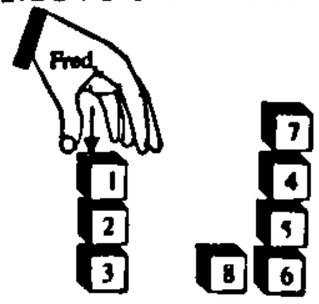
Move Fourteen

Fred acquires block 1.

Fred tries to stack block 1 on block 2.



Move Fifteen

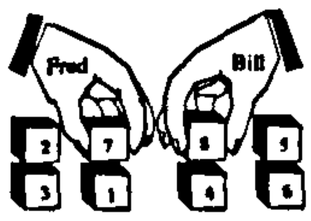


Move Sixteen

Fred completes his task.

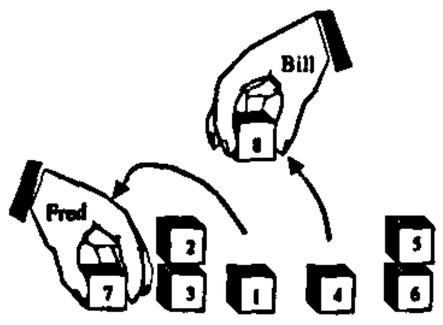
Figure D.5: Part (b): Fred↦Aggressive; Bill↦Unemotional.

Fred cannot help Bill until he knows which are Bill's blocks. Therefore he continues with his task by removing block 7 fromblock 1.



Move One

Bill attempts to remove block 8 from block 4.

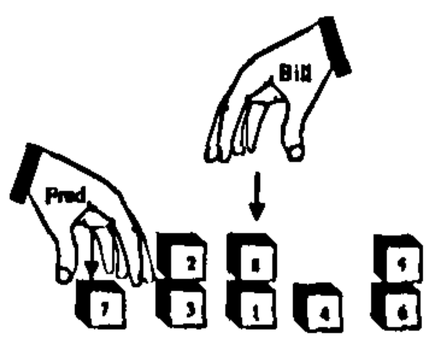


Move Two

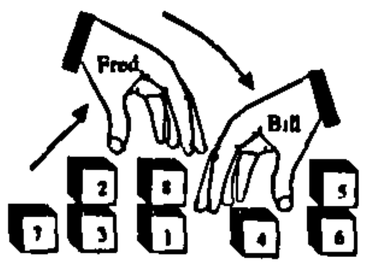
Fred has moved block 7 from block 1.
N.B. Fred must avoid moving above Bill.

Bill has moved block 8 from block 4.

Fred releases the block to continue with his task. Bill also releases the redundant block to continue with his task.



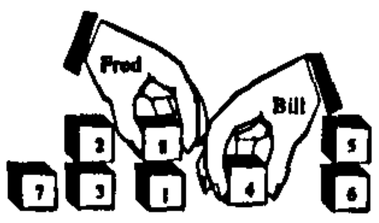
Move Three



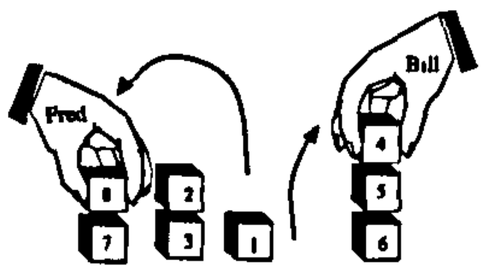
Move Four

Fred again tries to remove the block covering block 1. Bill continues with his task by stacking block 4 on block 5.

Fred again tries to remove the block covering block 1. Bill acquires block 4.



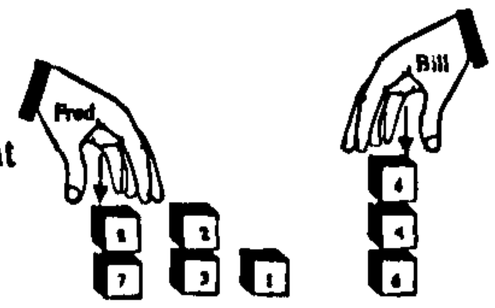
Move Five



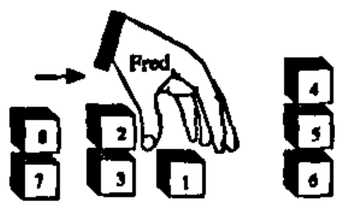
Move Six

Having removed the redundant block Fred moves into a position to drop it. Bill contines stacking block 4 on block 5.

Fred releases the redundant block.
Bill completes his task.



Move Seven

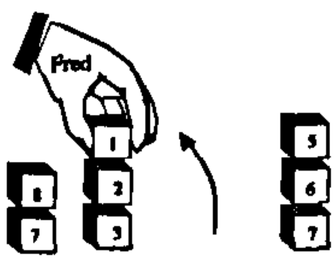


Move Eight

Fred can now continue with his task by acquiring block 1.

Fred acquires block 1.

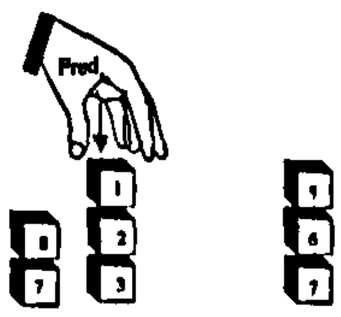
Move Nine



Move Ten

Fred tries to stack block 1 on block 2.

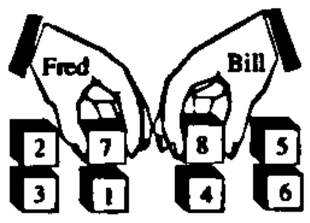
Fred completes his task.



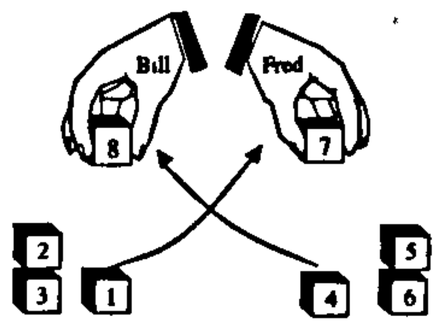
Move Eleven

Figure D.6: Fred↦Altruistic; Bill↦Unemotional.

Fred only reacts to personal threats . Since Fred is not threatened he continues with his task by removing block 7 from block 1. Bill tries to move block 8 from block 4.



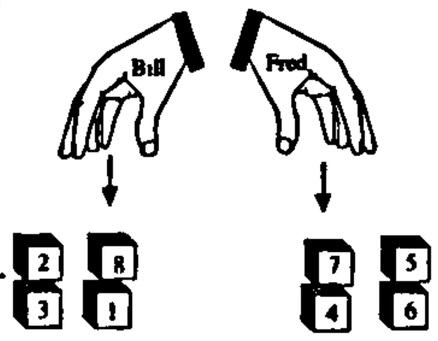
Move One



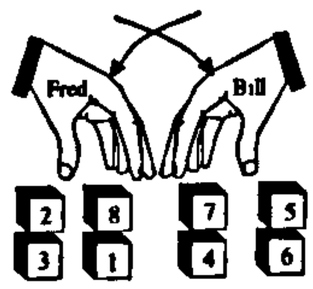
Move Two

Fred has moved block 7 from block 1.
Bill has moved block 8 from block 4.

Fred now recieves a threat since his block 1 is covered.



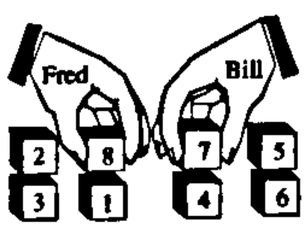
Move Three



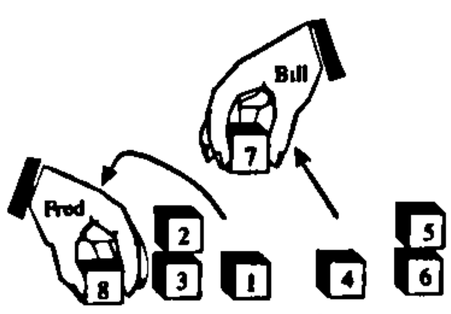
Move Four

Fred disrupts this threat by picking up block 8. Bill must remove the block Fred Has dropped.

Fred acquires block 8.
Bill acquires block 7.



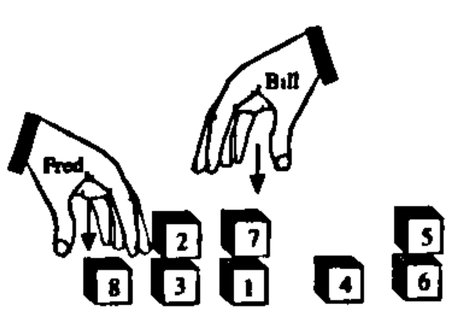
Move Five



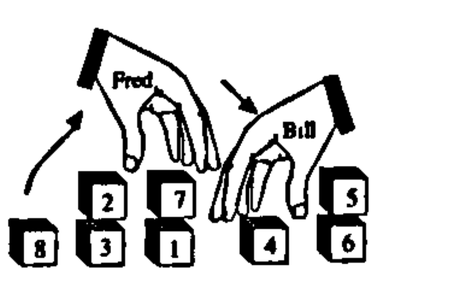
Move Six

Fred decides to place the offending block on the floor. Bill removes the redundant block 7 from block 4.

Fred drops block 8 on the floor.
Bill discards block 7.



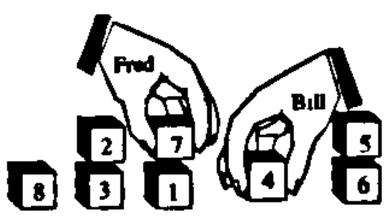
Move Seven



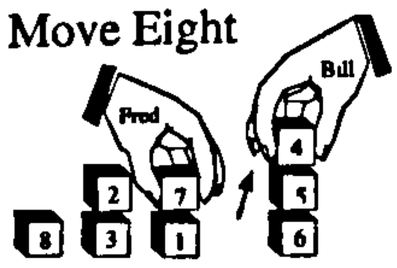
Move Eight

Yet again Fred recieves a threat since his block 1 is covered.
Bill can now acquire block 4.

Fred disrupts this threat by picking up block 7.
Bill acquires block 4.



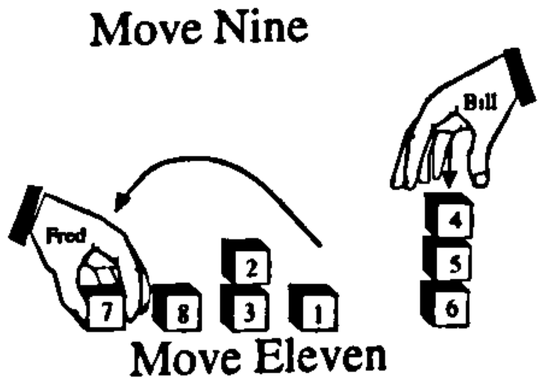
Move Nine



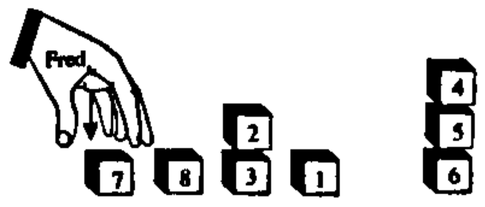
Move Ten

Fred has disrupted the threat but must now recuperate.
Bill tries to stack block 4 on block 5.

Fred decides to place block 7 on the floor.
Bill completes his task.



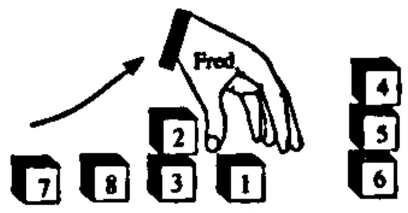
Move Eleven



Move Twelve

Fred drops block 7 on the floor.

Fred continues with the instrumental action of trying to complete his task.

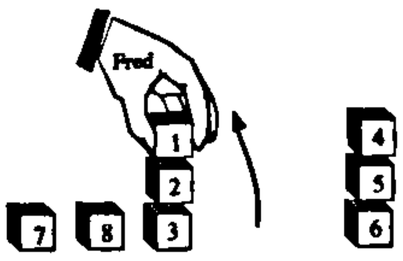


Move Thirteen

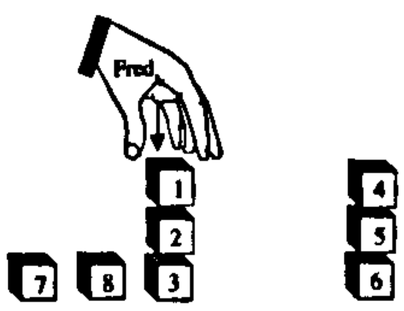
Move Fourteen

Fred acquires block 1 to place on block 2.

Fred tries to stack block 1 on block 2.



Move Fifteen

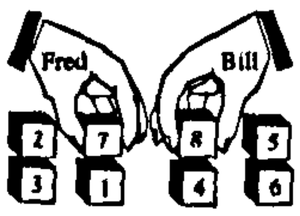


Move Sixteen

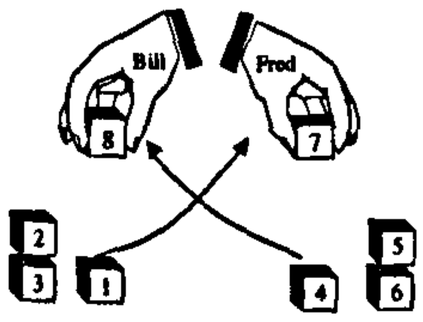
Fred completes his task.

Figure D.7: Fred↦Defensive; Bill↦Unemotional.

Fred establishes an opportunity for himself by continuing with his task by removing block 7 from block 1. Bill tries to move block 8 from block 4.



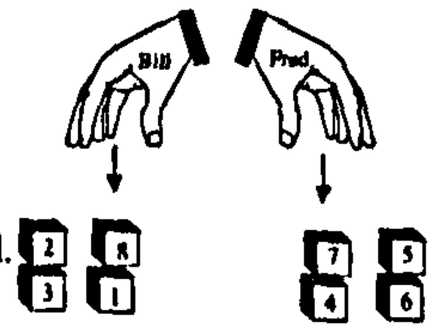
Move One



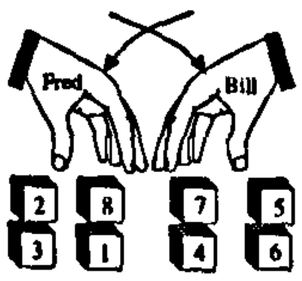
Move Two

Fred has moved block 7 from block 1.
Bill has moved block 8 from block 4.

Fred now recieves a threat since his block 1 is covered.



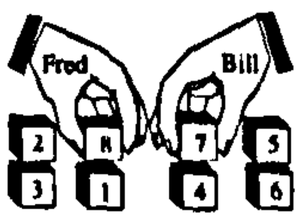
Move Three



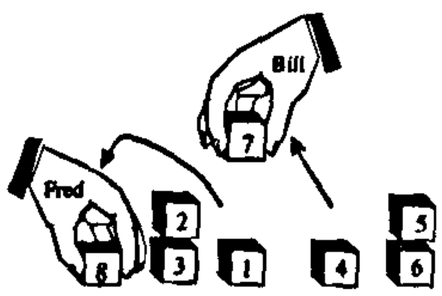
Move Four

Fred disrupts this threat by picking up block 8. Bill must remove the block Fred has dropped.

Fred acquires block 8.
Bill acquires block 7.



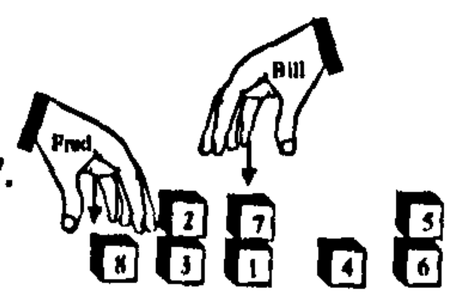
Move Five



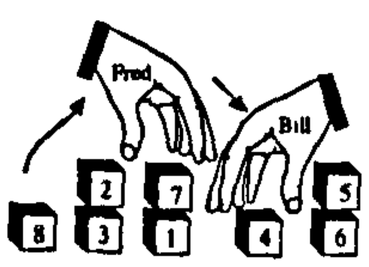
Move Six

Fred decides to place the offending block on the floor. Bill removes the redundant block 7 from block 4.

Fred drops block 8 on the floor.
Bill discards block 7.



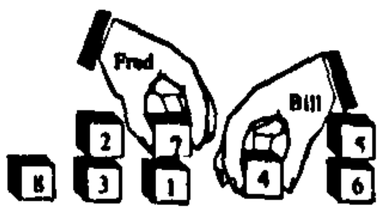
Move Seven



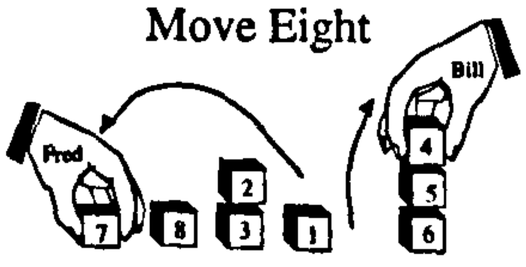
Move Eight

Yet again Fred recieves a threat since his block 1 is covered.
Bill can now acquire block 4.

Fred disrupts this threat by picking up block 7.
Bill acquires block 4.



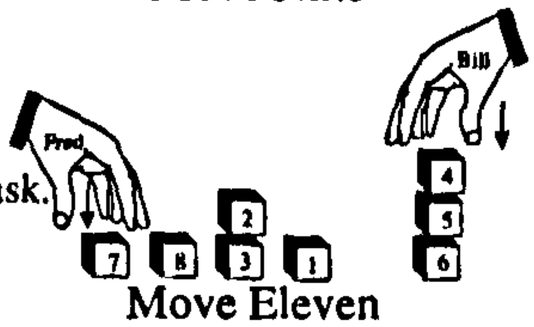
Move Nine



Move Ten

Fred decides to place the offending block on the floor.
Bill tries to stack block 4 on block 5.

Fred drops block 7 on the floor.
Bill complctes his task.



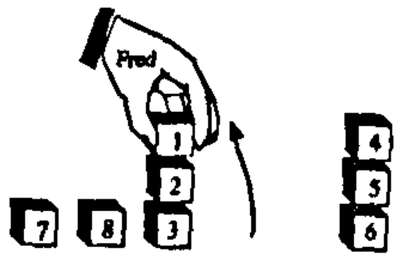
Move Eleven

Move Twelve

Fred maintains his opportunity by continuing with his task: he tries to stack block 1 on block 2.

Fred acquires block 1.

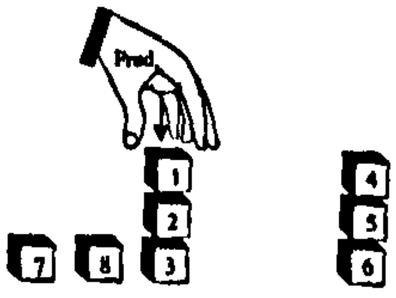
Move Thirteen



Move Fourteen

Fred tries to stack block 1 on block 2.

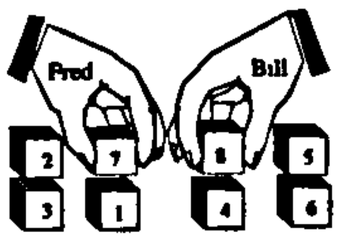
Fred completes his task.



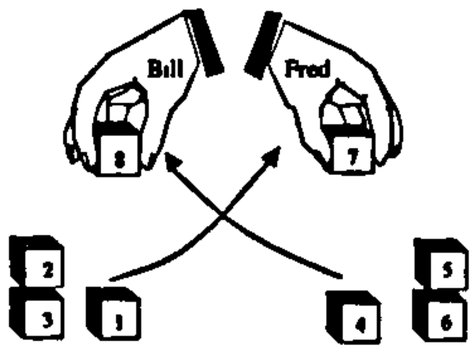
Move Fifteen

Figure D.8: Fred↦Normal; Bill↦Unemotional.

Fred actively seeks personal opportunities: he does this by continuing with his task i.e. removing block 7 from block 1.
Bill attempts to remove block 8 from block 4.



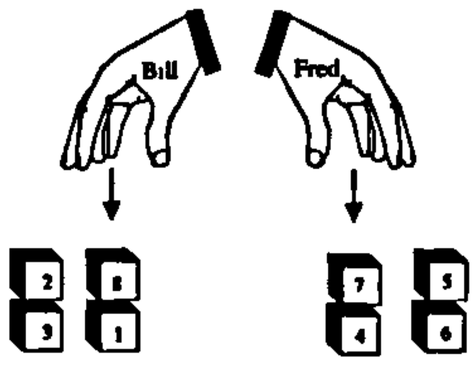
Move One



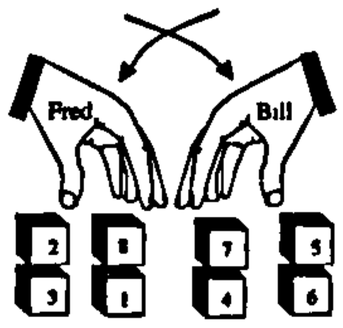
Move Two

Fred has moved block 7 from block 1.
Bill has moved block 8 from block 4.

Fred releases the block to continue with his task.
Bill also releases the redundant block to continue with his task.



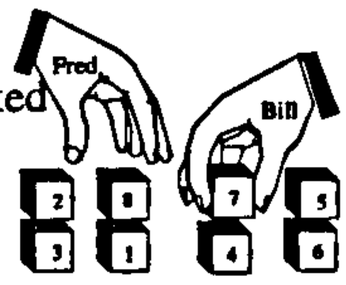
Move Three



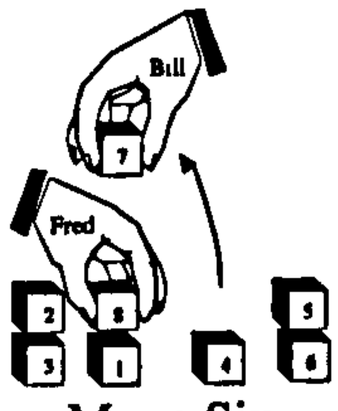
Move Four

Fred now has to remove the block Bill has dropped and vice-versa.
*****conflict*****

Fred's move to uncover block 1 is continuously blocked
He has no other option but to recuperate his energy.



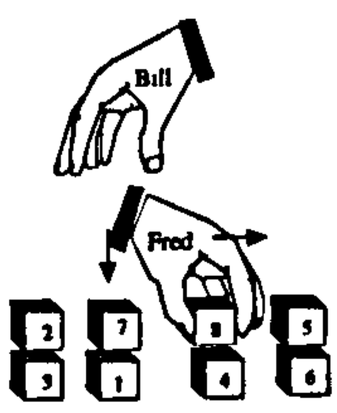
Move Five



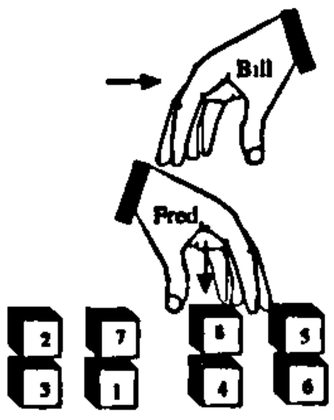
Move Six

Fred can now remove block 8.
Bill moves into a position to dropthe redundant block 7.

Fred makes an emergency move in response to the mortal threat. Bill drops the redundant block.



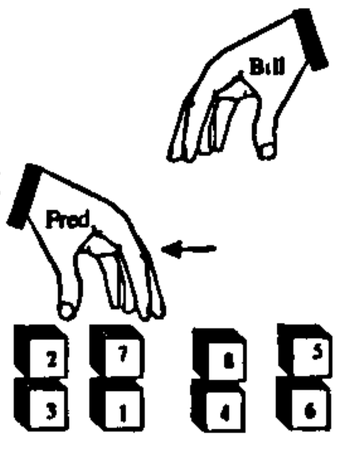
Move Seven



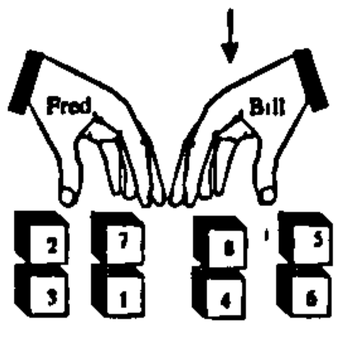
Move Eight

Fred releases the now redundant block 8 continue with his task.

Fred makes another emergency move thinking there is a mortal threat.
Bill has only just realised he can uncover block 4.



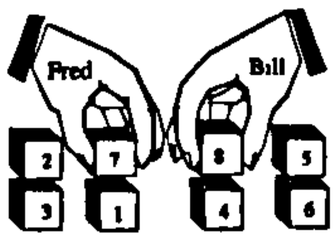
Move Nine



Move Ten

Fred recuperates his energy.
Bill tries to acquire block 8.

The conflict has reached a state of deadlock.
Moves 1 to 11 will be continuously repeated.



Move Eleven

Figure D.9: Fred↦Selfish; Bill↦Unemotional.

Appendix E

Conflict Scenario Four

E.1 Introduction

This appendix shows the moves various Emoters make in scenario four (see figure E.1) until the Emoter completes his prescribed task, is crushed by a block, or reaches a state of deadlock. Two versions of emotionality are represented. Figure E.2 represents moves that Emoters would make utilising physiology alone. Figures E.3 → E.7 represent moves that Emoters would make utilising both physiology and the behaviour derived from multiple goals, i.e. 'full' emotional behaviour.

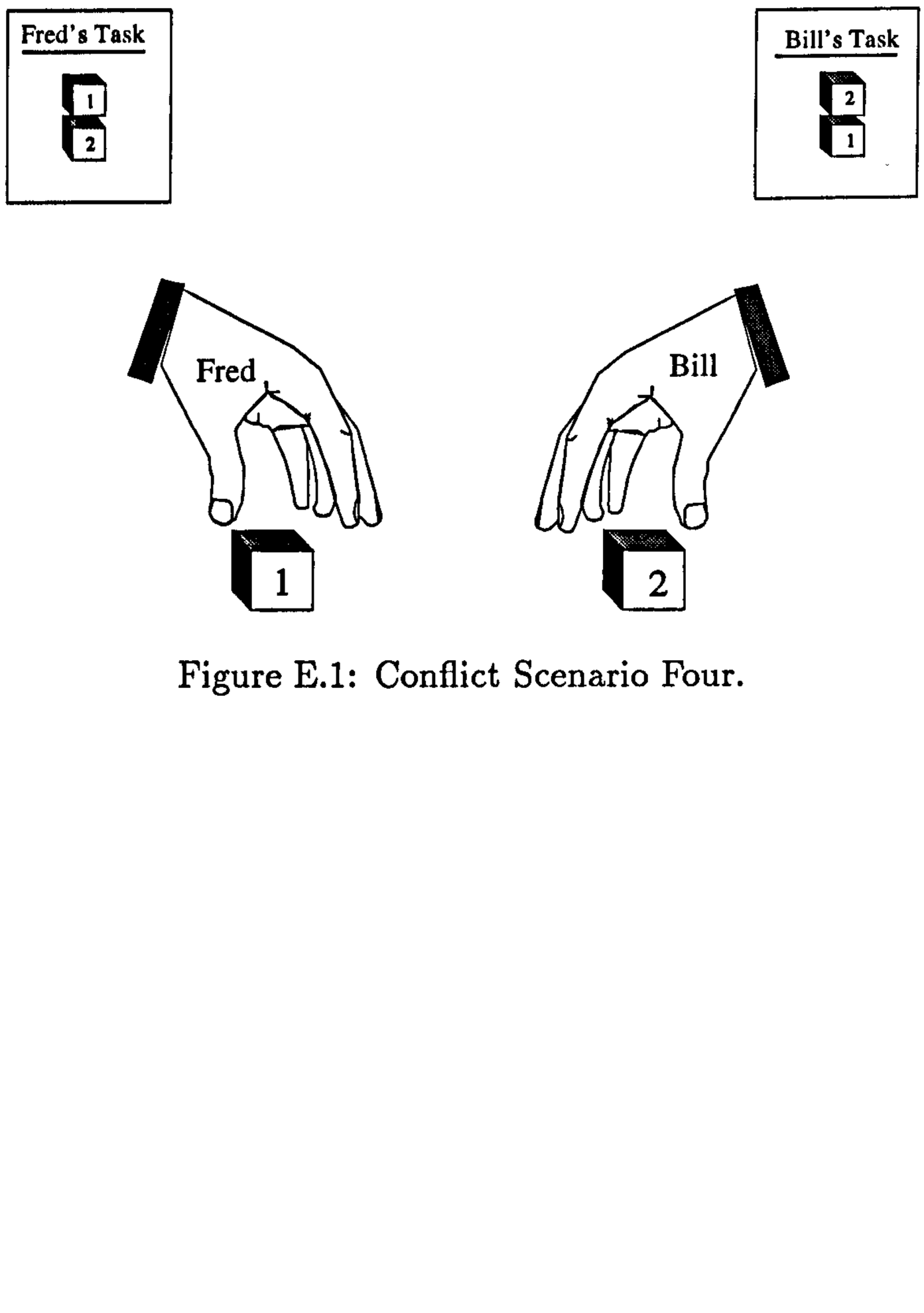


Figure E.1: Conflict Scenario Four.

E.2 The Sole Influence of Physiology on the Conflict

The following figure E.2 represents the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and only one goal of completing his prescribed task, would perform in conflict scenario four (see figure E.1). With each of the personalities, the Emoter follows a very similar course of action up until the actual conflict.

In scenario four (ref. E.1), all personality profiles follow the same course of action, i.e. figure E.2

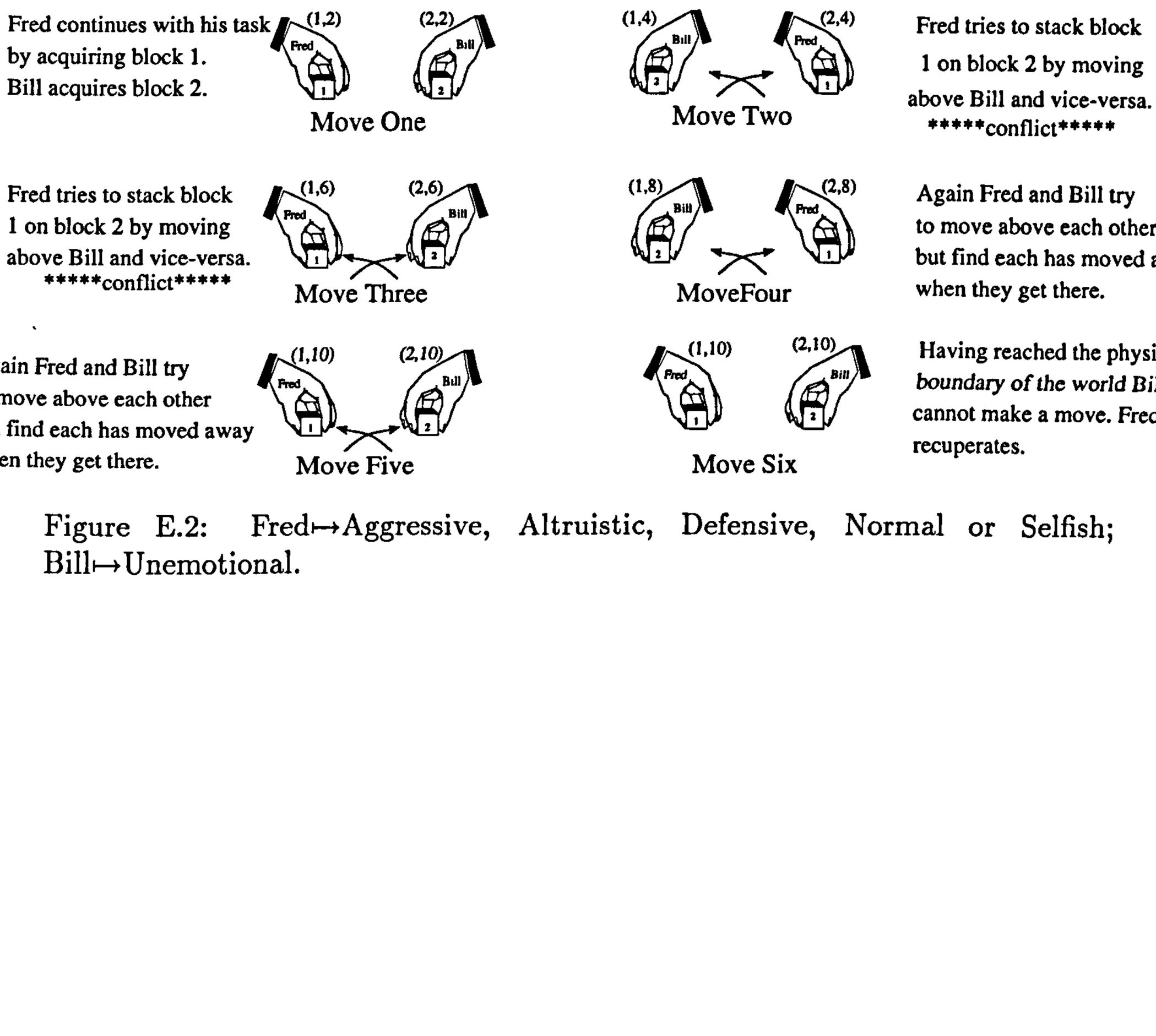
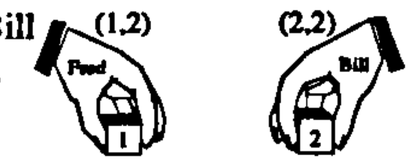


Figure E.2: Fred↦Aggressive, Altruistic, Defensive, Normal or Selfish; Bill↦Unemotional.

E.3 'Full' Emotional Behaviour

The following figures E.3 → E.7 represent the moves an unemotional agent, with only one goal of completing his prescribed task, and an Emoter, of various personalities and behaviour deriving from multiple goals and physiology, would perform in conflict scenario four (see figure E.1).

Fred maintains a threat to Bill by continuing with his task. Both agents acquire their necessary blocks.

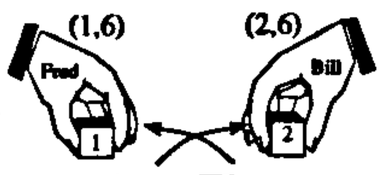


Move One

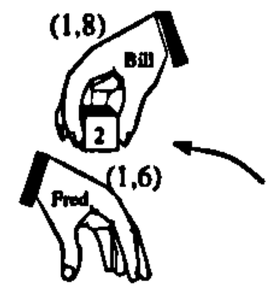
Move Two

Fred tries to disrupt the threat of Bill grasping Fred's task block by moving above him. Bill attempts to stack block 2 on block 1.

Again Fred and Bill try to move above each other but find each has moved away when they get there.



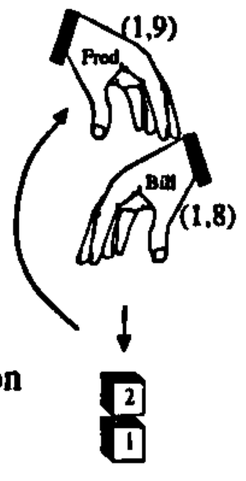
Move Three



MoveFour

Fred has now identified block 1 as one of Bill's task blocks since Bill continuously moves above that block. Fred tries to establish a threat to Bill by placing Bill's block 1on the floor. Unfortunately, this track is not a suitable threat since Bill moves above Fred to stack block 2 on block 1. Fred is now confronted with a mortal threat.

To counter the mortal threat, Fred moves above Bill hoping to impose a mortal threat. Bill releases his block 2 so *that it will stack on block 1.* He is not concerned with the position of Fred only the position of block 1. Bill completes his task.



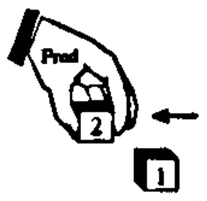
Move Five

Move Six

Fred must now reverse the stack. He must first uncover block 1.

Fred acquires block 2 to remove it from block 1.

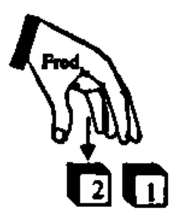
Move Seven



Move Eight

Fred uncovers block 1.

Fred can now move to acquire block 1.



Move Nine

Move Ten

Fred moves to acquire block 1.

Fred acquires block 1.

Move Eleven

Move Twelve

Fred moves to stack block 1 on block 2.

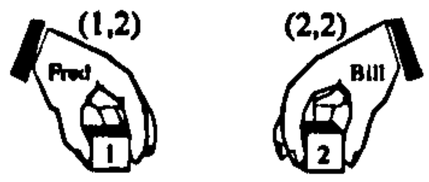
Fred completes his task.

Move Thirteen

Figure E.3: Fred↦Aggressive; Bill↦Unemotional.

Fred cannot help Bill until
he identifies Bill's blocks.

Fred continues with his task
by acquiring block 1.
Bill acquires block 2.

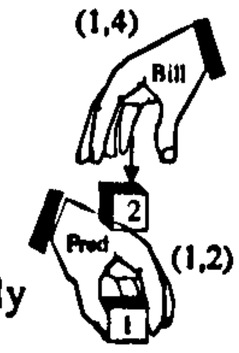


Move One

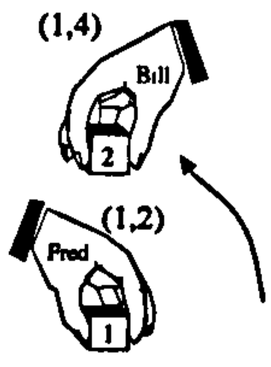
Fred is confronted with a
mortal threat - he maintains
this by not moving.

Bill drops his block to stack
it on block 1 and unintentionally
crushes Fred.

Bill completes his task.
****Fred dies****



Move Three



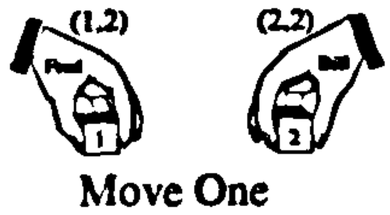
Move Two

Fred has identified Bill's block as block 2.
He decides to maintain Bill's opportunity
by not interfering - he does not move.

Bill moves above Fred to stack block 2
on block 1.

Figure E.4: Fred↦Altruistic; Bill↦Unemotional.

Fred only reacts to threats and so makes an instrumental move by continuing with his task by acquiring block 1.
Bill acquires block 2.

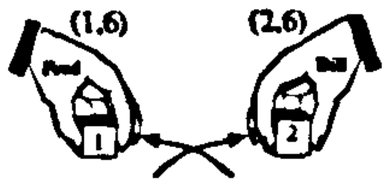


Move One

Move Two

Although Fred is threatened by Bill grasping block 1, he can only disrupt this threat by trying to place a block on Bill's block 1.
Fred tries to stack block1 on block 2 by moving above Bill and vice-versa. *****conflict*****

Fred tries to stack block 1 on block 2 by moving above Bill and vice-versa.
*****conflict*****

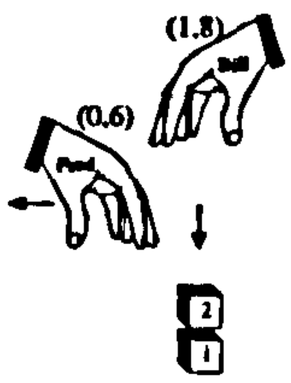


Move Three

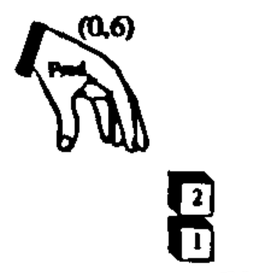
MoveFour

Fred has now identified another of Bill's blocks, i.e. block 1 that Bill continually tries to move above. He can now employ another option to disrupt Bill's threat - place Bill's block 1 on the floor. Unfortunately, this is inappropriate since Bill now confronts Fred with an unintentional mortal threat.

Fred makes an emergency move in reaction to Bill's threat. Bill completes his task by releasing block 2.



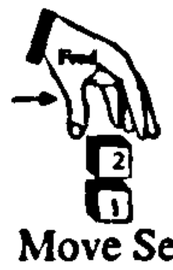
Move Five



Move Six

Fred is no longer threatened, but must recuperate his energy - he does not move.

Fred now makes an instrumental move by uncovering block 1.



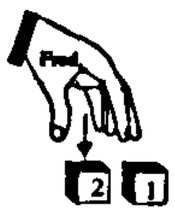
Move Seven

Move Eight

Fred acquires block 2 to uncover block 1.

Fred uncovers block 1.

Move Nine



Move Ten

Fred discards block 2 so that he can acquire block 1.

Fred moves to acquire block 1.

Move Eleven

Move Twelve

Fred acquires block 1.

Fred moves to stack block 1 on block 2.

Move Thirteen

Move Fourteen

Fred completes his task

Figure E.5: Fred↦Defensive; Bill↦Unemotional.

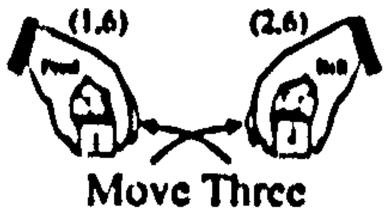
Fred maintains an opportunity for himself by continuing with his task - he does this by acquiring block 1. Bill acquires block 2.

Move One

Move Two

Although Fred is threatened by Bill grasping block 1, he can only disrupt this threat by trying to place a block on Bill's block 1. Fred tries to stack block1 on block 2 by moving above Bill and vice-versa. *****conflict*****

Fred tries to stack block 1 on block 2 by moving above Bill and vice-versa. *****conflict*****

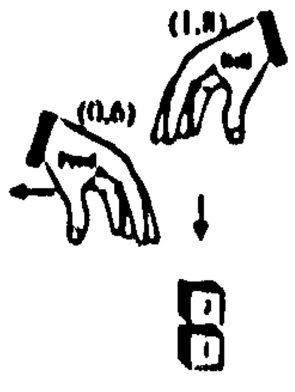


Move Three

MoveFour

Fred has identified another of Bill's blocks, i.e. block 1 that Bill continually tries to move above. He can now employ another option to disrupt Bill's threat - place Bill's block 1 on the floor. Unfortunately, this is inappropriate since Bill now confronts Fred with an unintentional mortal threat.

Fred makes an emergency move in reaction to Bill's threat. Bill completes his task by releasing block 2.



Move Five

Move Six

Fred is no longer threatened, but must recuperate his energy - he does not move.

Fred maintains an opportunity for himself by uncovering block 1.

Move Seven

Move Eight

Fred acquires block 2 to uncover block 1.

Fred uncovers block 1.

Move Nine

Move Ten

Fred discards block 2 so that he can acquire block 1.

Fred moves to acquire block 1.

Move Eleven

Move Twelve

Fred acquires block 1.

Fred moves to stack block 1 on block 2.

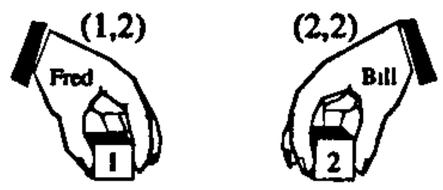
Move Thirteen

Move Fourteen

Fred completes his task

Figure E.6: Fred↦Normal; Bill↦Unemotional.

Fred maintains a minor **opportunity** by continuing **with** his task, he does this **by** acquiring block 1. **Bill** acquires block 2.

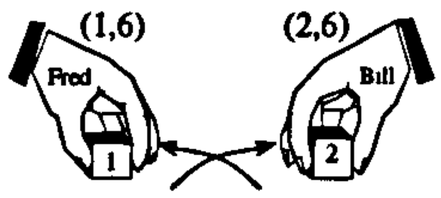


Move One

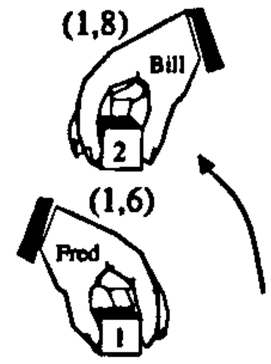
Move Two

Fred tries to stack block 1 on block 2 by moving above Bill and vice-versa. *****conflict*****

Fred tries to stack block **1 on** block 2 by moving **above** Bill and vice-versa.



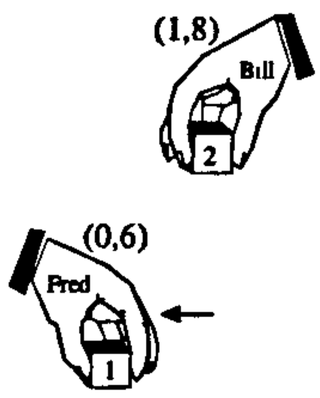
Move Three



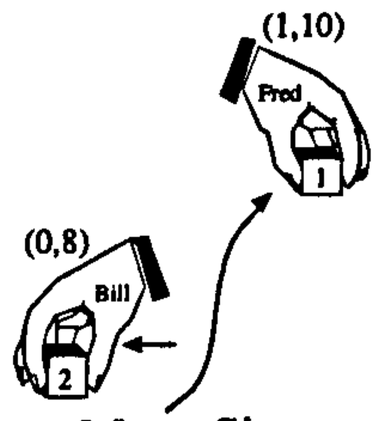
MoveFour

Fred's move is continuously blocked so he must try a different action option or allow the expression of another concern. He cannot realise another action option so he recuperates energy by not moving. Bill moves above Fred.

Fred makes an emergency **move** in reaction to the mortal **threat** posed by Bill. Bill is **unable** to stack block 2 on **block** 1 since it has moved.



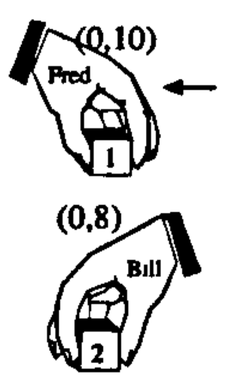
Move Five



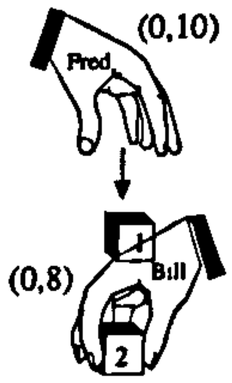
Move Six

Fred tries to stack block 1 on block 2 by moving above Bill and vice-versa. *****conflict*****

Fred tries to stack block 1 on block 2 by moving above Bill. Bill is restricted in moving above Fred because of the physical boundaries of the world - he cannot move.



move Seven



Move Eight

Fred is only concerned with stacking his block 1 on block 2 so he ignores the presence of Bill. Fred completes his task. Bill is crushed by block 1. *****Bill dies*****

Figure E.7: Fred↦Selfish; Bill↦Unemotional.

Appendix F

Successful Combatent

F.1 Introduction

The charts F.1 → F.8 in this appendix show the total number of moves that are made by an Emoter until he completes his prescribed task; is crushed by a block; or reaches a state of deadlock. Each of the four scenarios are described by two charts: one chart for Emoters that utilise physiology alone, and one chart for Emoters that utilise physiology and behaviour derived from multiple goals. Charts F.1→ F.4 represent information for Emoters that utilise physiology alone. Charts F.5→ F.8 represent information for Emoters that utilise physiology and behaviour derived from multiple goals.

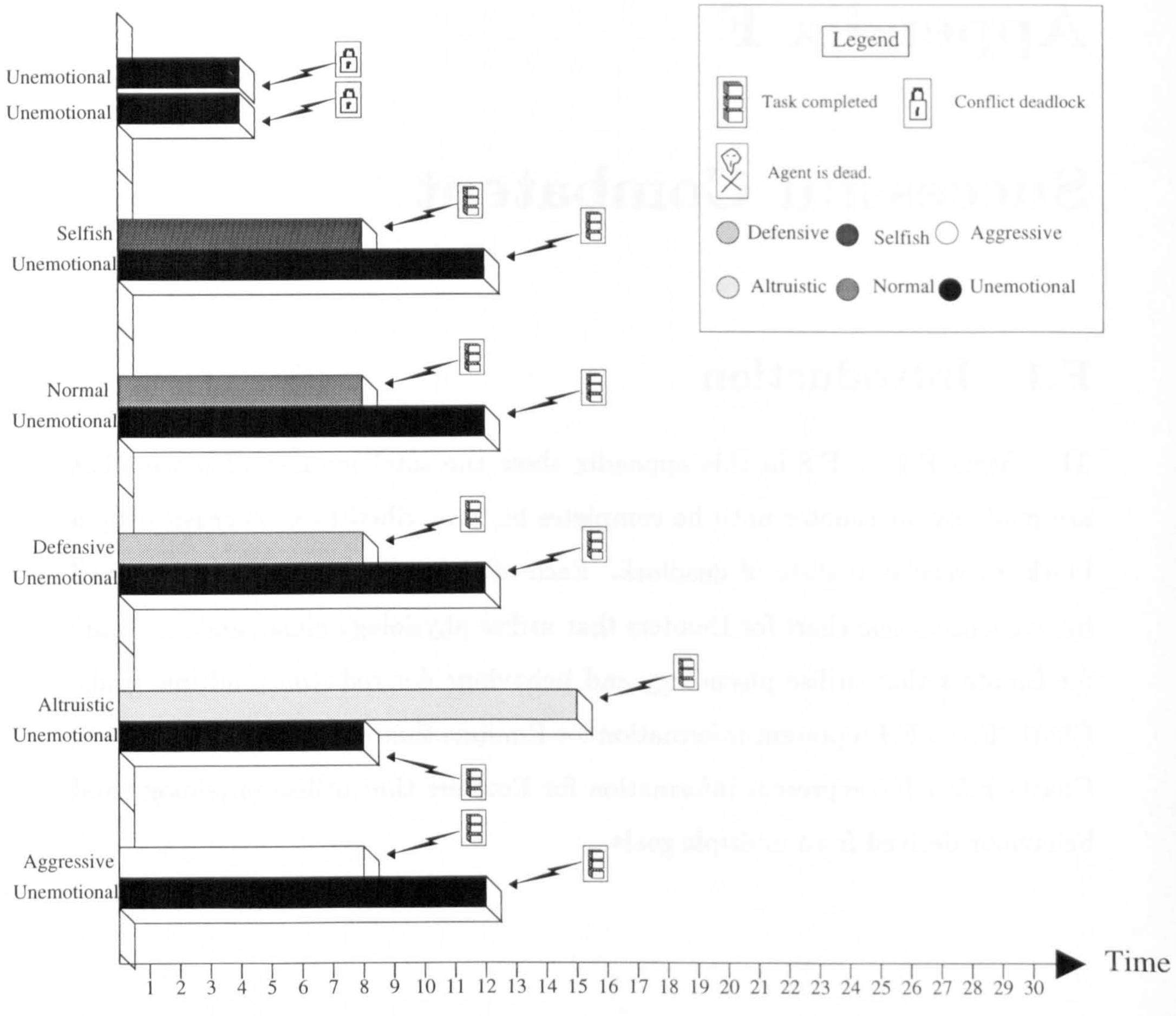


Figure F.1: Time Taken By Each Agent With Physiology Alone in Scenario One.

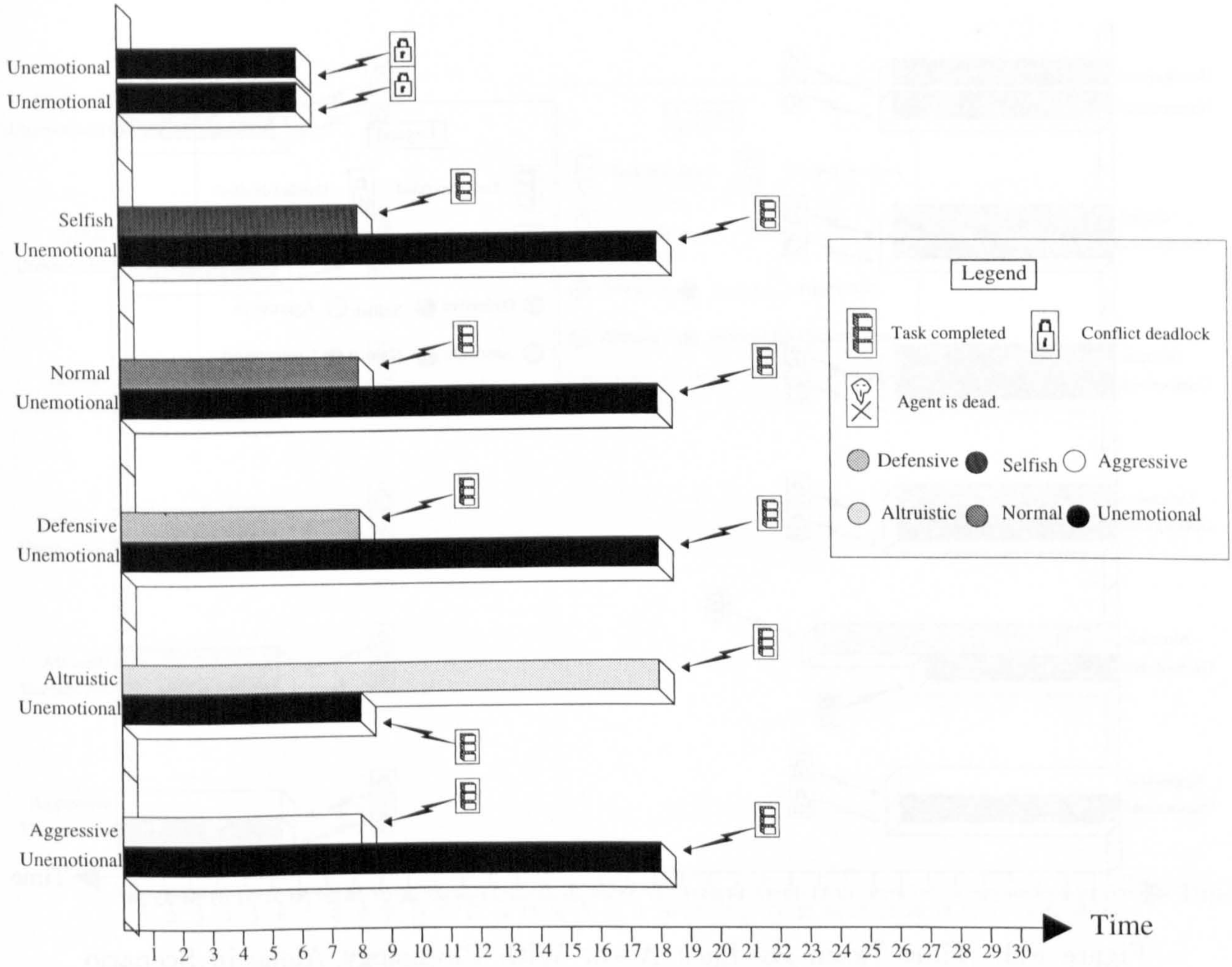


Figure F.2: Time Taken By Each Agent With Physiology Alone in Scenario Two.

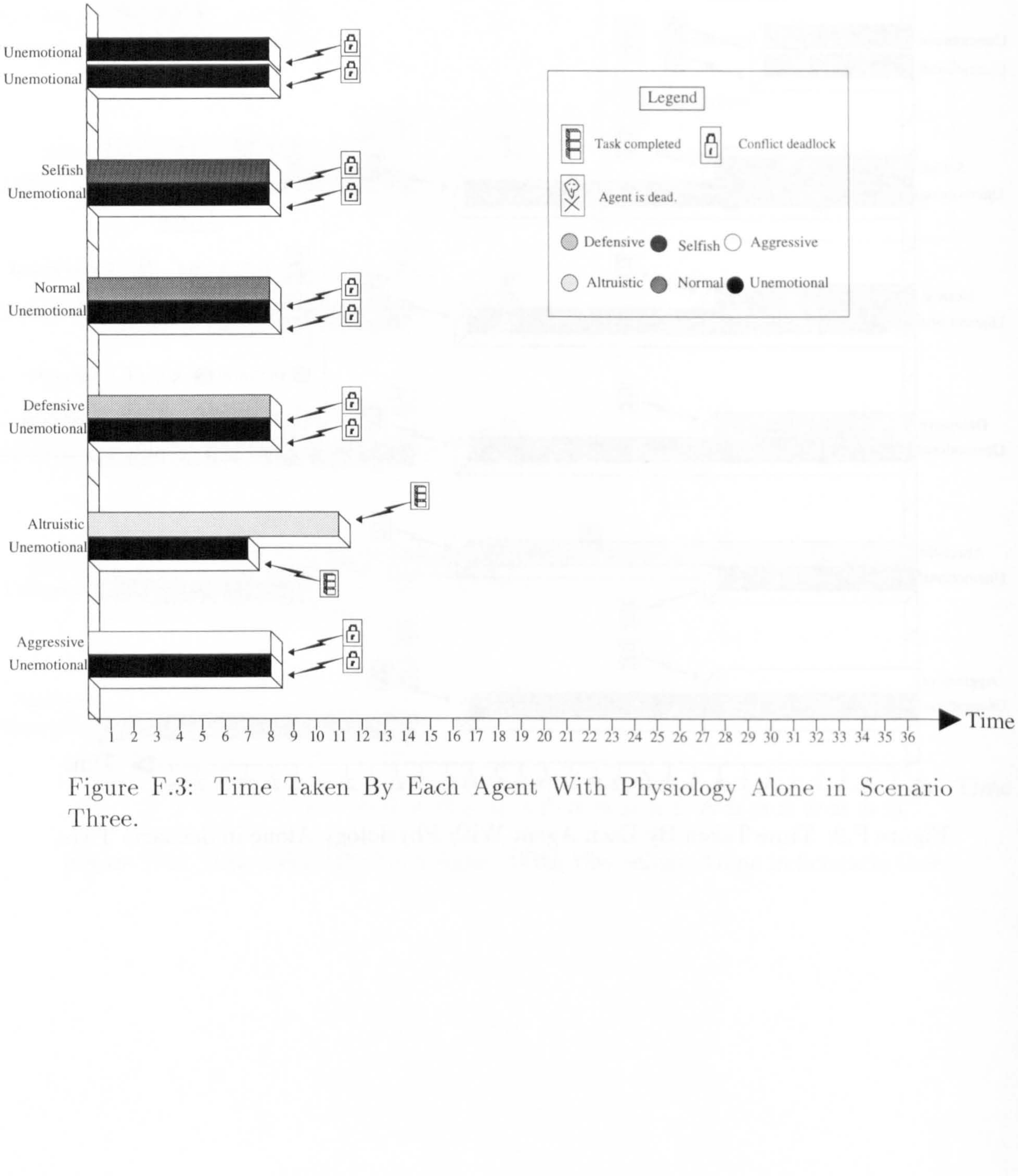


Figure F.3: Time Taken By Each Agent With Physiology Alone in Scenario Three.

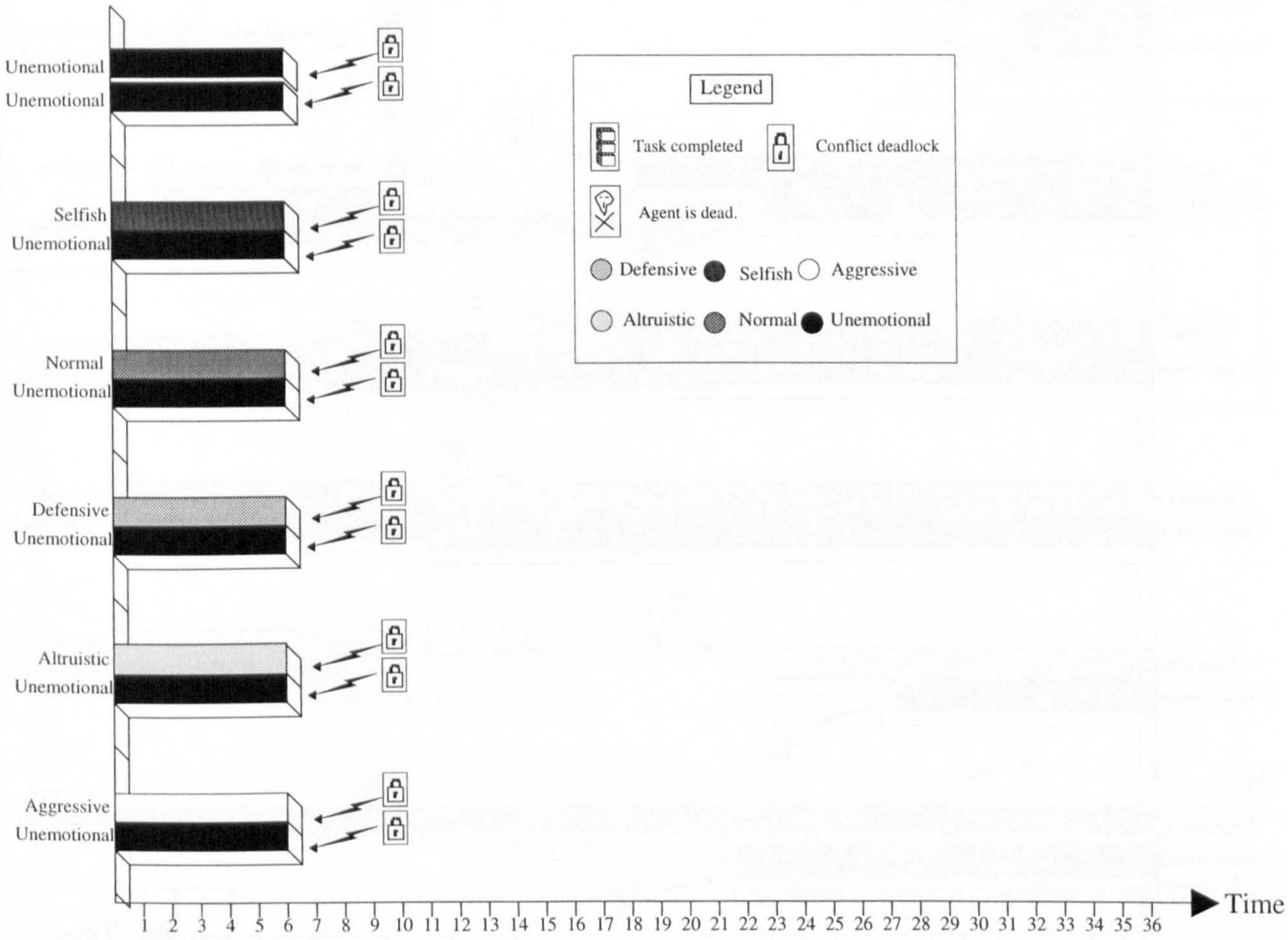


Figure F.4: Time Taken By Each Agent With Physiology Alone in Scenario Four.

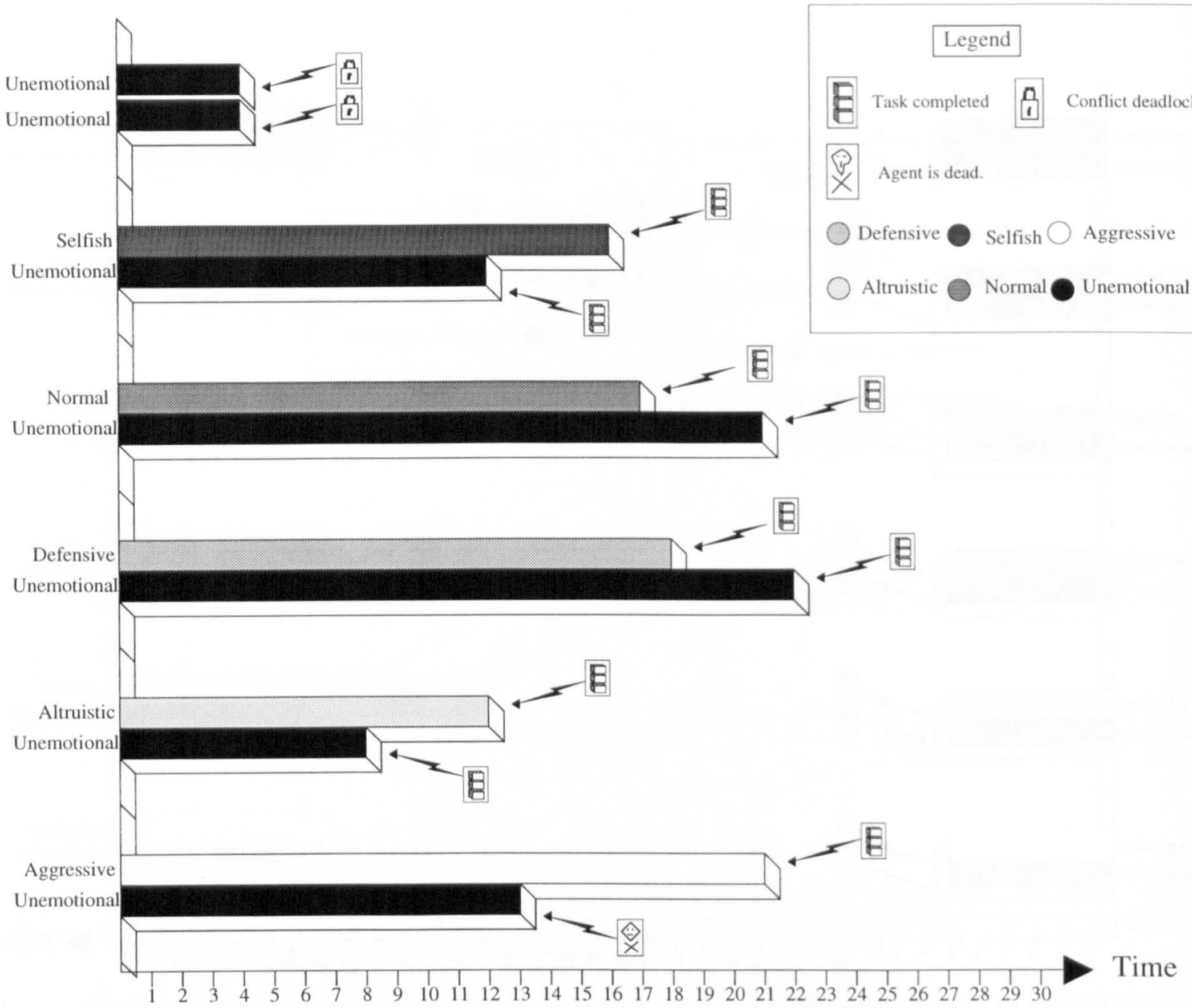


Figure F.5: Time Taken By Each Agent With 'Full' Emotional Behaviour in Scenario One.

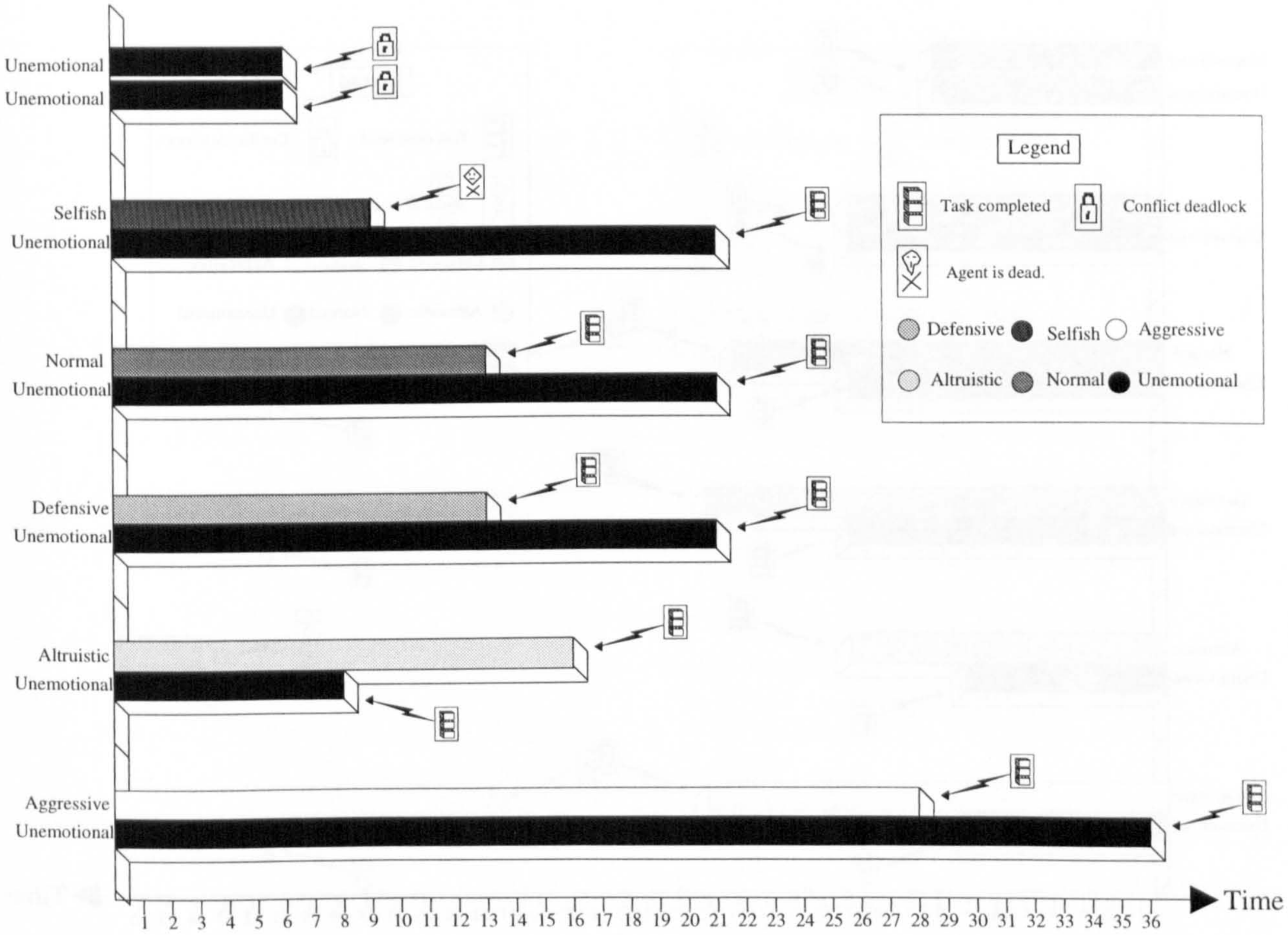


Figure F.6: Time Taken By Each Agent With 'Full' Emotional Behaviour in Scenario Two.

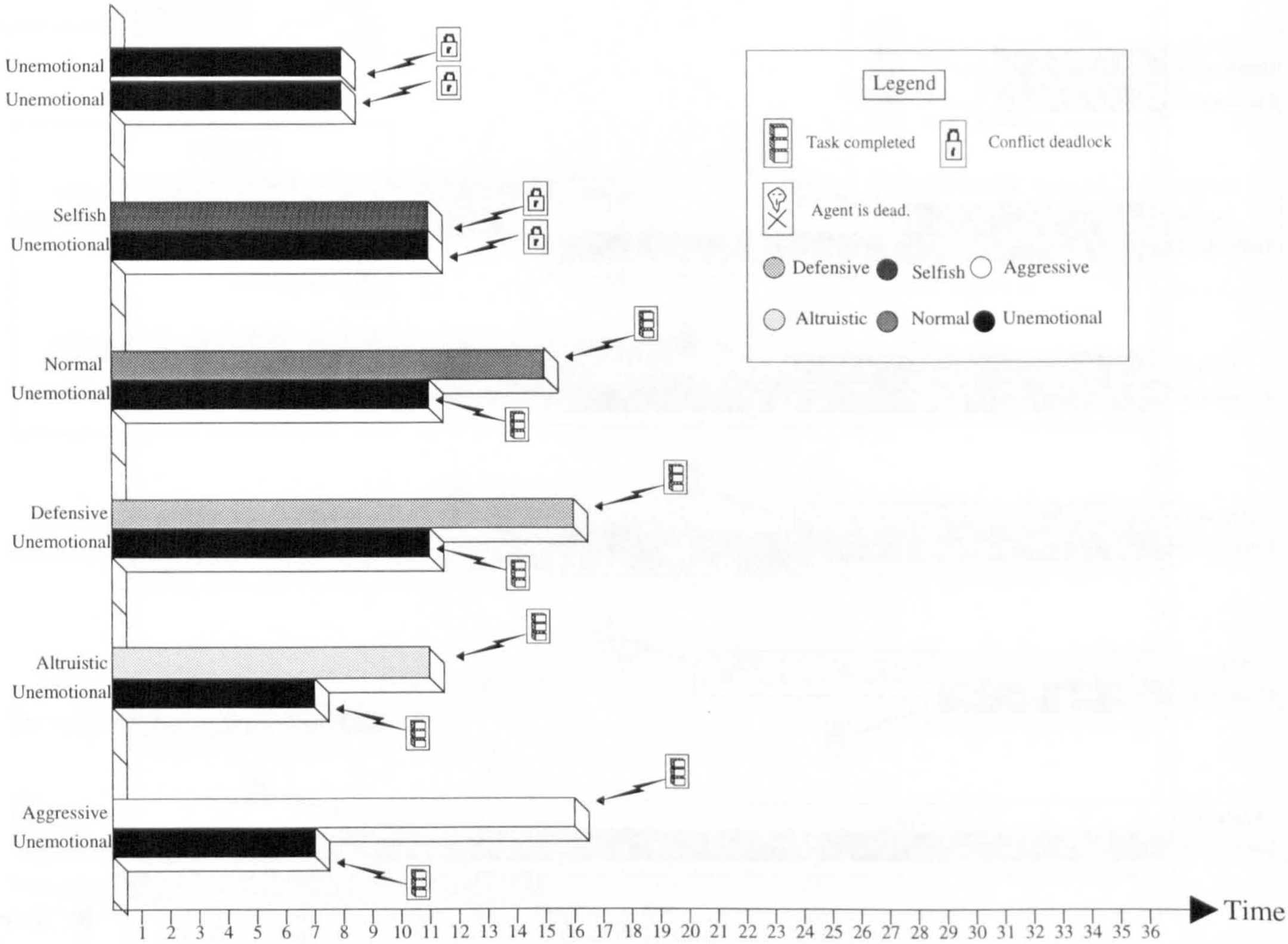


Figure F.7: Time Taken By Each Agent With 'Full' Emotional Behaviour in Scenario Three.

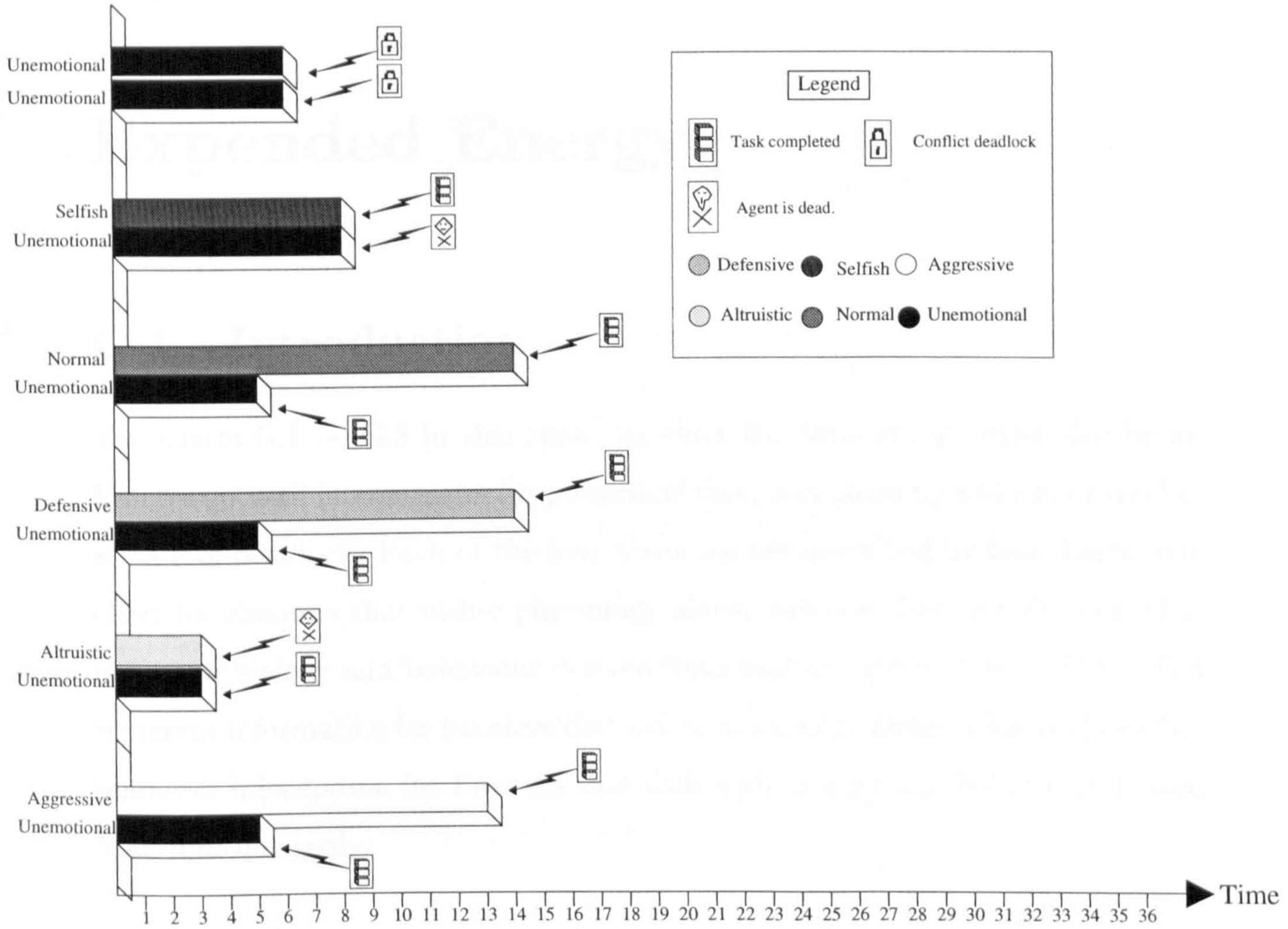


Figure F.8: Time Taken By Each Agent With 'Full' Emotional Behaviour in Scenario Four.

Appendix G

Expended Energy

G.1 Introduction

The charts G.1 → G.8 in this appendix show the total energy expended by an Emoter up until he completes his prescribed task; is crushed by a block; or reaches a state of deadlock. Each of the four scenarios are described by two charts: one chart for Emoters that utilise physiology alone, and one chart for Emoters that utilise physiology and behaviour derived from multiple goals. Charts G.1→ G.4 represent information for Emoters that utilise physiology alone. Charts G.5→ G.8 represent information for Emoters that utilise physiology and behaviour derived from multiple goals.

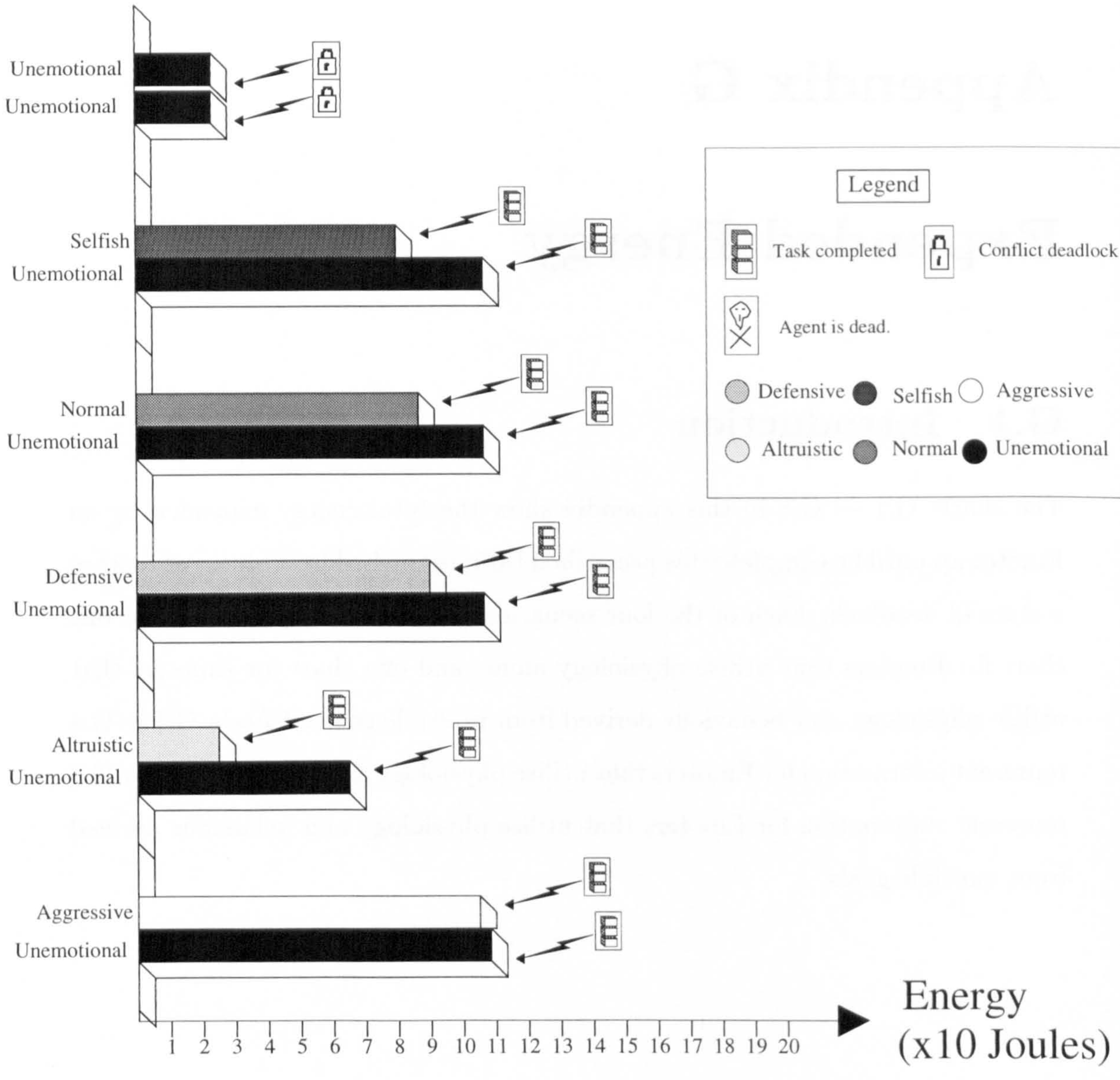


Figure G.1: Energy Expended By Each Agent With Physiology Alone in Scenario One.

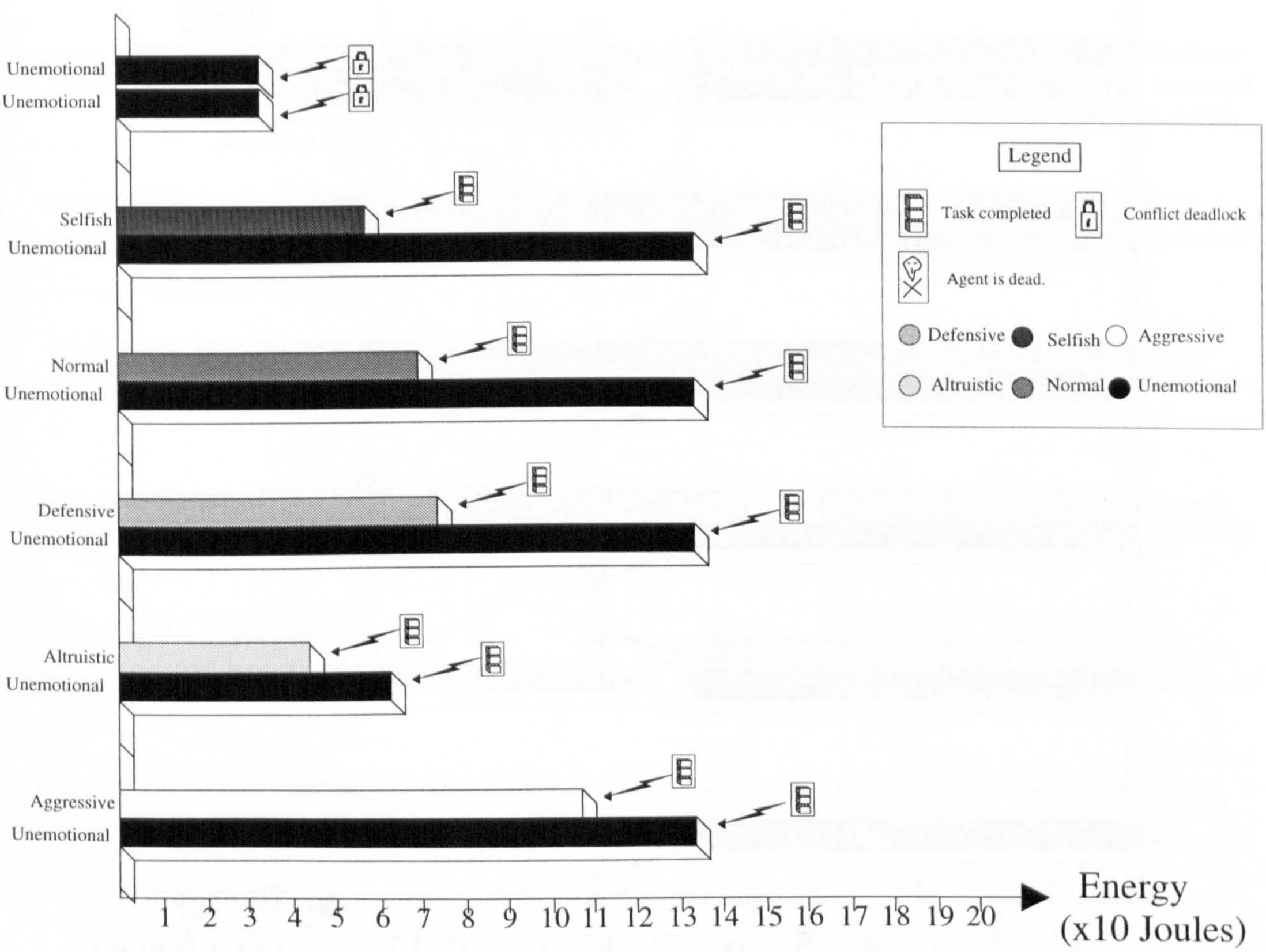


Figure G.2: Energy Expended By Each Agent With Physiology Alone in Scenario Two.

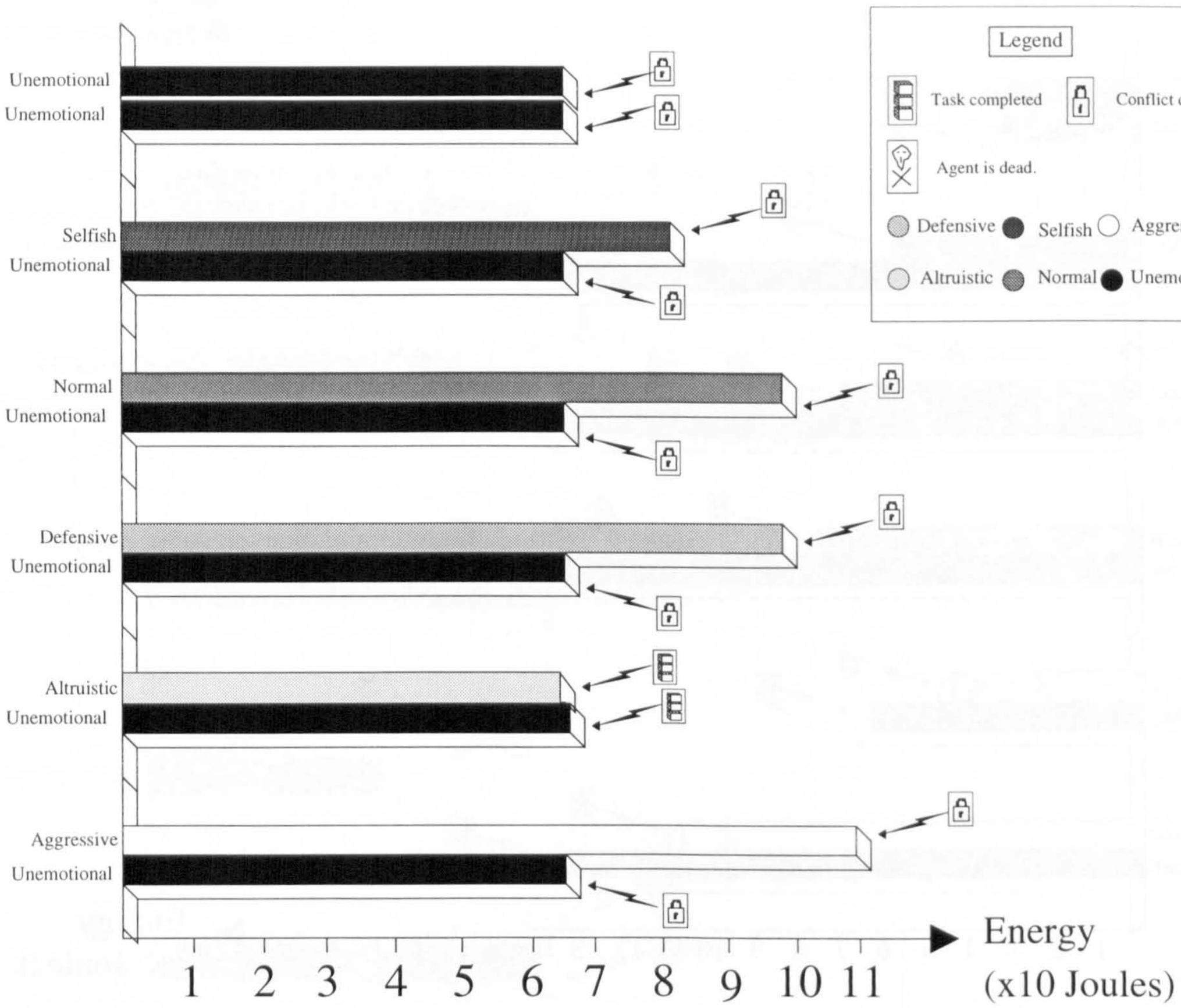


Figure G.3: Energy Expended By Each Agent With Physiology Alone in Scenario Three.

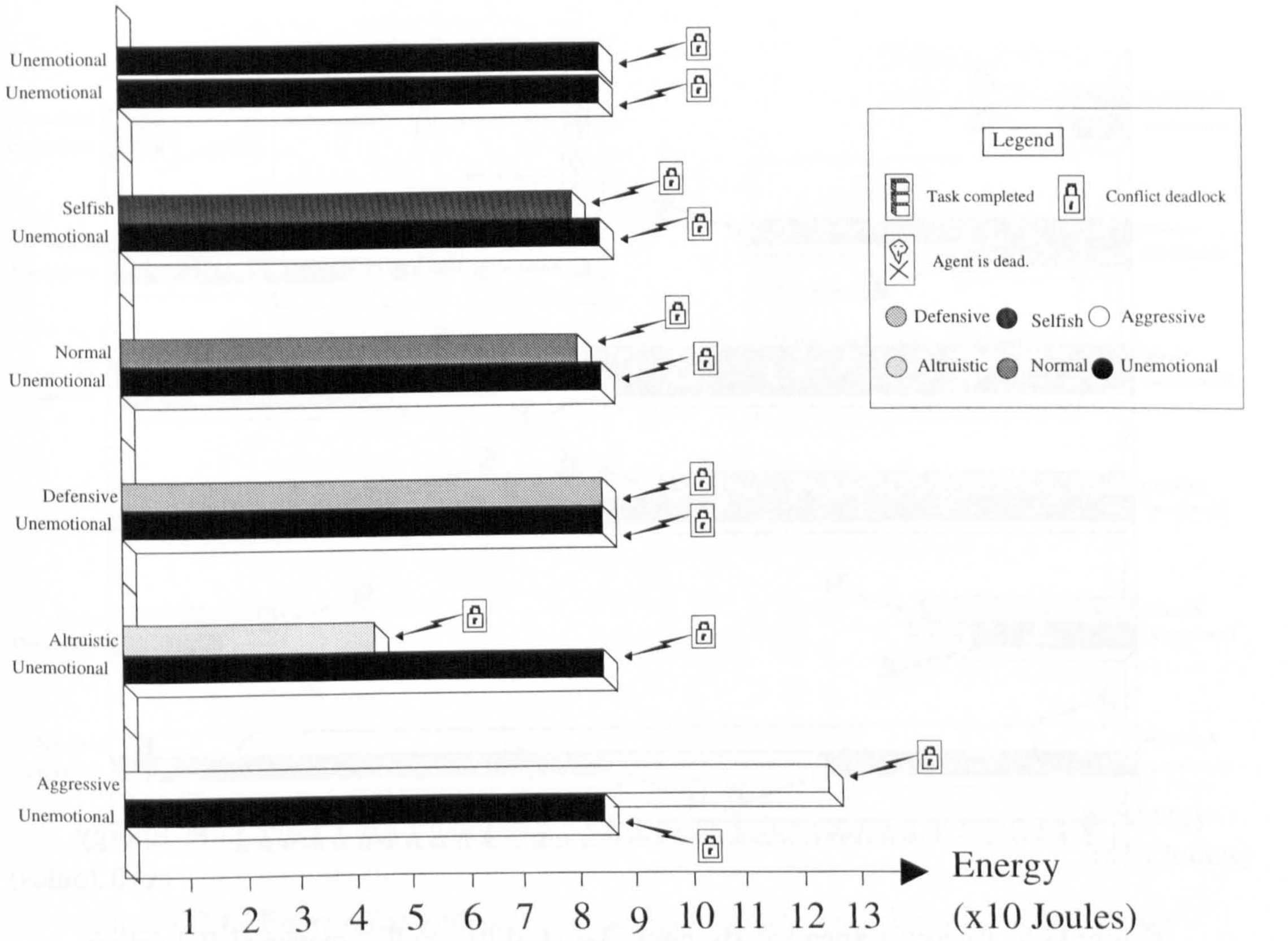


Figure G.4: Energy Expended By Each Agent With Physiology Alone in Scenario Four.

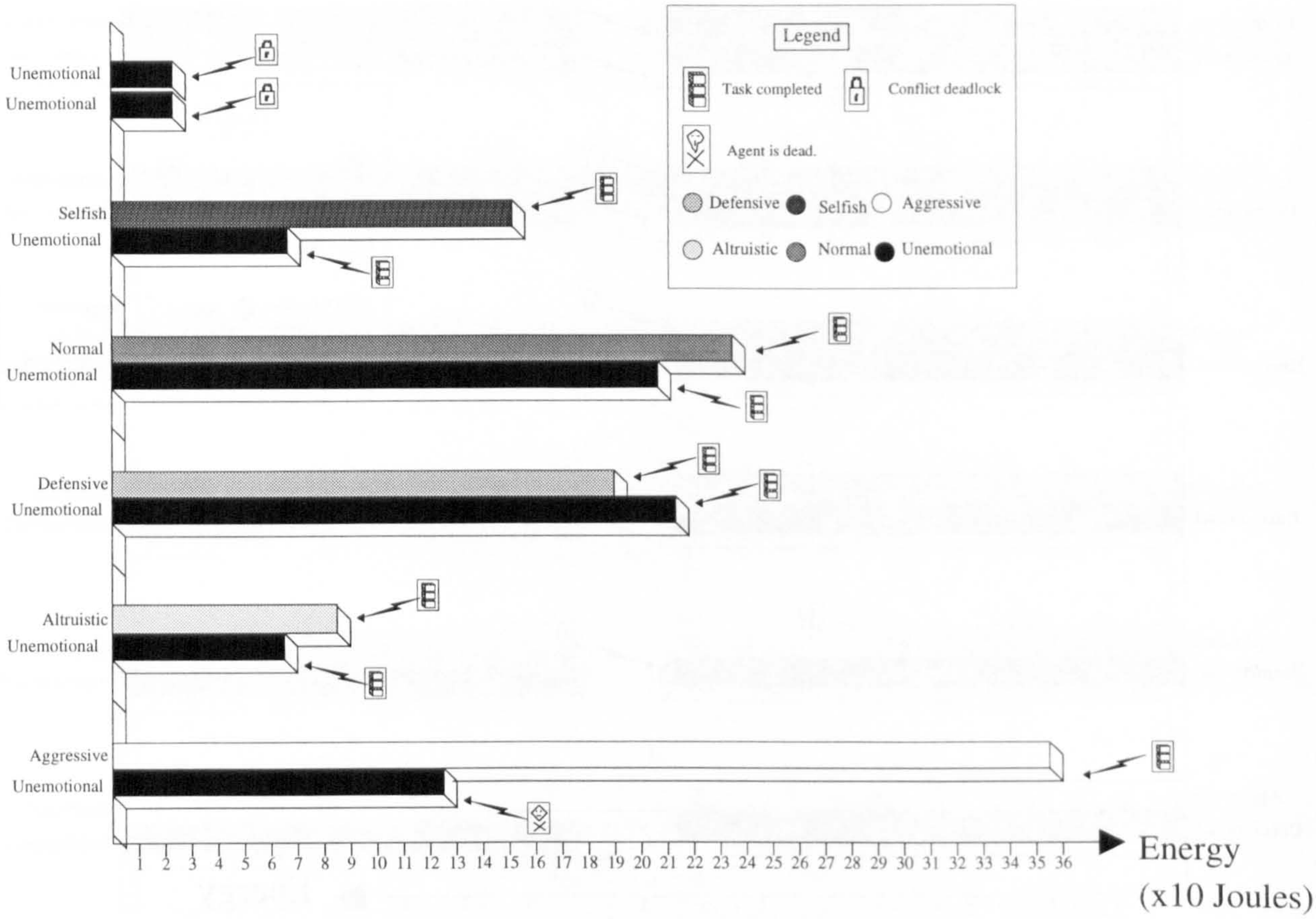


Figure G.5: Energy Expended By Each Agent With 'Full' Emotional Behaviour in Scenario One.

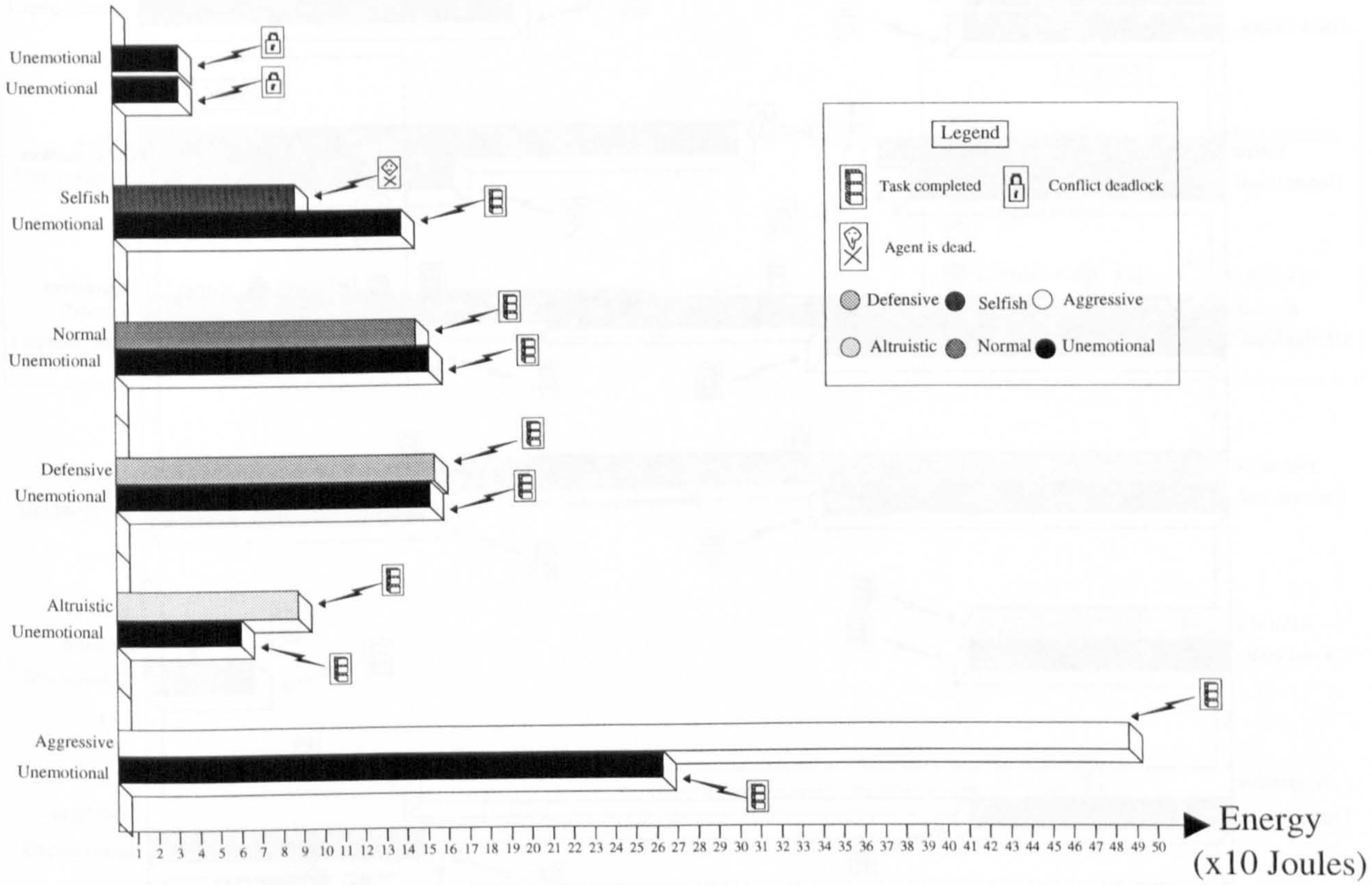


Figure G.6: Energy Expended By Each Agent With 'Full' Emotional Behaviour in Scenario Two.

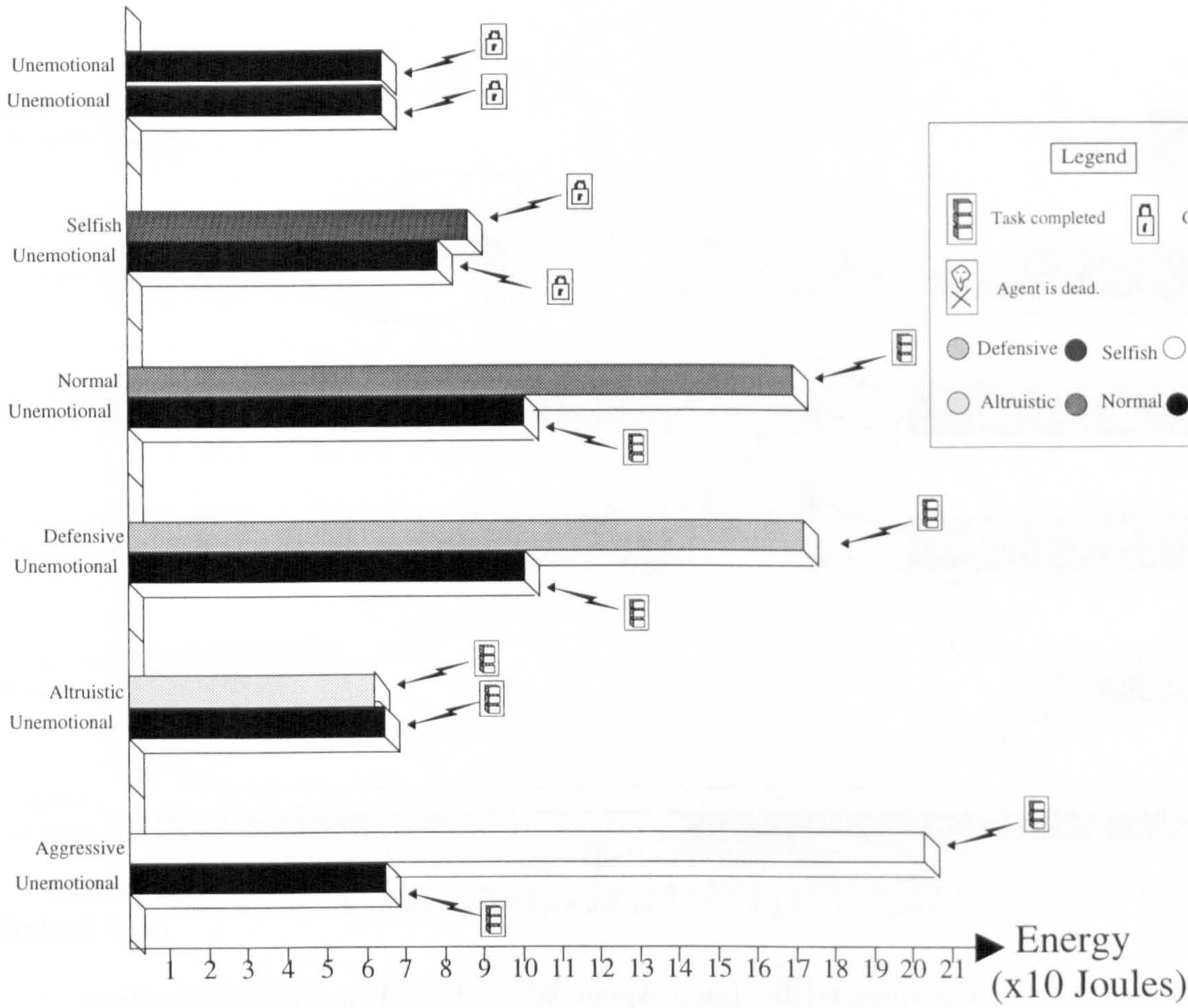


Figure G.7: Energy Expended By Each Agent With 'Full' Emotional Behaviour in Scenario Three.

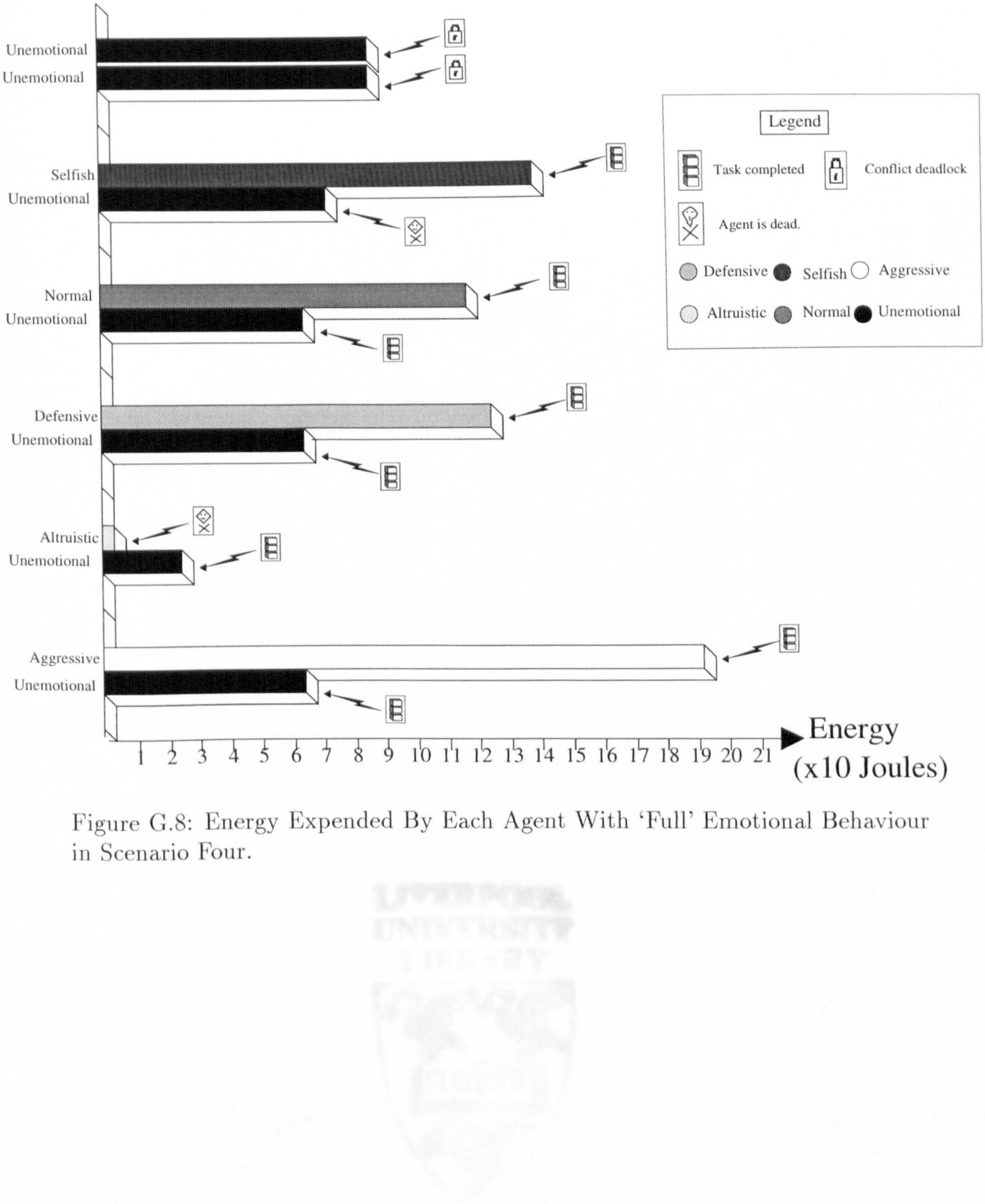


Figure G.8: Energy Expended By Each Agent With 'Full' Emotional Behaviour in Scenario Four.