**Cognitive Architectures for Supporting Strategic Behaviours in Adaptive Systems**

*"The Human-Electronic Crew: The Right Stuff?*
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## 1. SUMMARY

This paper discusses the design implications for human electronic air crew systems from the findings of recent research on the cognitive processes underlying the strategic behaviours and decision making of fighter pilots. A research aim was to explore whether Psycognition, a methodological approach which focuses on eliciting the subconscious processes which influence human behaviour, could contribute to our understanding of the cognitive requirements for adaptive air crew systems.

The Psycognition methodology was applied to an investigation of how fighter pilots' subconscious processes influenced their strategic behaviours in handling certain critical incidents. The research focused on pilot's strategic behaviours in three kinds of critical incidents: plan breakdown, control breakdown and information overload.

The key findings are:

- Despite the similarities in background, training, experience and the strength of the military culture, there were significant differences in how the subjects related to critical incidents.
- In these situations the subjects drew upon deeply rooted subconscious core beliefs to guide their decisions and actions, instead of conscious, rational cognition.
- The differences in strategic behaviours were evident in situations which involved a breakdown in plan or control, an overload of information or a compromise of principles and values.
- Psycognition provides us with a basis for predicting what these behaviours will be, the strategies that will be applied and the breakdown situations in which they will be triggered.

The identification of predictive subconscious behaviours at breakdown points can contribute to our understanding of the human requirements for future cognition adaptive systems. The paper considers the design implications of this research for candidate cognitive architectures for human electronic air crew systems. The consequences for embedding this knowledge (Psycognition) in system pilot models and HEC interfaces will be discussed. The implications of real time intervention through aiding and supporting strategies will be explored.

## 2. INTRODUCTION

Our research studied the strategic behaviours of fighter pilots in the handling of three kinds of critical incidents: plan breakdown, control breakdown and information overload. A research aim was to explore whether Psycognition, a methodological approach which focuses on eliciting the subconscious processes influencing human behaviour, could contribute to our understanding of the cognitive requirements for adaptive air crew systems.

Core to Psycognition is characterology, which was the framework used to examine the subjects' core strategies. Characterology refers to the set of core beliefs and emotional responses formed early in development and the strategic behaviours which are predicated on these core beliefs. The framework consists of six types of character strategies. (Ref 1) An abbreviated overview of the characterological types is provided in Table 1.

**Table 1: An Overview of Characterological Types**

| | **Orientation** | **Core Belief** | **Strategic Behaviour** |
|---|---|---|---|
| *Mr. Safety** | Safety & trust. | Dangerous world. | Over focused on detail & analysis<br>Creates own world –excludes external.<br>Information overload: chunk, filter, escape. |
| *Mr. Action** | Performance & recognition. | Self-worth stems from achievement. | Action & perfection.<br>Focus on the logical & rational.<br>Information overload: speed up. |
| *Mr. Endurance** | Indirect control & endurance. | Not good enough but must do one's best. | Subtle influence & control.<br>Bearing up, delaying, resisting.<br>Information overload: queuing & delaying. |
| *Mr. Freedom** | Freedom/control.<br>Be the best/win. | Must be in charge.<br>Not safe to give up control. | Ensures own choices & decisions.<br>Seeks adventure & excitement.<br>Information overload: abstraction, multiple channels, manipulation. |
| *Mr. Self-Reliant* | Challenge, going it alone. | Take care of oneself.<br>Never rely on others. | Proving self-reliance.<br>Mobilising self-support.<br>Personal challenge. |
| *Mr. Attention* | Getting attention & involvement. | Not being interesting & listened to. | Dramatises events/feelings to get attention & avoid separation. |

The research highlighted significant differences between the subjects' strategic behaviours in the three incidents, which led to four particular strategies emerging from the data. (Ref 2) The strategic themes that emerged suggested that each subject drew upon a core strategy to handle breakdown situations. The characterology framework was applied to the examination of these core strategies. This lead to explanations for the differences in the subject's strategies and the similarity in each subject's strategic approach to the incidents. Four of the six characterologies (identified by * in Table 1) emerged from the data, which was fortuitous. These are summarised in Table 2.

These findings lead us to conclude that the identification of dominant character orientation provides us with a basis for developing hypotheses about the subconscious strategic behaviours that will emerge in certain breakdown situations. This can make an important contribution to our understanding of the human requirements for future cognition adaptive systems.

## 3. COGNITIVE ARCHITECTURES FOR ADAPTIVE SYSTEM SUPPORT

The research findings have formed the basis for considering cognitive architectures to support pilots' strategic behaviours. It is our theory that there is potential for cognition adaptive systems to provide pilot support through structuring

information, providing control feedback and by handling basic operational functions. The cognitive architecture explored in this paper focuses on the strategic behaviours and barriers that emerge at breakdown points. In breakdown situations behaviours emerge which are intuitive and automatic. When this happens a strategy ceases to be effective, however, individuals will continue with the strategy despite signs it is no longer working. The underlying theory is that by bringing this subconscious behaviour to the forefront of the conscious awareness, we are able to interrupt the automatic behavioural process. This leads to more appropriate and effective strategies in breakdown situations.

**Table 2: Themes & Patterns in the Subjects' Strategic Behaviours**

| Strategy | Information Overload | Control Breakdown | Plan Breakdown |
|---|---|---|---|
| ***A - Mr. Safety*** | Not trusting information.<br>Seeks quantity in order to control overload. | Unsafe not to be in control.<br>Feels unsafe when gives up control. | Focus on manipulating situation to achieve goal.<br>Refusal to give up.<br>Withdraws goal if core values are compromised. |
| ***B - Mr. Action*** | Speeds up – faster.<br>Goes for detail. | Increases effort – tries harder.<br>Gives up if doesn't reflect negatively on him. | Focus on what is believed to be right.<br>Perseveres & changes strategic plan.<br>Accepts breakdown if rationally understood. |
| ***C - Mr. Endurance*** | Slows/delays things.<br>Does best & waits. | Attempts to understand.<br>Relinquishes control. | Focus on doing his best.<br>Adapts to breakdown.<br>Compromises if necessary. |
| ***D - Mr. Freedom*** | Deflects situation through abstraction.<br>Manipulates to maintain control. | Exerts power to control.<br>Superimposes own methods for control. | Focus on achieving what he wants, in his own way.<br>Impulse over-rides rational thinking/judgement.<br>Refuses to accept failed situation. |

Our research highlighted the interruption of two major functions in breakdown situations. (Ref 2) The clarity function is interrupted by an insight barrier and the effectiveness function by an action barrier. These two functions which are essential to situational appropriate behaviour begin with the clarity function. Clarity is derived from awareness, attention and information. When an insight barrier emerges, the clarity to move to the next function will be absent and the individual will continue to seek clarity. The effectiveness function is interrupted by a response barrier.

When this barrier emerges, the individual will experience difficulty in responding with appropriate and effective action. This process is illustrated in Figure 1.

**A Cognitive Architecture**

The interruption of the two primary functions led us to consider a cognitive architecture based on the two breakdown behaviours: the processing of information and taking appropriate action. The cognitive architecture presented in Figure 2 provides a framework for identifying the interventions and support required by individuals who experience these breakdowns. In circumstances when multiple strategies are drawn upon, for example, a breakdown in clarity shifts to a response breakdown, by tracking the individual's strategic process, an adaptive system could switch to the appropriate architecture.

**Figure 1: Cycle for Situational Appropriate Behaviour**

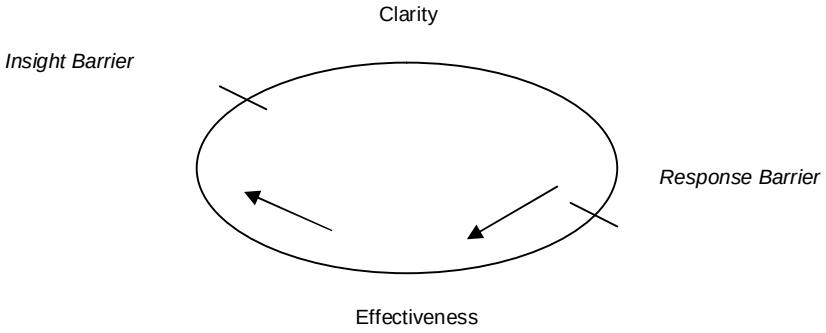
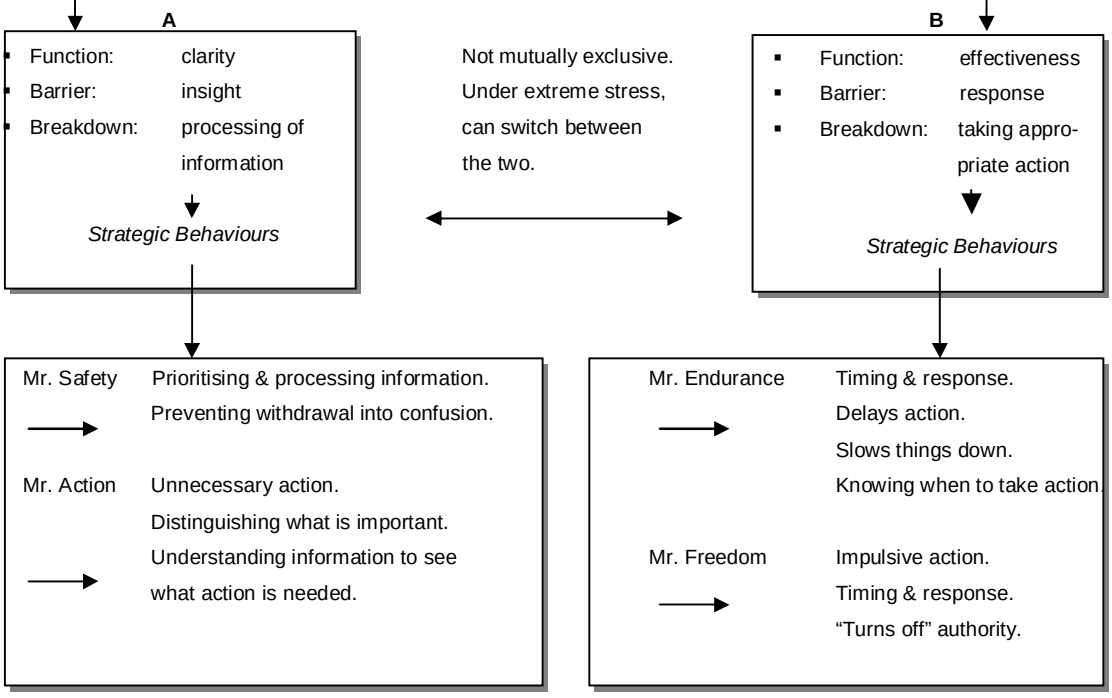



**Figure 2: A Cognitive Architecture**



Asserts own authority.

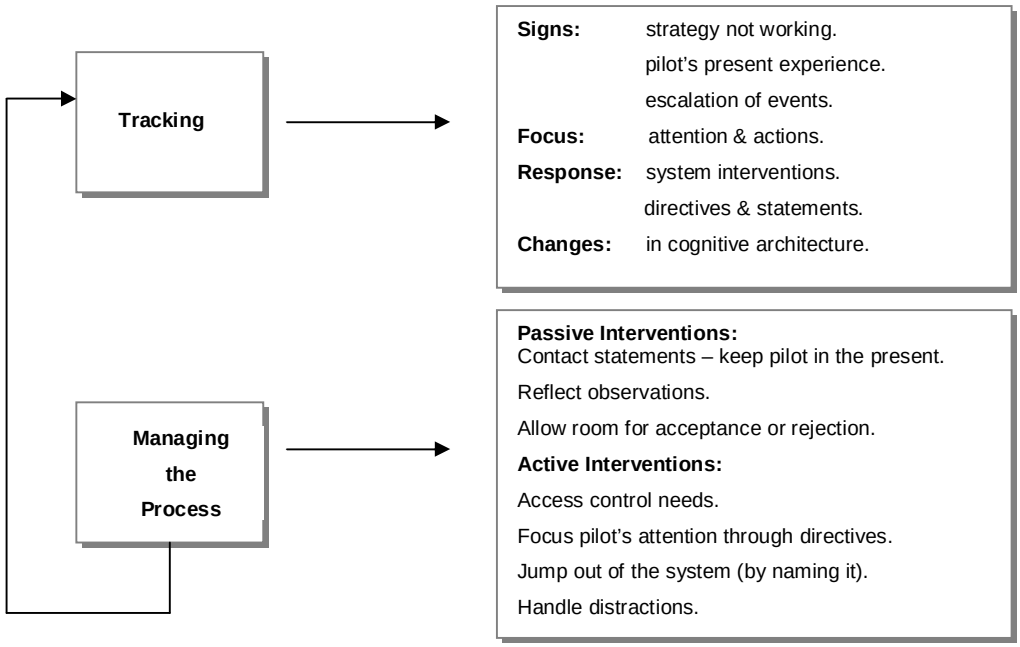
## 4. A MODEL FOR COGNITION ADAPTIVE SYSTEM SUPPORT OF STRATEGIC BEHAVIOURS

The model for supporting the cognitive architecture presented in Figure 3 is drawn from the Psycognition methodology. It is based on the process an expert analyst would apply in working with character strategy in a breakdown situation. This process was mapped on to a pilot breakdown scenario drawn from the research to determine how it could be applied to pilots' strategic behaviours. Parts of the process and certain interventions were found to be potentially applicable to the fighter pilot domain.

### 4.1 A Scenario – Cognition Adaptive System Support for Mr. Safety

*Inside the cockpit:* An information overload situation leading to a perceived control breakdown: a plethora of information inside and outside of the cockpit. Mr. Safety's internal dialogue is running, "How can I avoid being my own worst enemy? Are my priorities right" I'm losing it." He is suffering from distraction, "Why isn't that indicator light changing? Is this information important, can I trust it? Where is the bad guy, enemy radar is squirting something, I must avoid that storm!"

**Figure 3: A Model for Cognition Adaptive System Support of Strategic Behaviours**




The cognitive adaptive system 'knows' the cognitive architecture of Mr. Safety. It has a map of his behavioural strategies for handling a breakdown in the clarity function. The system will track his difficulties in processing information and will attempt to manage the process through interventions to reduce the insight barrier and to restore the clarity function. The system aims to slow things down for Mr. Safety so that he can understand the meaning of the information he is receiving. It attempts to break things into smaller, more manageable steps. It will also try to keep Mr. Safety in contact with the situation to prevent him from withdrawing into confusion or over analysis. The system does this by tracking signs of the strategy not working, which will be reflected in increased confusion and fragmentation. Examples of the system tracking process and

interventions are illustrated in Figures 4 and 5.

**Figure 4: System Tracking Intervention Process**

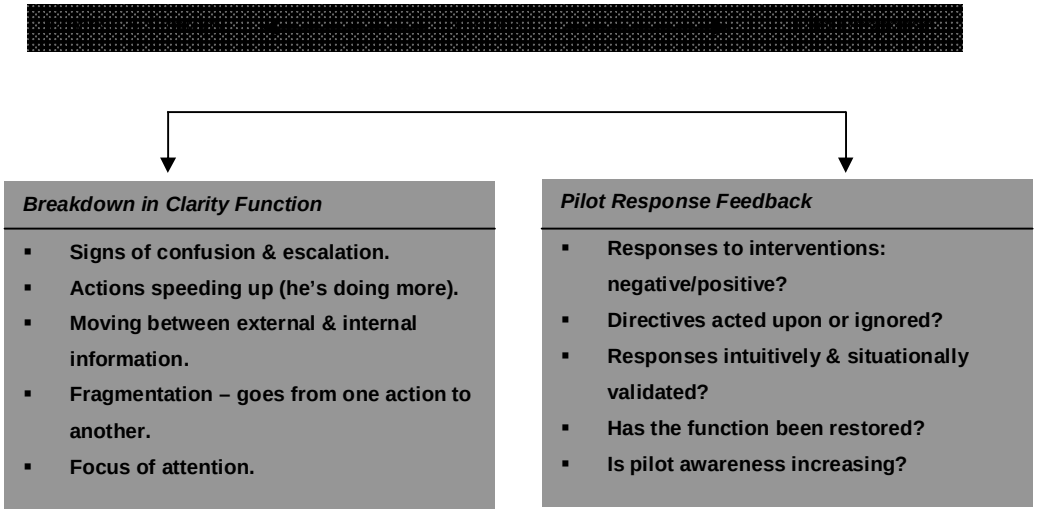



**Figure 5: Mr. Safety Intervention Scenario: Control Breakdown & Information Overload**

| ***Managing the Process:***<br>*Organise the speed by slowing down & focusing.*<br>*Simple precise & prioritising interventions.* | ***Intervention & Feedback Function*** |
|---|---|
| Take a moment, slow down & focus.<br>What would help you to regain control right now?<br>It seems like more information right now is not useful.<br>What kind of info would be useful to you right now?*<br>You have all the information you need for the moment.<br>Let's stop & consider what the priorities are.<br>You're doing fine, slow down & focus.<br>This is what is important. | Joots: naming the system<br>Focus: present & needs<br>Contact: maintain contact<br>Prioritise: important information<br>Joots: naming the system<br>Prioritise: priorities<br>Joots: system naming<br>Support: choice |
| ***Handing over: Support Function***<br>***I'm keeping an eye on this so you don't have to.*** | ***Pilot Validation & Acceptance Criteria*** |
| Let me handle the distractions so that you can focus.<br>I'll keep my eye on the red light so you don't have to.<br>I'll tell you when the fuel level changes.<br>I'll remind you when to turn the radio back on.<br>I'll take control, you check the plan. | Will I be more or less in control?<br>Do I need to or can I trust the system?<br>Can I trust the system?<br>Can I trust the system?<br>Can I trust the system? |

* *Offers three/four categories of information: e.g. pilot pushes button to select one: ground control, weather, electronic warfare, status of the cockpit.*

## 5. COGNITIVE REQUIREMENTS FOR ADAPTIVE SUPPORT SYSTEMS

- The locus of control must be appropriately balanced between the pilot and the cognition adaptive system. In situations where the locus of control lies with the system, the pilot's internal authority must remain in control.
- The pilot must know which of the system's functions s/he can override and which ones they cannot.
- The system must support and not inhibit rational intentionality. (It doesn't make sense to me, but you must have a good reason.")
- The system's interventions and behaviour must not contribute to the information overload or control breakdown. This will require close monitoring of the system impact on the pilot to determine when the interventions are helpful and when they are contributing to the problem.
- The relationship between the cognition adaptive system and the pilot needs to be well established outside of the cockpit.
- The cognition adaptive system's understanding of the pilot's cognitive architecture and behavioural strategies needs to be built up over a period of time. Initially, this understanding would be developed outside of the cockpit. However, it is essential that it developed further through adding behavioural material collected during each mission.
- There must be a high level of compatibility between the system and the pilot. This depends on the system supporting the appropriate cognitive architecture and on it's ability to switch to a more appropriate architecture if the pilot's behavioural strategy changes.

## 6. DESIGN IMPLICATIONS

An important implication of the cognition adaptive system scenario is the uncertainty around the behaviours that could result from the system interventions. Although the system intention is to evoke appropriate behaviours, instead it could lead to an increase in inappropriate behaviours.

In the scenario described above, the pilot's behaviour could be accentuated instead of diminished. For example, his reactions could lead to increases in delay, disorganised action, fragmentation, confusion and impulsive action.

System interventions could also inadvertently trigger core belief behaviours. For example, resistance, power, control, safety and trust. These implications need to be carefully researched.

The interpersonal dynamics between the system and the pilot will determine how effectively a system can provide cockpit support and guidance. Therefore the dynamics that could develop from different system interventions need to be carefully researched.

## 7. REFERENCES


1. Kurtz, Ron, "Body-Centered Psychotherapy". California, USA. Life Rhythm. 1990 (ISBN 0-940795-03-5).
2. Guevara, K., "Psycognition: An Exploration of the Strategic Behaviours Underlying Fighter Pilots' Decision Making in Critical Incidents." Consultant's Research Report, DERA, CHS, Farnborough, UK. July 1997.