The Executive System and its Disorders

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Attributes of the Executive System

The executive system has been traditionally quite hard to pin down, mainly due to what Burgess (1997) calls a lack of "process-behaviour correspondence". That is, there is no single behaviour which can in itself be tied to executive function, or indeed executive dysfunction. For example, it is quite obvious what reading impaired patients cannot do, but it is not so obvious as to exactly what executive impaired patients might be incapable of.

This is largely due to the nature of the executive system itself. It is mainly concerned with the dynamic, 'online' co-ordination of cognitive resources and hence its effect can only be observed by measuring other cognitive processes. Similarly, it does not always fully engage except in real-world situations. As Saver and Damasio (1991) found out, a patient with a severe day-to-day executive problems may still pass standard tests of executive function.

The executive system is also heavily involved in handling novel situations outside the domain of some of our 'automatic' psychological processes. Norman and Shallice (1980) (see also chapter 14 of Shallice, 1988) have outlined five types of situation where routine activation of behaviour would not be sufficient for optimal performance:

1. Those that involve planning or decision making.
2. Those that involve error correction or troubleshooting.
3. Situations where responses are not well-learned or contain novel sequences of actions.
4. Dangerous or technically difficult situations.
5. Situations which require the overcoming of a strong habitual response or resisting temptation.

The executive system is also involved in making actions and problem solving less effortful the more we encounter them. This means that the role of the executive system will change when the same person is tested with the same task, on different occasions. Again, this poses a problem for us as psychologists because we are in effect trying to hit a moving target.

Despite the seemingly ephemeral nature of the executive system, we know have a good idea of how it can break down after brain injury. This break down often follows damage to the pre-frontal cortex (PFC) with which the executive system is strongly linked, and can have wide ranging effects on a variety of psychological functions.

The Dysexecutive Syndrome: Problems with Affect and Social Judgement

Phineas Gage, the famous railroad worker who had a 4 foot tamping iron blown through the front of his skull in 1848, showed marked problems with social interaction after his injury. This was despite seemingly intact memory, and intelligence.

We now know that difficulties with emotional control and social interaction are not uncommon in dysexecutive patients (Saver and Damasio, 1991). Damasio himself explains this aspect of executive impairment in terms of his 'somatic marker hypothesis' (Damasio, 1998) which argues that the pre-frontal cortex is involved in marking internal representations of encountered situations with autonomic nervous system responses. These responses, according to Damasio, aid executive

decision making as they constitute an ‘automated alarm signal’ to warn of possible undesirable or potentially dangerous situations. For example, Damasio would argue that the executive system would be involved in ‘marking’ potential danger when walking down a dark alley by increasing our pulse rate, adrenaline output and so on.

Rolls (1996) on the other hand, interprets this aspect of executive function from more of a behaviourist perspective. He sees emotions as ‘response elicited by reinforcing signals’ and social functioning as learnt stimulus-response behaviour to perceived social cues, which he mostly attributes to the action of the orbito-frontal cortex (lies at the front of the frontal lobes, resting above the eyes). Consequently, Rolls would see social judgement problems as the result of an inability to make effective decisions from the available social cues.

Baron-Cohen (1995) however, sees this sort of impairment in terms of an impaired ‘theory of mind’, a notional process that allows us to infer another person’s internal state from their behaviour. For example, if I see someone in the street carefully examining the area around their feet I might infer that they are searching for a dropped object. Indeed, Channon and Crawford (2000) have shown that in their group of frontally damaged patients, there were marked problems in understanding stories that involved ‘theory of mind’ function. However, Fine, Lumsden and Blair (2001) have reported on patient BM who has marked ‘theory-of-mind’ problems but a seemingly intact executive system. It is notable that BM does not have damage to the pre-frontal cortex but an amygdala lesion, suggesting that the PFC may not be the primary site of involvement for ‘theory-of -mind’ function.

However, a recent report on a frontally damaged patient (JS) by Blair and Cipolotti (2000) would seem to demonstrate the classic behavioural signs of impaired affect and social functioning when signs predicted by the theories of Damasio (1998), Rolls (1996) and Baron-Cohen (1995) are not present. They argue that the executive system regulates social behaviour and mediates how past experience of related situations are used in the decision making processes for ‘here-and-now’ social cognition. Crucially, they stress that executive dysfunction is this domain may only be apparent in real life social functioning and might not be tapped by cognitively removed experimental tests.

The Dysexecutive Syndrome: Executive Memory

Baddley’s original and revised model of working memory (Baddley, 1986; Baddley, 2000) had the executive system as a central component for the co-ordination of memory resources. Similarly, Parkin (1997) has argued for executive involvement in longer term memory function.

Executive impairment can have specific effects on memory, as has been reported in the case of JB, a frontally damaged memory impaired patient (Parkin, 1997). Despite having excellent scores on standard tests of executive function, JB tended to confabulate, producing wild and unlikely recollections. Burgess and Shallice (1996a) relate such memory impairment to a disruption in the supervisory processes of the central executive which prevents the patient from adequately self correcting, internally specifying and assessing recalled memory traces.

In a more recent study Parkin et al, (1999) argued that JB’s other apparent deficit (reporting recognition of people, places and items he had never encountered before) was also due to the ineffective use of the executive system. However, this particular problem was not at the stage of memory retreival (as with his confabulation) but at the stage of memory encoding. Parkin et al (1999) argue that encoding events as effective memory traces required the executive system to prioritise or inhibit particular aspects of an event to be remembered. For example, when watching a film, it may be more important that we remember the story line rather than the cars the characters

are driving. In JBs case, it seems his executive dysfunction means he can only remember very general details but does not have the ability to make new memories unique enough to successfully recall and recognise with.

The Dysexecutive Syndrome: Abstract Thinking and Intentionality
The ability to conceptualise of abstract problems and execute tasks to a predetermined plan is a particularly complex set of mechanisms that can result in deficits with temporal organisation, rule attainment and action selection.

Deficits in task planning are often tested with Shallice's (1982) 'Tower of London' task, which involves moving disks from an initial state to a goal state using a minimum number of moves. Dysexecutive patients often find this task particularly difficult although the exact reasons why are a little contentious.

Recently, Carlin et al (2000) suggested there was 'no single cause of failure' (not surprising considering what we know about the lack of process-behaviour correspondence), although suggested contributing factors may be a problem with working memory and an inability to plan (or as they put it, an inability to compile moves into a 'structure event complex'). Similarly, Burgess and Shallice (1996b) found frontally injured patients had problems with rule attainment problems when tested on the 'Brixton' test, which involves guessing the underlying rules that govern how a coloured circle moves in a series of presentations.

One of the reasons given for dysexecutive patients' difficulties on the Brixton tests was their inability to suppress 'strange hypothesis'. In fact, a major function of the executive system seems to be to inhibit inappropriate behaviours. A dramatic example of this breaking down is in the case of 'utilisation behaviour' where patients are unable to inhibit actions triggered by the environment (see Shallice et al, 1989). For example a patient may be unable to pass a door without trying to open it. Perseveration is another result this sort of deficit, which results in the repetition of behaviours after they have ceased to be of use.

It is also apparent that the executive system is also involved in initiating action,. Another syndrome that may arise after frontal damage is that of akinetic mutism where self initiated action is almost absent (see Ure et al, 1998) even though patients seem to respond normally to externally motivated actions, such as being asked a question by another person.

Another essential feature we must do when performing multiple actions is to organise effectively so we are still able to complete whatever goal we have in mind. The executive system also plays a role here as demonstrated by Shallice and Burgess' (1991) multiple errands test where frontally damaged patients were taken to a local shopping centre and asked to carry out certain tasks. For example, buy a loaf of brown bread, find out the exchange rate for the French franc yesterday. However, there certain restrictions were applied e.g. 'You are to spend as little money as possible. No shop should be entered other than to buy something. You are not to use anything not bought on the street (other than a watch).'. As well as providing a variety of sub-tasks, this also requires the ability to conceptualise and plan short and long term strategies to complete the task due to the nature of the imposed restrictions. The three frontally injured patients found these tasks particularly difficult and made numerous errors of planning and task evaluation.

Models of Executive Function
So far we have seen a seemingly large and complex set of behavioural problems that may arise after damage to the executive system. It would perhaps seem difficult to try and explain these behaviours

in a single model, some of which even seem contradictory, for example the inability to suppress action in utilisation behaviour vs inability to initiate action in akinetic mutism. However, models have been proposed, two of which we'll examine.

Duncan, Burgess and Emslie (1995) have argued for executive impairments as a form of goal neglect, a concept they strongly link to Spearman's notional *g* factor, otherwise known as 'general intelligence', a proposed unitary measure of individual intellectual ability. Although frontal lobe damage does not necessarily affect intelligence as measured by the WAIS (Wechsler Adult Intelligence Scale) Duncan argues that this is because the WAIS relies of past experience. He relates executive functioning to 'fluid intelligence', as might be tested by Raven's Progressive Matrices, a non-verbal test supposedly free of influences from past experience. In a later paper Duncan et al (1997) describe *g* in terms of "constructing an effective task plan by activation of appropriate goals and requirements". Therefore Duncan sees the executive system as a goal focused process that marshals cognitive resources in pursuit of a preconceived plan. Does this really capture all of the executive system's capacity ? It does seem to sidestep more reactive processes such as those involved in social interaction that may not always be goal focused.

Norman and Shallice (1980) have the most complete account of the executive system with their Contention Scheduling / Supervisory Attentional System model. The executive system is conceptualised in terms of two pivotal components within a selection-for-action system.

The contention scheduler is considered to mediate the effect of the environment (which may 'trigger' certain actions) on the selection of automatic or routine actions. When triggered the contention scheduling component controls the mutual inhibition of competing actions (since many actions may be triggered at once) to select the most appropriate course of action. The supervisory attentional system is considered to intervene in non-routine situations when actions have to be altered or inhibited because of a novel encounter or decision making process.

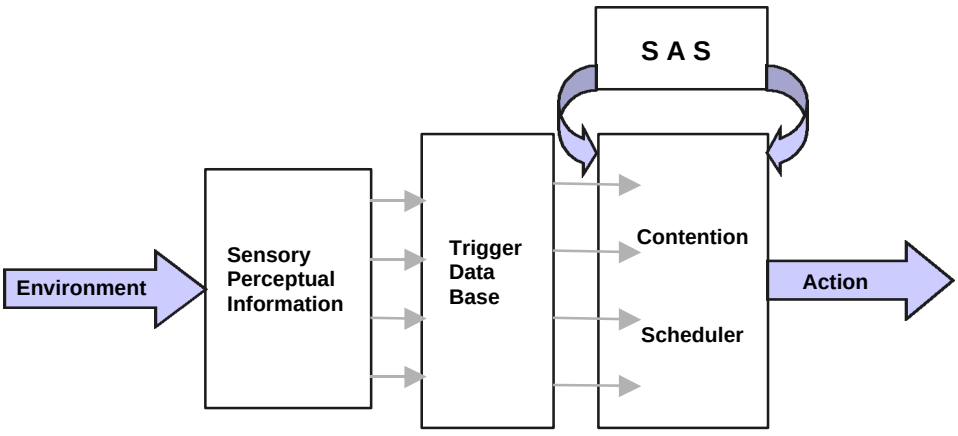

figure 1 – Supervisory attentional / contention scheduling model

This system provides an excellent theoretical basis for the executive system and accounts for the executive disorders we have covered. For example, utilisation behaviour can be explained as a deficit in the supervisory attentional system meaning inappropriate actions cannot be inhibited correctly. On the other hand, akinetic mutism can be explained as damage to the contention scheduling system so actions are not correctly initiated.

Conclusions

- The executive system is concerned with the co-ordination of other cognitive resources.
- It is needed when automatic psychological processes would not be sufficient, in cases of novel situations.
- Damage to the system can have a wide range of effects in different domains, for example in social interaction, executive memory and abstract thinking.
- Norman and Shallice (1986) have proposed a comprehensive model of executive functions (the contention scheduling / supervisory attentional model) which outlines a selection-for-action system which mediates the selection of automatic actions (contention scheduling) with the ability to intervene where necessary (supervisory attentional system).

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