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III The Development of the Will: A Neuropsychological Analysis of Gilles de la Tourette Syndrome.

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"No wise fish would go anywhere without a porpoise . . . Why, if a fish came to *me*, and told me he was going on a journey, I should say, "With what porpoise?" (The Mock Turtle, in *Alice in Wonderland*. Quoted by Boden, 1987, p.664).

In a volume concerned with the development of a concept of self and its dysfunction, it is important to begin with some key conceptual distinctions, so as to confine the discussion to specific mechanisms and processes. The concept of self is otherwise just too nebulous, too slippery, and in danger of being scientifically worthless. To this end, along with other contributors to this volume, we distinguish several different levels of self concept, namely, self-esteem, self-recognition, self-identity, self-consciousness, and self-control. In this chapter we restrict our discussion to a consideration of the last of these levels, self-control. Other chapters in this volume take up the various levels of self-concept that we do not address (see for example, Chandler, Harter and Marold, and Marold, this volume). Regarding terminology, we use the term self-control synonymously with the terms volition, or the will, and for brevity opt to use the last of these in most instances.

In the first part of the chapter, we discuss the development of the will, and the problems in defining this. We consider various criteria for identifying an act as volitional, and summarize some of the evidence from infancy research in relation to these different criteria. In the second part of this chapter we then consider the development of a specific neurocognitive mechanism, the *Intention Editor* (Baron-Cohen, Cross, Crowson, and Robertson, 1993), which we suggest begins to function in early childhood. We go on to review its status as a possible

We are indebted to Michael Trimble and Donald Cohen for their support and guidance in this work. Parts of this chapter are reprinted from Baron-Cohen, Cross, Crowson, and Robertson, 1993.

sub-system with the *Supervisory Attentional System* (Shallice, 1988), a mechanism that controls planning in general. The Intention Editor is examined as one key mechanism that underlies the will. We then turn to consider the hypothesis that a dysfunction in the development of the Intention Editor plays a significant role in the problems of children with Gilles de la Tourette Syndrome (GTS), and argue that experimental neuropsychological research in this area may be fruitful not only for learning about this disorder, but also for casting light on the development of this aspect of the self.

The Development of the Will in Infancy

Willed action has often been thought to be a quality unique to human beings. Young (1987, p. 147) argues that this view is mistaken, and that equivalent but simpler behaviours can be found in other organisms. But what is meant by the will? Libet (1985) defines an act as voluntary, and a function of the subject's will, "when (a) it arises endogenously, not in direct response to an external stimulus or cue; (b) there are no externally imposed restrictions or compulsions that directly or immediately control subjects' initiation and performance of the act; and (c) subjects *feel* introspectively that they are performing the act on their own initiative and that they are *free* to start or not start the act as they wish" (*ibid*, p.529–530). This definition works reasonably well for adults with language, who can act as informants. However, to make any headway in this area as regards infants, we are forced into identifying *behavioural criteria* for an infant's act being under self-control, or volition. We begin by examining some possibilities.

Criterion 1: Distinguishing Reflexive vs Flexible Behaviour

The traditional view is that willed action is behaviour that is *not reflexive*. This begs the question as to what a reflex is. This has been a major concern in the history of neurology and neuropsychology (Sherrington, 1906; see also Merton, 1987). In general, reflexes are "the automatic reactions of the nervous system to stimuli impinging on the body or arising within it" (*ibid*, p. 676).[1] Using this definition, it is clear that human babies manifest a range of reflexes (Prechtl, 1974, 1986). For example, infants show the pupil reflex to light, the knee jerk reflex, the startle reflex (involving arm flexion triggered by a loud noise), the Moro reflex (elicited by allowing the baby's head to drop slightly, which results in a sequence of arm-extension and fist clenching), and the stepping reflex (elicited when the infant is supported in an upright posture over a surface so

[1] Some reflexes do clearly come under a degree of voluntary control (e.g., coughing can be inhibited until the intermission of concerts; urination can be controlled by the second year of life, etc).

that pressure is exerted on the sole of the foot). Bremner (1988, p.35) provides a good review of these neonatal reflexes, and these seem relatively straight forward to identify. However, an important question to ask is what would count as examples of infant behaviour that are *not* reflexive, and may therefore be signs of early (volitional) self-control?

As Merton (1987, p. 677) writes, "The point at which an animal's responses to stimuli cease to be regarded as a reflex and are called deliberate or voluntary, or by some similar term, is ill-defined". In thinking about infancy, however, one candidate behaviour for being non-reflexive might be visual tracking. Whilst infants seem poor at controlling their limbs, they seem precociously in control of their eye movements. Neonates, for example, fixate interesting stationary objects and follow moving objects (Banks and Salapatek, 1983). Bremner (1988, p. 39) characterizes this as follows: "While their eye movements are rather sluggish and, in the case of tracking, very much less smooth than those of adults, we are quite definitely dealing with behaviours that are visually guided. Rather than running off in a fixed pattern after the initiating stimulus, these eye movements are altered more or less continuously in response to information about object position". Such *flexibility in response to an object* seems a plausible criterion in identifying non-reflexive behaviour. Of course, under a strict analysis, flexibility by itself need not imply a behaviour is volitional. It might simply be evidence of a reflex that is "wired" for flexibility. However, given the inflexibility of most reflexes, flexibility may be a *liberal* index of volition.

Criterion 2: Expressing Interest and Preferences

One important tool for investigating infant cognition is the preferential looking paradigm. In this method, the infant is presented with two stimulus displays simultaneously, and the duration of the infant's looking time to each display is measured. A longer looking time is taken as a measure of the infant's ability to discriminate the two stimulus sets, as well as their preference for one stimulus over the other. There is now a wealth of infancy data using this technique. A good review of this can be found in Karmiloff-Smith (1992). For example, Johnson and Morton (1991) presented infants with 2D stimuli on a head-shaped board. The stimuli included a "face" with normal configuration of the eyes, nose and mouth, and a "face" with a scrambled configuration of these features. The studies showed that neonates looked for longer periods at, and tracked further using both head and eye movements, the stimuli with face-like arrangements. Such experiments not only give us a clue about the starting state of the infant's perceptual system, to what it is pre-programmed to attend, but also what the infant "prefers".

If we accept the argument that longer looking time, i.e., preference, is an index of what the infant is *interested in*, can we extend the argument further to propose that interest is itself a sign of volition? There are problems in this argument, since a preference could simply be a "drive" to prefer stimulus A over stimulus B. Intuitively, it might seem that we *choose* to look at what we are interested in. Such intuitions may however be misleading.

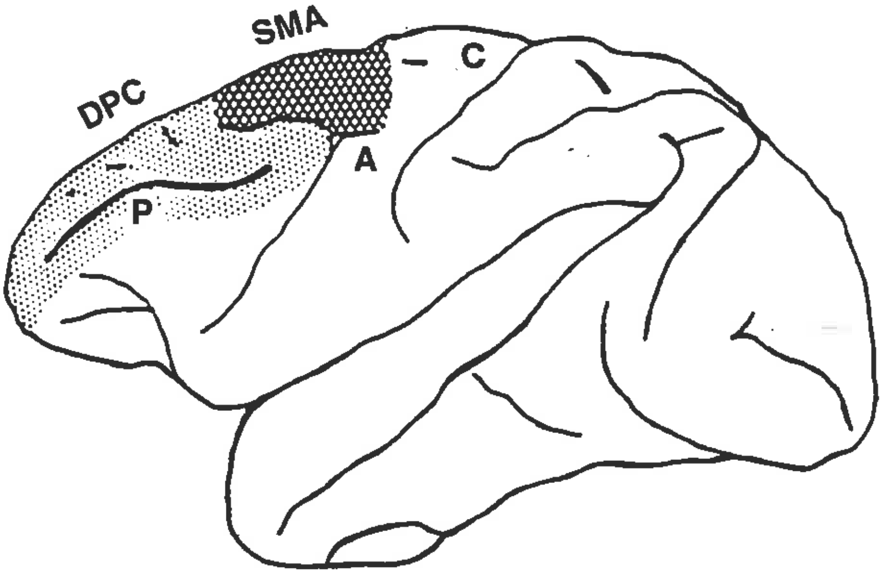

FIGURE 1 A lateral view of the rhesus monkey (*macaca mulatta*) brain, showing supplementary motor area (SMA) as hatched lines (SMA extends further down the midline than can be shown in this diagram), and dorsolateral prefrontal cortex (DPC) as dotted lines. C = central sulcus; A = arcuate sulcus; P = principal sulcus. Reproduced from Diamond (1991), with permission.

Criterion 3: Inhibition

Clearly, one crucial achievement in the early development of self-control must be *inhibition*. Diamond (1991) discusses the growth of inhibition as essentially the inhibition of action tendencies. The importance of motor inhibition has a relatively long history (e.g., Twitchell, 1965, 1970). Inhibition of action tendencies begin, on Diamond's account, around 8–12 months, and depends crucially on the maturation of the the dorsolateral prefrontal cortex (DPC: see Figure 1). An action response tendency she defines as the strongest response of the moment—e.g., reaching straight for a visible goal.

Diamond's notion of inhibition is in many ways synonymous with the notion of self-control, or the will. Thus, inhibition (or absence) of a routine response to a stimulus may count as a useful index of willed action.

Criterion 4: Identifying Intentions

Within philosophy of mind the problem of defining volition has been tackled by employing a different conceptual distinction, namely, identifying when behaviour is intentional versus non-intentional. Frye (1991) discusses some of the applications of the philosophical arguments to the analysis of infant behaviour. He highlights the work of the British philosopher, Anscombe (1957). In Anscombe's model, an act is intentional if it is performed to bring about a future state of affairs. Another way of putting this is to say that an act is intentional if the act is composed of both a goal and a means to that goal. Thus, an act is intentional if the actor did x in order to bring about y. This analysis allows one to distinguish an intentional act from non-intentional acts, such as accidents, coincidences, mistakes, or cases of "fortuitous success". Ascombe's criterion seems conceptually tighter than the previous criteria. However, without a way of identifying what the person's goal is, and whether their action was carried out as a means to that goal, we are left with the same problem of how to decide that their act was intentional. This is particularly troublesome in the case of infants, who have no language to inform us of their reasons for acting.

Frye (1991) argues that to some extent these problems are surmountable. His solution has been to carry out experiments in which the consequences of an infant's action are changed, and then observe if the infant shows a surprise reaction. The idea of using the surprise reaction as an index of cognition is discussed in detail elsewhere (Charlesworth, 1969). Frye reports the results of experiments of this nature, with infants age 8, 16, and 24 months. These found that even children in the youngest of these age groups were able to pull a cloth (the means) in order to bring a toy into reach (the goal), and showed surprise (as independently rated by blind observers) following the changed goal manipulations, when the toy went backwards or remained standing still when the cloth was pulled. Such studies suggest that intentional actions are probably present in 8 month olds. Naturally, such tests may underestimate intentionality in younger infants, since the tasks depend on motor skills such as pulling cloths, etc.

We are attracted by Frye's approach to the problem of defining volition, in that it places at centre stage the notion of *intentions* driving action.[2] In the next section, we extend this idea to argue that in the first 5 or 6 years of life, normal children develop the capacity to edit simultaneously competing intentions.

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[2] Note Boden (1987) on this notion: "Some psychologists refuse point blank to admit the concept of purpose into their theories, regarding it as not merely unhelpful but positively mystifying. Others are content to use it as convenient shorthand, but believe that purposive explanations of behaviour could in principle be replaced by complicated stimulus-response or neurophysiological explanations in which the concept of purpose would not appear. Yet others insist that psychology must give a central role to purpose, that action and experience cannot possibly be explained without it." (p. 664). We fall into this latter group, but hold the assumption—along with many these days—that intentions, purposes, etc, are representations that are instantiated on a cerebral level, and are therefore not pure "mind-stuff", nor are they mysterious. Positing intentions in no way entails dualism.

The Intention Editor

Our notion is that in early childhood, a qualitatively new stage of self-control emerges: the ability to edit simultaneously competing intentions. We suggest this reflects the maturation of a neurocognitive mechanism, which we call the Intention Editor (Baron-Cohen et al, 1993). For the purposes of explicating this idea, we need to clarify certain assumptions that we make. First, we assume that at one level of description, *intentions* drive action. They not only drive our motor action, but also our speech, and even some of our thought. Here, we define intentions as representations of future action, speech or thought. In Figure 2, which is a functional diagram of our model, intentions are shown as housed in a Store, and can be activated by either perceptual stimuli, or by each other, or by other cognitions (Frith and Done, 1989). As was noted in Frye's (1991) account earlier, such intentions contain information specifying not only the goal-state of a future action, utterance, or thought, but also information about how to implement or reach that goal state. This notion is consistent with the classical theories of volition (see Kimble and Perlmuter, 1970, for a review), such as that by William James (1890)[3].

Secondly, we assume that even after intentions have been accessed and activated, there is a point at which they can be inhibited. In Figure 2, we depict this by showing an Inhibitor, the function of which is simply to change the activation weight of a particular intention from positive to negative. The Inhibitor is held to be a very simple mechanism in that it can only act on one intention at a time. The notion of an Inhibitor of course reminds us that intentions are separable from the actions they drive.

However, what happens when *several* intentions have been activated? Here, the Inhibitor cannot deactivate these, because (as stated above) it can only operate on one intention at at time. Here we need to introduce the second mechanism, the Intention Editor, which is only triggered when there are *two or more competing intentions* that have been simultaneously activated, only one of which can actually be executed. The others are then deactivated, and are thus not executed.

So, when given a task such as **Do x** (e.g., push the blue button), this may entail just one intention being activated. We call this a *Single Intention Task.* Many of the examples of volitional behaviour in infancy described earlier would be examples of Single Intention actions. Here the Inhibitor would be able to control action versus inaction. Given a task which requires the subject to perform a sequence of actions, one at a time, such as **Do x, then do y** (e.g., push the blue button, then the red button), this, too, may entail just *one* intention being activated and executed *at a time.* We call this a (short) *Serial Intention*

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[3] In James' theory, an action is caused by an *image*. In Miller, Gallanter and Pribam's (1960) theory an action is caused by a *plan*. In Luria's (1966) theory, an action is caused by a *motor plan*. The term *plan* would do equally well in our model, but we opt for the term *intention*.

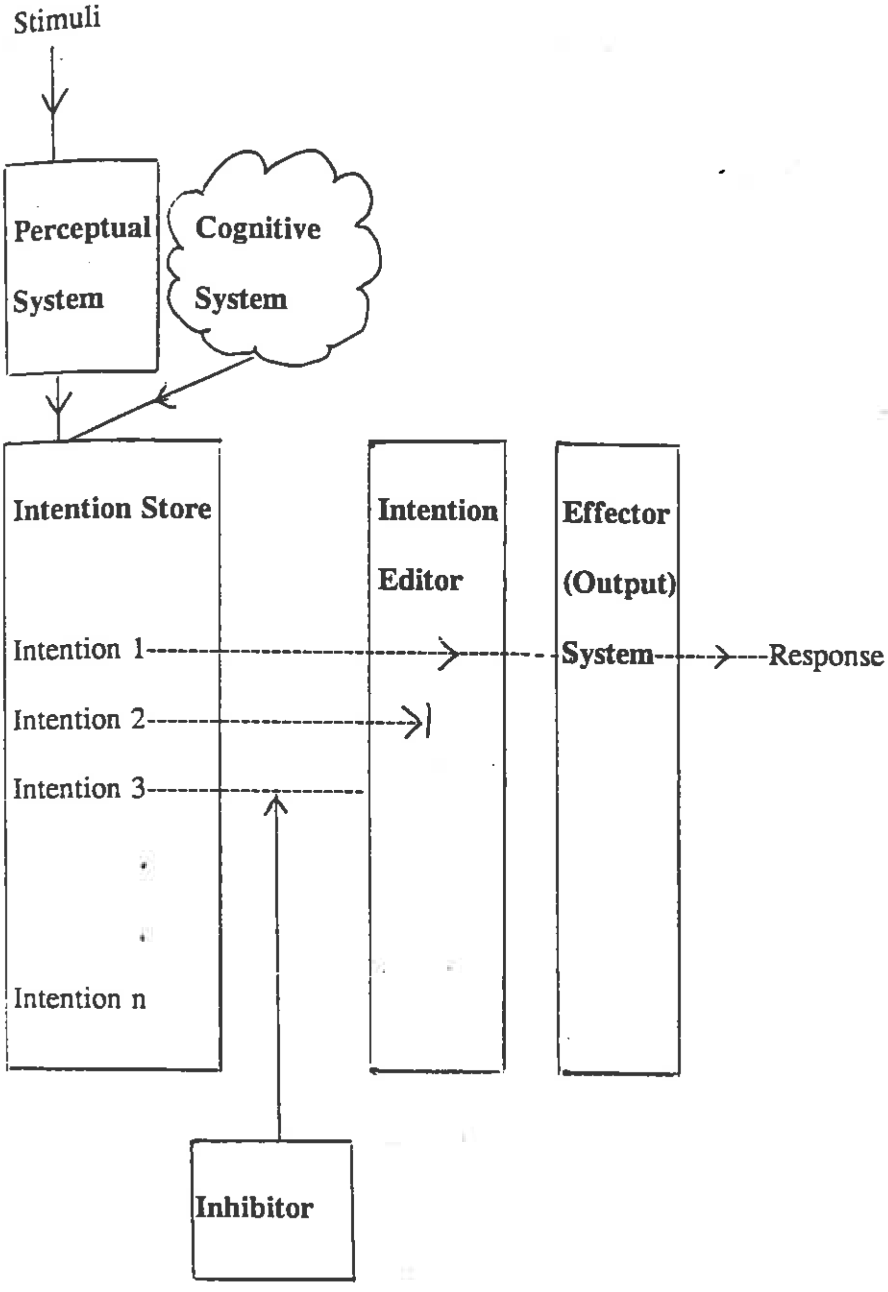

FIGURE 2 A functional model of intentional control. The Inhibitor changes the activation of an intention from +ive to −ive, but only acts on one intention at a time. (Here it is shown acting on Intention 3). The Intention Editor is triggered when several intentions are activated simultaneously. (Here, Intentions 1–3 are simultaneously activated). The Intention Editor passes one (here Intention 1) on to an Effector system, whilst deactivating the other(s: here Intention 2). In GTS, the Intention Editor is hypothesized to be impaired, whilst the Inhibitor is intact.

TABLE 1 Different Task Types

	Task Description	Intention Analysis of each Task
Simple Intention Task:	Do x.	Activate intention x, then execute intention x.
(Short) Serial Intention Task:	Do x; then do y.	Activate intention x, then execute intention x; then activate intention y, then execute intention y.
(Long) Serial Intention Task:	Do x; then do y; then do z.	Activate intention x, then execute intention x; then activate intention y, then execute intention y; then activate intention z, then execute intention z.
Parallel Intention Task:	Do x and y simultaneously.	Activate *both* intention x and intention y *simultaneously*, then edit one, then execute the other.

Task. It is what, in Diamond's (1991) earlier account, was called a "relational" ability. Similarly, if the task is **Do x, then do y, then do z** (e.g., push the red button, then the blue button, then the green button), this may still only entail *one* intention being activated and executed *at a time*, even though the sequence has lengthened. We call this a (long) Serial Intention Task. This would still come within Diamond's category of "relational" actions.

In contrast, the Intention Editor is *necessarily* triggered in *Parallel Intention Tasks*, in which the subject has to do two different things simultaneously. An clear example of a Parallel Intention Task, in our view, is the Stroop Test (Stroop, 1935), in which the intention to read the word is activated by the stimulus, yet an alternative intention (to name the colour of the ink) is activated by the Experimenter's instruction. These different Task Types are summarized in Table 1, along with analyses of each Task Type in terms of the number of intentions that are *minimally* activated in each.

We assume that intentions vary in terms of their potential for triggering the Editor. That is, some intentions are dangerous (e.g., the intention to hit, etc) and/or are socially disapproved of (e.g., the intention to swear in formal, public settings, etc). In our model, these sort of intentions are therefore tagged with high values. Other intentions are relatively harmless (e.g., the intention to fiddle with one's hair) and/or are socially acceptable (e.g., the intention to whistle a tune whilst walking in public). In our model, these are therefore tagged with low values. The Intention Editor is triggered more readily by intentions with higher values. The value tagged to an intention is presumably derived from both learning (e.g., a social rule) and biology (e.g., avoiding pain).

We conceive of the Intention Editor as part of our *central* processes. It does not operate on any one output system (motor, speech or thought), but rather it operates on the intentions themselves. For this last assumption to be correct, one would expect, for example, that once this mechanism had developed in the normal child, it should operate over the range of output systems. Later in this chapter, we review some preliminary evidence both for the gradual development of this mechanism in the normal case, and for its place in central processes. But first we turn to consider two key questions from the perspective of developmental psychopathology (Cicchetti, 1984): Might this framework for understanding the normal development of the will help make sense of a clinical phenomenon? If so, what light might this shed on the underlying processes? We have begun to explore the developmental psychopathology of the will by testing the hypothesis that children with GTS have an abnormality in the development of the Intention Editor (but not in the Inhibitor). Before considering our evidence relevant to this hypothesis, we first describe what GTS is.

Gilles de la Tourette Syndrome (GTS)

The first clear description of this syndrome was made by Itard (1825). Georges Gilles de la Tourette (1885) went on to describe 8 more similar cases, emphasizing a *triad* of symptoms: multiple tics, coprolalia (unprovoked swearing) and echolalia (repetitive speech). Current diagnostic criteria for GTS require the presence of multiple motor tics, and at least one vocal tic, both of which must exceed a year's duration and begin before the age of 21 years (American Psychiatric Association, 1987). The location, number, frequency, complexity and severity of the tics characteristically change over time.

Although the exact prevalence of GTS is unknown, a currently accepted figure is 1 in 1000 males, and 1 in 10,000 females (Leckman, Knorr, Rassmusson, and Cohen, 1991). The mean onset of the symptoms is seven years old. It is found in all social classes and across cultures (Robertson, 1989). Excellent and up to date reviews of the disorder can be found in Cohen (1991) or Roberston and Yakeley (1993).

As Gilles de la Tourette (1885) suggested, a triad of symptoms tends to cluster in these patients, justifying the use of the term 'syndrome'. In the light of more recent research, many authors have suggested that the triad be conceptualised in terms of (a) motor tics, (b) vocal tics, and (c) obsessive thinking, since different patients manifest all or any combination of these three symptoms. We briefly summarise these three areas of abnormality:

Motor tics: The most frequent initial motor tics involve the eyes (such as eye blinking), head nodding and facial grimacing. Patients also often exhibit movements such as touching, hitting, jumping, spitting, kicking and stamping, as well as abnormalities of gait (Robertson, 1989). Finally, motor tics with specific *content* (such as echopraxia [or the tendency to copy seen gestures involuntarily], and copropraxia [involuntary obscene gestures]) may also be present.

Vocal tics: These are either non-verbal (e.g., throat-clearing, barking, sniffing, hissing and clicking) or are word-related (e.g., palilalia [involuntary syllable repetition] and jargon), or are clearly verbal (e.g., explosive utterances, coprolalia, word-tics and echolalia).

Obsessive thoughts: Many patients with GTS also show Obsessive-Compulsive Behaviour (Frankel, Cummings, Robertson, Trimble, Hill, and Benson, 1986; Montgomery, Clayton, and Friedhoff, 1982; Robertson, Trimble, and Lees, 1988; Robertson, Channon, Baker, and Flynn, 1993). In addition, many relatives of patients with GTS also report obsessive thoughts and compulsive actions, in the absence of tics (Kurlan, Behr, J, Medved, L, Shoulson, I, Pauls, D, Kidd, J, & Kidd, K, 1986; Pauls, Leckman, Towbin, Zahner, and Cohen, 1986; Robertson & Gourdie, 1990).

GTS: An Abnormality in the Development of the Intention Editor?

Having briefly described the disorder of GTS, we move next to consider it in relation to the model described earlier. We suggest that the triad of motor tics, vocal tics and obsessive thoughts may all arise as a result of an abnormality in the Intention Editor, whilst the Inhibitor is intact. In our first empirical studies of this (Baron-Cohen et al, 1993), we reported two experimental tests of this hypothesis. The hypothesis seems plausible in that a failure of the Intention Editor would result in actions being performed involuntarily, words and sounds being uttered involuntarily, and a difficulty in "getting rid" of unwanted, intrusive thoughts - that is, the triad of symptoms in GTS. Moreover, we predicted this deficit would be seen only when the task involved several competing, simultaneously activated intentions (Parallel Intention Tasks), but would not be seen in control conditions (Simple or Serial Intention Tasks), in which the Inhibitor would be sufficient.

The Luria Hand Alternation Task

This task was first described by Luria (1966), and which he attributes to Ozeretskii (1930). The task involves *alternation* of different hand positions. The subject is shown how to do it and then asked to try it. The hand positions are simple: opening one hand while closing the other, then switching these *simultaneously*. This pattern must then be repeated over a series of trials. In formal terms, the task can be described as follows: **Do x and y simultaneously. Then switch to the opposite pattern.** This formal description meets the task requirements for the Intention Editor to be triggered (minimally a Parallel Intention Task). Luria's illustration of the task is shown in Figure 3.

McCarthy and Warrington (1990) discuss this task in relation to a pattern of errors Luria and other neurologists and neuropsychologists saw in patients with bilateral brain damage to the premotor cortex. These errors fell into 3 types: (a) non-fluent alternating, (b) non-simultaneous alternating, and (c) failure to alternate. The second and third of these error patterns are illus-

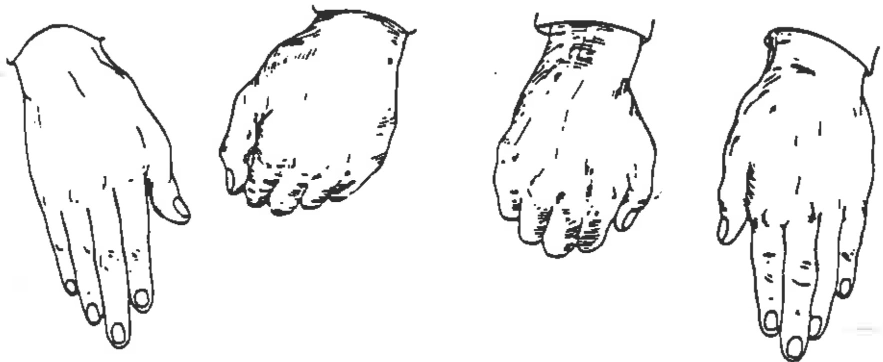

FIGURE 3 The Hand Alternation Task (reproduced from Luria, 1966, with permission).

trated in Figure 4 (reproduced from McCarthy and Warrington, 1990, with permission).

We predicted that if children with GTS were unable to edit intentions, then they would show errors on this task. In addition, we predicted that such errors would not occur in a normal control group of children. Our subjects were a group of 15 children with GTS, ranging from 6–18 years of age, with a mean of 12.31 years. They were all attending a specialist clinic at the National Hospital for Neurology and Neurosurgery in London, and had a clear diagnosis based on DSM-IIIR criteria. In order to collect data with this task from normal children, we assessed 15 normal children in each of 4 different age groups: 3, 4, 5, and 6 year olds. Finally, we predicted that children with GTS would not show errors on two different control tasks, which would only require the Inhibitor. The first control task was a (short) Serial Intention Task and therefore did not necessarily involve the Intention Editor. This task was as follows: open hands, then close hands, both hands performing the same action at the same time. In formal terms, it falls under the description **Do x, then do y.** The second control task was a (long) Serial Intention Task. This task was one of Luria's (1966) sequential movement tasks, the "fist-edge-palm" test: Using one hand, first make a fist, then hold out the hand in a rigid and vertical position, then turn the hand so that the palm faces upwards. In formal terms, it falls under the description **Do x, then do y, then do z.** In fact, all subjects with GTS achieved perfect performance (10 repetitions) on these control tasks, providing there was no pressure of time.

Figure 5 shows the mean best score for each group, on the experimental task. As can be seen, there is a clear progression among the normal groups, from 3 years through to 6 years of age. 3 year olds were significantly worse than 4 year olds and 4 year olds significantly worse than 5 year olds, though the 5 and 6 year olds did not differ. The five year olds were the youngest normal group to show ceiling performance (10 fluent, simultaneous alternations in a row), although this was not attained on the first trial by the majority of 5 year olds. In contrast, all but 3 of the 6 year olds were able to produce 10 correct alternations on the

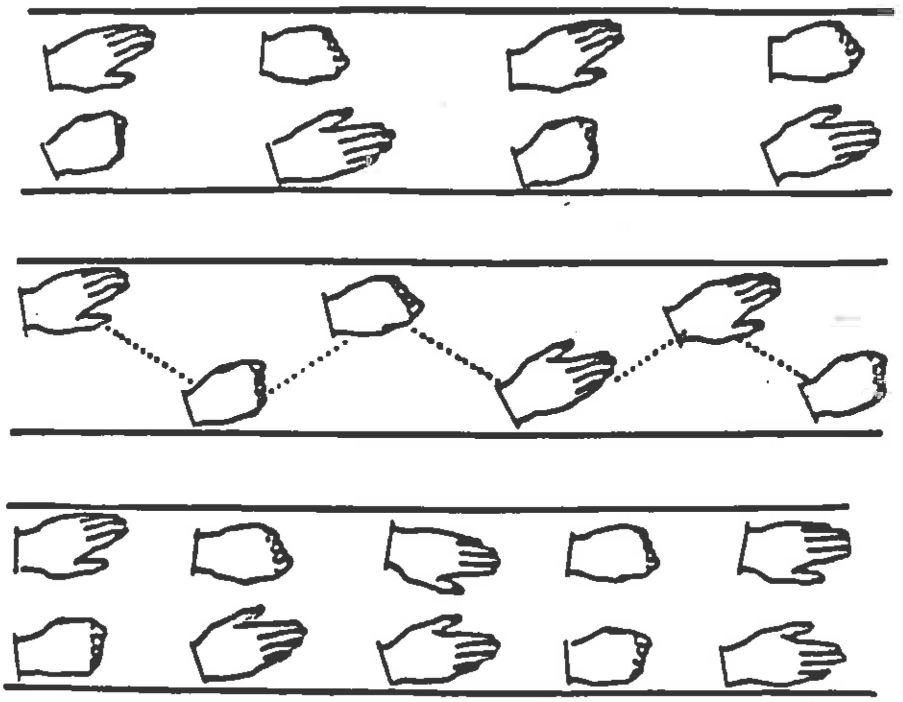

FIGURE 4 Correct and incorrect responses on the Hand-Alternation Task (reproduced from McCarthy and Warrington, 1990, with permission). Top line = correct; Middle line = Error 1 (Non-simultaneous alternating); Bottom line = Error 2 (Failure to alternate).

first trial, the other 3 doing so on the second trial. As predicted, the children with GTS made more errors than either the 5 or the 6 year olds.

On Luria's Hand Alternation Task, then, normal 5 and 6 year olds showed ceiling performance, after a relatively protracted development of this skill in the preceding two years. Llamas and Diamond (1991) report similar results. In contrast, we found that children with GTS, despite being considerably older, made significantly more errors than the 5 and 6 year olds. Given the similar deficits on this task by Luria's patients with damage to the frontal cortex, this would implicate a role for frontal pathology in children with GTS. There is some evidence for frontal abnormalities in GTS, from neuroimaging studies (Chase, Foster, Fedio, Brooks, Mansi, Kessler, and Dichiri, 1984; Chase, Geoffrey, Gillespie, and Burrows, 1986; Hall, Costa, Shields, Heavens, Robertson, and Ell, 1990).

The results from the Hand Alternation Task therefore constitute preliminary evidence in support of the hypothesis that these children have an abnormality in the development of the Intention Editor. However, by itself this might simply indicate a motor deficit, not a *central* impairment. This is particularly important because the task is quite complex in motor terms. We therefore employed an equivalent non-motor task, described next.

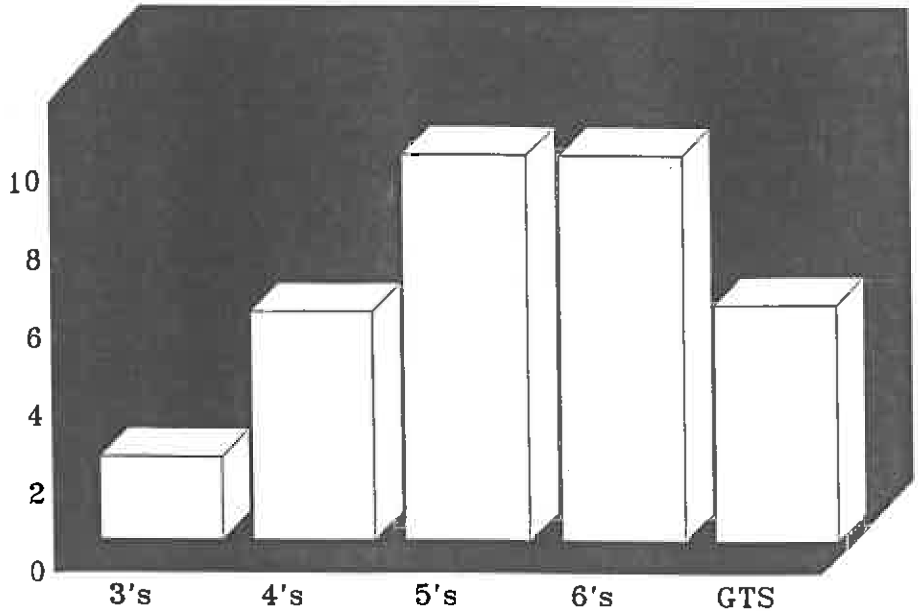

FIGURE 5 Results on the Luria Hand Alternation Test, expressed as mean best score (maximum = 10).

The Yes and No Game

Whereas in the Hand Alternation Task the subject had to execute one intention whilst inhibiting another in the motor domain, in the Yes and No Game we tested the subject's ability to do the same in the domain of speech. We used a well-known British game that is seen in parent-child play as well as child-child interaction, but which had not been used as a formal experimental procedure before, to the best of our knowledge. In this game, the subject is told that to win the game he or she must not say "Yes" or "No" in response to anything the experimenter might ask. Since these words are the usual ways of answering closed questions, the subject has to inhibit the strongly activated intention to say these words, and instead think of alternative ways to word their answer. For example, the experimenter might ask a subject called Michael "Is your name Michael?", to which the subject could reply "It is", or "That's right", etc. Whilst this task does not parallel the Luria Hand Alternation Task in all of its overt respects (e.g., in speech it is impossible to produce two observable responses simultaneously, whilst in movement this is possible), they are nevertheless similar in one key respect: They are both Parallel Intention Tasks, in that they both involve two intentions being activated simultaneously, one of which is edited and the other of which is translated into action.

In addition, the subjects with GTS were given a control task in which they simply had to say Yes, No, 10 times in a row. This is a (short) Serial Intention

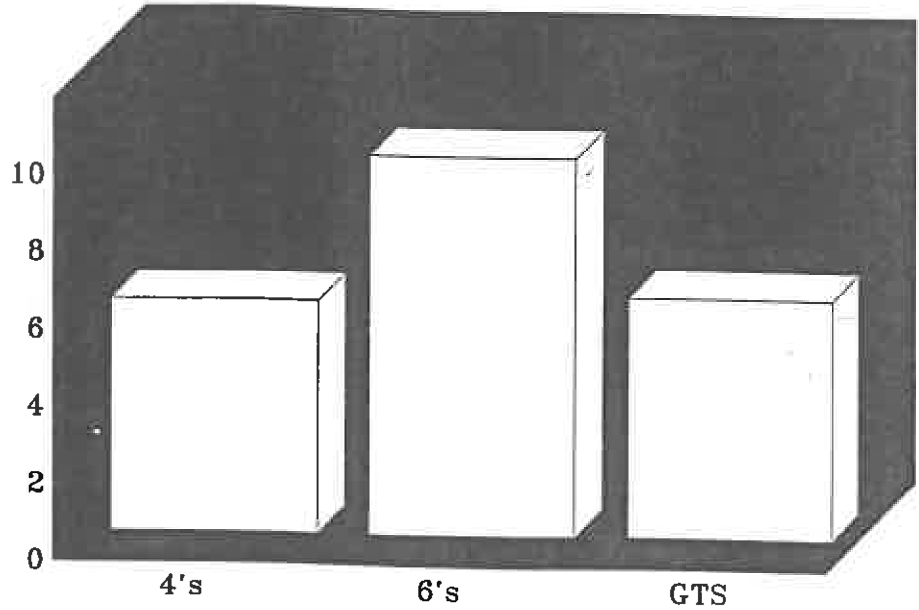

FIGURE 6 Results on the Yes and No Game, expressed as mean best score (maximum = 10).

Task, since in formal terms it falls under the description **Do x, then do y.** There were 10 trials, in random order. Any errors made were recorded. It was chosen in order to test the prediction that this would not present any difficulty for subjects with GTS, given that it could be carried out without having to activate two different intentions *simultaneously,* i.e., only involving the Inhibitor, but not the Intention Editor.

All of the subjects with GTS were at ceiling on the control task. Figure 6 shows the mean best score on the Experimental Task for each group. As can be seen, there is again a clear progression among the normal groups, from 4 to 6 years of age. 4 year olds were significantly worse than 6 year olds. All but 4 of the 6 year olds were able to produce 10 correct alternations on the first trial, the others doing so on the second or third trial. We assume that 6 year olds reflect the adult level of competence on this task. Again, as predicted, the children with GTS made more errors than the 6 year olds. The 4 year olds did not differ from the children with GTS.

Once again, then, both developmental change and pathology were identified on this task. There was an improvement between ages 4 and 6 in the normal groups, paralleling changes observed on the Luria Hand Alternation Task. Children with GTS, despite their chronological age advantage (to recap: they had a mean age of 12 years old), were significantly worse than normal 6 year olds at inhibiting an intention to say one thing (e.g., "Yes") whilst executing an intention to say something else (e.g., "That's right"). This was not due to failure to understand the rules of the game, as subjects always showed their awareness that they had made an error, by laughing and expressing 'annoyance' at their mistakes. Nor was it due to either perseveration, or an inability to follow simple instructions, or an inability to participate in a game, as their almost perfect performance on the control task demonstrated. It was only the Parallel Intention Task, which activates two different intentions *simultaneously*, and which is therefore held to require the Intention Editor, that elicited the deficit in subjects with GTS. These results are consistent with the hypothesis that the deficit detected in the Hand Alternation Task is not specifically motor in nature, but reflects a central system which operates on a range of output systems. We discuss the specificity of this mechanism next, by turning to a related mechanism.

The Supervisory Attention System

A related system is Shallice's (1988) *Supervisory Attentional System* (the SAS). To understand the SAS, we must first mention what Shallice calls the *Contention Scheduling System* (the CSS) which responds to external stimuli and repeats relevant, routine actions. For example, if a traffic light turns red when you are at a certain distance from it, you start braking. As Shallice (*ibid*, p.333) says, the "default option" is to brake. Another example he gives is reaching out to pull the light cord on entering a familiar room (Shallice, *ibid*, p.328). Both of these examples are routine action programs, or schemas, triggered simply by the situation. Shallice calls this process of routine selection between routine actions or thought operations "contention scheduling". This process sacrifices flexibility for speed of operation. The SAS, on the other hand, "has access to a representation of the environment and of the organism's intentions and cognitive capacities" (Shallice, *ibid*, p.335) and can oversee the CSS by activating or inhibiting alternative schemata. The primary function of the SAS therefore is to respond to novelty. Thus, in the A not B error (Diamond, 1991; Piaget, 1952), the SAS would be crucial in enabling the subject to switch responses appropriately. It is also seen as playing an essential part in decision-making. Shallice (1988) proposes that the SAS is impaired in patients with frontal lobe syndrome, resulting in disinhibition of actions.

We doubt that children with GTS are *generally* impaired in the SAS, in that they appear to be able to switch to new actions in an action sequence, and they do not appear to be simply stimulus-driven in their actions. For example, utilization behaviour (L'Hermitte, 1984), that is, being unable to resist grasping and using objects that are in sight, has not been documented in these patients (though systematic research in this area is largely lacking), and yet utilization behaviour is "how contention scheduling should operate when it is not subject to Supervisory System control" (Shallice, *ibid*, p.343). Nor do children with GTS seem unable to shift response in novel ways, which again would be predicted by a *global* SAS deficit. A relevant test of this would be the Wisconsin Card Sorting Test (Grant and Berg, 1948), which as far as we are aware has not been used with this group. Our prediction would be however that patients with GTS would be able to sort the cards according to novel rules when so instructed, rather than showing classic, "frontal" perseveration. If this is correct, this would suggest that in the case of children with GTS, the SAS is in general intact. One related test of the SAS that has been used with patients with GTS is the Go-No Go task, which found no specific impairment in this group (Sally Ozonoff, personal communication, 1993). However, it seems plausible that the Intention Editor is a specific component *within* the SAS, dedicated to editing out one of several intentions that are competing in *parallel*. This notion is compatible with Shallice's (*ibid*, p.352) proposal that the SAS is not internally equipotential, but may have modular sub-processes. In his later work (Shallice and Burgess, 1992) he addresses this issue directly, in discussing the possible fractionation of the SAS (p. 133).

The SAS is often discussed as a cognitive model of the "executive function" (Lezak, 1983; Milner and Petrides, 1984). By executive function is meant "the ability to maintain an appropriate problem-solving set for attainment of a future goal. (It includes) planning, impulse control, inhibition of prepotent but incorrect responses, set maintainance, organized search, and flexibility of thought and action" (Ozonoff, in press, p. 5, MS). It is clearly a broad concept. Executive function has been studied more often in relation to the adult system, but has become an area of inquiry in developmental neuropsychology recently too (Dennis, 1991; Stuss, 1992). Following adult neuropsychological research, there is now little doubt that executive function relies on the frontal lobes or, a little more precisely, the frontal system. Damage to this results in what Baddeley and Wilson (1988) call the "dysexecutive sydrome" - broad deficits in planning skills. Impairments in executive function as measured by classical frontal neuropsychological tests (the Wisconsin Cart Sorting Test, the Go-No Go Test, and others) have been documented in children with Attention Deficit Hyperactivity Disorder (Shue and Douglas, 1992), suggesting they may indeed suffer from a global SAS deficit.

In summary, the claim that children with GTS are impaired in the development of the Intention Editor is more specific than the claim that they have generalized frontal problems, or generalized executive system problems, or generalized SAS problems. Nevertheless, the relationship between the SAS and the Intention Editor remains to be investigated more fully.

Conclusions

In this chapter we have considered the development of one aspect of the self, namely self-control. We have reviewed our model that in early childhood self-control undergoes a qualitative change with the maturation of a new mechanism, the Intention Editor. We have presented some preliminary evidence that children with GTS have a deficit in the Intention Editor, and propose that this might underlie the key symptoms in their behaviour. In this respect, we have extended and narrowed down previous accounts of the psychology of GTS

(Cohen, 1991). To date, we have reported how the Intention Editor normally comes into operation in laboratory tasks involving simultaneously competing intentions. In the real world, such tasks might include talking politely to someone whom you think little of (editing a competing intention to use impolite language), or sitting quietly whilst working (editing intentions to jump up or move around). The motor and vocal tics, as well as coprolàlia and copropraxia, that are features of GTS, can be seen as exactly the kinds of behaviours one would expect to see if this mechanism failed.

Characterizing the early development of this mechanism will require further experimental studies. Its study in clinical populations will allow us to address the question of whether different psychological processes that are held to be 'frontal' are independent of one another. For example, Baron-Cohen and Ring (in press) argue that the orbito-frontal region is particularly involved in the ability to attribute mental states, or what is often called a "theory of mind". This claim is consistent with the models developed by Stuss (1992) and Dennis (1991). One prediction would be that whilst children with GTS are impaired in the development of the Intention Editor, they are unimpaired in the development of a theory of mind. In contrast, we would expect children with autism to show the opposite pattern, given previous evidence (Baron-Cohen, Leslie and Frith, 1985; Baron-Cohen, 1990, 1993).

Secondly, clinical populations force us to make explicit how a postulated cognitive deficit relates to symptomatology. To say that an executive function deficit explains an observed behaviour pattern is clearly inadequate if such deficits are found in populations as diverse as schizophrenia (Frith, 1992), hyperactivity (Shue and Douglas, 1992), and autism (Ozonoff, Pennington, and Rogers, 1991). On the other hand, demonstrating deficits that are *specific* to different clinical populations does move us forward in understanding the relation between cognition and behaviour. In this respect, it will be important to test the functioning of the Intention Editor in a range of disorders, to establish the specificity of this deficit.

Finally, clinical groups afford us the opportunity to understand the interface between brain and cognition. Thus, recent neuroimaging studies of patients with GTS using SPECT suggest abnormalities in both the anterior cingulate (Chase et al, 1986; Moriarty, et al, 1993) and in the basal ganglia (Hall et al, 1990). This is consistent with GTS being caused by abnormalities in the basal ganglia-frontal circuitry, as Singer (1993) has argued. We are interested to explore the relationship between the Intention Editor and these neural structures in future studies.

The study of processes such as the Intention Editor in the normal case allow us to pursue a different set of questions. For example, it is not clear if "action slips" (Norman, 1981) in the normal individual are due to transient (non-pathological) changes in the functioning in the Intention Editor, or are the result of different processes altogether. Similarly, when we swear involuntarily, or in any other way "lose" our self-control, in what way is the Intention Editor involved in such behaviour? Indeed, if our model is correct, is it the case that we would all have GTS, but for the normal development of the Intention Editor?

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