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Executive dysfunctions in schizophrenia

Relationships to clinical manifestation

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Abstract Studies suggest that executive functions in patients with schizophrenia are markedly impaired as compared with normal controls. Most previous studies employed tests of executive functions adopted from frontal lobe neuropsychological paradigms based on lesion studies. This study employed several more recently developed theory-driven tests of executive functions addressing the construct of the supervisory attentional system. We explore the pattern of executive function impairment using factor analysis and subsequently investigate the relationships between these executive function factors and the clinical features in a sample of chronic schizophrenic patients. A total of 51 patients with chronic schizophrenia were recruited. The Sustained Attention Response to Task (SART), Six Elements Test (SET) and Hayling Sentence Completion Test (HSC) were used to assess executive functions. Three factors were identified within the executive function tests: 1) The "semantic inhibition factor" comprised items in the HSC, 2) the "action/attention inhibition" factor comprised the SART commission error and the SET rule-breaking score and 3) the "output generation factor" comprised the SET raw score and the correct SART response. Significant relationships were found between these derived factors and clinical features after partialling out the confounding effect of age, education and illness duration. The three theory-based tests of executive function were shown to have good construct validity among the group of chronic schizophrenic patients.

Key words executive functions · schizophrenia · supervisory attentional system

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Introduction

Schizophrenia is associated with a wide range of cognitive impairments including attention, memory and the executive function in addition to a global decline in intellectual functioning [1–4]. Schizophrenic patients have been found to perform poorly in traditional executive function tests such as the Wisconsin Card Sorting Test, the Trail Making Test and the Verbal Fluency test, as well as other tests sensitive to frontal lobe lesions [5–11]. A disorder of the executive functions has been considered important in accounts of the neuropsychology of the disorder [5, 6, 12, 13].

Increasing interest has recently arisen in applying the concept of the "supervisory attentional system" [14, 15] in explaining the nature of these executive dysfunctions. The supervisory attentional system is considered to be a key to the effective control of action in daily life, particularly in novel and complex situations. It is involved in the control of information flow on tasks involving initiation, planning, mental set-shifting, strategy allocation, monitoring and inhibition. In this conceptualization, the enactment of well-learned and routine responses (in the form of schema) are governed by their level of activation relative to possible competitors for the control of perceptual and output systems. The level of activation is determined by the strength of external or internal cues and the strength of their association with particular patterns of behaviour. Within such framework, everyday life complex activities such as those involved in driving a car can be executed appropriately but in a rather automatic and "stimulus-driven" fashion [14, 15]. The role of such a supervisory attentional system is to construct novel responses and to modify or suppress schema expression when the most activated schema is inappropriate to an overall goal. Impairment in this system would be expected to result in the inability to formulate a goal, to plan and to choose between alternative sequences of behaviour in order to reach a particular goal.

Shallice and Burgess [16] demonstrated that there was pre-eminence of frontal/executive deficits in the group of chronic schizophrenic patients. Others [12, 17, 18] also showed that there were differential impairments in the various components of executive functions in schizophrenic patients. Importantly, these deficits seem to have been present at the onset of illness and they persisted despite clinical improvement [12].

In spite of the theoretical significance of supervisory attentional system, it was not until recently that this construct was incorporated in the clinical and experimental assessment of executive functions. For instance, the Behavioural Assessment of the Dysexecutive Syndrome (BADS) [19] is specifically designed to assess the everyday life deficits of the executive functions in clinical groups. The Six Elements Test (SET) in the BADS, in particular, has been shown to exhibit superior ecological validity and sensitivity compared with other sub-tests in patients with schizophrenia [13] and other neurological disorders [20]. The SET consists of three types of tests (simple arithmetic, written picture-naming and dictation) each of which has two sub-tasks (thus constituting a total of six sub-tasks). Participants are required to attempt at least part of each of the six sub-tasks within 10 minutes, following the rule that they are not allowed to switch directly from a sub-task of one type to its counterpart of the same type. In achieving a good performance in the test, participants are thus required to mobilize the most appropriate schemata across the different sub-tasks consistently and optimally. Stuss et al. [21] have applied the concepts of supervisory attentional control to the process of attentional strategy allocation. They argue that the supervisory attentional system contains explicit schemata of how the task has been conducted and how well it has been executed in a previous session. Explicit monitoring of task performance can thus be used to check against any mismatch of representations or incorrect operations throughout the testing session. In SET scenario, it refers to the ability to maintain an optimal performance while sticking to the given rule across different sub-tasks.

Robertson et al. [22, 23] incorporate the construct of the supervisory attentional system in their test of sustained attention – the Sustained Attention to Response Task (SART). In this task, regularly presented non-target visual responses should be withheld for a rare target digit of "3". Owing to the regular, rhythmic pacing and the rarity of targets, the task encourages a strategy of fast, anticipatory, automatic responding. Within a supervisory attention framework, while the non-target response is frequently exogenously activated and elicited by the task, the activation level of the target response must be endogenously maintained close to threshold if it is to compete successfully when appropriate. SART is therefore designed to tap the ability to maintain sustained attention, which requires the higher cognitive control function of the supervisory attentional system.

The semantic inhibition function of the supervisory attentional system has also been assessed with the Hayling Sentence Completion Test (HSC) [24]. In this test, participants are presented with sentences in which the last word is missing but is strongly cued by the rest of the sentence. The test is divided into two parts. The first part of the test requires the participants to give words which appropriately complete the sentence. In the second part, however, words that make no sense in the context of the sentence are required. In doing so, the participants are required to suppress the most "salient" responses. Salient responses are those that are rapidly and strongly triggered by dint of intensity, categorical or semantically related words. The second part of the test therefore captures the construct of semantic inhibition. Recent studies using the HSC [25–27] have demonstrated that schizophrenic patients perform significantly worse as compared with normal controls in inhibiting their semantic responses to related cued words.

Another strength of these newly developed tests in assessing the executive functions in schizophrenic patients is the provision of two types of description of test-taking behaviour on top of quantitative test scores – the excesses of rule-breaking behaviour (commission error) as well as the deficiencies of output performance (poverty of action). Taking a supervisory attentional system framework, the excesses of rule-breaking behaviour can be considered as a failure to inhibit well-learned routine behaviour. A deficiency in output generation can be regarded as a consequence of such perseveration of disinhibited behaviour in addition to a deficit in initiation and strategy allocation as well as in monitoring. The recording of such qualitative features of test responses or test-taking behaviour has proved particularly fruitful in eliciting executive deficits in different clinical groups. It has been consistently shown that it is this type of observation (i. e. a failure to comply with test instructions) in patients with frontal lobe lesions, which proves most discriminating when compared with normal controls [28–30]. However, the construct validity of these tests has yet to be examined systematically in schizophrenia.

The purpose of the present study was to determine the relationships between a set of theoretically based measures of executive functions and clinical features in schizophrenia. We focused on the factor structure of the executive function tests and explored the relationships between these derived factors of the executive functions with symptomatology in schizophrenia. Given the qualitative and quantitative nature of these tests, it was hypothesized that two factors concerning inhibition and output performance would be identified within this patient group. The first one concerned the excess of rule-breaking behaviour or commission errors, due to the failure of the supervisory attentional system to modify or suppress schema expression when the most activated schema is inappropriate to an overall goal. The second factor related to the deficiency of output generation as a result of the poverty of action, such as the deficit in action initiation and monitoring as well as strategy allocation.

Methods and materials

Participants

A total of 51 (47 men, 4 women) inpatients with chronic schizophrenia were recruited in a regional psychiatric hospital. All patients met the DSM-III-R criteria for schizophrenia. Consensus diagnosis was made by interview with the Structured Clinical Interview for DSM-III-R. The mean age was 44 years (SD = 9.58) and the educational level was 8.2 years (SD = 2.86), with a mean illness duration of 21.3 years (SD = 9.5). The mean daily antipsychotic dose was 1263.13 mg (chlorpromazine equivalence) (SD = 1577.74, range 700–7143 mg). All participants were right-handed according to the Edinburgh Inventory [31].

Measures

Background cognition

The information, arithmetic, digit forward and backward span subscales of the Wechsler Adult Intelligence Test – III [32] were administered to all participants. A composite score was computed to reflect verbal intelligence. The Logical Memory and the Visual Reproduction Tests of the Wechsler Memory Test – III [33] were also implemented to all participants assessing verbal and visual aspects of memory performance.

Executive functions

The executive function tests selected for the present study were based on two main criteria. Firstly, they had to be theory-driven tests targeting specific components of executive function. Secondly, they had to be able to reflect both quantitative and qualitative features of the corresponding construct. The tests needed to give rise to scores reflecting overall output deficiency as well as excessive behaviour as a result of disinhibition. On the other hand, they also needed to be able to reflect test-taking or qualitative features of the neuropsychological examination. We have adopted three tests that met these criteria. These are the Sustained Attention Response to Task (SART), the Six Elements Test (SET) and the Hayling Sentence Completion Test (HSC). The applicability of these measures has also been validated in the Hong Kong setting [34, 35]. Table 1 summarizes the qualitative features of these tests.

The SART is a computerized test of sustained attention [22, 23]. A total of 225 single stimuli (25 instances of each of the nine Arabic numeric digits) were presented visually over a 4.3 minute period. Each digit was presented for 250 ms followed by a 900-ms mask of a symbol. Participants were to respond with a key press to each digit, except on the 25 occasions when the digit "3" appeared, when they were to withhold their response. Participants used their preferred hand. The target stimuli were distributed amongst the 225 trials in a pre-fixed quasi-random fashion. Participants were asked to give equal importance to accuracy and speed in performing the task. The output deficiency score was the total number of correct responses whereas the excessive error score was the commission error on non-target digits [22, 36].

The SET consists of three types of tests (simple arithmetic, written picture-naming and dictation), each of which has two sub-tasks (thus constituting a total of six sub-tasks). Participants were required to attempt at least part of each of the six sub-tasks within 10 minutes, following the rule that they were not allowed to switch directly from a sub-task of one type to its counterpart of the same type. The output deficiency score was calculated as the number of sub-tasks attempted (maximum = 6) minus the number of occasions the participant broke the switching rule. The total excessive error score was the total number of rule-breaking behaviour on the above rule of the task.

The HSC was used to assess semantic inhibition function of the supervisory attentional system. Participants were presented with sentences in which the last word was missing but was strongly suggested by the rest of the sentence. The test is divided into two parts. Part A (initiation section) requires participants to complete the sentences with the expected word. Part B (inhibition section) requires participants to complete the sentence with a word that does not make any sense in the context of the sentence. Participants were required to inhibit a strongly cued automatic response and, in addition, to find an unrelated response. There are two types of error to Part B: not finding a completely relevant word (category A: The captain wanted to stay with the sinking vessel; vessel being the relevant word required to complete the sentence) and finding a word that is semantically related to the strongly cued word (category B: The captain wanted to stay with the sinking aeroplane; aeroplane here is a word semantically related to vessels which are also a means of transport). The present study adopted the number of correct items as well as that of errors (in both categories A and B) in part B as the dependent measures.

Clinical symptoms

The Positive and Negative Syndrome Scale (PANSS) was used for the assessment of symptoms [37]. All items were rated from either 1 (absent) to 7 (extreme) according to the standardized instructions. Interrater reliability for the PANSS was evaluated with the intra-class correlation coefficient (ICC). The ICC was 0.83 for the global PANSS

Table 1 Description of the executive function tests

Tests	Items
Background Cognition	
Wechsler Adult Intelligence Test – III	Verbal performance: information, arithmetic, digit forward and backward span
Wechsler Memory Test – III	Verbal memory: logical memory immediate score Visual memory: visual reproduction immediate score
Executive Function Test	
Sustained Attention Response to Task	*Deficiency score:* number of correct response *Excess score:* number of commission error
Six Elements Test	*Deficiency score:* raw score of the task according to the standard manual *Excess score:* total number of rule-breaking responses
Hayling Sentence Completion Test (Part B)	*Deficiency score:* number of correct responses *Excess score:* number of errors in categories A and B

score; 0.84 for the positive symptoms sub-scale and 0.73 for the negative symptoms sub-scale.

Procedure

The university and the corresponding hospital ethics committees had approved the research plan and the recruitment procedure of the participants with schizophrenia. Informed consent was obtained from all the participants prior to the testing session in accordance with the Declaration of Helsinki.

Data analysis

A correlation analysis of the relationship between background cognition, executive function and neurological signs was carried out using partial correlation coefficients and controlling for age, illness duration and education. Given the nature and characteristics of the executive function tests, an exploratory factor analysis using principal-components analysis with varimax rotation was conducted to examine the embedded factors within these executive function tests. Components with eigenvalues of one or greater were included in the analysis. The interpretation and labelling of each component was based on component loadings of 0.5 or higher. The composite scores of the derived factors were then computed by adding the standardized scores of the corresponding factor and were used for subsequent data analysis. Pearson product-moment correlations, controlling for age, education and duration of illness, were conducted to investigate the relationship between the factor composite scores and clinical symptoms. The significant level was set at $p < 0.05$. Given the small sample and the exploratory nature of the present study, a correlation coefficient of more than 0.3 and a p-value less than 0.1 was also interpreted as having a trend association.

Results

Table 2 shows the descriptive statistics of the symptomatology, background cognition and executive functions. Preliminary correlation analyses were undertaken on the data from the demographics, verbal performance and memory composite scores as well as executive functions. There were significant correlations between age and logical memory immediate recall ($r = -0.289$, $p = 0.04$), visual reproduction immediate recall ($r = -0.383$, $p = 0.006$), visual reproduction delayed recall ($r = -0.316$, $p = 0.024$), SET raw score ($r = -0.299$, $p = 0.033$), SART correct response ($r = -0.29$, $p = 0.039$) and HSC category A error ($r = 0.361$, $p = 0.013$). For educational levels, however, a significant correlation was found only in verbal performance ($r = 0.398$, $p = 0.012$). The duration of illness was also correlated with negative symptoms ($r = 0.41$, $p = 0.003$), social impulsivity ($r = 0.328$, $p = 0.02$), general psychopathology (0.27, $p = 0.05$), and total symptom score of PANSS ($r = 0.343$, $p = 0.015$).

The raw score of SET was significantly correlated with negative symptom ($r = -0.257$, $p = 0.05$), general psychopathology ($r = -0.398$, $p = 0.004$), social impulsivity ($r = -0.377$, $p = 0.001$), and total symptoms score of PANSS ($r = -0.414$, $p = 0.003$). SART correct response was associated with negative symptom ($r = -0.409$, $p = 0.003$), general psychopathology ($r = -0358$, $p = 0.01$), social impulsivity ($r = -0332$, $p = 0.015$), and total symptoms score of PANSS ($r = -0461$, $p = 0.001$). Number of category B error of HSC was also correlated with negative symptom ($r = -0.265$, $p = 0.05$).

Exploratory factor analysis of executive function tests

An initial exploration of the relationship between different executive function tests was performed using principal component analysis with varimax rotation. Three factors with eigenvalues greater than one were extracted, accounting for 71.7 percent of the variance (Table 3). Factor 1 comprises all the HSC Part B scores, which require the participants to inhibit the salient responses driven by the meaning of the sentence. It is therefore best labelled as a semantic inhibition factor that is particularly capturing semantic performance and the corresponding inhibition.

The tests that load on factor 2 are the number of commission error of the SART and the rule-breaking behaviour of SET. These scores are characterized by the ability to inhibit action and attention.

Factor 3 simply consists of items of the correct num-

Table 2 Summary of executive functions, background cognition and clinical symptoms

Items	Summary scores Mean (SD)
Positive and Negative Syndrome Scale	
Positive symptoms	15.63 (5.62)
Negative symptoms	17.92 (6.8)
General psychopathology	35.59 (8.23)
Social/impulsivity symptoms	4.49 (2.1)
Total profile symptoms	73.61 (15.14)
Non-Executive Function	
Information subscale	11.2 (5.13)
Digit backward span	5 (1.69)
Digit forward span	10.62 (2.53)
Arithmetic	7.22 (3.14)
Memory	
Logical memory	
Immediate recall	4.53 (3.04)
Delayed recall	2.17 (2.67)
Visual reproduction	
Immediate recall	13.24 (5.69)
Delayed recall	10.04 (6.58)
Executive Function	
Six Elements Test	
Raw score	2.41 (1.45)
Number of rule-breaking errors	3.39 (6.38)
Sustained Attention Response to Task	
Number of correct response	157.31 (37.7)
Number of commission errors	11.27 (6.77)
Hayling Sentence Completion Test	
Part B	
Number of correct response	2.81 (3.17)
Mean reaction time of correct response	8.4 s (10.06)
Number of category A error	7.05 (3.92)
Mean reaction time category A errors	7.06 (5.88)
Number of category B error	4.64 (2.33)
Mean reaction time category B errors	8.84 (8.44)

Table 3 Component loadings of the executive function measures

	Semantic Inhibition	Action/Attention Inhibition	Output Generation
HSC Part B: number of category A errors	–0.962		
HSC Part B: number of correct items	0.794		
Hayling Test Part B: number of category B errors	0.629		
SART: number of commission errors		0.819	
SET: number of rule-breaking responses		0.743	
SART: number of correct responses			0.803
SET: raw score			0.754
Eigenvalues	2.05	1.51	1.47
Variance	29.3%	21.5%	20.9%

ber of responses of SART and the raw score of SET, which are mainly the output performance score of the corresponding tests. It is therefore considered as the factor concerning attention allocation, generation and output performance.

Partial correlations between background cognition, the executive function and symptomatology

Given the potential confounding effect of age, education level and the duration of the illness, these variables were therefore controlled in subsequent partial correlational analysis. Table 4 shows the partial correlation coefficients between the factor scores of the executive function tests, symptomatology as well as background cognition after partialling out age, education level and illness duration. In general, significant correlations were found between the derived executive function factors and different types of symptoms in schizophrenia. The output generation factor was inversely correlated with negative symptoms ($r = -0.427$, $p = 0.004$), social/impulsivity symptoms ($r = -0.308$, $p = 0.045$) and the total PANSS score ($r = -0.421$, $p = 0.005$). A trend was also found in general psychopathology symptoms ($r = -0.271$, $p = 0.079$). A significant correlation was found in semantic inhibition and social/impulsivity symptoms ($r = 0.451$, $p = 0.01$). The action/attention inhibition factor was also significantly associated with social/impulsivity symptoms ($r = 0.293$, $p = 0.05$). No significant correlation was found between semantic inhibition and clinical symptoms.

Positive symptoms were associated with the logical memory immediate score ($r = 0.336$, $p = 0.048$) and the visual reproduction delayed score ($r = 0.385$, $p = 0.02$). Negative symptoms were inversely associated with logical memory (immediate score: $r = -0.389$, $p = 0.025$; delayed score: $r = -0.394$, $p = 0.019$) and the visual reproduction immediate score ($r = -0.384$, $p = 0.023$). A trend of correlation was found in verbal performance ($r = -0.316$, $p = 0.065$) and the visual reproduction delayed score ($r = -0.297$, $p = 0.083$). A trend of inverse correlation was found to exist between social/impulsivity symptoms and the Logical Memory delayed score ($r = -0.318$, $p = 0.063$).

Discussion

The primary aim of the present study is to investigate in more depth the construct validity of a set of executive function tests – the Sustained Attention Response to Task, the Six Elements Test and the Hayling Sentence Completion Test – based on the supervisory attentional system framework proposed by Norman and Shallice [14]. The findings generally confirm the construct validity of these tests. However, a 3-factor structure was identified against an a priori 2-factor structure. An examination of the nature of the items comprising the first two factors revealed that they involved two distinct inhibition mechanisms. In factor 1, it comprised all items of the Hayling Sentence Completion task Part B scores. As discussed above, this part demands the ability to inhibit salient responses that are categorical or semantical to

Table 4 Partial correlation coefficients between executive function factor scores, background cognition and symptoms

Clinical symptoms	Verbal Performance	Logical Memory (immediate)	Logical Memory (delayed)	Visual Reproduction (immediate)	Visual Reproduction (delayed)	Semantic Inhibition	Action/Attention Inhibition	Output Generation
Positive symptoms	0.233	0.336*	0.251	0.271	0.385*	0.119	0.073	–0.109
Negative symptoms	–0.316	–0.379*	–0.394*	–0.384*	*–0.297*	–0.058	–0.075	–0.427*
General pathological symptoms	0.027	–0.02	–0.084	0.253	0.253	–0.025	0.101	*–0.271*
Social/impulsivity symptoms	–0.021	–0.252	*–0.318*	–0.199	–0.003	0.451*	0.293*	–0.308*
Total symptoms	–0.025	–0.068	–0.154	0.061	0.171	0.022	0.096	–0.421*

* Significant level $p < 0.05$; correlation coefficient > 0.3 and $p < 0.1$ are shown in italics

one another. Theoretically, the findings are consistent with the underlying construct of the corresponding tests. In the Hayling Sentence Completion Test, inhibition is required to produce a word that does not fit at the end of the sentence; either by reasonably completing the sentence or by being semantically related to a word in the sentence. The process involves, first of all, the activation of the expected word and then the inhibition of this word. In the supervisory attentional framework, this factor concerns excessive rule-breaking behaviour (commission errors) due to the failure of the supervisory attentional system to modify or suppress schema expressions specific to the semantic system when the most activated schema is inappropriate to an overall goal.

Factor 2 seems to measure the construct of the disinhibition of action and attention in contrast to the semantic inhibition of factor 1. In the Sustained Attention Response to Task, the underlying construct tapped by this task is the ability to resist the habituated, rapid and rhythmic pacing response to the non-target stimuli and thus to withhold a response at an appropriate and unpredictable moment. A similar ability is also required in the Six Elements Test to resist any violation of the preset rule and it requires the participant to have a good attention allocation strategy in making a plan, following the plan and monitoring its process. This factor therefore acts to handle "non-routine" scenarios appropriately and to function optimally in the sense of a supervisory attentional framework. Recently, Chan and Wright [38] demonstrated that these two tasks actually lie along the same yardstick of a higher level of attentional performance, as opposed to other basic levels of attentional performance, suggesting that they tap the same construct. They function by a top-down activation or inhibition of attention and action schemata.

Factor 3 was in line with the a priori hypothesis of an output generation. Again, it comprised items concerning the higher level of attentional control in regulating the output of performance in the Sustained Attention Response to Task and the Six Elements Test. While withholding the ability to resist relatively automatic action (as demonstrated in factor 2), participants are also greatly required to allocate their attention appropriately in order to maintain the required output. In the supervisory attentional system framework, such deficiencies in output generation are a consequence of a deficit in initiation (being a slow action or no action at all in response to non-target stimuli in the Sustained Attention Response to Task), in strategy allocation (being the optimal allocation of time to perform all the sub-tasks in the Six Elements Test) and in monitoring the session (by regulating one's response time as well as maintaining accuracy in the Sustained Attention Response to Task).

The present findings also indicate that, although executive dysfunctions appear together as a cluster of different symptoms that are observed in etiology neurological groups with widespread damage, the executive dysfunctions could be fractionated into different component processes. Recent empirical studies have suggested that the supervisory attentional system can be fractionated into different component processes. Burgess and colleagues [20, 39] have demonstrated that patients with frontal lobe lesions exhibit a differential breakdown in the so-called "frontal-based" tasks. In particular, they found that those patients who perform well in the conventional frontal-based tasks perform disproportionately poorly in the Six Elements Test when compared with normal controls. Using a questionnaire tapping everyday life dysexecutive behaviour, Burgess et al. [20] also found that there were at least 3 factors – inhibition, intentionality and executive memory – that were relevant to the supervisory attentional system sub-components among a group of patients with a wide range of neurological impairments. A similar factor solution was also demonstrated in a subsequent study among a non-clinical group [40]. Stuss et al. [21] further propose that there are at least five component processes that are particularly important for the supervisory attentional system. These are the energization of schemata, the inhibition of schemata, the adjustment of contention scheduling, the monitoring of schemata activity and the control of "if-then" logical processes. Taken together, the present factors are very similar to the aforementioned studies in terms of energization, inhibition and the monitoring of schemata. These findings indicate the importance of looking for associations and/or dissociations among the hypothesized processes related to executive functions. In particular, the present results confirm and extend previous findings that the supervisory attentional system sub-components of executive functions can be fractionated in patients with chronic schizophrenia.

The present study, however, reserves a number of methodological limitations. We only adopted exploratory factor analysis to develop three different factor models. This method did not include any information regarding the goodness of fit of these models. Moreover, we did not include a comprehensive range of different executive function components in the present study. For example, the factor analysis seems to give a measure of general performance on one task which includes semantic inhibition (Hayling Test), a second measure of inhibition from 2 other tests and a general performance measure on the same 2 tasks. Yet executive function is more than inhibition such as the response planning and working memory function in schizophrenia. The interpretation of the findings was therefore limited by such a narrow range of Supervisory Attention System based tests recruited in the present study. Future study should employ a comprehensive set of executive function components like response planning, monitoring, inhibition, working memory (online updating), and strategy allocation in a larger sample. A more stringent confirmatory factor analysis should also be adopted to validate the latent structure of these theory-based tests in schizophrenia.

However, this study did pave the first step to include "second generation" executive function tests in examining the relationship between the executive functions and symptomatology in schizophrenia. It is worth saying that the newly developed tests of the executive function, in particular of supervisory attentional control, have exhibited good construct validity in a group of chronic schizophrenic patients. Two executive function factors were related to the inhibition of semantic and action/attention responses respectively, whereas the remaining factors concerned the regulation of general output performance. These factors seem to relate to clinical manifestations of schizophrenia.

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