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A direct examination of the cognitive underpinnings of multitasking abilities: A first study examining schizophrenia

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ABSTRACT

Many real world activities are complex and require multitasking abilities. However, the nature of these abilities remains poorly understood, and in particular in schizophrenia. The aim of the present study was to provide a better understanding of such abilities with the help of a newly developed computerized tool, the Computerized Meeting Preparation Task (CMPT). Fifty-seven individuals with schizophrenia and 39 healthy controls completed the CMPT and an extensive cognitive battery. Patients were also evaluated with a series of clinical measures. During the CMPT, participants are asked to prepare a room for a meeting while, at the same time, dealing with interruptions, solving problems, and remembering prospective memory instructions. The CMPT was found to significantly differentiate patients and healthy controls for several variables. Results also showed that multitasking abilities were related to a large array of cognitive functions and, in particular, to those associated to executive functioning. These relations were not explained by the presence of a general cognitive impairment. Finally, a double dissociation between multitasking abilities and performance on standard cognitive tests was observed. Altogether, these results underline the importance of evaluating multitasking abilities in schizophrenia as it allows detecting cognitive difficulties that cannot be identified by standard cognitive tests.

1. Introduction

Many real world activities are of a multitasking nature that is, they involve different and integrated cognitive processes and take place in an unstructured context. To date, previous studies demonstrated that multitasking abilities are essential for real world functioning (Bulzacka et al., 2016; Laloyaux et al., 2014; Shallice and Burgess, 1991). However, due to an absence of suitable assessment tools, these abilities have been largely unexplored in the literature. As a consequence, many issues remain unexplored such as the cognitive underpinnings of multitasking abilities.

According to Burgess (2000), multitasking activities are characterized by eight main features: (1) many tasks have to be completed; (2) the realization of the tasks require interleaving; (3) due to cognitive or physical constraints, only one task can be performed at a time - for this reason, everyday life multitasking activities are different from the dual task paradigm in which participants are instructed to perform two tasks at the same time; (4) unforeseen interruptions/unexpected outcomes can occur; (5) the realization of the different tasks requires delayed intention (prospective memory); (6) the different tasks vary in terms of priority, difficulty, and duration; (7) the targets of the tasks are defined by the person; (8) and there is no minute-by-minute performance feedback during the tasks. Standard cognitive tests, however, do not possess these characteristics as they are designed to assess one cognitive function in a well-structured and controlled environment (e.g., office setting). Moreover, there is evidence of a double dissociation between standard cognitive measures and multitasking abilities - at least in brain-injured patients (Burgess et al., 2009). That is, patients may present impaired multitasking abilities, yet preserved performances on standard cognitive tests and vice versa. Such results suggest that brain processes underpinning multitasking abilities are independent from those supporting standard cognitive tests (Burgess et al., 2009).

Multitasking abilities are particularly relevant for many clinical populations and especially for patients with schizophrenia as they encounter many difficulties in real world functioning (American Psychiatric Association, 2013). To date, no previous studies have directly examined multitasking abilities using a task that reflects all the characteristics of multitasking activities in psychiatric populations, including in schizophrenia.

Nevertheless, a previous study (Semkovska et al., 2004) suggested (albeit indirectly) that patients encounter difficulties of a multitasking nature. Semkovska et al. (2004) compared the performance of patients with healthy controls during three observation-based real world tasks: (1) choosing a three-course menu, (2) shopping for the missing ingredients, and (3) cooking a meal. Results showed that, for each of the three tasks, patients performed worse than controls, especially for the cooking task, which possessed a number of multitasking characteristics. In the patient group, performance on the cooking task was found to be related to executive functions, episodic memory, and selective attention. However, only a limited number of cognitive functions in relation to multitasking abilities were explored. Also, the study did not examine if broader cognitive functions such as processing speed and working memory have an influence on multitasking abilities. Indeed, in schizophrenia, these broader cognitive functions have been found to be two major deficits that can have an important influence on other, more specific cognitive functions (Dickinson et al., 2008; Silver et al., 2003). Finally, several authors (Laroi and Van der Linden, 2013; Raffard and Bayard, 2012) claim that schizophrenia is highly heterogeneous in terms of cognitive impairments. However, this heterogeneity has never been examined in regard to multitasking abilities by, for example, identifying different profiles.

Evaluating patients' performance on real world activities has the advantage of high ecological validity. However, observation-based assessments (such as those used in Semkovska et al., 2004) lack standardization as the testing environment may vary from one place to another. Moreover, a series of variables that may affect the performance (e.g., the amount of noise) cannot be controlled. Furthermore, only a limited number of variables can be measured as there are constraints as to how much the observer can note, and it is difficult to obtain precise measures. Finally, measures based on real world activities (e.g., cooking a meal) will also be influenced by participants' previous experiences. That is, a person who is familiar with the evaluated activity will rely less upon his/her executive functions compared to someone who is less familiar with the task, which complicates the interpretation of the results. There is thus a need for standardized tools that are accessible in a clinical setting and that are closely related to real world activities - but that at the same time place participants in an unfamiliar situation.

Recently, Laloyaux et al. (2014) developed a pilot version of a computerized task that takes into account certain characteristics of multitasking activities and places participants in an unfamiliar situation. In this task - the Computerized Meeting Preparation Task (CMPT) - participants are required to prepare a room for a meeting for 5 guests with the help of a list of instructions (e.g., containing the names of the guests, the required objects and participants' desired drinks). Results revealed that patients diagnosed with schizophrenia demonstrated significantly poorer performance on several variables compared to healthy controls (i.e., total time to complete the task, planning score, and respect of the rules). Moreover, CMPT performance was significantly correlated with planning abilities, cognitive flexibility, and real world functioning. Finally, performance on the CMPT significantly predicted up to 50% of real world functioning, whereas the prediction from the standard cognitive measures did not reach significance. However, this pilot version of the CMPT lacked some important characteristics of multitasking activities: it did not include interruptions/ unexpected outcomes and prospective memory instructions were not incorporated. Moreover, this study was conducted with a small sample of patients and only explored a limited number of cognitive functions in relation to multitasking abilities. Finally, the authors did not take into account the heterogeneous nature of schizophrenia by, for example, identifying different profiles.

The general objective of the present study was to directly explore the specificity and heterogeneity of multitasking abilities in regards to a large array of other cognitive functions in schizophrenia. In particular, one aim was to explore the cognitive underpinnings of multitasking abilities with the help of an extensive cognitive battery measuring functions that have never been directly explored in previous studies (i.e., source flexibility and time-based and event-based prospective memory). A second aim was to investigate if a double dissociation between standard cognitive measures and multitasking abilities could be observed in schizophrenia. A final objective was to explore the relations between multitasking abilities, symptoms, and real world functioning.

In order to meet these objectives, an improved version of an existing pilot computerized multitasking task (Laloyaux et al., 2014) was developed. The aim was to create a new task that takes into account all the characteristics of multitasking activities (Burgess, 2000) and that overcomes the above-mentioned limitations of existing tools. Indeed, there are several advantages with computerized tasks as they can efficiently place participants in complex, standardized, and unfamiliar situations. Additionally, a large array of variables can be reliably measured in a precise manner.

2. Methods

2.1. PARTICIPANTS

Fifty-seven persons diagnosed with schizophrenia according to DSM-IV (American Psychiatric Association, 1994) criteria were included in the study. Diagnosis was confirmed by the Mini International Neuropsychiatric Interview (Sheehan et al., 1998). Exclusion criteria were: the presence of a current or past neurological diagnosis and/or of other current psychiatric disorders including alcohol or drug dependency [measured with the Alcohol Use Disorders Identification Test (Saunders et al., 1993); and the Drug Use Disorders Identification Test (Berman et al., 2005)], lack of clinical stability, mental retardation (French National Adult Reading Test, fNART; Mackinnon and Mulligan, 2005; Nelson and O'Connell, 1978), absence of familiarity with computers, and major change of medication within one month before testing. Patients' medication dosages were converted into three indexes according to data from the literature (Boily and Mallet, 2008; Gardner et al., 2010; Taylor et al., 2009): benzodiazepine (diazepam equivalence in mg), antipsychotic (olanzapine equivalence in mg), and risk for anticholinergic side effects.

Thirty-nine healthy controls were selected based on their similarities with the patients in terms of sex, age, estimated premorbid IQ (fNART), and number of years of education. Exclusion criteria were the presence of any psychiatric and/or neurological disorder, the absence of familiarity with computers, and having a first-degree relative with schizophrenia. Both samples (patients and healthy controls) were different from those included in Laloyaux et al. (2014).

Familiarity with video games and computers was assessed with a questionnaire created by the authors. The questionnaire is composed of 6 questions asking participants to indicate the last time they used a computer or played with video games, the frequency of using a computer and playing with video games, their level of comfort with the utilization of a computer mouse and finding their way in a virtual environment while playing with video games. Each item was rated on a 4- point Likert scale. A total score of 0 was considered as an exclusion criterion.

All participants provided written informed consent and the project was approved by the local ethics committee. Based on independent Student's t-tests (Table 1), there were no significant differences between the two groups for age, education, or cannabis consumption. However, patients were significantly less familiar than controls regarding their degree of familiarity with video games and computers and estimated IQ. Nonetheless, the mean estimated IQ difference was only 4 points, which cannot be considered a clinically relevant difference. Finally, two-sided Fisher's exact test revealed that both groups did not differ in terms of gender *(p* = 0.77).

2.2. MEASURES

2.2.1. Computerized Meeting Preparation Task (CMPT)

The CMPT used in the present study is an adapted version of the one used in Laloyaux et al. (2014). The CMPT was designed: (a) to reflect the complex, multitasking nature of everyday life activities and (b) to place the participant in an unfamiliar situation in order to emphasize the implication of executive functions and in order to reduce the influence of level of task familiarity on task performance. Compared to the first version of the task (Laloyaux et al., 2014), a number of modifications were adopted in order to render the task fully compatible with the characteristics of multitasking activities (Burgess, 2000). More specifically, prospective memory instructions were introduced, in addition to interruptions during the task, and unexpected outcomes.

After a learning phase, that is designed to teach participants how to interact and move within the virtual environment - participants are told that the meeting preparation phase will start. To begin with, a short video clip explaining the environment is played. The main room (Fig. 1) is shown where the meeting is to take place, consisting of a large room with a screen and a video projector. Tables and chairs are placed in front of the screen. Moreover, name tags (with the names of the people participating in the meeting and distractors, i.e., the names of people not participating in the meeting) are also found in the room, in addition to a telephone, which can be used to order objects or contact someone. Finally, a cart is also available, which participants can use to transport objects. Participants also have access to two adjacent rooms: the kitchen and office material areas. These areas contain items that are pertinent for the task, in addition to a number of non-pertinent distractor items.

Table 1 *- Demographic and clinical characteristics of participants.*

	Patients (N = 57)		Healthy controls (*N* = 39)	
	Mean (*SD*)	Min-max	Mean (*SD*)	Min-max
Age	34.89 (8.72) NS	19-55	34.00 (10.24)	19-55
Sex (F/M)		8/49 NS		7/32
Education (years)	11.28 (2.51) NS	8-18	11.92 (2.05)	6-17
Employment (Yes/No)		5/52		25/14
IQ (fNART[1])	102.04 (9.55)*	84.40-119.82	105.92 (7.58)	85.94-122.90
Cannabis consumption (grams per day)	0.05 (0.18) NS	0-1	0.03 (0.10)	0-0.60
Familiarity video games/computers	12.12 (3.77)***	1-18	15.00 (2.82)	8-18
Duration of illness (years)	10.19 (6.10)	1-31		
Number of hospitalizations	4.75 (4.20)	0-20		
Hospitalized (Yes/No)	23/34			
Benzodiazepine (diazepam equivalence in mg)	10.37 (15.96)	0-70		
Antipsychotic (olanzapine equivalence in mg)	21.75 (14.13)	0-74		
Anticholinergic burden (side effect potential)	2.45 (2.26)	0-8		
FROGS[2]	60.85 (6.68)	49-79		
PANSS[3] positive	13.42 (3.23)	9-25		
PANSS negative	18.75 (4.01)	9-29		
PANSS general psychopathology	31.29 (5.52)	21-49		
IIS[4]	23.55 (6.47)	0-33		
HAD[5] - depression	6.07 (3.08)	0-15		
HAD - anxiety	8.82 (3.60)	2-19		

*NS = Non-significant; *p < 0.05; ***p < 0.001*

[1]French National Adult Reading Test.

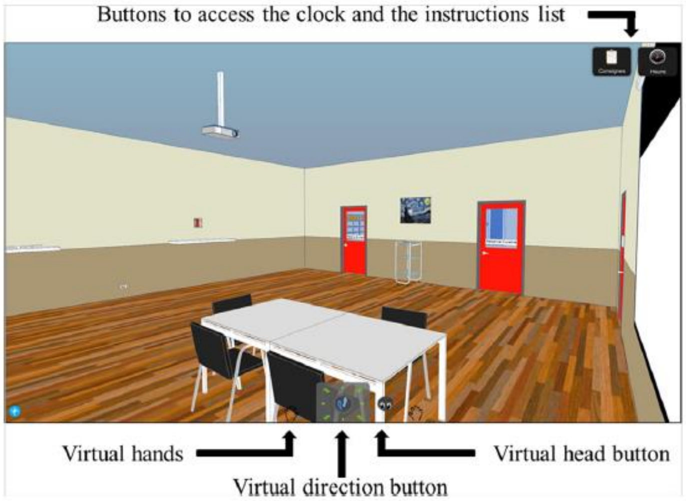
[2]Functional Remission Of General Schizophrenia.

[3]Positive And Negative Syndrome Scale.

[4]Initiative-Interest Scale.

[5]Hospital Anxiety and Depression Scale.

Figure 1. *The main room where the meeting takes place*



After this explanatory video, participants are told that it is 9:30 a.m. and that a meeting will start in 30 min, but that the secretary who is supposed to prepare the meeting room is sick and that participants must replace her. Participants also have access to a list of instructions and a clock. The instructions consist of the following information: *The meeting begins at 10* a.m. *but do not waste time to prepare the room; carefully respect the instructions, only put the required objects on the table; the moderator has to be placed in front of the video projection screen and requires a laptop computer; the assistant has to be placed next to the moderator; every guest requires a pencil, a notepad, a name tag, and a chair, including the moderator; if the telephone rings or that someone asks you at the door, you have to answer; finally, when you feel that you have finished, please ensure that the cart is empty and that it is placed where you first found it, and then exit the room.* There is also another list that contains the names of the guests and their desired drink during the meeting.

The task was designed so that the task's level of difficulty can be modulated (e.g., by modifying the number of guests, prospective memory instructions, problem detection and solving aspects, and interruptions). For the present study, however, the task was configured based on the previous pilot study (Laloyaux et al., 2014) so that it takes into account all the characteristics of multitasking activities while at the same time not being too difficult or too easy for patients. Thus, the participants have to prepare a room for 5 guests in addition to dealing with two distractors (a missing chair and a phone call signaling that a guest wants another drink during the meeting) and simultaneously have to maintain in memory two prospective memory instructions that are given orally at the beginning of the task without the possibility to write them down *("Give the camera to Chantal* (an avatar) *when she arrives"* and *"Put the coffee on the table at 9:40 a.m.").*

The following variables were calculated for the meeting preparation phase of the CMPT: (1) Total time to complete the task; (2) Respect for the rules (the written instructions); (3) Number of incorrect and forgotten objects on the table; (4) Planning score (a score combining the distance traveled, the number of times the cart has been used; and the number of times the phone, name tags, kitchen and office material areas have been visited); (5) Prospective memory score (the correct objects and time); (6) Distractor management (the missing chair and the phone call); (7) Checking score (based on the time gap between the last consultation of the instructions and participants left the room and whether the last instructions are respected or not, i.e., whether the cart is empty and placed back to its original spot or not); (8) First instructions consultation (the amount of time between task start and first instructions consultation).

2.2.2. Cognitive measures

All participants were evaluated with an extensive cognitive battery. The choice of tests was based on the cognitive functions hypothesized to be implicated in the CMPT. Another multitasking test was included to evaluate the concurrent validity of the CMPT.

The cognitive measures were:

- Processing speed: Symbol Search (Wechsler, 2000) (total score).
- Working memory: Letter-Number Sequencing (Wechsler, 2001) (LNS; longest correct span).
- Verbal episodic memory: Rey Auditory Verbal Learning Test (Rey, 1964) (total learning phase consisting of 3 recalls).
- Cognitive flexibility: Trail Making Test (Army Individual Test Battery, 1944) (TMT; time on Part B minus time on Part A).
- Inhibition: STOP-IT test, a computerized stop-signal task (Verbruggen et al., 2008) (Stop-Signal Reaction Time, SSRT).
- Planning: Zoo map version 1 (Wilson et al., 1996), in this test, participants are presented with a map of a zoo and are required to show how they would visit a series of designated locations. For the present study, the total score was used.
- Prospective memory (PM) test: this cognitive function was measured with a computerized test created by the authors and inspired from the tasks developed by Wang et al. (2008). During the task, two digits are simultaneously presented on a screen and participants are required to press the key on the side of the numerically bigger digit (ongoing task). Concerning the prospective memory instructions, participants are asked to press a specific key (space-bar) if one of the presented numbers is zero (event-based), and each time the stopwatch (presented on the upper-right hand corner of the keyboard) reaches a minute (e.g., 1:00, 2:00) (time-based). Sixteen different prospective memory stimuli are presented during the ongoing task (8 event-based and 8 time-based). The number of correct answers for the time-based and event based-stimuli were used.
- Source flexibility test: this cognitive function refers to the ability to switch attention between stimulus-independent thoughts and percepts (the environment) and vice versa (Burgess et al., 2007). The test used in the present study was a simplified version of one of the tasks developed by Gilbert et al. (2005). During this computerized task, participants are required to classify capital letters according to whether letters contain one or more curves (e.g., B) or only straight lines (e.g., A). The letters are presented in alphabetical order. During the task, participants need to judge either the letters that are shown on the screen (i.e., the external phase), or the mental representations of the letters (i.e., the internal phase, when there are no letters displayed on the screen) - and these two phases alternate during the whole task. For

the present study, the percentage of errors committed during the switching phases was used (i.e., internal to external and external to internal).

- Multitasking: Modified Six Elements Test (MSET; Wilson et al., 1996), in this test, participants are required to carry out three simple tasks (i.e., dictation, arithmetic, and picture naming) divided into two sets of each (A and B) in a fixed period of time (10 minutes). Moreover, they are told that they are not allowed to do the two sets (A and B) of the same task consecutively. The total score was used (based on Wilson et al., 1996).

2.2.3. Clinical measure

All patients were interviewed by a psychologist and rated on the Positive And Negative Syndrome Scale (PANSS, Kay et al., 1987) and the Functional Remission Of General Schizophrenia scale (FROGS, Llorca et al., 2009). The FROGS is a measure of patients' real world functioning. The total score is based on 19 items from 5 domains: daily life, activities, relationships, quality of adaptation, and health and treatment. Finally, patients also completed the Hospital Anxiety Depression scale (HAD, Zigmond and Snaith, 1983) and an informant was asked to complete a measure of the patient's degree of apathy (the Initiative-Interest Scale; IIS, Esposito et al., 2014).

2.3. STATISTICAL ANALYSES

Student's *t*-tests were computed to make group comparisons for cognitive measures and performance on the CMPT. Effect sizes were calculated using Cohen's *d*. Correlational analyses (Pearson) were then carried out within the patient group between the variables from the CMPT and the cognitive and clinical variables. Alpha (a) was set at 0.05. However, given the number of statistical analyses and the need to balance the amount of type 1 and type 2 errors, adjusted *p* values were calculated using a familywise error rate method combining Bonferroni and Rüger tests (Benjamini and Yekutieli, 2001; Hommel 1983, 1988). In particular, H0 was rejected if $p(k) \leq k\alpha/(nCn)$ where $Cn = 1 + 1/2 + ... + 1/n$. In other words, this test allows adapting the alpha level according to the number of conducted tests while, as the same time, being less conservative than Bonferroni correction. Thereafter, partial correlational analyses were conducted to examine whether the observed relations were due to general cognitive factors (processing speed and working memory). Stepwise regression analyses with backward elimination ($p > 0.05$) were then conducted to examine which set of cognitive measures best predict each CMPT variable in the patient group. Finally, individual profiles of cognitive and CMPT measures were examined in the patient group. To do so, the performance of each patient was converted into *z*-scores based on the results of the healthy controls.

3. Results

3.1. GROUP COMPARISON ANALYSES

With an alpha set at 0.014 (alpha adjusted for 19 tests), group comparison analyses (Table 2) demonstrated that performance on the CMPT significantly differentiated patients and healthy controls for all the variables except for First instructions consultation. Controlling for the familiarity with video games and computers or for the estimated premorbid IQ (fNART) (ANCOVA) did not change the group differences.

For the cognitive measures, performance was significantly different between healthy controls and patients for all variables except for source flexibility/internal to external and inhibition. These two variables were; however, significant before statistical correction.

3.2. CORRELATIONAL ANALYSES

Using a corrected alpha of 0.009 (alpha adjusted for 120 tests conducted between the 8 variables from the CMPT and the 11 cognitive and 4 clinical variables), correlational analyses (Table 3) demonstrated that working memory, cognitive flexibility, planning, time-based and event-based prospective memory, and source flexibility (internal to external and external to internal switch) correlated significantly with one or more of the CMPT variables. Additionally, Respect for the rules was found to be significantly correlated with the MSET. No significant correlation was found between the CMPT and the clinical or functional variables including scores on the PANSS positive and the PANSS negative, the IIS, or the FROGS.

Partial correlational analyses controlling for processing speed or working memory revealed no change in significance of the initial correlations between the CMPT and cognitive variables.

3.3. REGRESSION ANALYSES

Stepwise regression (Table 4) demonstrated that the cognitive measures significantly predicted between 8 and 39% of the variance in the CMPT variables. Several cognitive variables were particularly implicated in CMPT performance: working memory, episodic memory, cognitive flexibility, inhibition, planning, prospective memory (time-based and event-based) and source flexibility (external to internal and internal to external switch).

3.4. EXAMINATION OF INDIVIDUAL PROFILES

The percentages of participants demonstrating an impaired performance (below or equal to — 2 SD compared to healthy controls) on the CMPT and cognitive measures are presented in Table 2. Patients demonstrated heterogeneous profiles with a combination of both preserved and impaired performances. Moreover, analyses revealed 3 patients with preserved performances on the cognitive measures but impaired performances on the CMPT and in particular for Total time (*N* = 1), Respect for the rules (*N* = 1), Number of incorrect and forgotten objects on the table (N = 2), Planning score (*N* = 1), Distractor management (*N* = 1), and Checking score (*N* = 2). Inversely, 6 patients demonstrated the opposite profile, that is, preserved performances on the different CMPT variables but impaired performances on at least one cognitive measure including processing speed (*N* = 6), working memory (*N* = 3), episodic memory (*N* = 3), cognitive flexibility (*N* = 2), prospective memory/time-based (*N* = 1), and source flexibility/internal to external (*N* = 1).

Taken together, results revealed that 56% of patients presented difficulties in respecting the written instructions. Moreover, results demonstrated that such impairment was associated with poor abilities in maintaining and manipulating information in working memory, inhibiting a dominant response and switching from the outer world to internal representations (e.g., thoughts). Similarly, 56% of patients placed a number of incorrect objects on the table and forgot required items. These errors and omissions were related to poorer working memory and difficulties in switching from the outer world to internal representations. The majority of patients (54%) failed to achieve the prospective memory requirements of the CMPT. Such difficulties were found to be related to poor prospective memory performance (eventbased) but also to difficulties in planning abilities and inhibiting a dominant response. In addition, 53% of patients also presented impaired abilities in checking goal achievements that were found to be related to poor working memory and to difficulties in switching from internal representations (e.g., goals) to the external world. Beside these CMPT variables that were impaired in a majority of patients, four other variables were found to be impaired in a minority of them. In particular, 35% of patients demonstrated an increased total time to compete the task. This longer time was found to be related to difficulties in working and episodic memory and to poor planning abilities. In addition, 35% of patients demonstrated impaired abilities in dealing with interruptions and unexpected outcomes. Such disruptions were related to difficulties in switching from the outer world to internal representations. In this context, this probably involved difficulties creating an internal action plan to deal with distractors. Sixteen percent of patients also showed impaired planning abilities during the CMPT as they traveled a long distance during the task, visited different interactive areas a number of times, and rarely used the cart to transport objects. Such difficulties were related to poor planning abilities. Finally, 8% of patients took a particularly long time to consult the instructions list after the beginning of the task. Furthermore, this was found to be related to difficulties in shifting back and forth between multiple mental sets, and to poor prospective memory (time-based).

Discussion

The present study aimed to explore the specificity and heterogeneity of multitasking abilities in regards to other cognitive functions in schizophrenia. Another objective was to examine the cognitive underpinnings of multitasking difficulties in schizophrenia. A final aim was to explore the relations between multitasking abilities and symptoms and real world functioning.

Results showed that the CMPT possesses good sensitivity in its ability to distinguish patients from healthy controls. The CMPT also demonstrated good concurrent validity as it was significantly correlated with another measure of multitasking abilities, the MSET (Wilson et al., 1996). Furthermore, the CMPT was more sensitive than the MSET in differentiating between the two groups, and the CMPT provided a more detailed evaluation of multitasking difficulties (as many as 8 variables related to different facets of multitasking were calculated, compared to only one for the MSET).

Table 2 - Performance on the CMPT and cognitive measures for both groups.

	Patients (*SD*)	Healthy controls (*SD*)	*t (94)*	*d*	Percentage of participants demonstrating an impaired performance - Patients/Healthy controls	*F* - Group (controlling for the familiarity with video games and computers)	*F* - Group (controlling for fNART)
CMPT Total time (min)	24.14 (8.17)	15.57 (5.48)	5 71***	-1.19	35/8	16.88***	29.06***
Respect for the rules	6.31 (3.20)	9.66 (1.10)	6.27***	1.31	56/8	34.92***	33.08***
Number of incorrect and forgotten objects on the table	9.08 (6.72)	1.97 (2.84)	-6.23***	-1.30	56/5	34 17***	32.95***
Planning score	5.32 (2.23)	6.78 (1.90)	3.33***	0.69	16/5	6.06**	9.86**
Prospective	1.35 (0.93)	2.66 (0.76)	7 20***	1.51	54/8	36.91***	45 79***

memory score							
Distractor management	1.59 (1.33)	2.56 (0.85)	4.00***	0.84	35/3	12 79***	12.86***
Checking score	1.62 (0.85)	2.59 (0.36)	g 71***	1.40	53/0	34.32***	38.24***
First instructions consultation (S)	70.62 (108.08)	40.87 (65.99)	-1.53	-0.32	8/3	1.27	1.68
Cognitive measures							
Processing speed (symbol search)	24.36 (7.48)	39.28 (7.42)	9.62***	2.02	54/3		
Working memory (LNS)	4.50 (0.96)	5.94 (0.91)	7 32***	1.53	45/3		
Episodic memory (Rey)	22.87 (6.20)	29.61 (5.15)	5.58***	1.17	31/3		
Cognitive flexibility (TMT)	81.42 (64.87)	32.94 (14.68)	57***	-0.95	51/3		
Inhibition (ms)	309.09 (187.51)	237.50 (114.75)	-2.12*	-0.44	10/5		
Planning (Zoo)	2.33 (2.88)	6.16 (2.67)	6.56***	1.37	44/0		
Prospective memory - Time-based	6.22 (2.51)	7.74 (0.59)	3 70***	0.77	35/3		
Prospective memory - Event-based	6.71 (1.90)	7.76 (0.48)	3.38***	0.71	31/3		
Source flexibility/External to internal	12.58 (16.43)	5.06 (9.28)	-2.59**	0.54	24/5		
Source flexibility/Internal to external	7.09 (12.97)	2.67 (5.21)	-2.02*	0.42	19/8		
Multitasking (MSET)	4.59 (1.44)	5.74 (0.63)	4.63***	1.03	40/5		

**p* < 0.05; ***p* < 0.014 (adjusted alpha); ****p* < 0.001.

Table 3*- Correlations between cognitive variables and CMPT variables in the patient group.*

	Total time	Respect for the rules	Number of incorrect and forgotten objects on the table	Planning score	Prospective memory score	Distractor management	Checking score	First instructions consultation
Processing speed (symbol search)	−0.11	0.28	−0.19	0.03	0.09	0.03	0.26	−0.22
Working memory (LNS)	−0.31	0.43***	−0.46***	0.19	0.21	0.26	0.39**	−0.14
Episodic memory (Rey)	0.13	0.32	−0.14	0.18	0.04	0.14	0.19	0.00
Cognitive flexibility (TMT)	0.24	−0.39**	0.26	−0.05	−0.22	−0.26	−0.30	0.38**
Inhibition (ms)	0.02	−0.26	0.08	0.02	−0.18	−0.07	−0.12	−0.12
Planning (Zoo)	−0.41**	0.25	−0.33	0.38**	0.49***	0.21	0.14	−0.16
Prospective memory - Time-based	−0.14	0.21	−0.29	0.10	0.23	0.08	0.26	−0.39**
Prospective memory - Event-based	−0.09	0.23	−0.20	0.11	0.35**	0.18	0.10	−0.32
Source flexibility/External to internal	0.04	−0.38**	0.54***	−0.09	−0.28	−0.31	−0.29	0.34
Source flexibility/Internal to external	−0.01	−0.26	0.07	0.02	0.05	0.06	−0.35**	0.07
Multitasking (MSET)	−0.08	0.42***	0.29	0.06	0.32	0.28	0.31	−0.34

$^{**}p < 0.009$ (adjusted alpha); $^{***}p < 0.001$.

Table 4 *- Stepwise regression analyses with backward elimination examining the provision of each cognitive measure to the CMPT variables in the patient group.*

CMPT variable	*Adj. R*²	*F*	*d.f.*	Cognitive variables *ß*									
				Processing speed (symbol search)	Working memory (LNS)	Episodic memory (Rey)	Cognitive flexibility (TMT)	Inhibition	Planning (Zoo)	Prospective memory – Time-based	Prospective memory – Event-based	Source flexibility/ External to internal	Source flexibility/ Internal to external
Total time	0.26	7.87***	3, 53		−0.35**	0.25*			−0.40***				
Respect for the rules	0.28	8.49***	3, 53		0.37***			−0.22*				−0.27*	
Number of incorrect and forgotten objects on the table	0.39	19.31***	2, 54		−0.36***							0.46***	
Planning score	0.13	9.26**	1, 55						0.38**				
Prospective memory score	0.32	9.65***	3, 53					−0.27*	0.46***		0.23*		
Distractor management	0.08	5.96**	1, 55									−0.31**	
Checking score	0.21	8.44***	2, 54		0.34**								−0.29*
First instructions consultation	0.21	8.51***	2, 54				0.30**			−0.32**			

**p < 0.05 **p < 0.01 ***p < 0.05*

A great majority of patients with schizophrenia were found to encounter multitasking difficulties. In fact, 84% of patients demonstrated an impaired performance on at least one CMPT variable. Moreover, results showed that difficulties for a certain number of patients were only detected with the CMPT but were not with standard cognitive tests. This underlines the importance of evaluating multitasking abilities in schizophrenia as it allows detecting cognitive difficulties that cannot be identified by standard cognitive tests. In addition, the present study demonstrated that multitasking abilities are highly heterogeneous in patients with schizophrenia as patients showed different profiles with a combination of both preserved and impaired performances. Such a finding has never been demonstrated in previous studies. Finally, 84% of patients were found to demonstrate both multitasking difficulties and impaired performances on standard cognitive measures. Such results suggest that the co-occurrence of both types of difficulties may be highly prevalent in patients diagnosed with schizophrenia and this underlines the need for an extensive cognitive evaluation in clinical practice. In fact, such results are congruent with the observation that patients diagnosed with schizophrenia usually present deficits of large effect sizes in many cognitive domains (Bortolato et al., 2015).

The present study also provided a better understanding of the cognitive underpinnings of multitasking abilities. To begin with, multitasking difficulties in schizophrenia were not found to be due to a general impairment of processing speed or working memory. On the contrary, performance on the CMPT was found to be related to different cognitive functions including working memory, cognitive flexibility, inhibition, planning, prospective memory and source flexibility. These results are consistent with previous studies that have shown relations between executive functions and multitasking activities (Laloyaux et al., 2014; Semkovska et al., 2004). However, the present study also demonstrated the implication of prospective memory and source flexibility, two unexplored cognitive functions. In particular, it was observed that difficulties in disengaging from the environment to return to the internal plan and vice versa predicted poorer multitasking abilities.

Finally, different implications of event-based and time-based prospective memory were found in multitasking abilities. Indeed, the prospective memory variable of the CMPT was demonstrated to be related to event-based prospective memory. On the other hand, time-based prospective memory was significantly related to the time taken before consulting the instructions list for the first time. Taken together, these results are in agreement with the assumption that source flexibility (Burgess et al., 2007) and prospective memory (Burgess et al., 2000) are central cognitive processes in multitasking abilities.

A double dissociation was found between multitasking abilities and the other measured cognitive functions. Such a finding has never been previously demonstrated in patients with schizophrenia.

Taken together, these results show that multitasking abilities make demands upon cognitive functions that are not assessed with standard cognitive tests. Burgess et al., (2009) have suggested that this dissociation is related to source flexibility and prospective memory, and the present results demonstrated that these cognitive functions play an important role in multitasking abilities. However, two findings are of particular interest regarding the cognitive underpinnings of multitasking abilities. (1) To begin with, some patients demonstrated preserved multitasking abilities despite impaired performances on standard cognitive tests - including source flexibility and prospective memory. We have no clear explanation yet for this dissociation. Nevertheless, it may be related to compensatory strategies used by patients to deal with cognitive deficits and to the recruitment of other cognitive resources under complex situations. Future studies are clearly required in order to clarify the nature of multitasking difficulties and in particular in relation to the specific compensatory strategies used. (2) Another important issue is related to the fact that regression analyses revealed that the cognitive measures only predicted between 8 and 39% of the variance of the CMPT variables. Such results suggest the implication of other factors that were not measured in the present study. There is thus a clear need for future studies to further examine the cognitive functions underpinning multitasking abilities as well as other factors that may affect the performance (e.g., self-efficacy, motivation, and goal neglect) (Duncan et al., 1996).

No significant correlation was found between the CMPT and real world functioning. This absence of results is quite surprising as the pilot study using the first version of the CMPT conducted by Laloyaux et al. (2014) demonstrated relations between multitasking abilities and real world functioning. This may be attributed to the fact that the mean score on the FROGS lacks variance. In particular, and compared to the sample in Laloyaux et al. (2014), patients in the present study demonstrated a more homogeneous (Levene's test: $F = 3.93$, $p < 0.05$) and better level of functioning ($U = 281.5$, $p < 0.001$). However, it is also possible that patients reported a good level of functioning but encountered many difficulties during the CMPT. These differences may be related to the fact that patients usually live in relative isolation, in a well-structured and predictable environment, thus avoiding many multitasking situations. Interestingly, Bowie et al. (2007) found self-report measures of real world functioning to be inconsistent with more objective measures (caregiver- and observation-based) in patients with schizophrenia suggesting that the two types of measures assess different aspects of functioning. In accordance with these results, supplementary analyses revealed that employed patients ($N = 5$) - which could be considered as an objective measure of functioning - demonstrated a significantly better performance on the CMPT than the unemployed patients. In view of these findings, the relations between the CMPT and real world functioning need to be explored in more detail, albeit with more objective measures such as observation-based approaches, informant reports, and detailed information about employment status (e.g., full time, part time, sheltered workshop).

From a clinical perspective, the CMPT was designed to measure multitasking abilities in an optimal manner. In particular, it evaluates multitasking abilities in an ecological manner and in a standardized situation that reflects all the characteristics of multitasking activities as defined by Burgess (2000). In addition, in that participants are placed in an unfamiliar situation, the influence of the familiarity with the task is greatly reduced. Finally, the CMPT provides a number of specific and useful scores related to different aspects of multitasking abilities (e.g., prospective memory score, distractor management, planning abilities). For these reasons, the CMPT is the most complete available assessment tool for multitasking abilities and its use should be preferred to other traditional multitasking tests. For example, compared to the CMPT, the MSET (Wilson et al., 1996) only provides a unique global score, lacks a certain number of characteristics of multitasking activities (i.e., interruptions and unexpected outcomes, clear prospective memory instructions), and possesses a poor level of ecological validity as participants are asked to carry out tasks that are not related to each other and contains artificially constraining rules. The Executive Function Performance Test (Baum et al., 2008) is an observation-based task in which participants are required to carry out simple and familiar everyday life tasks (i.e., cook oatmeal, make a phone call, manage medication, pay bills). However, compared to the CMPT, this test lacks many characteristics of multitasking activities, as the realization of the tasks does not require interleaving and delayed intentions. Moreover, the level of familiarity with the activities will influence the performance on the Executive Function Performance Test. In addition, in that the task is observational, it is difficult to obtain precise measures of the performance and the observer can only encode a limited number of variables. Finally, it is important to note that the objective of the Executive Function Performance Test is different, as it aims at determining the level of support needed to perform the tasks, whereas the CMPT provides information about the abilities to carry out an unfamiliar and prototypical multitasking task. The aims of the two tests can be seen as complementary.

The CMPT is also an interesting tool in a cognitive remediation context. In particular, a unique characteristic of the task is that multitasking abilities have been broken down into different facets, and that it is possible to calculate a score for each of these. It is thus possible to identify which specific aspects of multitasking abilities are problematic and which are preserved. For example, the CMPT can help determine whether the patient needs cognitive remediation oriented towards the management of interruptions and unexpected outcomes, or towards the checking of goal achievements, or towards prospective memory, or towards the organization of the steps to achieve the aim of the task. In addition, it is possible to modulate the level of difficulty of the task (e.g., by modifying the number of guests, the number and the type of distractors and the prospective memory instructions) and thus clinicians may choose to expose patients to situations that are progressively more complex.

Although the CMPT provides a number of advantages as a multitasking assessment measure, a number of future steps may be envisioned. One such future step could be to create additional multitasking scenarios (e.g., preparing a birthday party) and environments (e.g., an apartment). The aim here would be (1) to provide parallel versions of the task to be used in cases of re-test (e.g., in order to test the efficacy of an intervention before versus after the intervention) and (2) to provide diverse situations to be used in a cognitive remediation context. This latter objective would allow training patients in many multitasking situations in order to maximize the generalization of the strategies acquired during the remediation program to everyday life activities. The use of immersive virtual reality (e.g., using a head-mounted display and interactive gloves) may also be a next step in the development of the CMPT. In particular, this technology may be of interest as interacting with the virtual environment may be more instinctive for people who have no previous experience with computers. However, the development of immersive environments is much more expensive than non- immersive computerized tasks (such as the CMPT) and requires further financial investment in terms of material needed for running the task (e.g., a more powerful computer, interactive gloves, and head-mounted display). Such obstacles may thus limit the accessibility of the tasks in a clinical context. Moreover, even if the degree of familiarity with video games and computers was found to be significantly lower in the patient group compared to healthy controls, controlling for this variable did not change the original group differences. In addition, supplementary analyses revealed that the degree of familiarity with video games and computers was only significantly related to less total time spent to complete the CMPT but not to the other variables (patients: $r = -0.39$, $p = 0.002$; healthy controls: $r = -0.40$, $p = 0.011$). Interestingly, the strength of the correlation was similar in both groups, which suggests that the degree of familiarity with video games and computers has the same impact on the task within each group. Taken together, these results showed that, in general, a basic degree of familiarity with new technologies is sufficient in order to complete the CMPT.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2018.06.060.

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