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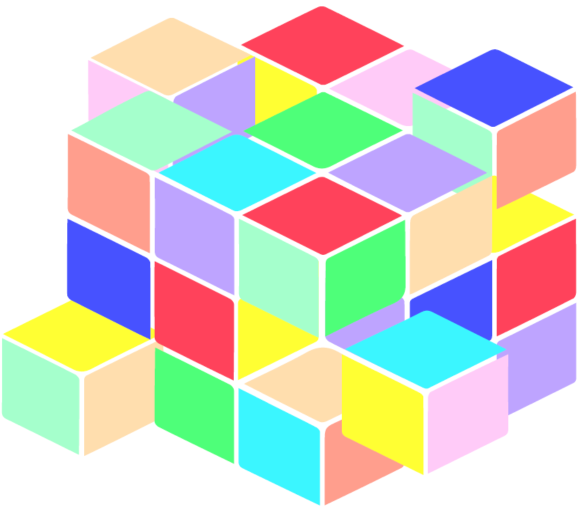
Multitasking abilities in psychosis: Assessment, cognitive correlates, and relations to real world functioning



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Sous la direction du Pr Frank Larøi

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Prologue

What it the common feature between being an astronaut aboard the Mir space station and preparing a meal?

"We had many system failures and they were in need of your constant attention. And, you know, many days, I'd start an experiment in the morning to get it running, then I'd run over, help hacksaw through a pipe and plug the ends, and then run back to my experiment. I'd have three or four watches on with alarms set to different things that I had to run back to, so I was multitasking in order to try to get everything accomplished" (Jerry Linenger describing his experience aboard the Mir space station; Fullerton-Smith & Lynch, 1998).

"One day about fifteen months after operation she had planned to get a simple supper for one guest and four members of her own family. She looked forward to it with pleasure and had the whole day for preparation. This was a thing she could have done with ease ten years before. When the appointed hour arrived she was in the kitchen, the food was all there, one or two things were on the stove, but the salad was not ready, the meat had not been started and she was distressed and confused by her long-continued effort alone. It seemed evident that she would never be able to get everything ready at once. With help the task of preparation was quickly completed and the occasion went off successfully with the patient talking and laughing in an altogether normal way" (description of the behavior of Penfield's sister after removal of the right frontal lobe, Penfield & Evans, 1935, p. 131).

Introduction

Chapter 1: Real world impairments in schizophrenia and bipolar disorder

Disabilities

According to the World Health Organization (WHO, 2008), among non-fatal conditions, mental illnesses are the most important causes of disability. In particular, psychoses, including schizophrenia and bipolar disorder are perceived as being among the most disabling mental illnesses (Salomon et al., 2015).

In a review of the literature, Tandon, Nasrallah, and Keshavan (2009) showed that patients diagnosed with schizophrenia are likely to be unemployed and homeless. More specifically, they revealed that only about 20% of patients are fully employed in the USA and in Europe. The authors also indicated that the majority of patients have a poor social life: they have reduced contact with their family, have few friends, and about two thirds of them have never been married. Similarly, another review by Lepage, Bodnar, and Bowie (2014) highlighted that a minority of patients diagnosed with schizophrenia live independently and are financially responsible for their residence, as the majority of them live in long-term community housing.

Concerning bipolar disorder, a review by Huxley and Baldessarini (2007) demonstrated that the majority of patients do not live independently and mostly reside with original family members. In addition, the authors also showed that many patients report interpersonal difficulties and that only around one fifth of them are married. Moreover, the employment rate was found to be relatively low in that only around 35% of patients suffering from bipolar disorder are employed in the USA. Concerning Europe, another review of the literature showed an employment rate around 30% (Fajutrao, Locklear, Priaulx, & Heyes, 2009).

Taken together, such results demonstrate that patients diagnosed with schizophrenia and bipolar disorder encounter many real world difficulties in various domains including work abilities, social life, and the ability to live independently. Nevertheless, patients with schizophrenia tend to present more severe difficulties than patients suffering from bipolar disorder (Bowie et al., 2010; WHO, 2008).

Symptoms

The main characteristic of patients diagnosed with schizophrenia and bipolar disorder is the presence of a variety of symptoms (American Psychiatric Association, 2013). Concerning schizophrenia, symptoms are formally divided into two categories (Andreasen & Olsen, 1982; Kay, Fiszbein, & Opler, 1987): negative and positive. Negative symptoms refer to impairments of affective expression, motivation, and language, including blunted affects, alogia, apathy, and social withdrawal. As for positive symptoms, they originally included florid manifestations such as hallucinations (e.g., hearing voices), delusions (e.g., persecution), and thought disturbances. However, more recently, some authors (Andreasen, Arndt, Alliger, Miller, & Flaum, 1995) divided positive symptoms into two categories: psychotic (or positive) and disorganization symptoms. In this new classification, psychotic symptoms refer to reality distortions, covering hallucinations and delusions; and disorganization includes disruption of thinking and behavior such as tangentiality and strange behaviors.

For its part, bipolar disorder is characterized by the alternation or combination of depressive and (hypo)manic episodes (American Psychiatric Association, 2013). During depressive episodes, patients can express depressed mood (e.g., sadness, hopelessness), diminished interest and pleasure, sleep disturbance, loss of energy, guilt, appetite or weight disturbance, diminished ability to think or concentrate, and thoughts of death. In contrast, (hypo)manic episodes are defined by distinct periods of elevated, expansive or irritable mood, and increased goal-directed activity and energy. During these periods, patients can express inflated self-esteem, decreased need for sleep, flight of ideas, and be more talkative and distractible. Moreover, patients usually involve themselves in many activities, some of which can have painful consequences (e.g., impulsively spend a large amount of money).

To date, several studies have explored the relations between symptoms and patients' real world functioning. However, the results varied across studies. Concerning schizophrenia, a meta-analysis by Ventura, Hellemann, Thames, Koellner, and Nuechterlein (2009) found that negative symptoms, but not positive, were significantly correlated with real world functioning when combining everyday life, work, and social functioning. Nonetheless, in another study, Bowie, Reichenberg, Patterson, Heaton, and Harvey (2006) showed that when separating these three domains, only social functioning was significantly correlated with negative symptoms as well as with depressive symptoms. Concerning bipolar disorder, Martino et al. (2009) demonstrated that depressive symptoms, but not manic, significantly predicted patients' real world functioning. However, Martinez-Aran et al. (2007) found no significant difference in terms of manic and depressive symptom severity between high and low functioning patients. Taken together, the discrepancy in the results suggests that symptoms do not have a major and systematic impact on patients' functioning. Nonetheless, this lack of constancy may be due, at least partially, to different patients' levels of symptom severity across the different studies and to the different tools used to assess real world functioning. Moreover, symptoms are not homogenous categories as they refer to different manifestations and behaviors. Some authors have suggested that the strength of the relations between symptoms and real world functioning may vary according to the specific type of symptom. In particular, Leifker, Bowie, and Harvey (2009) found in a sample of patients diagnosed with schizophrenia that specific negative symptoms, such as social withdrawal, blunted affect, and lack of spontaneity, were more important predictors of real world functioning than the global score on a scale assessing negative symptoms. Similarly, Faerden et al. (2010) also demonstrated in a sample of patients with schizophrenia that apathy was more strongly related to real world functioning than broader measures of negative and positive symptoms. More recently, Chang, Hui, Chan, Lee, and Chen (2016) found that apathy and anhedonia were the strongest predictors of functioning for patients with schizophrenia even when condensing other symptoms dimensions. Altogether, these results suggest that the impact of symptoms on patients' functioning may vary according to the specific type of symptom.

Cognitive impairments

Another primary common characteristic between patients with schizophrenia and bipolar disorder is the presence of cognitive impairments. In particular, Bortolato, Miskowiak, Kohler, Vieta, and Carvalho (2015) conducted a review of the different meta-analyses that have examined the cognitive impairments encountered by patients suffering from schizophrenia and bipolar disorder in regard to healthy controls. Concerning schizophrenia, the authors found that patients demonstrated deficits of large effect sizes in different cognitive domains: processing speed, working and episodic memory, attention, executive functions (including planning abilities, inhibition and cognitive flexibility), and prospective memory. Moreover, processing speed and episodic memory were found to be two major impairments in schizophrenia with the largest effect size estimates (respectively -1.25 and -1.23 g). Similarly, Bortolato et al. (2015) found that patients diagnosed with bipolar disorder encountered medium to large cognitive deficits in processing speed, working and episodic memory, attention and executive functions including planning abilities, inhibition, and cognitive flexibility. However, contrary to schizophrenia, the effect size estimates were found to be relatively equivalent throughout the different cognitive domains. Interestingly, Bortolato et al. (2015) also reviewed the meta-analyses that compared cognitive performances between patients with schizophrenia and bipolar disorder. They found that both diagnoses presented a similar cognitive profile but that patients with schizophrenia were characterized by more severe deficits compared to patients diagnosed with bipolar disorder. In other words, the differences between both diagnoses were quantitative rather than qualitative. Interestingly, beside these group studies, several authors have underlined the inter-individual heterogeneity of cognitive functioning in both patients with bipolar disorder (Martino et al., 2008) and schizophrenia (Kremen, Seidman, Faraone, Toomey, & Tsuang, 2004; Raffard & Bayard, 2012). In particular, patients were not homogeneous in terms of cognitive functioning and presented different profiles with a combination of preserved and impaired cognitive functions that varied across individuals.

Another issue is related to the nature of the cognitive impairments in schizophrenia and bipolar disorder. In particular, some authors raised the question whether the observed cognitive impairments were due, at least partially, to the influence of a general cognitive factor such as working memory or processing speed. In fact, Dickinson, Ragland, Gold, and Gur (2008) examined the latent structure of cognitive performances in a large sample of persons diagnosed with schizophrenia based on an extensive cognitive battery. The authors found six different factors related to processing speed, verbal abilities, spatial abilities, episodic memory, visual memory, and executive functions. Moreover, the analyses revealed the existence of a general unique factor sustaining performances on the different cognitive factors. More interestingly, the analyses also demonstrated a direct diagnostic effect on episodic and processing speed factors; suggesting that these cognitive domains may be particularly implicated in the cognitive deficits observed in schizophrenia. These results are consistent with a meta-analysis by the same authors (Dickinson, Ramsey, & Gold, 2007) demonstrating that among the different cognitive domains, processing speed is the most impaired cognitive functions in schizophrenia.

Similarly, Antila, Kieseppa, Partonen, Lonnqvist, and Tuulio-Henriksson (2011) examined the effect of processing speed on the other cognitive functions in patients diagnosed with bipolar disorder and healthy controls. Both groups were evaluated with an extensive cognitive battery which measured processing speed, verbal abilities, working memory, episodic memory, and cognitive flexibility. In both groups, processing speed was found to have a significant impact on the other cognitive measures. However, the impact was larger in patients diagnosed with bipolar disorder. Moreover, no significant difference was found between bipolar patients and healthy controls on the cognitive battery after adjustment for the effect of processing speed. Such results thus suggest that impaired processing speed contributes to the cognitive deficits observed in different cognitive domains in bipolar disorder.

Beside the hypothesis of the major role of processing speed in cognitive deficits observed in schizophrenia and bipolar disorder, other authors made the assumption that working memory could also have a particular implication. In accordance with this hypothesis, Silver, Feldman, Bilker, and Gur (2003) found that visual and verbal working memory was significantly correlated with several other cognitive domains in schizophrenia, including executive functions, long term visual memory, and motor speed. Similarly, Johnson et al. (2013) demonstrated in a sample of persons diagnosed with schizophrenia that visual working memory was significantly related to other cognitive tests measuring attention, processing speed, executive functions, episodic memory, and IQ. Taken together, these results suggest that impaired working memory contributes to the other cognitive deficits observed in schizophrenia.

To date, numerous studies have examined the relations between cognitive impairments and real world functioning in schizophrenia and bipolar disorder. However, the correlations and predictive values were found to be weak. Regarding schizophrenia, a meta-analysis by Fett et al. (2011) examined the relations between patients’ everyday life functioning and six different cognitive domains, including executive functions, processing speed, attention, working memory, verbal memory, and visual memory. Results revealed that the correlations ranged from .16 to .26. Attention was the least correlated with real world functioning (.16) whereas processing speed and verbal episodic memory were the most related domains (.25 and .26 respectively). Interestingly, processing speed and episodic memory were found to be the most impaired cognitive function in schizophrenia (Bortolato et al., 2015). Additionally, Fett et al. (2011) also found that overall cognition only predicted 6% of patients' real world functioning, leaving the majority of the variance unexplained.

Concerning bipolar disorder, another meta-analysis (Depp et al., 2012) examined the relations between real world functioning and different cognitive domains including verbal and visual memory, working memory, processing speed, executive functions, attention, and visuospatial abilities. Results demonstrated that the different cognitive domains were significantly related to patients' everyday life functioning. However, the correlations were found to be relatively weak, ranging from .22 to .29. More specifically, attention was the least related (.22) to real world functioning and working memory the most (.29). Taken together, these results suggest that cognitive impairments are related to real world functioning in schizophrenia and bipolar disorder. Nonetheless, these results also showed that the majority of the variance of real world functioning remains unexplained.

The need for another approach

Taken together, previous studies suggested that symptoms and cognitive deficits are weakly related to patients' real world functioning. In fact, as suggested by Larøi and Van der Linden (2013), many other factors may be related to everyday life functioning in schizophrenia. For example, the authors underlined the potential role of several psychological factors such as dysfunctional attitudes (e.g., defeatist beliefs), metacognition and insight. In addition, social factors can also have an impact on patients' functioning, such as family attitudes, environmental opportunities (e.g., for employment and housing), and social and internalized stereotypes. However, the authors also underlined the lack of ecological validity[1] for standard cognitive tests and particularly their inability to reflect the complex and multifaceted nature of real world activities. Indeed, 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 where the person has to initiate, carry out and alternate between different tasks, define the tasks' targets and face unexpected outcomes (Burgess, 2000). Clearly, standard cognitive tests do not possess such characteristics as they are designed to assess one isolated cognitive function in a quiet and well-structured environment (i.e., office). Such discrepancy between demands of real world activities and standard cognitive test may explain the weak observed relations between cognitive tests and patients' functioning (Depp et al., 2012; Fett et al., 2011).

Summary

Previous studies demonstrated that patients suffering from schizophrenia and bipolar disorder encounter many difficulties in real world functioning. Being able to accurately evaluate patients' functioning is thus a major aim in clinical practice in order to offer adaptive care. However, previous studies suggested that symptoms and cognitive functioning are weakly related to everyday life functioning. Such results are particularly astonishing considering the fact that patients tend to demonstrate major cognitive deficits. In fact, many other

[1] The ecological validity refers to the degree to which a measure is able to represent real life.

variables may influence real world functioning such as specific symptoms and other psychological and social factors. Nonetheless, it is possible that the lack of relation between cognitive tests and real world functioning may be due to the inability of standard cognitive tests to reflect the complex and multi-determined nature of real world activities. Indeed, standard cognitive tests are designed to assess one isolated cognitive function in a well-structured setting. However, many real world activities require the coordination of several cognitive functions and take place in an unstructured context. There is thus a need to create new assessment tools that take into account the complexity of everyday life activities in order to better predict patients' functioning and examine the impact of cognitive deficits on everyday life activities.

Chapter 2: Multitasking abilities and their cognitive and neuronal underpinnings

From everyday life to theory: What is multitasking?

The study of multitasking abilities began with the observation of neurological patients suffering from a frontal lobe injury who showed difficulties in real world functioning despite preserved performances on standard cognitive tests. In particular, these patients encountered many difficulties during complex, goal directed and ill-structured activities such as maintaining professional activity, shopping, preparing a meal or doing the housework (e.g., Eslinger & Damasio, 1985; Levine et al., 1998; Shallice & Burgess, 1991). These different complex activities shared some common characteristics that have been defined by Burgess in 2000.

According to Burgess (2000), multitasking[2] activities refer to goal directed and open-ended situations that are characterized by eight main features.

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[2] At this point, it is possible to make distinction between what is called "serial multitasking" and "concurrent multitasking" (Burgess, 2015). The concurrent multitasking refers to situations where people actively try to do two things at a time (e.g. talking on a mobile phone while shopping). On the other hand, serial multitasking refers to situations where people have to conduct a list of tasks and are trying to optimize their realization. This thesis will focus on the concurrent multitasking that will simply be called "multitasking."

1. Many tasks: a number of different tasks have to be completed (e.g., cooking a meal composed of roasted chicken, boiled potatoes and carrots);
2. Interleaving: the realization of the tasks requires interleaving (e.g., turning on the oven and chopping the carrots during the time it heats);
3. One task at a time: due to physical or cognitive constraints, only one task can be performed at a time (e.g., it is impossible to simultaneously chop the carrots, peel the potatoes and put the chicken in the oven);
4. Interruptions: unforeseen interruptions can occur (e.g., dropping some food on the floor or burning the carrots);
5. Delayed intentions: the realization of the different tasks requires prospective memory (e.g., remembering to put the chicken in the oven when it is hot and to check the food for doneness);
6. Differing task characteristics: the different tasks vary in terms of priority, difficulty, and duration (e.g., chopping the carrots will take more time than putting the chicken in the oven);
7. Self-determined targets: people define what constitutes adequate performance (e.g., food doneness);
8. No immediate feedback: there is no minute-by-minute performance feedback.

In the early nineties, Shallice and Burgess (1991) designed the first multitasking tests—namely the Multiple Errands Test (MET) and the Six Element Test (SET)—in order to overcome the inability of standard cognitive tests to characterize the difficulties encountered by some neurological patients during complex everyday life activities.

The MET is an observation-based task that takes place in a shopping precinct. During this test, participants are required to carry out eight tasks that vary in terms of complexity. For example, participants have to buy a brown loaf, meet the examiner at a certain time, or find the name of the coldest place in Britain on the previous day. Moreover, participants are required to respect some rules such as spending as little money as possible, not entering a shop other than to buy something, and staying in the defined boundaries.

For the second task, the SET, participants are required to carry out three simple tasks divided into two sets of each (A and B) in a fixed period of time (15 minutes). In particular, patients are required to dictate two routes, resolve arithmetical problems, and write the name of pictures of objects. Participants are told that they have to attempt at least some items of each set but that they do not have enough time to finish them all. Moreover, they are told that they are not allowed to do the two sets (A and B) of the same type (i.e., route dictation, arithmetic, or name task) one after another. For example, they are not allowed to name some pictures of objects of the set A and then name some pictures of the set B; they have to shift to another task such as arithmetic or route dictation.

In the original study of 1991, Shallice and Burgess described two patients (A.P. and D.N.) suffering from a frontal lobe lesion who presented an impaired performance on both the MET and the SET despite preserved performances on standard cognitive tests assessing Intelligence Quotient (IQ), language, perception, working and episodic memory, and executive functions such as inhibition, cognitive flexibility, planning, and verbal fluency. For instance, in the MET, patients demonstrated more inefficiencies (i.e., when a better strategy could have been applied such as entering the same shop more than once), rules breaks (e.g., going outside the boundaries), interpretation failures (i.e., misunderstanding of the requirements of a task), and task failures (i.e., tasks not appropriately completed) than healthy controls. Concerning the SET, patients started fewer different tasks and spent more time than controls on the ones they attempted.

Moreover, both patients reported many real world impairments and were unable to return to work. More specifically, A.P. showed difficulties in organizing everyday life chores such as shopping, doing the housework, or the laundry and usually forgot what he was doing. For instance, while shopping, he would buy one item at a time and return to his car after each purchase. Similarly, D.N. presented difficulties in spontaneously engaging and accomplishing many real world activities such as maintaining personal hygiene, cooking and doing the housework. For example, when shopping, he would rarely buy the items from the shopping list his wife has prepared.

Toward a double dissociation

To date, several studies have reported similar cases of neurological patients showing preserved performances on standard cognitive tests but multitasking difficulties. Two years after the original study by Shallice and Burgess (1991), Goldstein, Bernard, Fenwick, Burgess, and McNeil (1993) reported the case of a patient who underwent left frontal lobectomy following a frontal lobe tumor. This patient demonstrated preserved performances on standard cognitive tests (IQ, memory, perception, executive functions such as cognitive flexibility and inhibition) but multitasking difficulties as measured with the MET (Shallice & Burgess, 1991). More specifically, compared to healthy controls, the patient presented more errors, inefficiencies (e.g., he had to return several times to a shop), rules breaks (e.g., he went outside the boundaries), misinterpretations (e.g., he stuck the stamp on a wrong card), and failed to complete some tasks. Moreover, the patient presented difficulties in real world functioning and in particular during complex and open-ended situations. For example, he had to leave his employment due to lethargy and poor decision-making abilities (e.g., choosing which slides to use for a work presentation took him two weeks). Furthermore, the patient was described as being overfamiliar and having low anger control.

Similarly, Levine et al. (1998) described seven brain-injured patients presenting preserved performances on standard cognitive tests (assessing IQ, working memory, inhibition, cognitive flexibility, verbal fluency, verbal memory, and language) but impaired performance on a modified version of the original SET (Shallice & Burgess, 1991) – the strategy application task[3]. Unfortunately, as the authors did not assess patients' real world functioning, it is not possible to establish links between performance on the multitasking test and everyday life impairments.

A few years later, Bird, Castelli, Malik, Frith, and Husain (2004) reported the case of a patient who encountered a stroke in the frontal lobe. This patient demonstrated multitasking difficulties as measured with a shortened version of the SET (Wilson, Alderman, Burgess, Emslie, & Evans, 1996) as well as episodic memory impairment. However, she showed preserved performances on a wide

[3] Compared to the original SET, the strategy application task contains marked items that are worth more points than the unmarked. The best strategy to realize the task consists thus in focusing on these items.

range of standard cognitive tests assessing IQ, language (except some light signs of aphasia), perception, and executive functions (i.e., cognitive flexibility, verbal fluency, and inhibition) and theory of mind.

More recently, Roca et al. (2011) also reported seven patients suffering from a frontal lobe lesion who demonstrated multitasking and theory of mind difficulties in the context of preserved performances on standard executive tests (inhibition, working memory, and abstract reasoning). Multitasking abilities were assessed with the hotel task (Manly, Hawkins, Evans, Woldt, & Robertson, 2002), a test based on the SET (Shallice & Burgess, 1991). In this test, participants are required to work on five different tasks for 15 minutes: compile individual bills, sort coins, look up telephone numbers, sort conference labels, and proofread a hotel leaflet. In addition, participants also have to open and close the garbage door by pressing a button at a certain time (prospective memory instructions).

All these cases demonstrate a single dissociation between multitasking abilities and standard cognitive tests assessing IQ, executive functions, working and episodic memory, perception and language. A possible interpretation of such results would be that multitasking tasks are more difficult and multi-determined than standard cognitive tests. However, Burgess, Alderman, Volle, Benoit, and Gilbert (2009) recently reported cases of two neurological patients with severe brain damage who demonstrated impaired performances on different standard cognitive tests but preserved multitasking abilities. More specifically, the first patient (C4) showed impaired episodic memory and planning abilities. The second patient (ULI) showed impaired working and episodic memory, visual perception, processing speed, cognitive flexibility, planning abilities, and IQ (i.e., 62). However, both cases demonstrated preserved performance on a simplified version of the MET (Alderman, Burgess, Knight, & Henman, 2003). Compared to the original MET (Shallice and Burgess, 1991), the main modification concerned the instructions which were simplified to avoid possible misinterpretation. For example, the authors added a rule not to buy all the required items in the supermarket.

Taken together, such results suggest a double dissociation between standard cognitive measures and multitasking abilities and indicate that multitasking abilities make demands upon different cognitive functions than those assessed with standard cognitive tests. These results are indeed preliminary as this double dissociation has only been found in two patients, yet they are encouraging.

Cognitive underpinnings of multitasking abilities

Previous studies have suggested that multitasking abilities make demands upon cognitive functions that are not assessed with standard cognitive tests. However, these cognitive underpinnings are poorly understood. In fact, as it has been underlined by Burgess, Veitch, de Lacy Costello, and Shallice (2000), the evaluation of individual contributions made by each cognitive function to multitasking abilities is not methodologically straightforward as some of them are only required in the coordination of others, or are only stressed when the combination of tasks is required or in ill-structured situations. This methodological limitation renders the exploration of the cognitive underpinnings of multitasking abilities challenging.

To date, only two studies have directly examined the cognitive underpinnings of multitasking abilities in the literature (Burgess et al., 2000; Logie, Trawley, &

Law, 2011) and both resorted to the same procedure to overcome this methodological difficulty. In particular, the authors adopted a method that allowed keeping the behavioral sequence during the multitasking task but, at the same time, enabled decomposing it. The idea was to decompose the behavior in different sequences rather than to study each component in isolation. In particular, the authors required the participants to learn the instructions, plan the task, realize the task, and then to recall the instructions and what has been done. Thus, participants had to follow this specific sequence in order to evaluate the provision of each step.

In the first study, Burgess et al. (2000) assessed multitasking abilities in 60 brain-injured patients who varied in terms of brain lesion location and 60 heathy controls. Multitasking abilities were evaluated with the Greenwich test which is similar to the SET (Shallice & Burgess, 1991) except that there are more rules to follow. In this task, participants are required to realize three tasks in 10 minutes: (1) a bead task where participants have to sort - one by one - mixed beads according to their color (red or green) and alternate between color; (2) a tangled lines task where participants have to find the ends of 10 interlacing strings drawn on a sheet; and (3) a construction task where participants are asked to assemble little plastic pieces (Mecano®) to reproduce a model. During this test, participants are told that they are required to score as many points as possible but that it will not be possible to complete the three tasks in 10 minutes. Moreover, they have to follow some rules. For example, they are told that more points are attributed for the items they do earlier and for the red items (i.e., beads, strings, pieces of the construction kit).

In order to examine the individual cognitive components of multitasking abilities, the performance on the Greenwich test was sequenced. Participants were first required to learn the instructions by heart (variable called “learn”), then to plan the order in which they will carry out the errands (“plan”), and to perform the test (“score”). Performance on the test was reflected by one unique variable based on the number of tasks attempted, task switching rates, and following of the rules. This measure was supposed to be mainly related to prospective memory. In addition, the pre-established plan was compared to what has been actually realized by participants in order to obtain a measure of plan-following (“follow”). After the task, participants were also required to recall what they have done (“recount”) and the instructions (“remember”).

Patients demonstrated poorer performance than healthy controls on all the variables except for the “plan” variable. Moreover, Burgess et al. (2000) proposed a model of multitasking abilities using Structural Equation Modeling (SEM). This model was first tested separating healthy controls and patients. However, as the factor structure was similar across groups, patients and controls were merged. This model (Figure 1) claims that multitasking abilities are supported by three primary constructs: Memory (episodic memory), Plan, and Intent (that was supposed to mainly reflect prospective memory). Moreover, these latent variables were also related to each other in that unidirectional paths were described from Memory to Intent and from Memory to Plan. Such results indicate that the ability to plan and perform on the task depends upon information stored in memory.

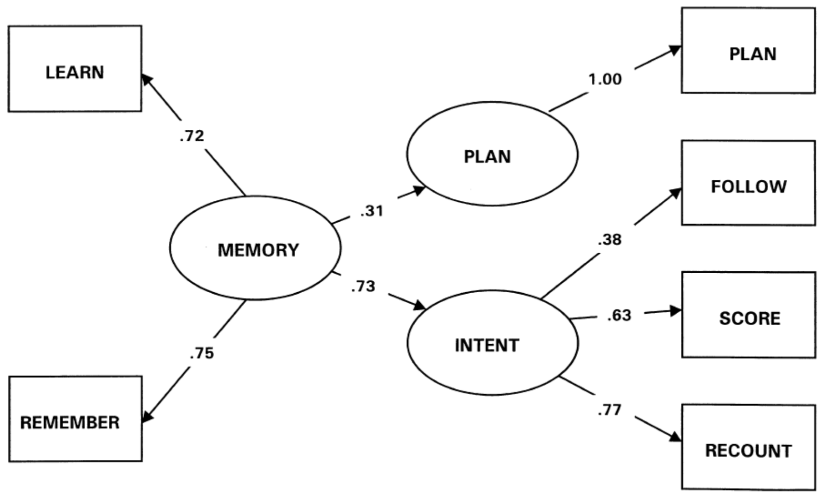

Figure 1: SEM of multitasking abilities (Burgess et al., 2000, p. 857). The squared variables represent the measured variables (indicators) and the circled variables represent the latent variables.

More recently, a second study exploring the cognitive underpinnings of multitasking abilities has been conducted by Logie et al. (2011) on a sample of 165 students. This time, multitasking abilities were assessed with a computerized task, the Edinburgh Virtual Errands Task (EVET) (Figure 2), which is based on the MET (Shallice & Burgess, 1991). During the EVET, participants find themselves in a virtual 4-floor building containing several rooms, stairs, and an elevator. In this virtual environment, they are required to realize eight errands within 8 minutes such as moving a package from one room to another, meeting a person at a certain time, turning off the lift, and getting the code to open a door. Moreover, participants have to follow several rules including using specific stairs to go up and others to go down, not entering a non-task-related room, and not picking up any non-pertinent object.

Figure 2: Screenshot of the EVET (Logie et al., 2011, p. 1564).

A similar method to the one adopted by Burgess et al. (2000) was used in order to examine the individual cognitive components of multitasking abilities. Thus, participants were first asked to learn the instructions (variable called “learn”), then to plan the order in which they will carry out the errands (“pre-plan”), to perform the task (“score”), and then to recall what they have done during the test (“recount”) and the instructions (“remember”). The pre-established plan was compared to what has been really realized by participants in order to obtain a measure of plan-following (“follow”). After the realization of the task, participants were asked to plan for another errand list (“post-plan”) as a second measure of planning. The total time participants were moving in the virtual environment was also recorded (“travel time”). Moreover, participants were evaluated with other standard cognitive tests assessing episodic memory, working memory (verbal and visual), prospective memory, and planning abilities (i.e., Travelling Salesman Problems[4], abbreviated “TSP” in Figure 3).

Based on the EVET and on the external cognitive variables, the authors proposed a new model of multitasking abilities using SEM. As in Burgess et al. (2000), this model (Figure 3) proposes that multitasking abilities are supported by three primary constructs: Memory (episodic and working visual and verbal memory), Plan, and Intent. Moreover, these latent variables were also related to each other such that unidirectional paths were described from Memory to Intent and to Plan, and from Plan to Intent. Such results indicate that the ability to plan depends upon working and episodic memory. Furthermore, the ability to perform on the task was also found to make demands upon memory and planning abilities.

[4] The Travelling Salesman Problems is a computerized planning test where participant are required to connect several targets in the order that formed the shorter possible path.

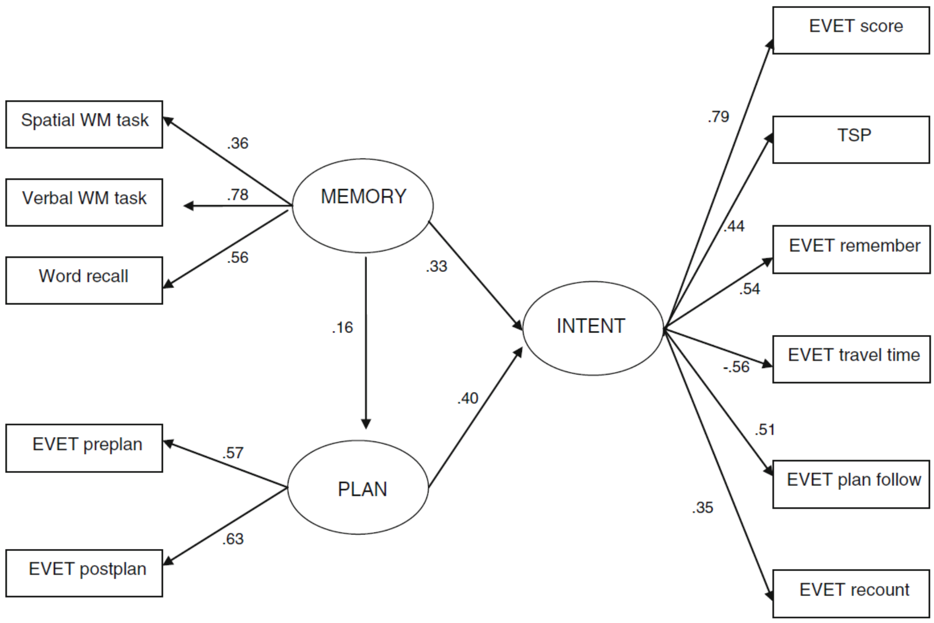

Figure 3: SEM of multitasking abilities (Logie et al., 2011, p. 1570). The squared variables represent the measured variables (indicators) and the circled variables represent the latent variables. The variable named "TSP" refers to the "Travelling Salesman Problems", the test used by the authors to assess planning abilities.

The external measure of prospective memory and the "learn" EVET variable were not included in the model due to a lack of contribution to any latent variable. In this study, prospective memory was measured by the breakfast task (Craik & Bialystok, 2006) which is a computerized test where participants have to shift between setting a virtual table and starting and stopping the cooking of different food items. The lack of contribution of this variable may be explained by the fact that performance on the task is multi-determined and rely upon many cognitive functions beside prospective memory, including planning abilities and working memory (Rose et al., 2015).

In fact, the two multitasking models (Burgess et al., 2000; Logie et al., 2011) present similarities and differences. To begin with, both models propose that multitasking abilities are supported by three primary constructs: memory, planning abilities, and intent. Furthermore, some relations between the latent variables were similar in both models. Specifically, paths were described from Memory to Intent and to Plan, indicating that the ability to plan and to perform on the tasks depends upon information stored in memory. However, Logie et al. (2011) also added a path from Plan to Intent suggesting that performance on the task also relies upon planning abilities. In fact, it was not possible for Burgess et al. (2000) to add such a path as SEM requires that the latent variables have more than one indicator (the plan latent variable in the model of Burgess et al. (2000) has only one indicator). Other specific differences can also be observed between both models when examining the indicators of the three latent variables. In particular, Logie et al. (2011) added external variables to their model, that is, variables representing performances on standard cognitive tests. Such an addition demonstrated the implication of cognitive functions that were not originally represented in the model of Burgess et al. (2000) including spatial and verbal working memory. Finally, the model of Logie et al. (2011) also introduced a distinction between (1) planning abilities as measured by asking participants to plan the order in which they will carry out the errands before or after conducting the task ("preplan" and "postplan") and (2) "online planning" as measured by the Traveling Salesman Problems. In particular, "preplan" and "postplan" variables were related to the plan latent variable whereas performance on the Traveling Salesman Problems was related to the intent construct. Such results indicate that despite having defined an action plan before conducting the task, participants tend to change it and plan "online" during the test.

These studies (Burgess et al., 2000; Logie et al., 2011) obviously provide a good basis for the understanding of multitasking abilities. However, both present a number of common limitations. The main issue is related to the fact that participants were required to follow a specific and sequential method to realize tasks. Such imposed method lacks ecological validity and artificially creates unidirectional relations between the cognitive underpinnings. For example, participants were first required to learn the instructions and then to plan the realization of the task based on their ability to remember them. Thus, if one forgets some instructions, it was not possible for him/her to take them into account during the planning phase. Indeed, during most real world multitasking activities, the realization of the task is not so sequential. For instance, during the preparation of a meal, one is not likely to learn the recipe by heart, then plan and then cook. He/she is more likely to read the recipe and plan the macro-structure of the meal preparation, then to prepare a part of the meal and then to go back to the cooking book and so forth. Thus, the different cognitive underpinnings constantly interact.

Another limitation is related to the multitasking tests used in the studies (i.e., the Greenwich task and the EVET). In particular, they do not take into account all the characteristics of multitasking activities (Burgess, 2000) such as the presence of interruptions/unexpected outcomes. Moreover, they both lack ecological validity as participants are required to realize different tasks that are not related to each other. For example, in the EVET, instructions ask participants to: *“pick up brown package in T4* (i.e., a room) *and take to G6; turn on cinema S7 at 5:30 min; turn off lift G floor;”* (Logie et al., 2011, p. 1565). Moreover, the tests impose explicit and artificially constraining rules to participants, which is not in line with real world activities. For instance, one rule of the Greenwich task states that participants will score more points for the red items and for items they do earlier than for items they do later.

Furthermore, performance on the multitasking tasks is only represented by one variable (i.e., “score”). The other measures are related to the performance before (e.g., learning the instructions) or after the task (e.g., recall what has been done). This reverts to an approach whereby specific cognitive functions (e.g., episodic memory) are measured and not multitasking abilities themselves. In fact, multitasking abilities may be composed of several facets related to different aspects of the activity such as the following of the rules or the ability to realize the task in an efficient way. There is thus a need to reflect multitasking performance with different variables that are measured during the test. In addition, Burgess et al. (2000) and Logie et al. (2011) explored a limited number of cognitive functions in relation to multitasking abilities, including episodic and working memory and planning. However, multitasking abilities may make demands upon other important cognitive functions that need to be explored. For example, during many real world activities, people have to create a plan of action (planning), to maintain this plan in mind throughout the task (memory), to explore the environment in an organized manner (planning), to try to remember as many required actions as possible (episodic, working, and prospective memory), to inhibit irrelevant stimuli during the task (inhibition), and to continuously shift between tasks and between internal (internal thoughts) and external (the environment) modes (cognitive and source flexibility).

In summary, only two studies have directly explored the cognitive underpinning of multitasking abilities: Burgess et al. (2000) in a sample of brain-injured patients and Logie et al. (2011) in a sample of students. Both studies have suggested that multitasking abilities are supported by three primary constructs related to memory (working and episodic), planning abilities, and intent (supposed to mainly reflect prospective memory). Nonetheless, these studies contain a number of major limitations related to the tasks used, the imposed sequential method to realize the tasks, and the limited number of cognitive functions examined in relation to multitasking abilities. There is thus a need to assess the cognitive underpinnings of multitasking abilities using a tool that is closely related to real world activities and where participants are free to adopt their own strategy to realize the task. Moreover, performance on the task should be represented by different variables measured during the test. Additionally, many cognitive functions need to be explored in relation to multitasking abilities.

Neuroanatomical underpinnings of multitasking abilities

Brain injuries

To the best of my knowledge, the first reported patient demonstrating relatively isolated disorganization of real world functioning was described by Penfield and Evans in 1935 and was actually Penfield's sister. Due to oligodendroglioma[5], this patient encountered an almost complete removal of the right frontal lobe. Unfortunately, she was not evaluated with formal tests assessing cognitive functions. However, according to Penfield and Evans, she presented no obvious impairment of memory, language, or perception, but

[5] A type a brain tumor related to the oligodendrocytes, a supportive type a brain cell implicated in the creation of the myelin sheath.

difficulties in the realization of complex, open-ended, and ill-structured activities. In particular, Penfield and Evans (1935, p. 131) wrote: "*One day about fifteen months after operation she had planned to get a simple supper for one guest and four members of her own family. She looked forward to it with pleasure and had the whole day for preparation. This was a thing she could have done with ease ten years before. When the appointed hour arrived she was in the kitchen, the food was all there, one or two things were on the stove, but the salad was not ready, the meat had not been started and she was distressed and confused by her long-continued effort alone. It seemed evident that she would never be able to get everything ready at once. With help the task of preparation was quickly completed and the occasion went off successfully with the patient talking and laughing in an altogether normal way.*"

Several years later, Eslinger and Damasio (1985) reported the case of a patient (EVR) operated on for a large bilateral orbitofrontal meningioma. After the surgery, EVR demonstrated no impairment in standard cognitive tests assessing IQ, episodic and working memory, executive functions (cognitive flexibility), language, and perception (excepting a bilateral anosmia). Moreover, the patient did not present any subsequent psychological or personality disorder and seemed to express normal comprehension of the social world and rules. For example, he was able to talk about politics, foreign affairs, and explain complex social situations. However, interviews conducted with the patient and his family revealed that EVR showed major difficulties in maintaining professional activity and making decisions. For instance, his employer complained about his tardiness, disorganization, and inappropriate manners and his wife left him after 17 years of marriage. Nonetheless, the patient remarried only one month after the departure of his wife (against the advice of his family) and divorced again after

2 years. EVR also lost a large amount of money due to risky investments. Moreover, the patient presented major difficulties in making decisions in his everyday life such as buying items in a supermarket or choosing a restaurant, as each aspect had to be discussed and compared (e.g., price). Finally, EVR had a tendency to cling to outdated and useless possessions such as dead plants, old phone books, and broken televisions. In summary, EVR was able to realize many cognitive tasks assessing different functions and seemed to express good social knowledge when assessed in an office context. However, the patient presented major difficulties when facing complex and open-ended situations.

These two cases (Penfield's sister and EVR) seem to have experienced multitasking difficulties even if multitasking abilities were not directly examined. In fact, as already mentioned in the beginning of this chapter, Shallice and Burgess (1991) and Goldstein et al. (1993) also described cases of brain-injured patients demonstrating preserved performances on standard cognitive tests but multitasking difficulties. Interestingly, all these cases suffered from a brain lesion in the frontal lobe.

Based on these cases (Eslinger & Damasio, 1985; Goldstein et al., 1993; Penfield & Evans, 1935; Shallice & Burgess, 1991), it is possible to draw the hypothesis that the frontal lobe plays a major role in multitasking abilities. However, these patients had large brain lesions rendering the identification of specific brain regions important for multitasking abilities difficult. Fortunately, in their 2000 study exploring the cognitive underpinnings of multitasking abilities, Burgess et al. also investigated the effects of different brain lesions on the behavioral sequence during the multitasking task (the Greenwich test). They found that patients presenting a lesion in the left rostral prefrontal cortex

(Brodmann's area 10, BA 10; Figure 4) tended to score poorly on the Greenwhich test. Moreover, this lesion had no effect on the other variables. Thus, these patients were still able to learn the rules, to plan, to remember their actions, and what they should have done but were unable to realize the task itself.

Figure 4: Brodmann area 10 (BodyParts3D, Mitsuhashi et al., 2009)

As already mentioned, Bird et al. (2004) have described the case of a brain-injured patient demonstrating impaired performance on a shortened version of the SET (Wilson et al., 1996) and episodic memory difficulties but preserved abilities on a wide range of standard cognitive tests (IQ, perception, theory of mind, and executive functions - cognitive flexibility, verbal fluency and inhibition). This patient is particularly interesting as her brain lesion was relatively specific. In fact, she encountered a rare form of stroke specifically affecting the medial aspect of area 10 bilaterally, suggesting the implication of this specific brain region in multitasking abilities.

Similarly, Roca et al. (2011) conducted a study that underlined the role of the BA 10 in multitasking abilities. More specifically, the authors compared the performance of patients suffering from a brain lesion in the BA 10, patients presenting a frontal lobe lesion but outside the BA 10 and healthy controls on tests assessing multitasking (the hotel task; Manly et al., 2002), executive functions (inhibition, working memory and abstract reasoning), and theory of mind. Results revealed that patients presenting a BA 10 lesion (in particular in the right lateral region) suffered from multitasking and theory of mind difficulties in the context of preserved performances on standard executive tests. Moreover, patients with a frontal lobe lesion but outside the BA 10 demonstrated impaired performance on standard executive tests but no multitasking difficulties.

Based on these previous studies, it could be maintained that brain lesions in the BA 10 induce multitasking difficulties. However, two studies have also suggested that patients presenting a BA 10 lesion suffer from prospective memory impairment. In particular, Umeda, Kurosaki, Terasawa, Kato, and Miyahara (2011) found that brain-injured patients who showed poor performance on a prospective memory test were more likely to have a lesion in the BA 10 than elsewhere in the frontal or temporal lobe. Moreover, results indicated that patients with a BA 10 lesion and participants with a brain lesion outside this zone were not significantly different for several tests assessing working and episodic memory, and executive functions (i.e., verbal fluency, cognitive flexibility, abstract reasoning). This association between a brain lesion in the BA 10 and prospective memory impairment was also found in a study by Volle, Gonen-Yaacovi, de Lacy Costello, Gilbert, and Burgess (2011). Interestingly, this impairment was independent of the used stimuli (words or images), meaning that the BA 10 has a nonspecific material role in prospective memory.

Taken together, these results suggest that the BA 10 is implicated in prospective memory and multitasking abilities. Indeed, these cognitive domains are highly related as the presence of delayed intentions is a main characteristic of multitasking activities (Burgess, 2000). However, none of the existing studies have assessed both multitasking abilities and prospective memory in the same sample, rendering impossible to make a direct link between them. Moreover, even if the integrity of the BA 10 seems important for multitasking, the cognitive functions underpinned by this specific brain region are still not well understood. After this review of the evidence provided by the study of brain-injured patients, the insights coming from neuroimaging studies will now be presented.

Neuroimaging

Coordination hypothesis

As pointed out in a review of the literature by Burgess, Simons, Dumontheil, and Gilbert (2005; see also Burgess & Wu, 2013), activation in the BA 10 observed under functional magnetic resonance imaging (fMRI) can be found during almost any kind of cognitive task, from basic to highly complex tasks such as auditory perception, motor learning, working and episodic memory, mentalizing, problem solving, or prospective memory. Moreover, a meta-analysis by Gilbert et al. (2006) suggested a functional specialization within BA 10 (Figure 5). More specifically, the authors found a lateral activation of the BA 10 during working and episodic memory tasks and a medial activation during mentalizing tasks. Gilbert et al. (2006) also showed that when confronted with the realization of more than one task at a time, participants demonstrated a particular activation in the rostral part of the BA 10. For example, during prospective memory tasks where an intention has to be kept in mind while conducting another task, or during tasks requiring the realization of goals and sub-goals. The authors suggested that the most rostral part of the BA 10 may support high level guidance and coordination of task performance.

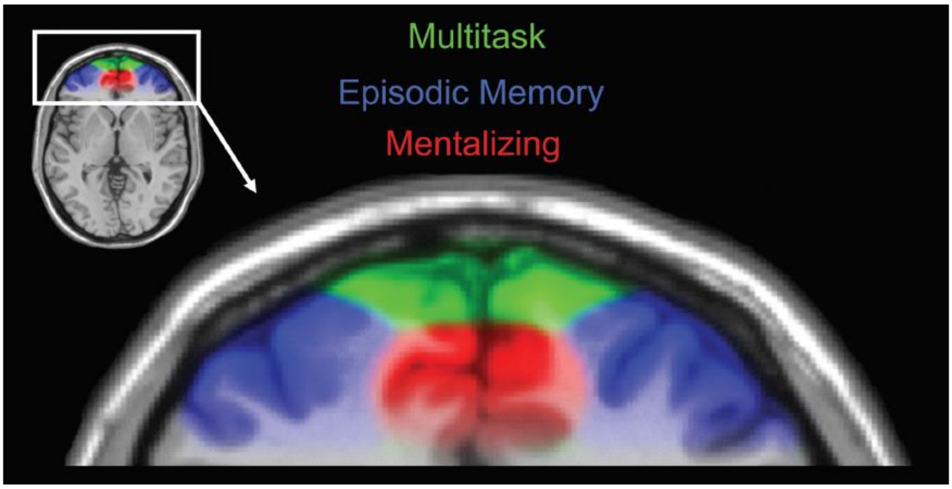

Figure 5: Partitioning of the BA 10 (Gilbert et al., 2006, p. 944).

A very similar view was expressed by Ramnani and Owen (2004) who conducted a review of the literature and proposed an interesting theory about the role of the BA 10. More specifically, the authors claim that the BA 10 would be engaged in situations involving several cognitive functions that need to be coordinated. In particular, the BA 10 would be implicated in situations requiring the integration and coordination of several separate cognitive operations. According to these authors, the role of the BA 10 would be to coordinate the different related cognitive operations, orchestrating the information processing and information transfer between multiple operations across supramodal cortex in the pursuit of a global goal. One major advantage of this theory is to integrate the connectional properties of the BA 10. In particular, the authors underlined the fact that the BA 10 is exclusively interconnected with supramodal cortex. Such an observation suggests that this brain region would particularly process abstract information. In fact, information transmitted into supramodal cortex from areas outside it (e.g., primary cortex) is represented at a more abstract level. The role of the BA 10 would thus be to further process this abstract information. This conceptualization is also in accordance with the hierarchical organization in the rostro-caudal axis (Badre & D'Esposito, 2009) suggesting that the BA 10 supports increasingly abstract representations.

In summary, activation of the BA 10 is found during almost all types of cognitive task. However, the most rostral region seems to be engaged during situations requiring the coordination of several cognitive operations. Indeed, such hypothesis may help explain why patients with a BA 10 lesion show preserved performances on standard cognitive tests assessing an isolated cognitive function, but difficulties in multitasking activities requiring the coordination of several cognitive functions. However, another insightful theory on the role of BA 10 in human cognition has been proposed by Burgess et al. (2005) – the gateway hypothesis.

Gateway hypothesis

The gateway hypothesis (Burgess, Dumontheil, & Gilbert, 2007; Burgess et al., 2005) claims that the BA 10 underpins an attentional gateway that allows one to control the degree to which one is engaging in stimulus-independent thoughts (i.e., the thoughts in one's head) or attending to external stimuli (i.e., environment) and switch between these sources – source flexibility. The authors state that this cognitive mechanism would be implied in many cognitive tasks but will not be critical for tasks involving routines or when the tasks' demands are well-specified by the task instructions or moment-by-moment feedback. This aspect explains why individuals with a BA 10 lesion present preserved performance on standard cognitive tests but multitasking difficulties, as the standard cognitive tests are well-specified. The authors also hypothesized that multitasking and prospective memory situations particularly imply this gateway because they require bearing in mind self-generated goals and task constraints while interacting with the environment. Moreover, multitasking activities are also likely to trigger internal attending with the person wondering what to do and plan *("what do I do now?")*.

Interestingly, the gateway hypothesis received some neuroanatomical support from fMRI studies. In particular, Burgess and his team (see Burgess et al., 2005 for a review) found that the medial BA 10 was particularly activated during stimulus oriented attending (i.e., when participants were oriented to the outer world) whereas the lateral BA 10 was more activated during the switching phases (from internal representations to the external world, and inversely) and internal attending. Moreover, they demonstrated that this activation was independent of the type of material or thought (e.g., visual or verbal material).

To date, a small number of studies have examined the relations between source flexibility and prospective memory and multitasking abilities. To begin with, a review of fMRI studies exploring the neuronal underpinning of prospective memory (Burgess et al., 2008; see also Burgess, Gonen-Yaacovi, & Volle, 2011) suggested that a lateral BA 10 activation was related to the maintenance of an intention whereas the medial BA 10 was more active during the ongoing task. Such results are consistent with the gateway hypothesis as the lateral BA 10 was found to be related to internal attending (e.g., the intention) whereas the medial BA 10 was related to stimulus oriented attending (e.g., the ongoing task). However, concerning multitasking abilities, only one study (Levaux, Van der

Linden, Larøi, & Danion, 2012) has suggested the implication of source flexibility in these complex activities. More specifically, Levaux et al. (2012) assessed a group of patients diagnosed with schizophrenia with a new observation-based test designed to assess multitasking abilities – a meeting preparation task. In this task participants are asked to prepare a room for a meeting for nine guests with the help of an instructions list containing the required objects and seating plan. Results demonstrated that the number of errors committed during the task as well as the prospective memory performance (i.e., time deviation regarding the required time to pick the coffee) was significantly related to source flexibility and in particular to the ability to switch from stimulus-oriented to stimulus-independent thoughts. Taken together, such results suggest that source flexibility is implicated in multitasking abilities and prospective memory. Unfortunately, no study has directly examined source flexibility in patients with a lesion in the BA 10. Indeed, demonstrating impaired source flexibility abilities in such patients would be a strong argument in favor of the gateway hypothesis.

Metacognition

Finally, some other authors have also suggested that the BA 10 would be implicated in metacognition (Burgess & Wu, 2013). In particular, Christoff and Gabrieli (2000) claimed that the role of this brain region would be to evaluate and control self-generated information. For instance, Johnson et al. (2002) found that the medial prefrontal cortex was particularly activated during a task requiring participants to judge statements about their own functioning (e.g., *"I forget important things"*). Similarly, Fleming, Weil, Nagy, Dolan, and Rees (2010) found a correlation between participants' ability to accurately judge their performance on a task and the gray matter volume in the prefrontal cortex. Indeed, the ability to reflect upon one's own performance may be particularly important in multitasking activities where people have to define for themselves what constitutes adequate performance and where the task does not contain feedback. However, interestingly, an implication of the BA 10 during metacognitive tasks could also be interpreted, at least partially, in regard to the gateway hypothesis as such self-judgments are likely to induce internal attending (Burgess et al., 2005).

Summary

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 where the person has to initiate, carry out, and alternate between different tasks, define the tasks' targets and face unexpected outcomes. To date, only two studies have directly explored the cognitive underpinnings of multitasking abilities and have suggested the implication of working, episodic, and prospective memory as well as planning abilities. However, these studies present many limitations in regard to the tests used to assess multitasking, the adopted method to examine the cognitive underpinnings, and to the few numbers of cognitive functions explored in relation to multitasking abilities. Additionally, several studies on brain-injured patients have suggested that multitasking abilities make demands upon different cognitive functions than those assessed with standard cognitive tests. Taken together, such results demonstrate the importance of evaluating multitasking abilities and the need to explore their cognitive underpinnings.

From a neuroanatomical point a view, multitasking abilities seem to rely upon the integrity of the rostral prefrontal cortex. Nevertheless, the role of this specific brain region is not clear. At present, three main hypotheses, that are not mutually exclusive, can be found in the literature: (1) the coordination hypothesis stating that the role of the BA 10 would be to coordinate different related cognitive operations, (2) the gateway hypothesis claiming that the BA 10 would underpin an attentional gateway between internal and external information, and (3) the hypothesis that the BA 10 would underpin metacognitive processes.

Chapter 3: Assessing multitasking abilities

As presented in Chapter 2, the first tools designed to assess multitasking abilities were created by Shallice and Burgess (1991), namely the Six Element Test (SET) and the Multiple Errands Test (MET). To date, several other tasks have been developed, but most of them were directly inspired from these first two tests. The following section will be dedicated to the description of the different existing assessment tools and their limitations. They are classified in regard to their method of assessment and origins, that is, whether tests were based on the tests created by Shallice and Burgess (1991) or directly inspired from real world activities. Four categories were created. (1) Questionnaires and scales that allow evaluating patients' real world functioning based on information provided by patients, their families, or clinicians. (2) Paper and pencil tests based on the SET and modified versions. They are designed to assess multitasking abilities in an office setting. (3) Observation-based tools created to assess multitasking abilities through the observation of patients during the realization of an activity. This category is subdivided into tests inspired from the MET and those directly based on real world activities that are of a multitasking nature. (4) Computerized tests offering the possibility to evaluate multitasking abilities by placing participants in a standardized and complex situation without leaving the office. This category is also subdivided into tests based on the MET and those inspired from real world activities.

Questionnaires/scales

In the literature, many different scales and questionnaires exist for measuring patients' level of real world functioning. There are several types based on the respondent. Either the patient him/herself (self-assessment), a family member (informant), or a clinician can be asked to complete the scale/questionnaire. However, to date, no questionnaire or scale has been designed to evaluate multitasking abilities. Indeed, some tools (e.g., the Specific Level Of Functioning assessment, Llorca et al., 2009; the Functional Remission of General Schizophrenia, Schneider & Struening, 1983) assess patients' ability to realize some complex everyday life activities such as housekeeping, shopping, or cooking a meal. Nonetheless, they mainly provide general information. For example, they can inform if a patient is able to cook or not but do not specify the kind of meals (e.g., fried eggs or full meal) or how the patient manages to prepare them.

Additionally, some characteristics of multitasking activities can be controlled or avoided in some cases. For example, one can turn off the phone while cooking and prepare only the vegetables, then the sausages, and warm them up together before eating. Thus, some activities can end up losing many characteristics of multitasking activities. Similarly, many everyday life activities are familiar and thus can be performed with the help of action schemata limiting the difficulty of the task. For example, it is possible to always prepare the same few meals. Moreover, it could be difficult for a person to verbalize how he/she manages to realize a multitasking activity. For instance, it may be possible for a person to explain how he/she realized a task, but it may be more difficult to explain how he/she managed to return to the main task after an interruption (e.g., did the person create a prospective memory intention or keep the information in working memory?).

Questionnaires and scales are also influenced by patients' lack of insight and social desirability bias. Similarly, informant assessments are limited by the lack of persons available to report on patients' real world functioning and by the informants' own cognitive, emotional, and psychiatric functioning. Taken together, these limitations render the questionnaires and scales not suitable to assess multitasking abilities.

Paper and pencil tests

Six elements test and modified versions

The original version (Shallice & Burgess, 1991) of the Six Elements Test (SET) has been described earlier in Chapter 2 as well as several derived versions of it such as a shortened variant (Wilson et al., 1998), the Greenwich test (Burgess et al., 2000), the strategy application task (Levine et al., 1998), or the hotel task (Manly et al., 2002). The idea behind the SET and adapted versions is to allow the assessment of multitasking abilities in an office setting. Even if these different tasks provide global indications about multitasking abilities, they present some common limitations. The main one is related to the fact that these tests do not reflect all the characteristics of multitasking activities as defined by (Burgess, 2000). For example, none of them contain any interruption/unexpected outcome and most of them do not possess clear prospective memory instructions. Moreover, they also lack ecological validity as they ask participants to realize different tasks that are not related to each other in a well-structured environment (i.e., an office). Finally, most of them impose explicit and artificially constraining rules, which is not in line with real world activities.

Observation-based assessments

Multiple Errands Test and modified versions

As presented in Chapter 2, the original version of the Multiple Errands Test (MET) was developed by Shallice and Burgess in 1991. To date, several adaptations of this test have been developed. To begin with, Alderman et al. (2003) proposed a simplified version of the MET that takes place in a shopping center. The main modification concerned the instructions that were simplified to avoid possible misinterpretation. For example, the authors added a rule not to buy all the required items in the supermarket. With a similar idea, Knight, Alderman, and Burgess (2002) have adapted the Alderman's test so that it can be used in a hospital setting.

However, similar to the original version of the MET, these modified versions contain several limitations. To begin with, these tests do not contain clear interruptions/unexpected outcomes, a characteristic required of multitasking activities (Burgess, 2000). Even though it is possible for participants to be interrupted during the realization of the task (e.g., by another customer), it may vary from one administration to another. Moreover, a series of other variables that may affect the performance cannot be controlled (e.g., the amount of noise and other distractors) and the testing environment may vary from one place to another. These tests thus lack standardization, rendering it virtually impossible to create normative data to use in a clinical setting in order to compare patients' performance and identify preserved and impaired multitasking facets.

Another limitation is related to the fact that these tests contain explicit and artificially constraining rules, which is not in line with real world activities. For example, one usual rule states that participants cannot enter a shop other than to buy something. However, this behavior could be an efficient strategy in real life (e.g., enter a shop to ask for directions).

Furthermore, only a limited number of variables can be measured as there are constraints as to how much the observer can note down and it is difficult to obtain precise measures. Finally, observation-based tests are difficult to administer in a clinical setting as they are time consuming and require available personnel to observe participants.

Tests based on real world activities

As many real world activities are of a multitasking nature, some authors have developed tests directly based on them. For example, different tasks were created where participants are required to shop for grocery store items in a supermarket (e.g., Hamera & Brown, 2000) or prepare a meal (e.g., Chevignard et al., 2008; Frisch, Forstl, Legler, Schope, & Goebel, 2012). Similarly, Semkovska, Bedard, Godbout, Limoge, and Stip (2004) developed an assessment tool where participants have to realize three activities: (1) choose a 3-set menu based on the available ingredients and the missing elements that will have to be bought in the supermarket respecting a certain budget; (2) shop for the missing ingredients in a local supermarket, and (3) cook a meal within an hour.

However, even if these tests offer the advantage of being highly ecological, one major limitation with such an approach is that performance on these tasks may be mediated by participants' familiarity with the activity. Thus, persons who are more familiar with doing the shopping/cooking in everyday life will have fewer difficulties performing the task and will not be relying on their executive functions as much in order to perform the task efficiently compared to persons who have only rarely shopped/cooked previously. Such influence complicates the interpretation of the results. Moreover, these tasks are frequently simplified in order to facilitate assessment but, as a result, end up not resembling the actual real world activity itself in that many of the characteristics of multitasking activities are lost. For example, a shopping task will be limited to the choice of items from a pre-established shopping list and exclude the payment at the cashier; or a meal preparation task will exclude some potential distractors such as a phone call.

In order to control for the influence of the familiarity with the task, Levaux et al. (2012) created a new observation-based task designed to assess multitasking abilities by placing the person in an unfamiliar situation. During this test, participants are required to prepare a room for a meeting for nine guests with the help of an instructions list containing the required objects (e.g., notepads, pens, and laptop) and seating plan (e.g., not to place a woman beside another woman). Moreover, they are also asked to pick the coffee at a certain time. While this task allows controlling for the familiarity with the situation (for people not used to prepare meetings), this tool also contains several limitations. To begin with, it does not take into account all the characteristics of multitasking activities as the test does not include interruption/unexpected outcome. Moreover, the prospective memory instructions are written and thus accessible at any time which is not compatible with the conceptualization of prospective memory tasks (Gonen-Yaacovi & Burgess, 2012). In fact, one important characteristic relies upon the impossibility for participants to realize the intended action immediately after the creation of the intention. The delay period between them should be filled with an activity (ongoing activity) preventing continuous rehearsal of the intention. Thus, if participants have access to the prospective memory instructions at any time, and read them periodically, it is possible to realize the action directly after the creation of the intention and without being disturbed by the ongoing activity.

More recently, Schneider et al. (2016) also designed a meeting preparation task for adolescents where participants are asked to prepare a room for five classmates with the help of an instructions list (e.g., prepare sandwiches and tea, the tables with the required objects and folders). However, even if this task contains an interruption (i.e., participants are told that one guest is not able to come), it does not contain clear prospective memory instructions.

Taken together, all these observation-based assessments present common limitations. In particular, they do not take into account all the characteristics of multitasking activities (Burgess, 2000) and lack standardization as the testing environment and conditions may vary from one place to another. Furthermore, only a limited number of variables can be measured as there are constraints to how much the observer can note down and it is difficult to obtain precise measures. Finally, observation-based tests are difficult to administer in a clinical setting as they are time consuming and require available personnel to observe participants. One way to overcome some of these limitations is to develop computerized tasks.

Computerized tasks

Computerized tests based on the Multiple Errands Test

As already mentioned in Chapter 2, Logie et al. (2011) developed a computerized test based on the MET (Shallice & Burgess, 1991) – the Edinburgh Virtual Errands Task. However, historically, it was not the first computerized adaptation of the MET.

The first adaptation was developed by McGeorge et al. (2001). In this test, participants find themselves in a recreation of the three floors of the psychology department at the University of Aberdeen (Figure 6). The task invites participants to imagine being a staff member of the psychology department and they receive a list of twelve errands to do within 20 minutes (e.g., read a magazine for ten minutes, make a cup of tea, meet a visitor at a certain time).They are told that they have to realize as many tasks as possible while respecting certain rules (e.g., use specific stairs to go up and others to go down). Indeed, this task is the first attempt to computerize the MET which is an important step towards the utilization of new technologies in psychology. However, as in the original version of the MET, it contains explicit and artificially constraining rules and lacks some important characteristics of multitasking activities (e.g., clear interruptions/unexpected outcomes). Moreover, the test provides feedback when an errand has been completed, which is not in line with the characteristics of multitasking activities (Burgess, 2000) stating that the task specifically should not contain feedback about the performance.

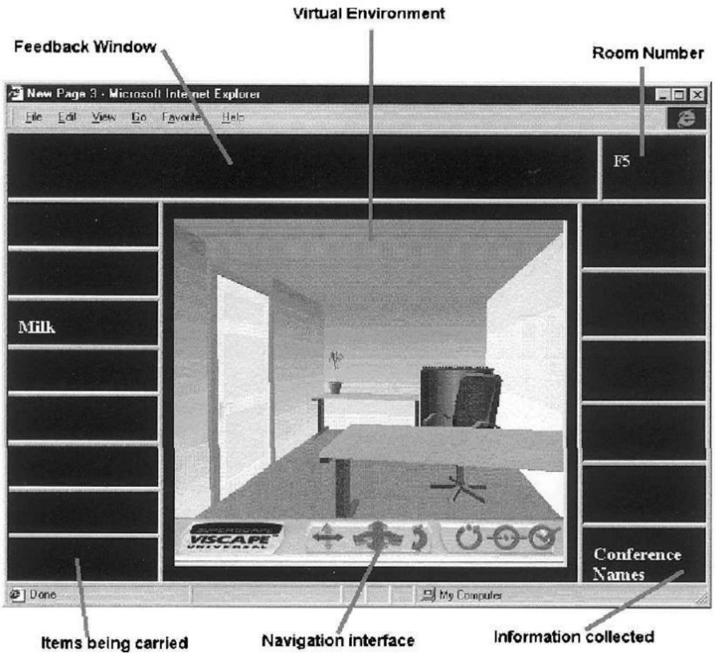

Figure 6: Screenshot of the task developed by McGeorge et al. (2001, p. 379).

More recently, Jovanovski, Zakzanis, Campbell, Erb, and Nussbaum (2012) proposed a new test with the idea to overcome some of the limitations of the original MET, such as the imposition of explicit and artificially constraining rules. Participants find themselves in a virtual city (Figure 7) composed of several buildings (e.g., participants' home, a pet store, a post office, and a bank) and are required to complete several tasks in 15 minutes (e.g., to buy six pens, go to see the doctor at a certain time, drop a letter off at the post office). However, this task was simplified in comparison to real world multitasking activities (moreover, the virtual environment is really basic) and lacks important characteristics of them (e.g., interruptions/unexpected outcomes).

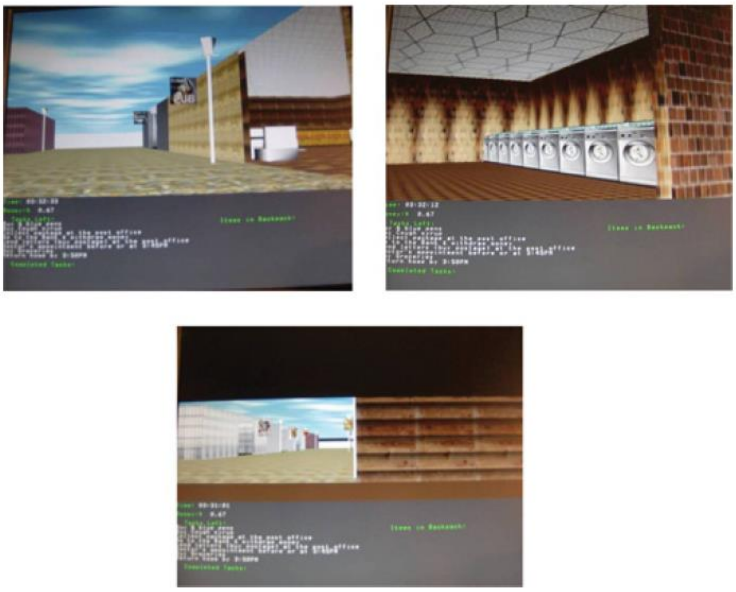

Figure 7: Screenshots of the virtual city task (Jovanovski et al., 2012, p. 174).

Another promising test was recently created by Jansari et al. (2014) – the Jansari assessment of executive functions (Figure 8) — where participants are required to play the role of an office worker who has to prepare a meeting. To do so, participants have to conduct several tasks such as arrange five agenda topics by order of importance, find a method to cover graffiti on a white board, turn on the projector 10 minutes before the start of the meeting, and make a note for any equipment that is broken. Unfortunately, the description of the task in the article is succinct and lacks important details, rendering it difficult to tell whether or not the task reflects all the characteristics of multitasking activities. Nevertheless, the task seems to lack theoretical basis in that the computed scores during the task refer to questionable cognitive constructs (e.g., selective thinking, creative thinking, and adaptive thinking).

Figure 8: Screenshot of the Jansari assessment of executive functions task (Jansari et al., 2014, p. 8).

Finally, other authors developed tasks based on the MET (Shallice & Burgess, 1991) in the context of shopping in a virtual supermarket or mall (e.g., Cipresso et al., 2014, Figure 9; Rand, Katz, Kizony, & Weiss, 2005; Raspelli et al., 2010). In these tests, participants have to carry out several tasks such as buy items, obtain information (e.g., the closing time of the supermarket), and conduct some prospective memory tasks (e.g., check the cart at a certain time). Moreover, participants have to respect some rules (e.g., do not buy more than two items from the same aisle). However, as in the original version of Shallice and Burgess (1991), these tasks lack some important characteristics of multitasking activities (e.g., clear interruptions/unexpected outcomes) and impose explicit and artificially constraining rules.

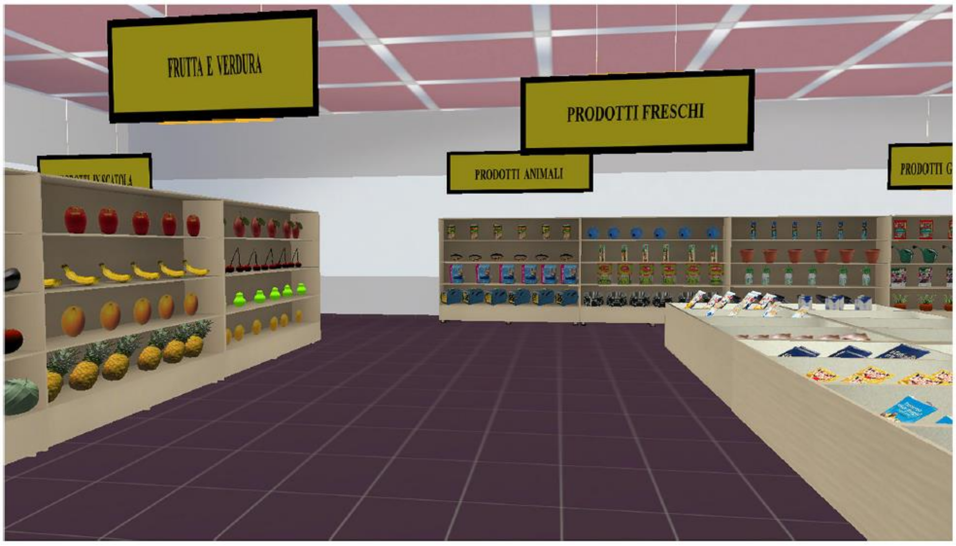

Figure 9: Screenshot of the Virtual MET (Cipresso et al., 2014, p. 5).

Computerized tests based on real world activities

Beside these adaptations of the MET (Shallice & Burgess, 1991), some other authors have developed computerized tasks directly inspired from real world activities that vary in terms of complexity and multitasking characteristics. For example, two different teams, Klinger, Chemin, Lebreton, and Marie (2006) and Larøi, Canlaire, Mourad, and Van der Linden (2010) (Figure 10), have developed shopping tasks where participants are required to shop for a list of grocery store items in a virtual supermarket. However, these two tests differ on several characteristics. In particular, compared to the task of Klinger et al. (2006), the test of Larøi et al. (2010) is closer to a real world shopping activity. For example, the task contains distractors in the presence of other customers, music played in the background and loud-speaker announcements. Similarly, some other authors developed cooking tasks where participants are required to prepare a meal (e.g., Zhang et al., 2003) (Figure 11) or coffee (Allain et al., 2014; Cao, Douguet, Fuchs, & Klinger, 2010; Klinger, Cao, Douguet, & Fuchs, 2009). More recently, Ruse et al. (2014) created a test designed to assess several real world tasks: the ability to check the availability of items to complete a recipe, take the bus, shop in a supermarket, and manage currency. However, most of these tasks were simplified compared to the real life activities and thus lack some important multitasking characteristics. Finally, as in the observation-based assessments inspired from real world activities, performance on such tasks can be modulated by participants' familiarity with the evaluated situation.

Figure 10: Screenshots of the computerized shopping task developed by Larøi et al. (2010).

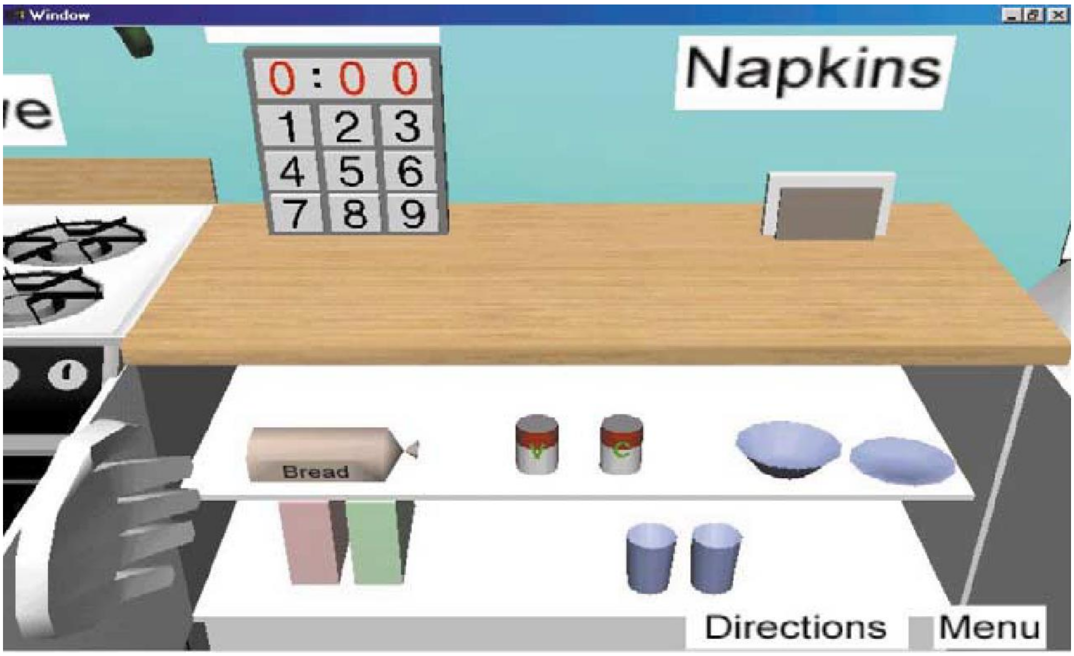

Figure 11: Screenshot of the virtual kitchen created by Zhang et al. (Zhang et al., 2003, p.1121).

Summary

The literature shows that countless research groups all over the globe have developed different tools to assess real world functioning and multitasking abilities. The effort and creativity have been tremendous, yet there are limitations to all these tools. In particular, the questionnaires and scales only provide general information about patients' functioning and are dependent on patients' level of insight and on persons available to report on patients' abilities. Moreover, they do not seem suitable to assess multitasking abilities as they seem difficult to verbalize. In addition, some characteristics of multitasking activities can be controlled or avoided in some cases, ending up having lost many characteristics of them. Similarly, many everyday life activities are familiar which limits their difficulty. Taken together, these limitations render it difficult to assess the extent to which patients encounter multitasking difficulties with questionnaires and scales. Other authors have developed observation-based assessments but most of them do not reflect all the characteristics of multitasking activities. Furthermore, they lack standardization, only providing a limited number of variables, and are difficult to apply in a clinical setting as they are time consuming, require available personnel to observe participants, and sometimes to leave the hospital (e.g., to go to a mall). One way to overcome some of these limitations is to develop computerized tasks. However, the existing tasks also present several limitations as most of them do not take into account all the characteristics of multitasking activities. Moreover, a transversal limitation to the many observation-based and computerized tools is related to the fact that performance on these tasks may be mediated by participants' level of familiarity with the activity, which complicates the interpretation of the results. Moreover, these tests also lack ecological validity as many of them impose explicit and artificially constraining rules that are not found in real world activities. Taken together, all these different tools show that creating a task without limitation is virtually impossible. That being said, new tasks which overcome as many limitations as possible are urgently needed. In particular, there is a clear need for standardized tools that are accessible in a clinical setting, which are closely related to real world activities – but that at the same time, place participants in an unfamiliar situation.

Chapter 4: Multitasking abilities in schizophrenia and bipolar disorder

After the review of the different existing multitasking tests, the evidence on the multitasking abilities in persons suffering from schizophrenia and bipolar disorder will now be reported. Indeed, difficulties in real world functioning are core features of those clinical populations (WHO, 2008). In particular, these patients seem to have problems with the more complex activities of real world that are of a multitasking nature, such as maintaining professional activity, shopping, preparing a meal, or doing the housework.

However, only one study has indirectly examined this issue in schizophrenia. Semkovska et al. (2004) conducted a study to explore the relations between executive impairments and real world activities. Semkovska et al. (2004) compared the performance of patients diagnosed with schizophrenia with healthy controls during the realization of three real world tasks where participants had to: (1) choose a 3-set menu, (2) shop for the missing ingredients in a local supermarket, and (3) cook a meal within an hour. Moreover, they examined the relationships between performance on these tasks and standard cognitive tests and severity of symptomatology. Results showed that patients performed worse than controls for all three tasks. In particular, one task could be considered as being especially of a multitasking nature, namely the cooking task, and was found to be the most impaired in patients. In fact, participants had different tasks to complete (i.e., preparing soup, potatoes, meat, and a cake) that required interleaving and delayed intentions and were likely to encounter unexpected outcomes (e.g., something that was burning). These results suggested that patients diagnosed with schizophrenia particularly encounter difficulties in activities of a multitasking nature. Moreover, results demonstrated that performance on the cooking task was significantly correlated with executive functions (i.e., cognitive flexibility, verbal fluency, planning, sequential thinking, and inhibition), but also with verbal and non-verbal episodic memory, selective attention and negative symptom severity.

To date, a small number of studies have more directly explored multitasking abilities in schizophrenia and bipolar disorder using the tests originally developed by Shallice and Burgess (1991). For example, using a shortened version of the SET (Wilson et al., 1996), three studies (Evans, Chua, McKenna, & Wilson, 1997; Katz, Tadmor, Felzen, & Hartman-Maeir, 2007; van Beilen, Withaar, van Zomeren, van den Bosch, & Bouma, 2006) have found that patients with schizophrenia demonstrated poorer performance than healthy controls (i.e., a lower global score), suggesting the presence of multitasking difficulties. Nonetheless, the relations between performance on the SET and measures of real world functioning varied across studies. In particular, Katz et al. (2007) showed a significant correlation between the SET and an observation-based measure of real world functioning. However, Evans et al. (1997) did not find any significant relation between the SET and self and informant evaluations of real world functioning. The authors explained this absence of results by the difficulty in differentiating between the impact of symptoms and cognitive difficulties on real world functioning and patients' lack of insight.

Interestingly, some results of these studies suggest the heterogeneity and specificity of multitasking abilities in schizophrenia. More specifically, Evans et al. (1997) found a double dissociation in schizophrenia between multitasking abilities and memory (episodic and prospective). In particular, two patients were found to present an impaired performance on the SET but not on the memory test and two patients demonstrated the opposite profile. As it has been found in brain-injured patients (Burgess et al., 2009), this double dissociation between performance on a multitasking test and memory suggests that multitasking abilities make demands upon different cognitive functions that are not assessed with standard cognitive tests.

Another intriguing finding about the SET has been demonstrated by van Beilen et al. (2006). Specifically, these authors found that one third of the patients included in the study used a continuous switching strategy to realize the task. Instead of dividing their time over different tasks, these patients switched continuously after each item. However, this method was practically never used by healthy controls or brain-injured patients. Supplementary analyses showed that the patients who used this strategy demonstrated poorer abilities in episodic memory and sustained attention compared to the patients who did not use it. The authors suggested that the use of this specific strategy could reflect a coping strategy to face cognitive impairments. It is indeed possible that patients with schizophrenia who encounter developmental cognitive impairments acquire better coping abilities compared to brain-injured patients who have to deal with their recent deficits. These results suggest the heterogeneity of multitasking abilities in schizophrenia as two different profiles were identified that varied in the strategy adopted to realize the SET.

To date, only two studies have used an adapted version of the original MET (Shallice & Burgess, 1991) to assess multitasking abilities in schizophrenia and bipolar disorder in comparison to healthy controls. These studies used a similar methodology except that Torralva et al. (2012) only included patients diagnosed with bipolar disorder whereas Caletti et al. (2013) assessed patients diagnosed with bipolar disorder and those with schizophrenia. In these studies, patients were asked to realize the hospital version of the MET (Knight et al., 2002) and an adapted version of the hotel task (Manly et al., 2002; Torralva, Roca, Gleichgerrcht, Bekinschtein, & Manes, 2009) in addition to a cognitive battery assessing processing speed, memory, and executive functions. Results showed that patients demonstrated a significantly poorer performance than healthy controls on the MET (e.g., more inefficiencies and rule breaks) and on the hotel task (e.g., less tasks attempted).

Furthermore, Torralva et al. (2012) found that performance on the hotel task, but not on the MET, was significantly correlated with real world functioning in patients diagnosed with bipolar disorder. Similarly, Caletti et al. (2013) demonstrated that performance on both the MET and the hotel task was related to real world functioning. However, the authors conducted these analyses on a group consisted of patients with bipolar disorder and schizophrenia, and healthy controls which complicates the interpretations of the findings. In addition, Torralva et al. (2012) found that cognitive flexibility and working memory abilities were related to performance on the hotel task, suggesting the implication of these cognitive functions in multitasking abilities in patients diagnosed with bipolar disorder. Interestingly, in Torralva et al. (2012), patients with bipolar disorder demonstrated multitasking difficulties despite preserved performances on standard cognitive tests, underlining the importance of evaluating multitasking abilities and suggesting the specificity of these difficulties. Finally, Caletti et al. (2013) also found that patients diagnosed with bipolar disorder presented fewer multitasking difficulties than patients with schizophrenia. Such results are consistent with the observation that patients with bipolar disorder generally demonstrate better cognitive (Bortolato et al., 2015) and real world functioning (Bowie et al., 2010; WHO, 2008) than patients diagnosed with schizophrenia.

More recently, Bulzacka et al. (2016) have also administered an adapted version of the MET (Shallice & Burgess, 1991) to a sample of patients suffering from schizophrenia in addition to standard executive tests and a clinician evaluation of real world functioning. Results demonstrated that the global score of the MET (taking into account inefficiencies, rule breaks, and task failures) was related to planning abilities and cognitive flexibility. Moreover, the different variables of the MET (e.g., rule breaks, inefficiencies, task failures) were revealed to be significantly correlated with real world functioning whereas the standard executive tests did not reach significance. Unfortunately, patients' performances were not compared to healthy controls. However, from a qualitative point of view, the authors observed that most patients did not create an action plan and realized the different errands following the order of the written instructions. Interestingly, patients were generally not able to adequately judge the accuracy of their performance. Finally, patients tended to avoid social interactions during the tests or adopted inappropriate social behaviors. These last results may be explained by the presence of psychotic symptoms. However, relations between symptoms and performance on the MET were not directly assessed.

Taken together, previous studies using the MET and the SET (and modified versions such as the hotel task) suggest that persons diagnosed with schizophrenia and bipolar disorder encounter multitasking difficulties. Moreover, these difficulties were found to be related to real world functioning. However, these studies only provided a few elements to the understanding of the cognitive underpinnings of multitasking abilities, as the vast majority of them did not explore the relations between multitasking abilities and other cognitive measures. Furthermore, the tests used to assess multitasking abilities have some important limitations as they do not reflect all the characteristics of multitasking activities, lack ecological validity, and only provide a limited number of variables. Finally, none of these studies explored the relations between multitasking tests and symptoms. However, it is interesting to underline that a study by Raffard et al. (2016) found a link between performance on the shortened version of the SET (Wilson et al., 1996) and a dimension of apathy related to interest and self-awareness in schizophrenia. Such results suggest that apathy may have an impact on multitasking abilities in schizophrenia.

Addressing some of the limitations of previous studies that used the MET or SET, some studies (Josman, Schenirderman, Klinger, & Shevil, 2009; Larøi et al., 2010) have been conducted which explore the relations between complex tasks inspired from real world activities and cognitive functions in patients diagnosed with schizophrenia. For example, Larøi et al. (2010) developed a computerized shopping task where participants are required to shop for a list of seven grocery store items in a virtual supermarket. The authors found that compare to healthy controls, patients diagnosed with schizophrenia took significantly more time to complete the task, bought less correct articles, went more often in the same aisles, visualized more non-pertinent shelves (i.e., number of times participants zoomed on non-pertinent shelves with the gamepad), consulted the shopping list more often and spent more time consulting it. Moreover, Larøi et al. (2010) found that these variables were mainly correlated with executive functions, including cognitive flexibility, planning abilities, inhibition, verbal fluency, but also with episodic memory and processing speed. Performance on the shopping task was also demonstrated to be related to real world functioning (clinician evaluation) and more severe symptoms (positive and negative). Finally, the patients who successfully collected the required items during the shopping task were compared to those who did not in terms of cognitive performance, symptoms, and real world functioning. Results revealed no significant difference between subgroups, suggesting the influence of other factors. Similarly, Josman et al. (2009) also found that patients diagnosed with schizophrenia performed worse than healthy controls on a computerized shopping task. In particular, patients purchased fewer correct items, realized fewer correct actions (e.g., they proceeded to an unattended checkout counter), and took more time to pay at the checkout. Moreover, performance on the shopping task was found to be significantly related to negative symptoms and other cognitive tests assessing planning, cognitive flexibility, and multitasking (SET).

Taken together, these results suggest that multitasking abilities in patients suffering from schizophrenia may be mainly related to executive functions. However, the implication of more specific cognitive functions, such as prospective memory, was not explored. Moreover, the tasks used by Larøi et al. (2010) and Josman et al. (2009) present some limitations. In particular, these tasks lack some characteristics of multitasking activities such as the presence of interruptions/unexpected outcomes and clear prospective memory instructions. Furthermore, these tests suffer from the influence of 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.

In order to control for the familiarity with the task, Levaux et al. (2012) created a new observation-based test designed to assess multitasking abilities by placing the person in an unfamiliar situation – a meeting preparation task. For this study, forty-five patients with schizophrenia and paired healthy controls were asked to complete this new test in addition to a cognitive battery assessing processing speed, attentional control, inhibition, working memory, cognitive and source flexibility (in particular the time taken to switch from the outer world to internal representations), and multitasking (shortened version of the SET, Wilson et al., 1996). Results showed that patients performed worse than healthy controls for the observation-based multitasking test. More specifically, patients made more errors (e.g., placed a number of incorrect objects on the table and forgot required items), achieved fewer goals (i.e., placed fewer required objects), broke more rules regarding the required object and the seating plan, and presented difficulties in respecting the prospective memory instructions (i.e., pick the coffee at a certain time). Results also demonstrated that the number of errors was predicted by the cognitive measures and in particular by source flexibility (10% of the variance), working memory (9%), and processing speed (9%). Similarly, the cognitive variables and in particular source flexibility (16% of the variance) were also found to significantly predict the prospective memory variable (i.e., time deviation regarding the required time to pick the coffee). Finally, patients' performance on the meeting preparation task was highly heterogeneous as patients showed different profiles with a combination of both preserved and impaired variables. Moreover, some patients were found to encounter more difficulties during the multitasking test compared to the cognitive measures and some patients demonstrated the opposite profile. Such results underline the fact that multitasking abilities make demands upon cognitive functions that are not assessed with standard cognitive tests.

The results of Levaux et al. (2012) thus suggest the implication of processing speed, working memory, and source flexibility in multitasking abilities in persons diagnosed with schizophrenia. However, the possible influence of some other important cognitive functions, such as prospective memory, was not assessed. Moreover, even if the task developed by Levaux et al. (2012) offers the advantage of limiting the influence of the familiarity with the evaluated situation, the test presents other limitations. For example, it lacks some characteristics of multitasking activities (e.g., interruptions/unexpected outcomes), is difficult to carry out in a clinical setting, and lacks standardization as the testing environment may vary from one place to another.

A major contribution of the study by Levaux et al. (2012) was to suggest the implication of source flexibility in multitasking abilities. In fact, source flexibility is hypothesized (Burgess et al., 2007) to be important for the realization of complex and multitasking activities, as they require keeping a global goal in mind while conducting another task and are likely to trigger internal attending in order to create an action plan. In the study by Levaux et al. (2012), the authors only focused on the ability to switch from the outer world to internal representations. However, source flexibility is a multifaceted construct (Gilbert, Frith, & Burgess, 2005) and the ability to switch from internal representations to the outer world could be related to multitasking abilities as well. Moreover, performance on the source flexibility task was reflected by reaction times. Yet, such measures could be influenced by processing speed which is usually impaired in schizophrenia (Dickinson et al., 2007).

Taken together, the previous studies demonstrated that multitasking abilities may be related to different cognitive functions including processing speed, selective attention, episodic and working memory, cognitive and source flexibility, planning abilities, and inhibition. However, none of these studies have examined if these relations were due to the influence of a general cognitive factor. In particular, processing speed (Dickinson et al., 2008; Dickinson et al., 2007) and working memory (Johnson et al., 2013; Silver et al., 2003) have both been demonstrated to be two large deficits in schizophrenia that can impact the performance on tests assessing other cognitive functions. Indeed, processing speed and working memory contribute, at least partially, to many different cognitive abilities. It is thus possible that a deficit in one of these domains impacts the performance on other tests. Similarly, some authors have also suggested that processing speed impairment would contribute to a range of cognitive difficulties in bipolar disorder (Antila et al., 2011).There is thus a need to differentiate the effects of specific cognitive impairments from a more general deficit of working memory or processing speed.

Summary

Many real world activities are of a multitasking nature. However, to date, only a small number of studies have explored multitasking abilities in schizophrenia and bipolar disorder using different tests. These studies have suggested that patients encounter multitasking difficulties and that these abilities are related to real world functioning. However, the nature of these difficulties is poorly understood. In fact, several studies have suggested that multitasking abilities are related to different cognitive domains such as executive functioning, memory, and attention. Nonetheless, multitasking abilities also seem to make demands upon different cognitive functions that are not assessed with standard cognitive tests. Furthermore, the potential implications of several cognitive functions were not explored nor were the effects of a general cognitive factor. Finally, the impact of symptoms on multitasking abilities has rarely been examined. Taken together, these results demonstrate the importance of evaluating multitasking abilities in clinical practice. However, the existing tools present several limitations as many of them lack characteristics of multitasking activities, lack standardization, are influenced by familiarity with the task, and are difficult to apply in a clinical setting. There is thus a clear need for standardized tools that are accessible in a clinical setting and closely related to real world activities – but that at the same time place participants in an unfamiliar situation. Using these tools, there is a need to explore the cognitive and clinical correlates of multitasking abilities.

Interlude

Summary of the existing literature

Persons diagnosed with schizophrenia and bipolar disorder encounter difficulties in real world functioning. Some evidence suggests that it would be particularly the case during multitasking activities. However, multitasking abilities have rarely been properly examined in the literature due to the absence of suitable assessment tools. Moreover, previous studies on brain-injured patients have found that these abilities make demands upon different cognitive functions that are not assessed with standard cognitive tests. Nonetheless, the nature of these cognitive underpinnings is not well understood. To date, a small number of studies have suggested that multitasking abilities are related to executive functioning, memory, and attention. However, these studies possess several limitations as multitasking abilities were not assessed with tools reflecting all the characteristics of multitasking activities. Furthermore, the potential implications of several cognitive functions were not explored nor were the effects of a general cognitive factor. Finally, the impact of symptoms on multitasking abilities was rarely examined. There is thus a clear need for standardized tools that are accessible in a clinical setting, that are closely related to real world activities – but that at the same time place participants in an unfamiliar situation. Moreover, the cognitive underpinnings of multitasking abilities as well as the relations with symptoms need to be explored.

Aims of the thesis

The present thesis aims for two main goals:

1) To examine multitasking abilities in bipolar disorder using the computerized shopping task developed by Larøi et al. (2010). A second aim was to explore the cognitive underpinning of multitasking abilities in bipolar disorder, particularly regarding the effects of a general cognitive impairment of processing speed. Finally, it was also an aim to examine the ability of the shopping task to predict patients' real world functioning and to explore the relations between multitasking abilities and symptoms.

2) To explore multitasking abilities in persons diagnosed with schizophrenia using a new standardized tool designed to assess multitasking abilities which reflects all the characteristics of multitasking activities (Burgess, 2000) – but at the same time that places participants in an unfamiliar situation – the Computerized Meeting Preparation Task (CMPT). A second aim was to explore the cognitive underpinnings of multitasking abilities in persons diagnosed with schizophrenia. In particular, the aim was to examine the relations between multitasking abilities and both specific and general cognitive functions. A last aim was to explore the ability of the CMPT to predict patients' real world functioning and investigate the relations between multitasking abilities and symptoms.

History of "Neworld"

The "Neworld" project began in 2005 with the intention to render the evaluation of cognitive functioning for patients easier in a hospital setting. However, the project was quickly redirected to the creation of computerized tools allowing the assessment of real world functioning. The first task imagined by the research group consisted of a computerized shopping task designed as a measure of real world functioning.

With this experience of the shopping task, the group began to work on the development of a second test. The first idea about it was to assess multitasking abilities with the help of a computerized meal preparation task. However, as the familiarity with the evaluated task can have a great impact on the performance, the group imagined putting patients in an unfamiliar situation by asking them to prepare a room for a meeting – the Computerized Meeting Preparation Task was born.

Experimental section

Performance on a computerized shopping task significantly predicts real world functioning in persons diagnosed with bipolar disorder

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Abstract

Persons diagnosed with bipolar disorder often suffer from cognitive impairments. However, little is known concerning how these cognitive deficits impact their real world functioning. We developed a computerized real-life activity task, where participants are required to shop for a list of grocery store items. Twenty one individuals diagnosed with bipolar disorder and 21 matched healthy controls were administered the computerized shopping task. Moreover, the patient group was assessed with a battery of cognitive tests and clinical scales. Performance on the shopping task significantly differentiated patients and healthy controls for two variables: Total time to complete the shopping task and Mean time spent to consult the shopping list. Moreover, in the patient group, performance on these variables from the shopping task correlated significantly with cognitive functioning (i.e., processing speed, verbal episodic memory, planning, cognitive flexibility, and inhibition) and with clinical variables including duration of illness and real world functioning. Finally, variables from the shopping task were found to significantly explain 41% of real world functioning of patients diagnosed with bipolar disorder. These findings suggest that the shopping task provides a good indication of real world functioning and cognitive functioning of persons diagnosed with bipolar disorder.

Introduction

Persons diagnosed with bipolar disorder frequently suffer from cognitive impairments, which include deficits in attention, episodic memory, executive functioning (Quraishi & Frangou, 2002) and processing speed (Bora, Yucel, & Pantelis, 2007; Torres, Boudreau, & Yatham, 2007). Furthermore, studies show that these impairments are major predictors of poor real world functioning (Martinez-Aran et al., 2007; Altshuler, Bearden, Green, van Gorp, & Mintz, 2008; Bowie et al., 2010). Few studies have examined how these cognitive deficits impact real world functioning in patients with bipolar disorder. Only two studies (Bowie et al., 2010; Mausbach et al., 2010) have investigated this question by using the short version of the University of California San Diego Performance Based Skills Assessment (UPSA-B; Mausbach, Harvey, Goldman, Jeste, & Patterson, 2007), which is a measure of functional capacity where participants are required to perform brief and simple everyday tasks in areas of communication (i.e., call to reschedule a doctor's appointment, make an emergency call) and finances (i.e., count change, read a utility bill). Mausbach et al. (2007) demonstrated that poor performance on the UPSA-B was related to poor levels of residential independence, activities and work (Specific Level of Functioning, Schneider & Struening, 1983) and IQ, and greater severity of positive and negative symptoms. Similarly, in Bowie et al. (2010), results indicated multivariate path models linking real world functioning with: cognitive functioning, functional capacity (UPSA-B, financial, and social skills) and symptoms.

More recently, Torralva et al. (2012) explored the usefulness of more ecological tests that are sensitive to executive dysfunction in order to detect cognitive deficits in a group of persons diagnosed with bipolar disorder. They used the Multiple Errands Test - Hospital Version (MET-HV; Knight, Alderman, & Burgess, 2002), which is an observation-based assessment that requires patients to carry out a number of tasks simulating real world tasks in a hospital setting (e.g., purchase items, collect information such as the price of a dinner menu, call the evaluator 20 minutes after the test has begun) while at the same time respecting certain rules (e.g., not buying more than 2 items in the hospital shop, not going back into a building that the participant has already been in). An adaptation of the Hotel Task (Manly, Hawkins, Evans, Woldt, & Robertson, 2002) was also included in the study, which requires participants to manage simple tasks that a person would plausibly need to undertake while working in a hotel (i.e., compile invoices, sort the charity collection, look up phone numbers, sort conference labels, and proofread the hotel leaflet). Participants were also administered a thorough battery of standard cognitive tests (assessing attention, memory, language and executive functions) and an evaluation of real world functioning (Global Assessment Functioning, GAF; American Psychiatric Association, 1994). Results showed that there were no significant differences between patients with bipolar disorder and healthy controls regarding their performance on the cognitive tests, but that patients demonstrated significantly poorer performances on 2 (i.e., strategy inefficiencies and rule breaks) of the 4 variables of the MET-HV and one (i.e., the number of tasks attempted) of the 2 variables of the Hotel task. Moreover, performance on the Hotel task was related to executive (i.e., cognitive flexibility and working memory) and real world functioning (GAF) but performance on the MET-HV was not related to cognitive or real world functioning. The authors concluded that the inclusion of more ecological tests is useful to detect subtle deficits that could impact real world functioning.

There are, however, a number of limits associated with measures such as the UPSA-B and the Hotel Task. In particular, participants are asked to perform relatively simple tasks, which do not reflect the complex and multi-tasking nature of many real world activities. In addition, observation-based assessments, such as the MET-HV, may be difficult in practical terms (e.g., finding the time and staff to observe patients during activities) and frequently include artificially constraining rules that are rarely encountered in real world activities. Furthermore, a series of variables cannot be controlled (e.g., variations in the number of shoppers in the case of a shopping task, the amount of noise, etc.). It is also difficult to obtain precise measures of performance when conducting qualitative observations and only a limited number of variables can be encoded.

One way of addressing these limits is to develop computerized versions of more complex tasks (that more accurately reflect real world activities), where the environment is the same for all participants and where a large number of variables can be calculated. In this context, Larøi, Canlaire, Mourad and Van Der Linden (2010) developed a computerized shopping task. Thirty individuals diagnosed with schizophrenia and 30 healthy controls were administered this task and a battery of cognitive tests. Performances on the shopping task significantly differentiated patients and healthy controls for several variables and these variables correlated with a global measure of social functioning and with various cognitive and clinical variables. The authors concluded that the computerized shopping task represents a good measure of real world functioning of persons diagnosed with schizophrenia.

To date, a number of different types of shopping tasks have been used in the literature. Matsui, Sumiyoshi, Yuuki, Kato and Kurachi (2006), for instance, included a task that examined the specific shopping schema in patients diagnosed with schizophrenia using three tasks: free recall of a typical scenario of shopping at a supermarket; frequency judgment of several events that can occur during shopping; and sequencing typical shopping events. Results showed that patients diagnosed with schizophrenia had poorer performances on all three tasks compared to the healthy controls, suggesting an impairment of this specific event schema.

The Test of Grocery Shopping Skills (TOGSS; Hamera & Brown, 2000) is another shopping task. The TOGSS is an observation-based assessment that requires participants to shop for 10 items (presented in a shopping list) in a real grocery store. The results of studies using this task with patients diagnosed with schizophrenia (Rempfer, Hamera, Brown, & Cromwell, 2003; Greenwood, Landau, & Wykes, 2005; Zayat, Rempfer, Gajewski, & Brown, 2011) have demonstrated that performance on the TOGSS is related to cognitive functioning, and in particular to executive functioning. Similarly, Semkovska, Bedard, Godbout, Limoge, & Stip (2004) compared the performances of patients diagnosed with schizophrenia with healthy controls during the realization of 3 tasks of everyday life where participants had to: (1) choose a 3-set menu, (2) shop for the missing ingredients in a local supermarket, and (3) cook a meal. Results showed that patients performed worse than controls for all three tasks, and that performance was significantly correlated with executive functions. Results from all these studies point to the main role of executive functions in complex real world activities.

The goal of the present study was to contribute to a better characterization of the nature of bipolar patients' everyday life difficulties by using Larøi et al.'s computerized shopping task. More specifically, the first objective of this study was to examine the performance on a real-life computerized shopping task in a group of patients diagnosed with bipolar disorder compared to healthy controls. The second objective was to examine the relations between performance on this shopping task and cognitive and clinical variables in the bipolar group. Finally, we wished to examine the extent to which the shopping task represents a good predictor of real world functioning in patients diagnosed with bipolar disorder, and furthermore, to examine the predictive value of the cognitive measures.

It was hypothesized that performance on the shopping task would significantly differentiate patients with bipolar disorder and healthy controls. Furthermore, we hypothesized significant correlations between patients' performance on the shopping task and cognitive measures and clinical variables. Finally, we predicted that the patients' performance on the shopping task would be a good predictor of real world functioning.

Methods

Participants

Twenty-one persons fulfilling DSM-IV (American Psychiatric Association, 1994) criteria for bipolar disorder were recruited from local psychiatric hospitals and were included in the study. Exclusion criteria included the presence of Axis 1 comorbidity including substance abuse disorder, a history of head injury, neurological illness, mental retardation, the presence of any clinical condition that could affect cognitive performance and age outside the range of 18-65 years. Diagnosis was made by several experienced clinical psychiatrists with the aid of a semi-structured interview based on DSM-IV criteria for bipolar disorder. Mood states were determined with the Beck Depression Inventory Short-Form (BDI-SF; Beck & Steer, 1993) and the Young Mania Rating Scale (YMRS; Young, Biggs, Ziegler, & Meyer, 1978; Favre et al., 2003). Ten patients were classified as in a euthymic state, 3 as manic or hypomanic, 6 depressed and 2 as in a mixed episode. Fifteen patients were inpatients and 5 were outpatients. Concerning psychotropic treatment, 15 patients were taking an antipsychotic medication, 14 benzodiazepines, 13 mood stabilizers, 12 antidepressants, 3 anticholinergics and 1 anticonvulsant medication.

Twenty-one healthy controls were also included who were matched with patients according to sex, age and educational level. The healthy controls (based on self-report) did not have any psychiatric (including substance abuse) or neurological (including head injury) disorder, nor was there any history of psychiatric disorders in first-degree family members.

All participants were asked to indicate their level of familiarity with video games and with shopping in a supermarket. All participants provided written informed consent and the project was approved by the local ethics committee. Participant characteristics are presented in Table 1. Based on independent t-tests, there were no significant differences between the two groups for age, educational level, and shopping and video game familiarity.

Table 1: Demographic characteristics of participants

	Patients (n=21)		Healthy controls (n=21)	
	Mean (SD)	Min-max	Mean (SD)	Min-max
Age	48.95 (10.24)	24 - 62	49.76 (9.93)	26 - 62
Education (years)	12.33 (2.78)	6 - 19	12.28 (2.66)	8 - 19
Sex (female/male)		11/10		11/10
Age of onset of illness	36.19 (9.77)	19-54		
Duration of illness (years)	12.76 (9.50)	1 - 30		
Number of hospitalizations	5.85 (3.90)	1 - 15		
Total duration of hospitalizations (months)	16.02 (19.88)	2 - 84		
Number of suicide attempts	1.85 (2.79)	0 - 10		
Number of depressive episodes	7.09 (5.64)	0 - 20		
Number of manic episodes	5.28 (3.86)	1 - 12		
YMRS[1]	9.71 (8.84)	0 - 33		
BDI[2]	10.14 (6.42)	3 - 27		
PSP[3]	53.00 (21.94)	19 - 85		
Video game familiarity	.76 (1.22)	0 - 5	.95 (1.39)	0 - 4
Shopping familiarity	5.00 (2.50)	0 - 8	5.42 (1.32)	3 - 8
Pre-morbid IQ (NART[4])	109.34 (8.62)	90.07 - 122.50		

Measures

Computerized shopping task

All participants completed the computerized shopping task on a portable computer using a gamepad in a quiet, soft-lightened testing room. They first completed a learning phase and thereafter the shopping task. For both, instructions were given both visually on the screen and orally via a computerized voice.

Learning phase

The main goal of the learning phase is to systematically familiarize all the participants with the basic actions and functions that are required in the shopping task, and to do so successfully. The learning phase was based on the principles of errorless learning. In this context, the learning phase consisted of carrying out task-relevant actions (i.e., those that are required during the shopping task) in a progressive and error-limiting manner. To begin with, participants were required to perform very simple actions (e.g., move forward and backward) followed by gradually more demanding and complex actions (e.g., pick up and drop objects, consult a list of instructions). Only when participants performed each action successfully, did they proceed to the next level of the learning phase. If the participant committed an error at any time during the learning phase, the error was registered, the participant was alerted of this error, the instructions were repeated, and the participant was asked to continue until the action was performed correctly. The following variables were calculated for the learning phase: Total number of correct actions, Total number of incorrect actions and Total time to complete the learning phase.

Shopping task

After the learning phase, instructions concerning the shopping task were given and the shopping list containing 8 items (representing different categories such as beverages, meat, fruits and vegetables) was displayed. All items were the same for each participant, and there was no time limit. Participants were also given 20 € in order to make their purchases and were asked not to exceed this sum. The shopping task was constructed on the basis of a middle-sized grocery store and includes all the typical aspects when shopping in a real supermarket. More specifically, the grocery store consisted of 18 aisles and included the following aisles: stationary, cleaning products, washing powder and toilette paper, perfume and hygienic products, coffee and tea, chocolate and biscuits, cereals and jellies, beverages, wine, meat and fish tins, fruit and vegetable tins, condiments and sauces, pasta and rice, products on sale, fruits and vegetables, bakery, delicatessen, cheese, meat, dairy products, and frozen food. Moreover, music was played in the background throughout the task and a certain number of distracters were provided during the task, which included both visual (i.e., non-pertinent articles on sale and the presence of other shoppers) and auditory (i.e., loud-speaker announcements) distractors.

During the task, by pressing button A of the gamepad, participants could perform interactive actions (e.g., a close-up of the aisle). By pressing button B, participants could consult the list of items and the shopping cart. Movement was done by using the left-hand side of the gamepad. The task ends when the participant approaches the till.

The following variables were calculated for the shopping task: Total time to complete the shopping task, Distance travelled in the virtual supermarket during the task (in meters), Number of intrusions (i.e., number of purchases that were made by the participant but that were not included in the shopping list), Shelf redundancy (i.e., number of times the same shelf was visualized by the participant), Mean time spent consulting the shopping list (i.e., total time spent consulting the shopping list divided by the number of times the participant consulted the list), Mean time spent consulting the shopping cart (i.e., total time spent consulting the cart divided by the number of times the participant consulted the cart), Total amount of the purchase (in Euros), and Number of missed shelves (i.e., number of times a participant went towards a pertinent aisle but did not approach the shelf despite the fact that it contained a pertinent item).

As the shopping task was constructed on the basis of a typical middle-sized grocery store and includes all the typical aspects of shopping in a supermarket, the task has good face validity. Moreover, several studies using the same shopping task with persons diagnosed with schizophrenia and alcoholic dependency (Larøi et al., 2010; Laloyaux et al., 2012) have already demonstrated good sensitivity in that performance on the task significantly differentiated between clinical groups and healthy controls. Moreover, performance on the shopping task in these studies was significantly related to real world functioning measures (convergent validity).

Cognitive measures

Patients were also assessed with a battery of cognitive tests. The choice of tests was based on the major functions (i.e., planning, memory, inhibition, selective attention, and cognitive flexibility) implicated in the shopping task.

Pre-morbid IQ was measured with the National Adult Reading Test (NART; Nelson & O'Connell, 1978; Mackinnon & Mulligan, 2005) (total score converted to IQ equivalent). Processing speed was assessed using the WAIS Symbol Search

(Wechsler, 2000) (total number of correct responses minus errors). Assessment of working memory consisted of the Backward digit span (Wechsler, 2001) (longest correct backward digit span). We measured selective attention using the D2 Test of Attention (Brickenkamp, 1966) (percentage of errors) (total number of errors and number of omitted stimuli divided by the total number of treated stimuli). Verbal episodic memory was assessed with the California Verbal Learning Test (CVLT; Delis, Freeland, Kramer, & Kaplan, 1988; Poitenaud, Deweer, Kalafat, & Van der Linden, 2007) (total recall 1-5). Finally, several measures of executive functions were administered including the Zoo map for the assessment of planning (Wilson, Alderman, Burgess, Emslie, & Evans, 1996) (execution time); the Trail Making Test (TMT; Army Individual Test Battery, 1944) (time on Part B minus time on Part A) to measure cognitive flexibility and the Stroop Time interference factor (Golden, 1978) (time interference minus color naming time) to assess inhibition. Cognitive performance of the bipolar patients is included in Table 2. For each measure, the percentage of patients demonstrating an impaired performance was calculated based on the norms from the literature. As there were no corresponding norms for the version of the Zoo map test used in the present study, we could not compare performances for this test.

Table 2: Performance on the cognitive measures (raw scores) in the patient group.

	Mean (SD)	Percentage of patients demonstrating an impaired performance
WAIS Symbol Search	23.19 (6.83)	47
Digit span backward	3.85 (1.11)	4
D2 percentage of errors	7.85 (7.57)	23
CVLT: Total recall 1-5	43.09 (12.72)	43
Zoo time	2.74 (1.16)	
TMT B-A	92.71 (72.12)	33
Stroop Time interference factor	67.33 (32.56)	9

Clinical measures

All patients were evaluated with the Young Mania Rating Scale (YMRS; Young et al., 1978; Favre et al., 2003), the Personal and Social Performance Scale (PSP; Morosini, Magliano, Brambilla, Ugolini, & Pioli, 2000), and the Beck Depression Inventory Short-Form (BDI-SF; Beck & Steer, 1993). The PSP is a global measure of real world functioning based on four domains (i.e., self-care, socially useful activities such as work and studies, personal and social relationships and disturbing and aggressive behaviors) and the YMRS assesses major manic symptoms.

All clinical ratings were carried out by an experienced clinical psychiatrist. The clinical ratings were made during the same period, i.e., between the computerized shopping task and the cognitive assessment. The time between administration of the cognitive battery and the computerized shopping task never exceeded 7 days.

Statistical analysis

Group comparisons were analyzed with Student's independent t-test for performances on the learning phase (i.e., Total number of correct actions, Total number of incorrect actions and Total time to complete the learning phase) and the shopping task (i.e., Total time to complete the shopping task, Distance travelled, Number of intrusions, Shelf redundancy, Mean time spent consulting the shopping list, Mean time spent consulting the shopping cart, Total amount, and Number of missed shelves). Variables that significantly distinguished both groups in the learning phase and the shopping task were correlated (Pearson) with cognitive (i.e., WAIS Symbol Search, Digit span backward, D2 percentage of errors, CVLT: Total recall 1-5, Zoo time, TMT B-A, and Stroop Time interference factor) and clinical (Duration of illness, Number of hospitalizations, Number of manic episodes, Number of depressive episodes, YMRS, BDI, and PSP) variables for the patient group. Multiple linear regression analysis was used to investigate the capacity of the shopping task and cognitive measures to predict patients' real world functioning (PSP). Alpha was set at .05, however, given the number of the statistical analyses, and the need to balance the amount of type 1 and type 2 errors, we calculated adjusted p values with the false discovery rate method for multiple testing (Benjamini & Yekutieli, 2001). The false discovery rate controls the expected proportion of falsely rejected null hypotheses. This method has been shown (Benjamini & Hochberg, 1995; Benjamini & Yekutieli, 2001) to be much more powerful than methods that control the familywise error rate (e.g., Bonferroni).

Results

Patients and healthy controls were compared (independent t-tests) concerning their performances on the learning phase and the shopping task (Table 3). A Benjamini-Hochberg-Yekutieli correction revealed a critical value (alpha) of .016. Results demonstrated that performance on the learning phase significantly differentiated patients and healthy controls for Total time to complete the learning phase. Concerning the shopping task, analyses revealed significant differences for Total time to complete the shopping task and Mean time spent to consult the shopping list.

Table 3: Performance on the learning phase and the shopping task in the two groups

	Patients (SD)	Healthy controls (SD)	t	p
Learning phase				
Total time to complete the learning phase	Sec : 627.80 (186.77) Min : 10.46 (3.11)	Sec : 489.33 (139.86) Min : 8.16 (2.33)	2.72	.009*
Number of correct actions	15.71 (1.18)	15.90 (.94)	-.57	.568
Number of incorrect actions	11.00 (6.10)	10.23 (5.69)	.42	.678
Shopping task				
Total time to complete the shopping task	Sec : 1334.19 (481.99) Min : 22.24 (8.03)	Sec : 960.80 (264.51) Min : 16.01 (4.41)	3.45	.001*
Mean time spent to consult the shopping list (seconds)	19.87 (7.49)	14.34 (5.41)	2.74	.009*
Number of missed shelves	3.19 (1.50)	2.23 (1.41)	2.12	.041
Distance travelled (in meters)	224.92 (69.32)	191.70 (42.14)	1.88	.068
Mean time spent to consult the shopping cart (seconds)	15.87 (14.84)	8.07 (12.02)	1.87	.069
Number of intrusions	.57 (.81)	.76 (.70)	-.81	.420
Total amount (in Euros)	16.95 (2.53)	16.59 (1.95)	.51	.612
Shelf redundancy	1.14 (1.10)	1.19 (1.40)	-.12	.903

*= $p<.016$ (Benjamini-Hochberg-Yekutieli correction)

These variables from the learning phase and the shopping task that significantly differentiated between groups were then correlated (Pearson) with results from the cognitive tests and clinical variables (Table 4) of the patient group. A Benjamini-Hochberg-Yekutieli correction was carried out, revealing a critical value (alpha) of .011.

Concerning the learning phase, there were significant correlations between Total time to complete the learning phase and processing speed (WAIS Symbol Search), selective attention (D2), verbal episodic memory (CVLT), cognitive flexibility (TMT B-A) and duration of illness.

Concerning the shopping task, analyses revealed significant correlations between Total time to complete the shopping task and: processing speed (WAIS Symbol Search), verbal episodic memory (CVLT), planning (Zoo), cognitive flexibility (TMT B-A), inhibition (Stroop), duration of illness and real world functioning (PSP). Moreover, Mean time spent consulting the shopping list was significantly correlated with processing speed (WAIS Symbol Search), verbal episodic memory (CVLT), and duration of illness.

Table 4: Correlations between cognitive and clinical variables and performance on the learning phase and the shopping task in the patient group

	Total time to complete the learning phase	Total time to complete the shopping task	Mean time spent to consult the shopping list (seconds)
WAIS Symbol Search	-.72**	-.78**	-.58*
Digit span backward	-.28	-.37	-.21
D2 percentage of errors	.57*	.25	.51
CVLT: Total recall 1-5	-.60*	-.62*	-.64*
Zoo time	.50	.63*	.21
TMT B-A	.60*	.70**	.29
Stroop Time interference factor	.42	.68**	.26
Duration of illness	.72**	.58*	.74**
Number of hospitalizations	.18	.03	.42
Number of manic episodes	.18	.06	.21
Number of depressive episodes	.05	-.04	-.02
YMRS	.26	.20	.48
BDI	-.02	-.09	.14
PSP	-.51	-.60*	-.51

* = p<.011 (Benjamini-Hochberg-Yekutieli correction); **=p<.001

Multiple linear regressions were then carried out with the two shopping task variables (i.e., Total time to complete the shopping task and Mean time spent to consult the shopping list) as predictors of the patients' PSP score. This revealed that these shopping variables significantly explained 41% of the variance of the PSP score (Multiple R^2= .41; Adjusted Multiple R^2= .34; F=6.31; df= 2, 18; p<.01). Thereafter, multiple linear regressions were carried out with the seven cognitive variables (i.e., WAIS symbols, Digit span backward, D2 percentage of errors, CVLT: Total recall 1-5, Zoo time, TMT B-A, and Stroop Time interference factor) as predictors of PSP. This revealed that none of the cognitive variables significantly predicted any portion of the variance of the PSP score (Multiple R^2= .58; Adjusted Multiple R^2= .35; F=2.58; df= 7, 13; p>.05).

As the patient group was heterogeneous in terms of current mood state, we conducted supplementary analyses to assess if euthymic and non-euthymic patients (i.e., depressed, manic, and mixed) differed in terms of their performance on the cognitive tests and the learning phase and the shopping task. Furthermore, due to the small sample size, we conducted non-parametric analyses (Mann-Whitney U test) to compare the results for the euthymic (N=10) and non-euthymic patients (N=11). Results showed no significant group differences for performances on the learning phase and the shopping task (Total time to complete the learning phase: U=44; p>.05; Total time to complete the shopping task: U=45; p>.05; and Mean time spent to consult the shopping list: U=29; p>.05). Concerning the cognitive tests, only performance on the selective attention test (D2) revealed a significant group difference (U=26; p<.05) with the non-euthymic patients committing more errors than the euthymic patients.

Thereafter, as the patient group varied in terms of degree of cognitive impairment, we conducted supplementary analyses that compared patients with high and low degree of cognitive impairment in terms of their performance on the learning phase and the shopping task. Patients with high degree of cognitive impairment were defined as those with two or more cognitive impairments (based on the norms from the literature) and those with low cognitive impairment were those with one or no cognitive impairment. Non-parametric analyses (Mann-Whitney U test) were used to compare the low (N=13) and high (N=8) cognitive impaired patient groups. Results showed that only the Total time to complete the learning phase was significantly different between the groups (Total time to complete the learning phase: U=21; $p<.05$; Total time to complete the shopping task: U=38; $p>.05$; and Mean time spent to consult the shopping list: U=28; $p>.05$) with the high patient group taking longer to complete the learning phase than the low group.

Finally, we wanted to examine whether the low cognitive impaired patient group demonstrated a significantly different performance on the learning phase and the shopping task than the healthy control group. Non-parametric analyses (Mann-Whitney U test) were again used to compared the low cognitive impaired patient group (N=13) to healthy controls (N=21). Results demonstrated that only the Total time to complete the shopping task was significantly different between the groups (Total time to complete the shopping task: U=75; $p<.05$; Total time to complete the learning phase: U=101; $p<.05$; and Mean time spent to consult the shopping list: U=92; $p>.05$) with the patient group taking longer to complete the shopping task than the healthy controls.

Discussion

The present study examined relations between performance on a real-life computerized shopping task with cognitive and clinical variables in a group of individuals diagnosed with bipolar disorder compared to a group of healthy controls.

Performance in the learning phase significantly differentiated patients and healthy controls for Total time to complete the learning phase. Furthermore, in the patient group, this variable correlated significantly with cognitive (i.e., processing speed, selective attention, verbal episodic memory, cognitive flexibility) and clinical (i.e., duration of illness) measures.

Performance on the shopping task significantly differentiated patients and healthy controls for two variables: Total time to complete the shopping task and Mean time spent to consult the shopping list. Moreover, in the patient group, performance on these variables correlated significantly with cognitive measures including processing speed, verbal episodic memory, planning, cognitive flexibility, and inhibition.

Indeed, effective shopping behavior requires the involvement of all of these cognitive functions: a novel situation is presented to participants, who are then required to create a plan of action (planning), to maintain this plan in mind throughout the task (memory), to efficiently explore the grocery store in an organized manner (planning), to try to remember as many items on the shopping list as possible (memory), to inhibit irrelevant stimuli during the task (inhibition), and to continuously shift between internal (internal thoughts) and external (stimuli presented to the participant by the computer screen) modes (cognitive flexibility). Furthermore, many of these cognitive functions have been found to be main predictors of poor real world functioning in bipolar disorder (Martinez-Aran et al., 2007; Altshuler et al., 2008; Bowie et al., 2010).

In the patient group, performance on the computerized shopping task was significantly correlated with clinical variables including duration of illness and PSP, suggesting that performance on the computerized shopping task is tapping into patients' level of real world functioning. Moreover, multiple linear regressions demonstrated that two shopping variables (i.e., Total time to complete the shopping task and Mean time spent to consult the shopping list) significantly explained 41% of the variance of the PSP. Concerning the cognitive tests, multiple linear regressions demonstrated that the cognitive variables did not significantly explain any part of the variance of the PSP. However, it is interesting to note that both models demonstrated a similar Adjusted Multiples R^2 (i.e., .34 for the shopping task variables and .35 for the cognitive variables), suggesting that both models explains a similar part of variance of the PSP in the population. However, given the small sample size and the difference in the number of variables included in the multiple linear regression analyses (i.e., 2 for the shopping task model and 7 for the cognitive variables model, explaining the differences between the two Multiple R^2), it is possible that the model including the cognitive variables presents a lack of power and that a larger sample would demonstrate a significant model. Future studies are needed that include larger samples and that incorporate confirmatory analyses instead of exploratory analyses. Nevertheless, the model including the shopping variables needs fewer variables than the model including cognitive variables to be significant and per se, represents an easier way to predict real world functioning (PSP) in persons diagnosed with bipolar disorder. Indeed, the present result could also reflect the fact that the shopping task puts the patient in a more demanding (i.e., more complex and multi-tasking) situation that furthermore involves several cognitive functions, thus rendering the task more sensitive to detect certain cognitive impairments that impact real world functioning compared to standard cognitive measures.

As expected, both groups were differentiated for a certain number of variables and, furthermore, this was the case for both phases (i.e., learning and shopping) of the task. The main purpose of the learning phase is to teach participants how to interact with the virtual environment. However, based on the present results, it is suggested that this phase also provides important information concerning patients' level of cognitive functioning, but less so for real world functioning (PSP). This latter result could be related to the fact that the learning phase is relatively simple and therefore does not reflect the complex and multi-tasking nature of many real world activities.

As this is the first study of its kind with patients with bipolar disorder, it is not possible to compare the results from the present study with previous studies. Nevertheless, two studies that administered the same computerized shopping task, albeit with patients with schizophrenia (Larøi et al., 2010) and alcohol dependency (Laloyaux et al., 2012), also observed similar results. Interestingly, in all 3 studies (including the present study), the variable Total time to complete the shopping task significantly differentiated between clinical and healthy control groups and correlated significantly with a number of cognitive and clinical variables, including level of real world functioning, suggesting that this variable is the most sensitive to real world and cognitive impairments.

Moreover, in the present study, supplementary analyses revealed that Total time to complete the shopping task was also the most sensitive variable as it significantly differentiated low cognitive impaired patients from healthy controls. Similarly, patients with low cognitive impairment were significantly differentiated from patients with high cognitive impairments only for the Total time to complete the learning phase and not for the shopping phase, suggesting that the high group demonstrated poorer learning abilities than the low group.

Furthermore, in Larøi et al. (2010), performance on the computerized shopping task significantly differentiated patients diagnosed with schizophrenia and healthy controls for a number of variables, including two time-related measures (i.e., Total time to complete the shopping task, Total time spent consulting the shopping list) and measures related to the execution of the task (i.e., Number of correct articles purchased, Aisle redundancy, Number of times a non-pertinent aisle was visualized). In the present study, however, performance on the computerized shopping task only significantly differentiated patients diagnosed with bipolar disorder from healthy controls for two measures, both of which were time-related measures (i.e., Total time to complete the shopping task and Mean time spent to consult the shopping list). These measures seem to be the most sensitive variables given the fact that they reflect a more global aspect of the performance on the task and are influenced by several cognitive functions. The fact that patients diagnosed with bipolar disorder demonstrated poorer performance than controls only for the more sensitive variables (i.e., global time-related measures) is consistent with the fact that patients diagnosed with bipolar disorder generally demonstrate better cognitive performance than patients diagnosed with schizophrenia (for a review, see Krabbendam, Arts, van Os, & Aleman, 2005) and better real world functioning (Simonsen et al., 2011).

The fact that only time-related measures (i.e., Total time to complete the shopping task and Mean time spent to consult the shopping list) differentiated patients and controls could suggest a greater influence of processing speed, which furthermore has been shown to be an important aspect in bipolar disorder (Torres et al., 2007; Bora et al., 2009). In order to clarify the correlations analyses, we conducted partial correlation analyses controlling for the impact of processing speed on the other correlational analyses between performance of the patient group on the learning phase, the shopping task and cognitive and clinical variables. In order to have a more global measure of processing speed, we created a processing speed index consisting of a global Z score composed of the WAIS Symbol Search, time on part A of the Trail Making Test, and time on the color naming part of the Stroop (based on the norms from the literature). Results of the correlational analyses remained basically the same, with some exceptions. That is, concerning the Total time to complete the shopping task, results showed that the correlations with verbal episodic memory (CVLT) and real world functioning (PSP) were no longer significant. All the others correlations remained significant and of the same strength. These results suggest that even if processing speed is an important aspect in bipolar disorder, the shopping task, like real world activities in general, place the participant in a situation that is both complex and multifaceted and that involves a number of different and integrated cognitive processes that need to be coordinated together. Thereby, the shopping task provides different information regarding cognitive functioning than do standard cognitive tests, which are designed to measure one, isolated cognitive process.

Finally, findings from the current study demonstrated that performance on the shopping task was significantly related to cognitive functioning in the patient group and, in particular, to executive functioning (i.e., planning, flexibility and inhibition). These results are consistent with previous studies with patients diagnosed with schizophrenia (Rempfer et al., 2003; Semkovska et al., 2004; Greenwood et al., 2005; Zayat et al., 2011), which included observation-based measures of shopping, and which similarly revealed significant relations between the performance on this measure and executive functioning - thus underlying the impact of executive functioning in complex real world activities.

This study has various limitations that should be taken into account. It could be argued that the patient group is very heterogeneous in terms of current mood state. However, as this is the first study of its kind and thus an exploratory study, we wished to include a representative sample of patients with bipolar disorder that includes patients with different mood states. Moreover, supplementary analyses revealed that performances on the leaning phase and the shopping task were not significantly different between euthymic and non-euthymic patients (i.e., depressed, manic, and mixed), and that only one of the seven cognitive tests revealed a group difference (i.e., selective attention). These results suggest that the difficulties encountered by the patients during the learning phase and the shopping task could not be entirely explained by their mood state at the moment of testing.

Another point concerns the number of participants. Indeed, this study included 21 patients diagnosed with bipolar disorder and 21 healthy controls, which could be considered a small sample. However, the patients and healthy controls were carefully matched for age, sex and educational level, and furthermore for level of familiarity with video games and shopping in a supermarket, which enhances the reliability of the results. Further studies are clearly needed that will include a larger number of healthy controls and patients with different mood states.

Real world functioning was assessed with the PSP, which is a widely used measure, but which only provides a general indication of real world functioning. Further studies are needed that include more specific and detailed scales of real world functioning in order to more adequately examine the shopping task's ability to predict real world functioning.

It could be argued that the patients' medication could have impacted their performance on the shopping task and on cognitive measures. The majority of patients suffering from bipolar disorder take medication daily and it could potentially impact their real world functioning. It thus seems reasonable to suppose that their medication would impact real world functioning, performance on the shopping task and cognitive measures in the same way.

Another point is that while computerized versions of everyday tasks possess several advantages, undoubtedly, there are differences between such a task and the same task in a natural setting. Thus, a necessary addition to the present study's methodology would be to administer both a real-life shopping task and the computerized shopping task in order to examine the external validity of the computerized shopping task. Such a study is currently underway.

In general, findings from the present study demonstrate that the computerized shopping task can significantly differentiate patients with bipolar disorder from healthy controls for two variables: Total time to complete the shopping task and Mean time spent to consult the shopping list. Moreover, in the patient group, these variables are significantly associated with cognitive (i.e., processing speed, verbal episodic memory, planning, cognitive flexibility, and inhibition) and clinical (i.e., duration of illness) variables, and with real world functioning. Moreover, patients' performance on the shopping task was found to be a good predictor of real world functioning. These findings suggest that the shopping task provides a good indication of the real world functioning and cognitive functioning of persons diagnosed with bipolar disorder.

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Multitasking capacities in persons diagnosed with schizophrenia: A preliminary examination of their neurocognitive underpinnings and ability to predict real world functioning

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Abstract

Difficulties in everyday life activities are core features of persons diagnosed with schizophrenia and in particular during multitasking activities. However, at present, patients' multitasking capacities have not been adequately examined in the literature due to an absence of suitable assessment strategies. We thus recently developed a computerized real-life activity task designed to take into account the complex and multitasking nature of certain everyday life activities where participants are required to prepare a room for a meeting. Twenty-one individuals diagnosed with schizophrenia and 20 matched healthy controls completed the computerized task. Patients were also evaluated with a cognitive battery, measures of symptomatology and real world functioning. To examine the ecological validity, 14 other patients were recruited and were given the computerized version and a real version of the meeting preparation task. Results showed that performance on the computerized task was significantly correlated with executive functioning, pointing to the major implication of these cognitive processes in multitasking situations. Performance on the computerized task also significantly predicted up to 50% of real world functioning. Moreover, the computerized task demonstrated good ecological validity. These findings suggest the importance of evaluating multitasking capacities in patients diagnosed with schizophrenia in order to predict real world functioning.

Introduction

Difficulties in everyday life activities (real world functioning) are core features of persons diagnosed with a psychiatric disorder and in particular with schizophrenia (American Psychiatric Association, 1994; Bowie, Reichenberg, Patterson, Heaton, & Harvey, 2006; Leifker, Bowie, & Harvey, 2009; Tandon, Nasrallah, & Keshavan, 2009). A number of everyday life activities, such as cooking a meal, are complex and require multitasking abilities. According to Burgess (2000), multitasking refers to performing activities where the person has to: carry out and alternate between different activities that vary in terms of priority, difficulty and duration; define the tasks' targets; and where the person is faced with unexpected problems during the realization of these tasks.

Patients with schizophrenia, in particular, seem to have problems with activities of everyday life of a multitasking nature. In the only study that has (albeit indirectly) examined this issue, Semkovska, Bedard, Godbout, Limoge and Stip (2004) compared the performance of patients diagnosed with schizophrenia with healthy controls during the realization of 3 tasks of everyday life where participants had to: (1) choose a 3-set menu, (2) shop for the missing ingredients in a local supermarket, and (3) cook a meal within an hour. Other measures included cognitive functioning and severity of symptomatology. Results showed that patients performed worse than controls for all three tasks and, in particular, for the multitasking cooking task. Moreover, in the patient group, performance on this task was significantly correlated with executive functions (i.e., cognitive flexibility and planning) and negative symptom severity.

The capacity to deal with two tasks at a time is a main characteristic of multitasking, for example when keeping an eye on the sausages frying in the pan while at the same time reading the next steps of the recipe. Studies that have used the dual task paradigm where the person is asked to deal with the realization of two simple tasks after a training phase (automatization) for the first task, have found that persons diagnosed with schizophrenia demonstrate an impaired performance compared to healthy controls (Granholm, Asarnow, & Marder, 1996; Serper, Bergman, & Harvey, 1990; van Raalten, Ramsey, Jansma, Jager, & Kahn, 2008). Moreover, this impairment was not related to a failure in automatization of information processing, suggesting reduced resource availability in patients.

However, at present, patients' multitasking capacities have not been adequately examined due to an absence of appropriate assessment strategies. To date, the most suitable test has been developed by Shallice and Burgess (1991), who created a multiple sub-goal task - the Multiple Errands Test. Here, participants have to acquire items (e.g., buy a packet of throat pastilles) and information (e.g., the price of a pound of tomatoes) in an unfamiliar pedestrian precinct while at the same time respecting certain rules (e.g., participants cannot enter a shop other than to buy something). However, the rules that participants need to respect are artificially constraining and explicit, which is not in line with many multitasking activities of everyday life where task objectives often need to be defined and completed by the persons themselves while facing environmental constraints (Chevignard, Taillefer, Picq, Poncet, & Pradat-Diehl, 2006).

Moreover, in general, there are a number of limits related to the fact that data is obtained based on qualitative observations (as is the case, for example, in the Multiple Errands Test and in the task used in Semkovska et al., 2004). For instance, only a limited number of variables can be encoded and calculated as there are constraints as to how much the observer can note down. It is difficult to obtain precise measures in observer-based tasks. A series of variables that may affect performance (e.g., the amount of noise and other distractors) cannot be controlled. Such a test is difficult to carry out due to practical constraints (e.g., finding the opportunity to observe patients) and human resource limits (e.g., having the available personnel that can leave the clinical setting). Finally, participants may find it particularly stressful to be observed during the realization of an activity in a real life situation, which could influence participants' performance.

Others have created instruments that assess specific activities of everyday life, such as a shopping task (Josman, Schenirderman, Klinger, & Shevil, 2009; Larøi, Canlaire, Mourad, & Van der Linden, 2010) or a cooking task (Zhang et al., 2003; Semkovska et al., 2004). However, one major limit with such an approach is that performance on such tasks may be mediated by the participant's level of task familiarity. Thus, a person who is more familiar with doing the shopping/cooking in everyday life will have fewer difficulties performing the task and will not be relying on his/her executive functions as much in order to perform the task efficiently compared to someone who has only rarely done the shopping/cooking previously. Moreover, such tasks are frequently simplified in order to facilitate assessment but, as a result, unfortunately, end up not resembling the actual everyday life activity itself in that many of the characteristics of multitasking activities, such as those defined by Burgess (2000), are lost.

In this context, a new computerized task was created, which was directly based on everyday life activities – and that was particularly designed (a) to reflect the complex, multitasking nature of everyday life activities and (b) which places the participant in a new 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. Furthermore, there are several advantages with computerized tasks in general: the environment is controlled (i.e., every participant interacts in the same environment), characteristics of the task (e.g., level of difficulty) can be modulated, a large number of variables can be measured in a precise manner, the task is easy to administer in a clinical context and, finally, performing a computerized task may be less stressful for patients compared to being observed in a real setting.

The main objective of the present study was to investigate the multitasking capabilities of a group of persons diagnosed with schizophrenia with a newly developed computerized task: the Computerized Meeting Preparation Task (CMPT). Furthermore, the nature of the cognitive processes implicated in multitasking capabilities was also examined. We also wished to assess the tasks' ability to predict real world functioning. Finally, the ecological validity of the CMPT was assessed by examining relations between performance on the computerized version and a real version of the meeting preparation task.

It was hypothesized that performance on the CMPT would significantly differentiate the group of patients from healthy controls. Moreover, we expected significant correlations between patients' performance on the CMPT and cognitive (in particular with executive functions) and clinical (in particular with real world functioning) measures. We also hypothesized that the CMPT would be a good predictor of real world functioning. Finally, it was hypothesized that performance on both versions (computerized and real) of the task would be significantly correlated.

Methods

Participants

Twenty-one persons diagnosed with schizophrenia according to DSM-IV criteria (American Psychiatric Association, 1994) were included. Patients were recruited from local psychiatric services. Diagnosis was made by experienced psychiatrists based on DSM-IV criteria for schizophrenia and was furthermore confirmed by an experienced clinical psychologist in light of information from the Positive And Negative Symptoms Scale (PANSS; Kay, Fiszbein, & Opler, 1987) interview. Patients with schizo-affective or schizophreniform disorder were not included in the study. Exclusion criteria consisted of: the presence of neurological and/or other psychiatric disorders, patients who were not stabilized (i.e., presence of treatment non compliance and lack of decrease of severity of positive symptoms), mental retardation, and major change of medication within one month before testing. We considered patients to be stable if the patient's psychiatrist deemed that the patient showed a clinically significant reduction of psychotic symptoms such as delusions, hallucinations and psychotic excitement. Moreover, none of the patients demonstrated any severe residual symptoms based on the PANSS. Further, the patient was required to voluntarily agree to be treated and report that he/she was taking his/her medication appropriately. This latter information was also confirmed by the patient's psychiatrist and by nursing staff or the caseworker.

Patients' medication was converted into three indexes: benzodiazepine (diazepam equivalence in mg), antipsychotic (olanzapine equivalence in mg), and anticholinergic. Regarding the benzodiazepine index, each benzodiazepine drug was converted into a diazepam equivalence based on the existing data of the literature (e.g., Taylor, Paton, & Kapur, 2009), and a total score was calculated by adding up each medication. Similarly, the antipsychotic index involved converting each antipsychotic medication into olanzapine equivalence based on the rates given in the literature (e.g., Davis and Chen, 2004; Gardner, Murphy, O'Donnel, Centorrino, & Baldessarini, 2010), and a total score was calculated. Finally, for the anticholinergic index, all medications were rated from 0 (signifying no known risk of anticholinergic effects) to 3 (signifying high risk of anticholinergic effects) based on the literature (e.g., Boily and Mallet, 2008), and a total score was calculated by adding up each rated medication.

Twenty controls were also included who were matched according to sex, age, estimated premorbid IQ and number of years of education. The controls were recruited from announcements on social networks and hearsay. The healthy controls did not have any psychiatric or neurological disorders, nor was there any first-degree family history of schizophrenia, schizo-affective or schizophreniform disorder.

Participants' familiarity with video games/computers was assessed by asking them to rate their mean frequency of playing with video games, the frequency of playing with video games during the last two weeks, and the mean frequency of using a computer. Each item was rated on a 5-point Likert scale revealing a total score ranging from 0 to 12.

All participants provided written informed consent and the project was approved by the local ethics committee. Participant characteristics are presented in Table 1. Based on independent t-tests, there were no significant differences between the two groups for age, education, estimated premorbid IQ, and cannabis consumption. However, patients were significantly less familiar than controls concerning their degree of familiarity with video games/computers ($t = -3.94$; $p < .001$).

Table 1: Demographic characteristics of participants

	Patients (N = 21)		Healthy controls (N = 20)	
	Mean (SD)	Min-max	Mean (SD)	Min-max
Age	31.33 (4.53)	23-40	29.30 (7.81)	20-43
Sex (female/male)	2/19		2/18	
Education participants (years)	12 (2.79)	8-19	13.30 (1.81)	10-17
Education mother (years)	12.83 (5.27)	0-17	11.62 (2.18)	6-15
Education father (years)	12.30 (5.79)	0-21	12.17 (1.18)	9-15
IQ (NART[a])	101.56 (8.02)	85.94-115.20	103.80 (5.79)	92.1-112.12
Cannabis consumption (grams per day)	.08 (.26)	0-1	.11 (.20)	0-1
Familiarity video games/computers	7.57 (3.29)	1-12	10.85 (1.75)***	7-12
Duration of illness (years)	12.02 (7.05)	1.5-26		
Number of hospitalizations	6.42 (7.85)	1-35		
Hospitalized (yes/no)	13/8			
Benzodiazepine (diazepam equivalence in mg)	18.09 (21.53)	0-66.66		
Antipsychotic (olanzapine equivalence in mg)	22.94 (16.97)	0-61.41		
Anticholinergic burden (side effect potential)	2.47 (1.50)	0-6		
PSP[b]	44.05 (13.42)	25-66		
FROGS[c]	52.5 (9.26)	36-66		
PANSS[d] Total score	73.05 (13.10)	43-96		
PANSS Negative score	19.35 (6.03)	9-32		
PANSS Positive score	15.65 (4.73)	9-25		
PANSS General Psychopathology	38 (6.81)	25-52		

[a] National Adult Reading Test
[b] Personal and Social Performance Scale
[c] Functional Remission of General Schizophrenia
[d] Positive And Negative Syndrome Scale
*** = p < .001.

In order to examine the ecological validity of the meeting preparation task, a second patient group was constituted that included fourteen patients (13 males) diagnosed with schizophrenia according to the same criteria as in the first group. Mean age was 32.21 years (SD = 4.37), mean years of education was 11.07 (SD =

1.81) and mean duration of illness was 10.85 years (SD = 6.08). In order to counterbalance the order of both versions of the task, seven patients from the first study were given the real version of the meeting preparation task after the CMPT and seven new patients were recruited who were given the real version before the CMPT.

Measures

Computerized Meeting Preparation Task (CMPT)

All participants first completed the learning phase of the CMPT and, thereafter, completed the meeting preparation task.

Learning phase of the CMPT

The main goal of this learning phase is to systematically familiarize all the participants with the basic actions and functions that are required during the meeting preparation phase, and to do so successfully. The learning phase is based upon the principles of errorless learning. In this context, the learning phase consists of carrying out task-relevant actions in a progressive and error-limiting manner. To begin with, participants are introduced to simple actions (i.e., how to move the avatar by sliding the virtual direction button and how to look around using the virtual head button) followed by more demanding actions (i.e., how to grasp objects by double-clicking or sliding the objet into the hands zone; and how to drop an object by clicking the object and then sliding it into the chosen place). Only when participants perform each action successfully, do they proceed to the next level of the learning phase. If the participant commits an error at any time during the learning phase - the error is registered, the participant is alerted of this error, the instructions are repeated, and the participant is asked to continue until the action is performed without committing an error.

The following variables were calculated for the learning phase: Total time to complete the learning phase (in minutes) and Total number of incorrect actions in the learning phase.

Meeting preparation phase of the CMPT

After the learning phase, participants are told that the meeting preparation phase will begin. At first, a video 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. One table is also already placed in front of the screen and another table and 5 chairs are placed in the other end of the room. Moreover, nametags (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 to 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.

After this explanatory video, participants are told that a meeting will start in 30 minutes, but that the secretary who is supposed to prepare the meeting room is sick and that the participant must replace her. After this, a picture of the final result is shown to participants for 4 seconds. Participants also have access to a list of instructions and a clock. The instructions consist of the following information: carry out the task as quickly as possible and respect the rules (i.e., the moderator has to be placed in front of the video projection screen and requires a laptop computer; the secretary has to be placed next to the moderator; every guest requires a pencil and a notepad; cups, glasses, drinks, etc. are in the kitchen area; office equipment is in the office materials area; a cart is available in order to transport the required objects; finally, when you have finished the task, please ensure that the cart is empty, place the cart back where you found it, and exit the room). There is also another list that contains the names of the guests and their desired drink during the meeting.

The following variables were calculated for the meeting preparation phase of the CMPT: Total time to complete the meeting preparation phase (in minutes); Number of times the instructions list was consulted; Number of incorrect and forgotten objects on the table; Respect of the rules (i.e., is the second table placed next to the first one? is the moderator placed in front of the screen with a laptop? is the secretary placed next to the moderator? has the cart been emptied and placed back to its original spot? and, number of correct drinks); Planning score (i.e., a score combining the distance traveled, the number of times the cart has been used; the order that the table, chairs and nametags were placed; and a score combining the order in which the objects were placed and the number of times a participant went into a room); Initiation (a score that combines both the time taken to make the first move and the time to consult the instructions list for the first time).

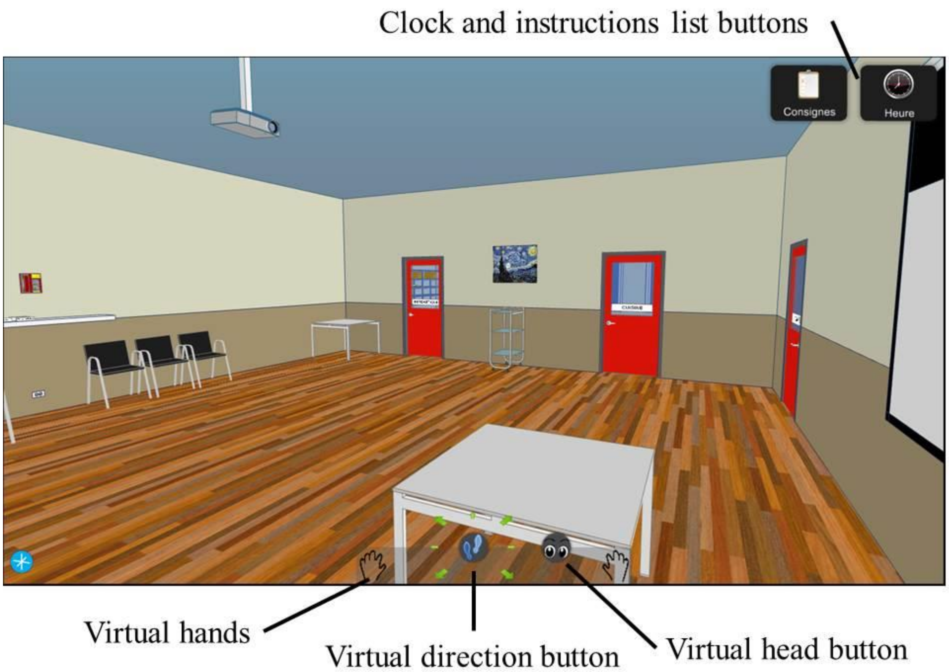

Figure 1: The main room where the meeting takes place

Cognitive measures

Patients were also assessed with an extensive battery of well-known, standardized cognitive tests. The choice of tests was based on the major cognitive functions (i.e., planning, working and episodic memory, selective and sustained attention, cognitive flexibility, and processing speed) implicated in the CMPT.

- Pre-morbid IQ: National Adult Reading Test (NART; Nelson and O'Connell, 1978; Mackinnon and Mulligan, 2005) (total score converted to IQ equivalent).

- Processing speed: Symbol search (Wechsler, 2000) (total score).

- Working memory: Digit span (Wechsler, 2000) (longest correct digit span backward).

- Selective attention: D2 Test of Attention (Brickenkamp, 1966) (percentage of errors).

- Verbal episodic memory: Rey auditory verbal learning test (Rey, 1964) (delayed recall).

-Sustained attention (based on Silverstein, Light, & Palumbo, 1998): In this task, 2 squares showing continuously different colors are presented on a computer screen. Participants are instructed to click the mouse button when the 2 squares are the same color (number of omission and commission errors).

- Executive functions: Cognitive flexibility: Trail Making Test (TMT; Army Individual Test Battery, 1944) (time on Part B minus time on Part A); Planning: Tower of London (Krikorian, Bartok, & Gay, 1994) (total score) and the Commissions test (Martin, 1972), where participants are asked to plan the order in which they will carry out 11 instructions with the help of a village map (total score).

The cognitive performance of patients diagnosed with schizophrenia (raw scores) is included in Table 2. For each measure, the percentage of patients demonstrating an impaired performance was calculated based on the norms from the literature. For those tests where there are no corresponding norms (i.e., Rey auditory verbal learning test, Sustained attention test, Tower of London test), the maximum possible score was reported in the Table.

Table 2: Performance on the cognitive measures (raw scores) in the patient group.

	Mean (SD)	Percentage of patients demonstrating an impaired performance/ maximum score
Symbol search	27.05 (7.01)	24%
Digit span backward	4.6 (1.27)	0%
D2 % of errors	4.14 (3.43)	19%
Rey - Delayed recall	9.35 (2.88)	15
Sustained attention – omission and commission errors	9.25 (4.94)	0
TMT B-A	61.65 (42.87)	33%
Tower of London – total score	18.75 (3.59)	24
Commissions – total score	44.31 (22.81)	52%

Clinical measures

All patients were evaluated by an experienced clinical psychologist with the Functional Remission Of General Schizophrenia (FROGS; Llorca et al., 2009), the Personal and Social Performance Scale (PSP; Morosini, Magliano, Brambilla, Ugolini, & Pioli, 2000) and the Positive And Negative Symptoms Scale (PANSS; Kay et al., 1987). The FROGS is a measure of functional remission, in other words, the level of patients' real world functioning. The total score is based on 19 items from 5 subscales: daily life, activities, relationships, quality of adaptation, and health and treatment. The PSP is a global measure of personal and social functioning based on four domains of real world functioning (i.e., self-care, socially useful activities such as work and studies, personal and social relationships, and disturbing and aggressive behaviors). Finally, the PANSS is a measure of severity of schizophrenia-related symptomatology.

Additional measure: The meeting preparation phase – real version

The real version of the meeting preparation phase was designed in order to resemble the computerized version as much as possible. That is, patients found themselves in an actual room of the hospital comprising a screen and a video projector. One table was also already placed in front of the screen, and another table and 5 chairs were placed in the other end of the room. Nametags were also found in the room. Two tables with pertinent and distractor items were placed on two opposite sides of the room. These two tables represented the kitchen and office material areas of the computerized version of the task. Finally, another table was placed in the room with the list of instructions (similar to the instructions presented in the computerized version) and a clock. All patients carried out both versions of the meeting preparation phase in a counterbalanced order and within a 1-week interval.

As in the computerized version, the following variables were measured: Total time to complete the meeting preparation phase; Number of times the instructions list was consulted; Number of incorrect and forgotten objects on the table; Respect of the rules (i.e., is the second table placed next to the first one? is the moderator placed in front of the screen with a laptop? and is the secretary placed next to the moderator? the number of correct drinks).

Statistical analysis

Group comparisons for demographic variables were analyzed using Student's t-test (Table 1). Thereafter, group comparisons were conducted for the performance on the learning phase and the meeting preparation phase of the CMPT (Student's t-test). Correlational analyses (Pearson) were then carried out between (a) those variables that significantly distinguished both groups in the learning phase and the meeting preparation phase, and (b) the cognitive, clinical and real word functioning variables. Thereafter, multiple linear regression analyses were used to investigate the capacity of the meeting preparation phase to predict real world functioning (FROGS and PSP). The same analyses were conducted albeit with the cognitive measures. Alpha was set at .05. However, given the number of the statistical analyses and the need to balance the amount of type 1 and type 2 errors, we calculated adjusted p values with the false discovery rate method for multiple testing (Benjamini and Yekutieli, 2001). Briefly, the false discovery rate controls the expected proportion of falsely rejected null hypotheses. This method has been shown (Benjamini and Hochberg, 1995; Benjamini and Yekutieli, 2001) to be much more powerful than methods that control the familywise error rate (e.g., Bonferroni).

Additionally, in order to examine the relations between cognitive and clinical variables, and performance on the CMPT in the patient group in more detail - we compared the cognitive and clinical profiles of patients in regards to their performance on the CMPT. More specifically, patients' performances on the task were converted into Z scores based on control group's results. The patient group was then divided into 2 subgroups: those patients who demonstrated an impaired performance on the variables of the meeting preparation phase (Z score < -1.66), and those who did not. Finally, performances of both subgroups on the cognitive and clinical measures were compared (due to the small sample sizes, the Mann-Whitney U comparison test was used).

Finally, in order to evaluate the ecological validity of the CMPT, correlational analyses were then carried out between variables from the CMPT and variables from the real version of the meeting preparation phase (due to the small sample size, Spearman analyses were used).

Results

Patients and healthy controls were compared (t-test) in regard to their performance on the learning phase and the meeting preparation phase of the CMPT (Table 3). A Benjamini-Hochberg-Yekutieli correction revealed a critical value (alpha) of .018. Results demonstrated that performance on the computerized task significantly differentiated patients and healthy controls for the following variables: Total time to complete the learning phase, Total number of incorrect actions in the learning phase, Total time to complete the meeting preparation phase, Planning score, and Respect of the rules. Results also revealed that the Number of incorrect and forgotten objects on the table was significant ($p < .05$), however, this variable was no longer significant after the statistical correction (Benjamini-Hochberg-Yekutieli).

Table 3: Performance on the meeting preparation phase of the CMPT for both groups

	Patients (SD)	Healthy controls (SD)	t (39)
Total time to complete the learning phase	7.71 (2.25)	5.35 (.93)	4.33***
Total number of incorrect actions in the learning phase	7.61 (5.83)	3.5 (2.4)	2.97**
Total time to complete the meeting preparation phase	23.03 (8.53)	13.60 (4.25)	4.44***
Planning score	8.98 (2.93)	12.09 (1.73)	-4.11***
Respect of the rules	8.41 (2.82)	10.50 (1.15)	-3.06**
Number of incorrect and forgotten objects on the table	7.57 (8.04)	2.80 (5.66)	2.18*
Initiation	149.33 (164.03)	78.75 (56.01)	1.82
Number of times the instructions list was consulted	11.61 (5.09)	12.65 (4.03)	-.71

* = p < .05; ** = p < .018 (Benjamini-Hochberg-Yekutieli correction); *** = p < .001

Thereafter, correlational analyses (Pearson) were carried out in the patient group between (a) the variables that significantly differentiated the patient group from the healthy control group on the CMPT and (b) cognitive, clinical and real word functioning measures (Table 3). More specifically, Total time to complete the learning phase, Total number of incorrect actions in the learning phase, Total time to complete the meeting preparation phase, Planning score, and Respect of the rules were all correlated with measures relating to: cognitive performance (Symbol search, Digit span, D2, Rey, Sustained attention, TMT, Tower of London, Commissions), real world functioning (FROGS, PSP), clinical variables (PANSS, Number of hospitalizations), and familiarity with video games/computers. For the learning phase, results showed that the Total time to complete the learning phase was significantly correlated with selective attention (D2) and that the Total number of incorrect actions in the learning phase was significantly related to working memory (Digit span), selective attention (D2), verbal episodic memory (Rey) and planning (Tower of London and Commissions). Concerning the meeting preparation phase, results demonstrated significant correlations between the Total time to complete the meeting preparation phase and verbal episodic memory (Rey), sustained attention (Sustained attention), planning (Commissions), and real world functioning (FROGS). Moreover, the Planning score was significantly related to selective attention (D2), planning (Commissions), and real world functioning (FROGS). Finally, the Respect of the rules was significantly correlated with working memory (Digit span backward), cognitive flexibility (TMT), planning (Commissions), and real world functioning (FROGS and PSP). Statistical correction (Benjamini-Hochberg-Yekutieli) revealed a critical value (alpha) of .01. After this correction, five correlations remained significant: between the Total number of incorrect actions in the learning phase and planning (Tower of London); the Total time to complete the meeting preparation phase and real world functioning (FROGS); the Planning score and planning (Commissions); the Respect of the rules and cognitive flexibility (TMT) and real world functioning (FROGS).

Table 4: Correlations between clinical variables and variables from the CMPT in the patient group

	Total time to complete the learning phase	Total number of incorrect actions in the learning phase	Total time to complete the meeting preparation phase	Planning score	Respect of the rules
Symbol search	-.40	-.17	-.38	.25	.40
Digit span backward	-.23	-.45*	-.18	.27	.50*
D2 % of errors	.45*	.52*	.36	-.45*	-.28
Rey - Delayed recall	-.43	-.48*	-.49*	.36	.43
Sustained attention – omission and commission errors	.36	.37	.50*	-.34	-.06
TMT B-A	.21	.30	.38	-.43	-.56**
Tower of London – total score	-.28	-.58**	-.09	.05	.25
Commissions – total score	-.39	-.44*	-.50*	.57**	.54*
FROGS	-.36	-.24	-.58**	.47*	.69***
PSP	-.21	-.13	-.34	.01	.48*
PANSS Negative	.19	.08	.40	-.25	-.33
PANSS Positive	.31	.38	.11	-.10	-.23
Number of hospitalizations	.03	-.15	-.12	.24	.11
Familiarity video games/computers	-.11	-.06	-.38	.15	.29

* = p < .05; ** = p < .01 (Benjamini-Hochberg-Yekutieli correction); *** = p < .001

Multiple linear regressions were then carried out with the three meeting preparation phase variables that significantly differentiated the patient group from the healthy control group on the CMPT (i.e., Total time to complete the meeting preparation phase, Planning score, and Respect of the rules) as predictors of real world functioning (FROGS and PSP). No sign of multicollinearity was detected for any variable: Total time to complete the meeting preparation phase (Tolerance = .38), Planning score (Tolerance = .40) and Respect of the rules (Tolerance = .82). Results revealed that these meeting preparation phase variables significantly explained 50% of the variance of the FROGS score (Multiple R^2 = .58; Adjusted Multiple R^2 = .50; F = 7.39; df = 3, 16; $p < .01$) and 32% of the PSP score (Multiple R^2= .43; Adjusted Multiple R^2 = .32; F = 4.04; df = 3, 16; $p < .05$).

Further inspection revealed that only the Respect of the rules (ß= .54; F = 9.24; $p < .01$; partial η^2 = .36) significantly explained any part of the variance of the FROGS score apart from the variance already explained by the other variables. The contributions of the Total time to complete the meeting preparation phase (ß = -.34; F = 1.78; $p > .05$; partial η^2 = .10) and the Planning score (ß = .00; F = .00; $p > .05$; partial η^2 = .00) were non-significant. Concerning the PSP score, Planning score (ß = -.65; F = 4.91; $p < .05$; partial η^2 = .23), Total time to complete the meeting preparation phase (ß = -.66; F = 4.77; $p < .05$; partial η^2 = .23) and Respect of the rules (ß = .44; F = 4.52; $p < .05$; partial η^2 = .22) explained a significant part of the variance apart from the variance already explained by the other variables.

Thereafter, multiple linear regressions were carried out with the eight cognitive variables (i.e., Symbol search, Digit span, D2, Rey, Sustained attention, TMT, Tower of London, Commissions) as predictors of real world functioning (FROGS and PSP). No sign of multicollinearity was detected for any variable: Symbol search (Tolerance = .48), Digit span (Tolerance = .46), D2 (Tolerance = .48), Rey (Tolerance = .48), Sustained attention (Tolerance = .59), TMT (Tolerance = .32), Tower of London (Tolerance = .52), Commissions (Tolerance = .59). Results revealed that none of the cognitive variables significantly predicted any portion of the variance of the FROGS score (Multiple R^2= .46; Adjusted Multiple R^2 = .04; F =

1.09; df = 8, 10; $p > .05$) nor the PSP score (Multiple R^2 = .38; Adjusted Multiple R^2 = -.11; F =.76; df = 8, 10; $p > .05$).

Based on the results from the meeting preparation phase for the control group (i.e., Total time to complete the meeting preparation phase, Planning score, and Respect of the rules), performances of the patient group were converted into Z scores. The patient group was then divided into 2 subgroups: those patients who demonstrated an impaired performance on the variables of the meeting preparation phase (Z score < -1.66), and those who did not. Finally, performances of both subgroups on cognitive (i.e., Symbol search, Digit span, D2, Rey, Sustained attention, TMT, Tower of London, Commissions) and real world functioning (FROGS and PSP) measures were compared (Mann-Whitney U). A Benjamini-Hochberg-Yekutieli correction revealed a critical value (alpha) of .012.

For the Total time to complete the meeting preparation phase, the impaired subgroup (N=11) showed a significantly lower performance than the unimpaired subgroup (N=9) for planning (Commissions) (U=13; $p < .01$). The other measures were non-significant. Concerning the Planning score, the impaired subgroup (N=12) demonstrated a significantly lower performance than the unimpaired subgroup (N=8) for planning (Commissions) (U = 16.5; $p < .012$). The other measures did not reveal any significant differences between subgroups. Finally, for the Respect of the rules, the impaired subgroup (N=8) showed significantly lower performances than the unimpaired subgroup (N=12) for planning (Commissions) (U=8; $p < .01$) and FROGS score (U = 3.5; $p < .001$). The other measures did not reach significance.

Finally, correlational (Spearman) analyses were carried out between the variables from both the computerized version of the meeting preparation phase and the real version (i.e., Total time to complete the meeting preparation phase, Number of incorrect and forgotten objects on the table, Number of times the instructions list was consulted, Respect of the rules). The results revealed that the computerized and real versions were significantly correlated with each other for: the Total time to complete the meeting preparation phase ($r = .54$; $p < .05$); the Number of incorrect and forgotten objects on the table ($r = .73$; $p < .01$); and the Respect of the rules ($r = .86$; $p < .001$). However, this was not the case for the Number of times the instructions list was consulted ($r = .28$; $p > .05$).

Discussion

We created a novel computerized task (CMPT) that takes into account the multitasking nature of real world activities and where participants find themselves in a novel and complex situation. The main objective of this study was to investigate the multitasking capacities of a group of persons diagnosed with schizophrenia with this newly developed computerized task. Furthermore, the nature of the cognitive processes implicated was also examined. Finally, we wished to examine the tasks' ability to predict real world functioning and the ecological validity.

Results demonstrated that performance on the learning phase of the CMPT significantly differentiated patients and healthy controls for the Total time to complete the learning phase and the Total number of incorrect actions in the learning phase. Furthermore, this latter variable was significantly correlated with planning. Performance on the meeting preparation phase of the CMPT significantly differentiated patients and healthy controls for the Total time to complete the meeting preparation phase, the Planning score, and the Respect of the rules. These variables also significantly correlated with executive (i.e., cognitive flexibility and planning) and real world functioning (FROGS).

Furthermore, these variables from the meeting preparation phase significantly explained 50% and 32% of the two measures of real world functioning (FROGS and PSP, respectively). However, the cognitive measures did not significantly explain any part of the variance of any of the two measures of real world functioning (FROGS and PSP). Moreover, the impaired patient subgroup on the meeting preparation phase variables demonstrated a lower performance than the unimpaired subgroup for one planning measure (i.e., Commissions). In addition, the impaired subgroup on the Respect of the rules also demonstrated a lower score for real world functioning (FROGS). Finally, results demonstrated that a computerized version of the meeting preparation phase was significantly correlated with a real version of the task for several variables (i.e., Total time to complete the meeting preparation phase; Number of incorrect and forgotten objects on the table; Respect of the rules).

Findings from the present study revealed that Respect of the rules was a key variable. Indeed, not only did patients demonstrate a poorer performance than healthy controls for this variable, it was also a main predictor of real world functioning in both predictive models (FROGS and PSP). Interestingly, Respect of the rules has already been shown to be an important aspect in multitasking situations (Shallice and Burgess, 1991), suggesting that this variable is particularly sensitive to real world functioning. The present results also demonstrated that performance on this variable was significantly related to cognitive flexibility and planning, thus demonstrating the importance of executive functioning. Indeed, in order to respect the rules/instructions during the task - and more generally during real world activities (e.g., a list of things to do), the person has to continually switch between the instructions, his plan of action and its application during the task - while at the same time taking into account the environmental constraints.

As it was hypothesized, the CMPT significantly differentiated patients from healthy controls for a number of variables, suggesting good sensitivity. Moreover, the CMPT was significantly correlated with a real version of the task, pointing to good ecological validity. Also consistent with our hypotheses, the variables from the meeting preparation phase demonstrated a high degree of predictive value for real world functioning, demonstrating the validity of the task and the importance of evaluating multitasking abilities when one wishes to predict real world functioning. As the CMPT puts the patient in a new situation, we hypothesized significant correlations between executive functioning and patients' performance on the meeting preparation phase. Indeed, variables from the meeting preparation phase mainly correlated with executive functions and, in particular, with planning and cognitive flexibility. Moreover, subgroup analyses revealed that patients who demonstrated impaired performance on the variables from the meeting preparation phase also showed poorer planning abilities compared to the unimpaired patients. These results are consistent with assumptions that executive functioning particularly affects real world functioning in patients diagnosed with schizophrenia and (Semkovska et al., 2004; Velligan et al., 2007), in particular, during multitasking activities.

In the present study, we included a measure of participants' familiarity with video games/computers (i.e., frequency of playing with video games, frequency of playing with video games during the last two weeks, and the mean frequency of using a computer). The results revealed that patients were significantly less familiar than controls concerning their degree of familiarity with video games/computers. It could be argued that this difference influenced the results on the CMPT (e.g., it may have been easier for the control group to interact with the virtual environment). However, no significant correlations were found between the level of familiarity with video games/computers, and performance on the CMPT. This suggests that the level of expertise with video games/computers does not significantly influence CMPT performance. Important to add is that every participant included in the study reported having some previous experience with computers.

As this is the first study of its kind, it is not possible to directly compare the present results with previous studies. Nevertheless, in Semkovska et al. (2004), patients diagnosed with schizophrenia demonstrated a poorer performance than healthy controls during the realization of a multitasking cooking task. More specifically, compared to healthy controls, patients demonstrated significantly more sequencing and macrostep errors of actions (planning), more repetitions and omissions of actions, and took more time to complete the cooking task. Indeed, these variables could be compared to variables from the present study, namely, the Planning score, the Respect of the rules, the Number of incorrect and forgotten objects on the table, and the Total time to complete the meeting preparation phase. Moreover, the present results revealed that these variables were mainly correlated with planning and cognitive flexibility. Interestingly, in Semkovska et al. (2004), performance on the multitasking cooking task was also related to planning and cognitive flexibility. The fact that the results of the present study are quite similar to those in Semkovska et al. (2004) suggests that the CMPT is tapping into real world multitasking activities as they were also measured by Semkovska et al. (2004). Moreover, the present results also indicate the informative value of variables that assess: the total time to complete a task, planning capacities, and the degree to which rules/instructions are respected. Furthermore, these results underline the major implication of executive functions in real world functioning, and in particular in multitasking situations.

Previous studies have observed that cognitive measures explain between 16 and 60% of the variance on real world functioning in patients diagnosed with schizophrenia (Green, Kern, Braff, & Mintz, 2000; Koren, Seidman, Goldsmith, & Harvey, 2006; Velligan, Bow-Thomas, Mahurin, Miller, & Halgunseth, 2000). This was not found in the present study as the cognitive measures included in this study did not significantly explain any part of the variance of any of the two measures of real world functioning. This may be related to several issues such as the fact that different cognitive measures and different measures of real world functioning were used in the present study, compared to previous studies. Indeed, the choice of cognitive measures included in the present study was based on the measures' ability to assess those specific cognitive processes that are hypothesized to be implicated in multitasking abilities. However, previous studies have, for example, many times included broader measures (e.g., the Wisconsin Card Sorting Test), which rely on several cognitive functions, and this is probably the reason why these studies have observed that cognitive measures significantly predict real world functioning. Nevertheless, it is worth mentioning that the most recent meta-analysis in the literature (Fett et al., 2011), which included 52 studies, reported a much lower number, in that they found that cognitive measures only predicted 6% of the variance on real world functioning.

The present results have several potential implications. Indeed, predicting real world functioning of patients diagnosed with schizophrenia in a reliable way is highly valuable. For example, after a hospitalization, performance on a task such as the CMPT could provide important information in regards to how the patient will face everyday life or how s/he may evolve over time. It may also help assess the functional impact of an intervention. Finally, using such a task in the context of a remediation program that focusses on improving participants' multitasking abilities may prove interesting.

Although the results of the present study are encouraging, the CMPT needs to be improved even further in order for it to become even more sensitive to everyday life difficulties. More specifically, the task should also take into account certain characteristics of multitasking activities (see Burgess, 2000) such as the inclusion of distractors and prospective memory. In parallel, there is also a need to include more specific cognitive measures (e.g., prospective memory) in order to explore the cognitive functions implicated in multitasking in a more detailed manner. Such a study is currently underway.

This study contains other limitations that deserve to be mentioned. It could be argued that the sample size is quite small for the amount of analyses that were conducted. Nevertheless, it is noteworthy to mention that patients and healthy controls were carefully matched for a number of variables including age, educational level (not only of the patient, but also of his/her parents) and IQ. Furthermore, for every statistical analysis, the alpha level was corrected for multiple comparisons. The small sample size was particularly evident in the context of subgroup analyses (impaired versus unimpaired patients on their performance of the meeting preparation phase). Clearly, further studies with larger numbers of patients are needed to confirm the present results. Patients' medication could have negatively impacted performance on the CMPT, however, supplementary analyses revealed that there were no significant correlations between medication levels and CMPT variables.

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Multitasking abilities in schizophrenia: Cognitive underpinnings and clinical implications

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Abstract

Many real world activities are complex and require multitaking abilities, which involve different and integrated cognitive processes that are not assessed with standard cognitive tests. To date, few studies have examined the multitasking abilities of patients diagnosed with schizophrenia due to the absence of suitable assessment tools. Moreover, the nature of cognitive processes involved in multitaking activites is poorly understood.

The aim of the present study was to provide a better understanding of multitasking abilities in patients with schizophrenia with the help of a newly developed computerized tool (the Computerized Meeting Preparation Task, CMPT) that reflects the complex multitasking nature of real world activities.

Fifty-seven individuals diagnosed with schizophrenia and 39 matched 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.

Results demonstrated that performance on the CMPT significantly differentiated patients and healthy controls for several variables. Results also showed that multitasking abilities were related to working and episodic memory, cognitive flexibility, inhibition, planning, prospective memory and source flexibility. Moreover, these relations were not explained by a general impairment of processing speed or working memory. Patients demonstrated heterogeneous profiles with a combination of both preserved and impaired performances. In particular, a double dissociation between multitasking abilities and performance

on standard cognitive tests was observed. Taken together, these results suggest the importance of evaluating multitasking abilities in schizophrenia.

Introduction

A major characteristic of patients diagnosed with schizophrenia is the presence of difficulties in real world functioning (American Psychiatric Association, 2013). 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 where the person has to initiate, carry out and alternate between different tasks, define the tasks' targets and face unexpected outcomes (Burgess, 2000). However, standard cognitive tests do not possess these characteristics as they are designed to assess only one isolated cognitive function in a well-structured and controlled environment (office setting). Moreover, there is evidence of a double dissociation between standard cognitive measures and multitasking abilities – at least in brain-injured patients (Burgess, Alderman, Volle, Benoit, & Gilbert, 2009). That is, patients may present impaired multitasking abilities, yet preserved performances on standard cognitive tests (and inversely). Such results demonstrate that real world activities make demands upon specific cognitive functions that are not assessed with standard cognitive tests.

To date, few studies have examined the abilities of patients diagnosed with schizophrenia to realize multitasking activities. In a first study, Semkovska, Bedard, Godbout, Limoge, and Stip (2004) compared the performance of patients diagnosed with schizophrenia with healthy controls during the realization of 3 real world (observation-based) tasks: (1) choose a 3 set menu, (2) shop for the missing ingredients in a local supermarket and, (3) cook a meal. Results showed that for the three tasks, patients performed worse than controls, especially for the cooking task, that possessed a number of multitasking characteristics. Moreover, in the patient group, performance on the cooking task was significantly correlated with executive functions (i.e., cognitive flexibility, verbal fluency, planning, and inhibition), but also with verbal and non-verbal episodic memory, selective attention and negative symptoms.

Evaluating patients' performance on real world activities has the advantage of being highly ecological. However, observation-based assessments 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 down and it is difficult to obtain precise measures. Finally, assessing multitasking abilities with real world activities (e.g., cooking a meal, shopping in a supermarket) suffer from the influence of 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 clear need for standardized tools that are accessible in a clinical setting, that are closely related to real world activities – but that at the same time place participants in an unfamiliar situation.

Computerized tasks address these limitations as they can place participants in complex and unfamiliar situations that take into account the characteristics of multitasking activities. They also have the advantage of being standardized, thus offering the possibility to create normative data. Additionally, a large number of variables (e.g., speed, errors, and omissions) can be reliably measured.

Recently, Laloyaux et al. (2014) developed a pilot computerized task that takes into account the characteristics of multitasking activities. 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, required objects and desired drinks). Results showed 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 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. Moreover, this study was conducted on a small sample of patients and 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. Indeed, some studies have suggested that patients vary on a great number of dimensions including cognitive impairments and real world functioning (Larøi & Van der Linden, 2013). However, this heterogeneity is rarely taken into account in the scientific literature and has never been examined in regard to multitasking abilities.

Based on the preliminary task developed by Laloyaux et al. (2014), an improved version of the CMPT was proposed that takes into account all the characteristics of multitasking abilities and that overcomes the other observed limitations of existing tools. The general objective of the present study was thus to explore the specificity and heterogeneity of multitasking abilities in schizophrenia. In particular, one aim was to investigate if a double dissociation between standard cognitive measures and multitasking abilities could be found in schizophrenia. A second aim was to elucidate the cognitive underpinnings of multitasking difficulties. Indeed, previous studies (Laloyaux et al., 2014; Semkovska et al., 2004) did not examine the implication of specific cognitive functions that may be important for multitasking abilities, such as prospective memory and source flexibility (the ability to switch between environmental stimuli and mental representations, Burgess, Dumontheil, & Gilbert, 2007). Whether or not general cognitive factors (such as processing speed and working memory) have a major influence on multitasking abilities was also an aim. A final objective was to explore the relations between multitasking abilities and clinical variables including symptoms and real world functioning.

Methods

Participants

Fifty-seven persons diagnosed with schizophrenia according to DSM-IV (American Psychiatric Association, 1994) criteria were recruited. Diagnosis was confirmed by the Mini International Neuropsychiatric Interview (M.I.N.I.; Sheehan et al., 1998). Exclusion criteria consisted of: the presence of neurological and/or other psychiatric disorders including alcohol or drug dependency (measured with the Alcohol Use Disorders Identification Test, Saunders, Aasland, Babor, de la Fuente, & Grant, 1993; and the Drug Use Disorders Identification Test, Berman, Bergman, Palmstierna, & Schlyter, 2005), patients who were not stabilized, mental retardation (French National Adult Reading Test, fNART; Mackinnon &

Mulligan, 2005; Nelson & O'Connell, 1978), absence of familiarity with computers and major change of medication within one month before testing. Patients' medication was converted into three indexes according to data from the literature (e.g., Boily & Mallet, 2008; Gardner, Murphy, O'Donnell, Centorrino, & Baldessarini, 2010; Taylor, Paton, & Kapur, 2009): benzodiazepine (diazepam equivalence in mg), antipsychotic (olanzapine equivalence in mg), and risk for anticholinergic side effects.

Thirty-nine healthy controls were also included in the study and were matched according to sex, age, estimated premorbid IQ (fNART) and number of years of education. Exclusion criteria consisted of the presence of any psychiatric or neurological disorder, the absence of familiarity with computers, and having any first-degree family history of schizophrenia.

Participants' familiarity with video games and computers was assessed by asking them to indicate the last time they used a computer or played with video games, the mean 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.

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, and cannabis consumption. However, patients were significantly less familiar than controls concerning their degree of familiarity with video games and computers and estimated IQ. Nonetheless, the mean IQ difference was only 4 points, which cannot be considered a clinically relevant difference.

Table 1: Demographic characteristics of participants

	Patients (N=57)		Healthy controls (N=39)	
	Mean (SD)	Min-max	Mean (SD)	Min-max
Age	34.89 (8.72)	19-55	34.00 (10.24)	19-55
Sex (F/M)		8/49		7/32
Education (years)	11.28 (2.51)	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)	.05 (.18)	0-1	.03 (.10)	0-.6
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	23.55 (6.47)	0-33		
HAD[4] – Depression	6.07 (3.08)	0-15		
HAD[5] – Anxiety	8.82 (3.60)	2-19		

*=p<.05; ***=p<.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

Measures

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). Some modifications were adopted in order to render the task compatible with the characteristics of multitasking activities (Burgess, 2000). More specifically, clear prospective memory instructions were introduced in addition to interruptions and unexpected outcomes (See supplementary material for a full description).

Learning phase of the CMPT

During this first phase, participants are introduced to the basic actions and functions that are required during the meeting preparation phase such as moving the avatar and carrying objects by using the computer mouse.

Meeting preparation phase of the CMPT

During the test, participants find themselves in a virtual environment (Figure 1[6]) composed of a main room where the meeting is to take place and 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. Participants are told that a meeting will start in 30 minutes and that they have to prepare the room. To do so, participants have access to a list of instructions (containing the required objects, information about the seating plan and the guests list), and a clock.

[6] Supplementary screenshots of the CMPT can be found in Annex 1.

The task was designed so that it takes into account all the characteristics of multitasking activities. Thus, the participants have to prepare a room for 5 guests in addition to dealing with two distractors (a missing chair and an interrupting phone call) while at the same time maintaining in memory two prospective memory instructions (give the camera to an avatar when it arrives and put the coffee on the table at 9:40AM).

The following variables were calculated: Total time to complete the task; Respect of the rules (i.e., the written instructions); Number of incorrect and forgotten objects on the table; 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); Prospective memory score (the correct objects and time); Distractor management (the missing chair and the phone call); Checking score (whether the cart is empty and placed back to its original spot or not; time gap between the last consultation of the instructions and participants exited the room); First instructions consultation (the time taken to consult the list of instructions for the first time).

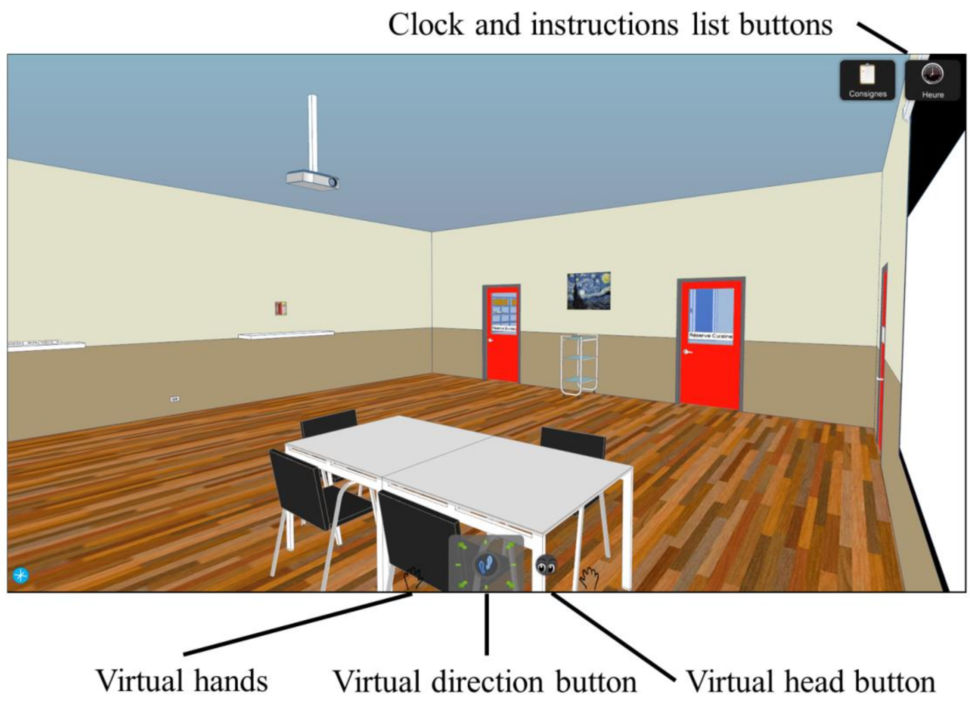

Figure 1: The main room where the meeting takes place

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. The aim was to include tests assessing general (i.e., processing speed and working memory) and specific cognitive functions as well as another multitasking test to evaluate the concurrent validity of the CMPT.

-Processing speed: Symbol search (Wechsler, 2000) (total score).

-Working memory: Letter and Number Sequencing (LNS; Wechsler, 2001) (correct longest span).

-Verbal episodic memory: Rey Auditory Verbal Learning Test (Rey, 1964) (total learning phase consisting of 3 recalls).

-Cognitive flexibility: Trail Making Test (TMT; Army Individual Test Battery, 1944) (time on Part B minus time on Part A).

-Inhibition: STOP-IT test, a computerized stop-signal task (Verbruggen, Logan, & Stevens, 2008) (Stop-Signal Reaction Time).

-Planning: Zoo map (Wilson, Alderman, Burgess, Emslie, & Evans, 1996) (total score).

-Prospective memory (PM): this cognitive function refers to the ability to create and remember future intentions. It was measured with a computerized test created by the authors (see supplementary material) inspired from the tasks developed by Wang et al. (2008) to measure event-based and time-based prospective memory.

-Source flexibility: this cognitive function refers to the ability to switch attention between stimulus-independent (the thoughts) and stimulus-oriented thoughts (the environment). The test used in the present study was a simplified version (see supplementary material) of one of the tasks developed by Gilbert, Frith, and Burgess (2005). The percentages of errors committed during both switching phases were used (internal to external and external to internal).

-Multitasking: Modified Six Element Test (SET; Wilson et al., 1996) (total score).

Clinical measures

All patients were evaluated by a psychologist during an interview with the Positive And Negative Symptoms Scale (PANSS; Kay, Fiszbein, & Opler, 1987) and the Functional Remission Of General Schizophrenia (FROGS; Llorca et al., 2009). Finally, patients also completed the Hospital Anxiety Depression scale (HAD; Zigmond & Snaith, 1983) and an informant was asked to complete a measure of apathy (the Initiative-Interest Scale, IIS; Esposito et al., 2014).

Statistical analyses

Group comparisons for demographic variables, cognitive measures and performance on the CMPT were analyzed using Student's t-test. Effect sizes were calculated using Cohen's d. Correlational analyses (Pearson) were then carried out in the patient group between the variables from the CMPT and the cognitive and clinical variables. Alpha was set at .05 and adjusted with the false discovery rate method for multiple testing (Benjamini and Yekutieli, 2001). Thereafter, partial correlation analyses were conducted in order to examine if the observed relations were due to general cognitive factors (i.e., processing speed and working memory). Finally, stepwise regression analyses with backward elimination method ($p>.05$) were conducted in order to examine the provision of each cognitive measure to the CMPT variables in the patient group (no sign of multicollinearity was detected for any variable). Finally, individual profiles were examined in the patient group. To do so, performance on the CMPT and cognitive measures of each patient were converted into z-scores based on the results of the healthy controls.

Results

Group comparison analyses

Patients and healthy controls were compared (t-test) in regard to their performance on the CMPT and cognitive measures (Table 2). Alpha was set at .014.

Results 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 (ANCOVA) did not change the group differences.

Concerning cognitive measures, results showed that performances were significantly different between healthy controls and patients for all the variables before statistical correction. However, source flexibility/internal to external and inhibition were no longer significant after statistical correction.

Table 2: Performance on the cognitive measures for both groups

	Patients (SD)	Healthy controls (SD)	t (94)	d	Percentage of patients demonstrating an impaired performance
CMPT					
Total time (min)	24.14 (8.17)	15.57 (5.48)	-5.71***	-1.19	40
Respect of the rules	6.31 (3.20)	9.66 (1.10)	6.27***	1.31	56
Number of incorrect and forgotten objects on the table	9.08 (6.72)	1.97 (2.84)	-6.23***	-1.30	56
Planning score	5.32 (2.23)	6.78 (1.90)	3.33***	.69	17
Prospective memory score	1.35 (.93)	2.66 (.76)	7.20***	1.51	54
Distractor management	1.59 (1.33)	2.56 (.85)	4.00***	.84	35
Checking score	1.43 (.74)	2.38 (.31)	7.52***	1.57	54
First instructions consultation (sec)	70.62 (108.08)	40.87 (65.99)	-1.53	-.32	10
Cognitive Measures					
Processing speed (Symbol search)	24.36 (7.48)	39.28 (7.42)	9.62***	2.02	54
Working memory (LNS)	4.50 (.96)	5.94 (.91)	7.32***	1.53	45
Episodic memory (Rey)	22.87 (6.20)	29.61 (5.15)	5.58***	1.17	31
Cognitive flexibility (TMT)	81.42 (64.87)	32.94 (14.68)	-4.57***	-.95	50
Inhibition (msec)	309.09 (187.51)	237.50 (114.75)	-2.12*	-.44	10
Planning (Zoo)	2.33 (2.88)	6.16 (2.67)	6.56***	1.37	43
Prospective memory - Time-based	6.22 (2.51)	7.74 (.59)	3.70***	.77	35
Prospective memory - Event-based	6.71 (1.90)	7.76 (.48)	3.38***	.71	31
Source flexibility/External to internal	12.58 (16.43)	5.06 (9.28)	-2.59**	.54	24
Source flexibility/Internal to external	7.09 (12.97)	2.67 (5.21)	-2.02*	.42	19
Multitasking (SET)	4.59 (1.44)	5.74 (.63)	4.63***	1.03	40

* = p<.05 ; ** = p<.014 (Benjamini-Hochberg-Yekutieli correction); *** = p<.001

Correlational analyses

Correlational analyses (Pearson) between the CMPT and cognitive and clinical variables were then conducted in the patient group. Alpha was set at .009. Results (Table 3) demonstrated that the CMPT variables were significantly correlated with working memory, cognitive flexibility, planning, prospective memory/time-based and event based and source flexibility/internal to external. Additionally, Respect of the rules was found to be significantly correlated with the SET ($r=.42$, $p<.009$). No significant correlation was found between the CMPT and clinical variables including the PANSS positive and negative, the IIS and the FROGS.

Partial correlation analyses controlling for processing speed revealed no change in the initial correlations between the CMPT and cognitive variables. Similarly, controlling for working memory generally did not affect the results (only the correlation between Respect of the rules and cognitive flexibility was no longer significant).

Table 3: Correlations between clinical variables and CMPT variables in the patient group

	Total time	Respect of 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)	-.11	.28	-.19	.03	.09	.03	.24	-.22
Working memory (LNS)	-.31	.43**	-.46**	.19	.21	.26	.43**	-.14
Episodic memory (Rey)	.13	.32	-.14	.18	.04	.14	.27	.00
Cognitive flexibility (TMT)	.24	-.39*	.26	-.05	-.22	-.26	-.31	.38*

Inhibition (msec)	.02	-.26	.08	.02	-.18	-.07	-.20	-.12
Planning (Zoo)	-.41*	.25	-.33	.38*	.49**	.21	.14	-.16
Prospective memory- Time-based	-.14	.21	-.29	.10	.23	.08	.27	-.39*
Prospective memory- Event-based	-.09	.23	-.20	.11	.35*	.18	.05	-.32
Source flexibility/External to internal	.04	-.38*	.54**	-.09	-.28	-.31	-.22	.34
Source flexibility/Internal to external	-.01	-.26	.07	.02	.05	.06	-.30	.07

* = p< .009 (Benjamini-Hochberg-Yekutieli correction); ** = p<.001

Regression analyses

Stepwise regression analyses with backward elimination were conducted in order to examine the provision of the cognitive measures to the CMPT variables in the patient group. Results (Table 4) demonstrated that the cognitive measures significantly predicted between 8 and 39% of the variance of the CMPT variables. Moreover, several cognitive variables were particularly implicated in the CMPT: working memory, episodic memory, cognitive flexibility, inhibition, planning, prospective memory (time based and event based) and source flexibility (external to internal switch).

Table 4: Stepwise regression analyses with backward elimination examining the-

CMPT variable	Adj. R^2	F	df
Total time	.26	7.87***	3, 53
Respect of the rules	.28	8.49***	3, 53
Number of incorrect and forgotten objects on the table	.39	19.31***	2, 54
Planning score	.13	9.26**	1, 55
Prospective memory score	.32	9.65***	3, 53
Distractor management	.08	5.96**	1, 55
Checking score	.17	12.65***	1, 55
First instructions consultation	.21	8.51***	2, 54

* = p<.05; ** = p< .01; *** = p<.001

-provision of each cognitive measure to the CMPT variables in the patient group

Cognitive variables ß									
PS[1]	WM[2]	EM[3]	Cog. Flex.[4]	Inhi.[5]	Plan.[6]	PM-TB[7]	PM-EB[8]	Source flex. Ext.-Int.[9]	Source flex. Int.-Ext.[10]
	-.35**	.25*			-.40***				
	.37***			-.22*				-.27*	
	-.36***							.46***	
					.38**				
				-.27*	.46***		.23*		
								-.31**	
	.43***								
			.30**			-.32**			

[1]Processing speed (Symbol search)
[2]Working memory (LNS)
[3]Episodic memory (Rey)
[4]Cognitive flexibility (TMT)
[5]Inhibition
[6]Planning (Zoo)
[7]Prospective memory - Time based
[8]Prospective memory - Event based
[9]Source flexibility/ External to internal
[10]Source flexibility/ Internal to external

Examination of individual profiles

The percentages of patients 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 of 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 and in particular for 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).

Discussion

The present study aimed to explore the specificity and heterogeneity of multitasking abilities in schizophrenia. Another objective was to clarify the cognitive underpinnings of multitasking difficulties in schizophrenia and, in particular, regarding the effects of specific and general cognitive functions. A final aim was to explore the relations between multitasking abilities and clinical variables including symptoms and real world functioning.

In order to address these aims, an adapted version of the pilot task (the CMPT) developed by Laloyaux et al. (2014) was used. The task was modified so that it takes into account all the characteristics of multitasking activities (Burgess, 2000). Interestingly, the computerized task was well tolerated by the patients who reported finding the assessment more entertaining than standard cognitive tests. Concerning the psychometric properties, the present study demonstrated that the CMPT presents good sensitivity in its ability to distinguish patients from healthy controls. Moreover, the CMPT was found to possess good concurrent validity as it was significantly correlated with the SET (Wilson et al., 1996) -- another measure of multitasking abilities. Furthermore, the CMPT was more sensitive than the SET in differentiating between the two groups, and the CMPT provided a more detailed evaluation of multitasking abilities (as many as 8 variables related to different facets of multitasking were calculated, compared to only one for the SET).

In accordance with previous studies (Laloyaux et al., 2014; Semkovska et al., 2004), the present results demonstrated that patients diagnosed with schizophrenia suffer from multitasking difficulties. However, patients' performance on the CMPT was highly heterogeneous as patients showed different profiles with a combination of both preserved and impaired performances. In particular, 56% of patients presented difficulties in respecting the written instructions. Moreover, results revealed that such impairment was associated with poor abilities in maintaining and manipulating information in working memory, shifting back and forth between multiple mental sets, inhibiting a dominant response and switching from the outer world to internal representations (e.g., a plan or thoughts). Similarly, 56% of patients placed a number of incorrect objects on the table and forgot required items. Interestingly, 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%) also presented impaired abilities in checking goal achievements that were found to be related to poor working memory. In addition, 54% of patients failed to achieve the prospective memory requirements of the CMPT. Indeed, such difficulties were found to be related to poor prospective memory performance (event-based) but also to difficulties in planning abilities and inhibiting a dominant response. 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, 40% 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. Interestingly, 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. Seventeen 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. Indeed, such difficulties were related to poor planning abilities. Finally, 10% of patients took a particularly long time to consult the instructions list for the first time 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).

Such results demonstrated the sensitivity of the CMPT and the heterogeneity of multitasking abilities in schizophrenia. Moreover, they provided a better understanding of the cognitive underpinnings of multitasking abilities. To begin with, the results showed that multitasking difficulties in schizophrenia are not due to a general impairment of processing speed or working memory. Indeed, these cognitive functions have been found to be two main cognitive deficits in schizophrenia (Dickinson, Ramsey, & Gold, 2007; Silver, Feldman, Bilker, & Gur, 2003). However, partial correlational analyses revealed that controlling for working memory or processing speed does not influence the observed relations between the CMPT variables and the other cognitive functions. In contrast, performance on the CMPT was found to be related to different specific 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 in 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, the results found that difficulties in disengaging from the environment to return to the internal plan predicted poorer multitasking abilities. Moreover, the present results also demonstrated different implications of event-based and time-based prospective memory in multitasking abilities. Indeed, the prospective memory variable of the CMPT was found to be related to event-based, but not with time-based prospective memory. Such results could be explained by the fact that event-based prospective memory is more represented in the CMPT than time-based. On the other hand, time-based prospective memory significantly predicted the time taken before consulting the instructions list for the first time. This relation may be explained by difficulties in monitoring the actions in both the prospective memory task and the CMPT. Taken together, these results are in agreement with the assumption that source flexibility (Burgess et al., 2007) and prospective memory are central cognitive processes in multitasking abilities (Burgess, Veitch, de Lacy Costello, & Shallice, 2000).

For the first time in the literature, a double dissociation was found in schizophrenia between multitasking abilities and the other measured cognitive functions. Such results are consistent with a previous study (Burgess et al., 2009) that have described a double dissociation in brain-injured patients and suggest 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 unexplored cognitive functions sustained by the rostral prefrontal cortex such as source flexibility, prospective memory and metacognition. Indeed, the present results demonstrated the main role of source flexibility and prospective memory in multitasking abilities. However, not all patients with preserved multitasking abilities presented unimpaired source flexibility or prospective memory. Moreover, regressions analyses revealed that the cognitive measures (including source flexibility or prospective memory) only predicted between 8 and 39% of the variance of the CMPT variables. Taken together, such results suggest the influence of other factors. Further studies are thus required to explore the nature of multitasking difficulties. One possibility would be the presence of an integrative cognitive process which orchestrates the other cognitive functions that are necessary to accomplish complex or novel tasks (Stuss, 2011). Whatever the case may be, the influence of specific strategies used to realize the task as well as the impact of other psychological factors (e.g., self-efficacy and motivation) need to be examined.

In the present study, no significant correlation was found between the CMPT and real world functioning. This absence of results is quite surprising as a previous study has demonstrated relations between multitasking tests and real world functioning (Laloyaux et al., 2014). This may be attributed to the fact that the mean score on the FROGS presents a clear lack of variance. In particular, compared to the sample of Laloyaux et al. (2014), patients in the present study demonstrated a more homogeneous (Levene's test: F=3.93, p<.05) and better level of functioning (U=281.5, p<.001). Moreover, the rating of the FROGS was uniquely based on information collected from patients during an interview, which is influenced by confounding factors such as patients' degree of insight and a social desirability bias. In addition, 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 (e.g., caregiver- and observation-based) in patients diagnosed with schizophrenia. 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, relations between the CMPT and real world functioning need to be explored in more detail, albeit with objective measures such as observation-based approaches and sociodemographic data such as employment status.

Finally, the present study revealed no significant correlations between symptoms and multitasking abilities. These results are not consistent with Semkovska et al. (2004) that found significant correlations between a multitasking cooking task and negative symptoms. However, these differences may be explained by the fact that patients in the present study had fewer symptoms than in Semkovska et al. (2004). Indeed, in the present study, patients demonstrated a mean PANSS score of 13.42 for positive symptoms, 18.72 for negative and 31.23

for general psychopathology, whereas in Semkovska et al. (2004), the mean scores were respectively of 18.1, 21.3 and 37.7. Taken together, these results suggest the independence and specificity of multitasking abilities in stabilized patients diagnosed with schizophrenia, but that more severe symptoms can potentially have an impact on multitasking abilities.

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Supplementary material

Full description of the Computerized Meeting Preparation Task (CMPT)

Learning phase of the CMPT

The main goal of the learning phase is to systematically familiarize participants with the basic actions and functions that are required during the meeting preparation phase, and to do so successfully. The learning phase consists of carrying out task-relevant actions in a progressive and error-limiting manner. To begin with, participants are introduced to simple actions (e.g., how to move the avatar by sliding the virtual direction button; how to look around using the virtual head button) followed by more demanding actions (e.g., how to grasp objects by double-clicking; how to drop an object by clicking the object and then sliding it into the chosen place). It is only when participants perform each action successfully that they may proceed to the next level of the learning phase. If participants commit an error at any time during the learning phase - the error is registered, participants are alerted of this error, the instructions are repeated, and participants are asked to continue until the action is performed without committing an error.

Meeting preparation phase of the CMPT

After the learning phase, 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.

After this explanatory video, participants are told that it is 9:30 AM and that a meeting will start in 30 minutes, but that the secretary who is supposed to prepare the meeting room is sick and that the participant 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 AM 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; 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 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 without being too difficult nor 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) while at the same time maintaining 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 an avatar when it arrives and put the coffee on the table at 9:40 AM).

Other cognitive tests

-Prospective memory (PM): 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; 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 prospective memory stimuli are presented during the ongoing task (8 event-based and 8 time-based).

-Source flexibility: The test used in the present study was a simplified version of one of the tasks developed by Gilbert, Frith, and Burgess (2005). During this computerized task, participants are required to classify capital letters according to whether the letter presented on the screen contains one or more curves (e.g., B) or only straight lines (e.g., A). The letters are presented in alphabetical order. During the task, the participants have to judge either the letters that are shown on the screen (external phase), or the mental representations of the letters (i.e., internal phase) – 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).

Discussion

Persons diagnosed with schizophrenia and bipolar disorder encounter many difficulties in real world functioning. In particular, patients seem to have problems with more complex real world activities that are of a multitasking nature, such as maintaining professional activity, shopping, preparing a meal, or doing the housework. Indeed, being able to carry out such activities is required in order to live independently. However, multitasking abilities have rarely been examined in these populations due to the absence of suitable assessment tools that take into account all the characteristics of multitasking activities. Furthermore, the nature of these difficulties is not well understood. In particular, a small number of studies have suggested that multitasking abilities are related to executive functioning, memory, and attention. Nonetheless, multitasking abilities also seem to make demands upon different cognitive functions that are not assessed with standard cognitive tests. In addition, the potential implication of several cognitive functions has never been explored nor the effects of a general cognitive factor. Finally, the impact of symptoms on multitasking abilities has rarely been examined. There is thus a clear need for standardized tools that are accessible in a clinical setting and are closely related to real world activities. Moreover, the cognitive underpinnings of multitasking abilities as well as the relations with symptoms need to be explored.

The goals of the present thesis are twofold. (1) To examine multitasking abilities in persons diagnosed with bipolar disorder using the computerized shopping task developed by Larøi et al. (2010). A second aim was to explore the cognitive underpinnings of multitasking abilities in bipolar disorder, particularly regarding the effects of a general cognitive impairment of processing speed. Finally, it was also an aim to examine the ability of the shopping task to predict patients' real world functioning and to explore the relations between multitasking abilities and symptoms. (2) To explore multitasking abilities in persons diagnosed with schizophrenia using a new standardized tool designed to assess multitasking abilities which reflects all the characteristics of multitasking activities—but at the same time that places participants in an unfamiliar situation—the Computerized Meeting Preparation Task (CMPT). A second aim was to explore the cognitive underpinnings of multitasking abilities in persons diagnosed with schizophrenia. In particular, the aim was to examine the relations between multitasking abilities and specific and general cognitive functions. A last aim was to explore the ability of the CMPT to predict patients' real world functioning and investigate the relations between multitasking abilities and symptoms.

Multitasking abilities in bipolar disorder

Performance on the shopping task

The first goal of this thesis was to examine multitasking abilities in persons diagnosed with bipolar disorder. To do so, a first study was conducted using the computerized shopping task developed by Larøi et al. (2010). Performance on the shopping task was represented by eight variables: total time to complete the task, mean time spent consulting the shopping list, number of missed shelves (i.e., number of times a participant went towards a pertinent aisle but did not approach the shelf despite the fact that it contained a pertinent item), distance traveled, mean time spent consulting the shopping cart, number of intrusions (i.e., number of purchases that were made by the participant but that were not included in the shopping list), total amount (in Euros), and shelf redundancy (i.e., number of times a same shelf was visualized by the participant, that is, the number of times participants zoomed on the shelf).

Results demonstrated that compared to healthy controls, patients took more time to realize the task and spent a longer mean time consulting the shopping list. The other variables were not significant. Thus, these results suggest that when confronted with a multitasking shopping activity, patients diagnosed with bipolar disorder globally require more time to complete the activity but present a good performance from a qualitative point a view. In particular, patients were able to buy the required articles respecting the budget and explore the supermarket in an organized manner, that is, without traveling any extra distance, missing pertinent shelves, or having to go back several times to the same shelves. Interestingly, patients and healthy controls reported similar levels of familiarity with video games and with shopping in a supermarket. Thus, the differences observed between groups on the shopping task could not be explained by the influence of such variables.

The present study thus suggests that patients with bipolar disorder encounter multitasking difficulties. Such results are consistent with the only two previous studies (Caletti et al., 2013; Torralva et al., 2012) that explored multitasking abilities in bipolar disorder. In particular, results of these studies revealed that patients presented poorer performances than healthy controls on the hospital version of the MET (Knight et al., 2002) and on an adapted version of the hotel task (Manly et al., 2002; Torralva, et al. 2009). However, as this is the first study that has explored multitasking abilities in bipolar disorder using a complex task inspired from real life activities, it is not possible to directly compare the present results with previous studies. In particular, the variables measured during the shopping task are relatively different from those measured with the MET and the hotel task.

As a reminder, in the adapted version of the hotel task (Manly et al., 2002; Torralva et al., 2009), participants are required to realize five different (simple) tasks for 15 minutes: compile individual bills, sort coins, look up telephone numbers, sort conference labels, and proofread a hotel leaflet. Participants are told that they have to attempt at least some items of each task, but that they do not have enough time to finish them all. In addition, participants also have to open and close the garbage door by pressing a button at a certain time (prospective memory instructions). However, this prospective memory aspect of the task was not measured either in Caletti et al. (2013) or in Torralva et al. (2012). Performance on the hotel task is only reflected by the number of tasks attempted and the total time deviation regarding a predefined optimal time allocation (i.e., three minutes per task as there are five tasks to try for 15 minutes). In both previous studies (Caletti et al., 2013; Torralva et al., 2012), patients attempted fewer tasks than healthy controls.

As for the hospital version of the MET (Knight et al., 2002), participants are required to carry out 12 errands in a hospital setting (e.g., buy items, find the price of a dinner menu, and call the evaluator 20 minutes after the beginning of the task) while respecting some rules (e.g., not to go back into an already visited building). Performance on the task is represented by four broad variables: (1) the number of task failures that includes errands of different nature (e.g., buy items, find information, respect prospective memory instructions); (2) inefficiencies referring to the utilization of a non-optimal strategy (e.g., entering a shop more than once, start the test without checking the time); (3) interpretation failures (i.e., misunderstanding of the requirements of a task), and (4) the number of rule breaks that covers both the written rules (e.g., going out of the defined boundaries) and implicit social rules that were broken (e.g., not to steal something). In both studies (Caletti et al., 2013; Torralva et al., 2012), patients were found to make more inefficiencies and rule breaks than healthy controls. However, in Caletti et al. (2013), patients also completed fewer tasks and committed more interpretation failures.

Contrary to the broad variable measured during the MET and hotel task, the shopping task provides really specific variables such as the time spent consulting the shopping list, the distance traveled, and the shelf redundancy. The differences between the measured variables across the three tests do not allow directly comparing them. In particular, the nature of the variables that significantly differentiated patients from healthy controls varies across studies. In fact, the present results demonstrated that only time-related variables significantly differentiated patients from healthy controls. However, previous studies (Caletti et al., 2013; Torralva et al., 2012) that used the MET and hotel task found differences in variables related to the execution of the tasks. This difference between studies is interesting and may be explained by the fact that the shopping task assesses a more familiar activity than the MET and hotel task. This hypothesis is particularly relevant regarding the fact that patients in the present study showed a lower level of real world functioning than patients in Torralva et al. (2012) and Caletti et al., (2013). It would thus have been expected that patients would demonstrate more difficulties in the shopping task. Another possible interpretation would be that the shopping task is simpler and easier than the MET and hotel task. However, this hypothesis does not hold regarding the fact that the hotel task only requires participants to do a little of five different basic tasks, in any order, and without any further instructions.

Cognitive underpinnings

A second aim of the present study was to examine the cognitive underpinnings of multitasking abilities in bipolar disorder, particularly regarding the effects of a general cognitive impairment of processing speed. To do so, correlational analyses were conducted exploring the relations between multitasking abilities and an extensive cognitive battery. Results revealed that a longer total time taken to complete the task was significantly correlated with poorer performances on standard cognitive tests assessing processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. Similarly, a longer mean time spent consulting the shopping list was related to poorer performances on processing speed and episodic memory tests. In fact, effective shopping behavior requires the involvement of all of these cognitive functions: a complex situation is presented to participants, who are then required to create an action plan to explore the supermarket in a fast and organized manner (processing speed and planning), to maintain this plan in mind throughout the task and try to remember as many items on the shopping list as possible (episodic memory), to inhibit irrelevant stimuli during the task such as non-pertinent items and loud speaker announcements (inhibition), and to continuously shift between the shopping list, the cart and the virtual environment, and between pertinent and non-pertinent items. In particular, processing speed was related to both the total time taken to complete the task and the mean time spent consulting the shopping list, indicating that faster information processing is important to better explore the supermarket and pick the required items and read faster the shopping list. Similarly, episodic memory was found to be correlated with both shopping variables. Clearly, episodic memory is implicated in trying to remember the items from the shopping list and in realizing the task faster. In the present study, executive functions were revealed to be particularly related to the ability to conduct the task in a shorter amount of time. Indeed, good planning abilities are required to explore the supermarket in an efficient manner. Similarly, cognitive flexibility is important when shifting between the different tasks (e.g., pick the items, check the shopping list, and the cart) and the different perceived stimuli (e.g., the different articles in the aisles). Finally, inhibition is clearly required to inhibit the irrelevant stimuli (e.g., loud-speaker announcements and non-pertinent items).

The fact that only time-related variables significantly differentiated patients from healthy controls could suggest a greater influence of processing speed. Moreover, a deficit in processing speed has been hypothesized to contribute to a range of cognitive difficulties in bipolar disorder (Antila et al., 2011). However, controlling for the impact of processing speed (partial correlation analyses) did not change the observed relations between performance on the shopping task and the other cognitive functions. Such results indicate that even if processing speed obviously plays a role in multitasking situations, such impairment could not explain the observed relations between the shopping task and the other cognitive functions.

These results are divergent compared to the previous study by Antila et al. (2011) that found no significant difference between bipolar patients and healthy controls on an extensive cognitive battery after adjustment for the effect of processing speed. However, this discrepancy between the results could be explained by the different nature of standard cognitive tests and multitasking situations. In particular, standard cognitive tests are designed to assess one isolated cognitive function in a quiet and well-structured environment whereas multitasking situations, such as the shopping task, involve different and integrated cognitive processes and take place in an unstructured context. Processing speed thus seems to play a main role in cognitive deficits observed in bipolar disorder as measured by standard cognitive tests. However, its role is greatly diminished in complex situations that make demands upon different and integrated cognitive functions. Such results are consistent with the hypothesis that multitasking abilities rely upon different cognitive functions that are not assessed with standard cognitive tests (e.g., Burgess et al., 2009).

In the present study, supplementary analyses were also conducted comparing patients presenting one or no impaired performance on standard cognitive tests with patients with more than one cognitive deficit. Results revealed that both sub-groups were not significantly different on the shopping task. However, compared to healthy controls, patients with one or no cognitive impairment presented a significantly poorer performance on the shopping task. Such results indicate that impaired performance on standard cognitive tests is neither a necessary nor a sufficient condition to present multitasking difficulties. These results are consistent with the study by Torralva et al. (2012) that demonstrated that patients with bipolar disorder presented multitasking difficulties despite preserved performances on standard cognitive tests. Taken together, these observations suggest that multitasking abilities make demands upon cognitive functions that are not assessed with standard cognitive tests. Such results underline the importance of evaluating multitasking abilities in persons diagnosed with bipolar disorder in clinical practice. However, even if the present study included an extensive cognitive battery, some potentially important and more specific cognitive functions were not assessed. For example, some authors have suggested that multitasking abilities make demands upon prospective memory (Burgess, 2000; Burgess et al., 2000; Logie et al., 2011) and source flexibility (Burgess et al., 2007). It is thus not possible to more precisely determine the cognitive underpinnings of multitasking abilities in persons diagnosed with bipolar disorder. Future studies are clearly required to better characterize these specific difficulties.

In summary, the present results revealed that multitasking abilities in persons diagnosed with bipolar disorder are significantly related to processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. Moreover, results also suggested that multitasking difficulties are not due to a general slowing of processing speed and that multitasking abilities make demands upon cognitive functions that are not assessed by standard cognitive tests. To date, only one previous study (Torralva et al., 2012) has examined the links between performance on a cognitive battery (assessing processing speed, working and episodic memory, language, and cognitive flexibility) and multitasking abilities in patients diagnosed with bipolar disorder. Multitasking abilities were measured by an adapted version of the hospital version of the MET (Knight et al., 2002) and the hotel task (Manly et al., 2002; Torralva et al., 2009). The authors found that patients' performance on the MET was not significantly correlated with any cognitive measure. However, performance on the hotel task was found to be significantly correlated with cognitive flexibility and working memory. These results, or rather this relative absence of results, are astonishing in regard to the present study where several significant correlations were found between performance on the shopping task and several standard cognitive tests. Such a discrepancy between both studies is particularly challenging. Nonetheless, some differences between both studies can help to explain these findings.

The present study found that performance on the shopping task was related to standard cognitive tests. Similarly, Torralva et al. (2012) found that performance on the hotel task was related to standard cognitive tests whereas the MET did not reveal any significant correlation. A main point in common between the shopping task and the hotel task is that the administration is standardized as the environment is perfectly controlled. On the contrary, the hospital version of the MET lacks standardization. In particular, a series of variables that may affect the performance cannot be controlled (e.g., the amount of noise and other distractors) and influence the results. For instance, some patients can be assessed during a relatively calm moment of the day whereas others can be evaluated when the hospital is more crowded, rendering the task more difficult. This lack of standardization means that participants end up not realizing the same task and may not make demands upon similar cognitive functions or with the same intensity. For example, patients in a crowded condition may make more demands upon inhibition than patients in the calm environment. The fact that the conditions of administration vary from a participant to another could explain the lack of significant correlation between performance on the MET and standard cognitive tests in Torralva et al. (2012).

Among the standard cognitive tests included in the study by Torralva et al. (2012) (assessing processing speed, working and episodic memory, language and cognitive flexibility), patients' performance on the modified version of the hotel task was only found to be significantly correlated with cognitive flexibility and working memory. However, results of the present study demonstrated that performance on the shopping task was significantly correlated with a higher number of cognitive functions including processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. This discrepancy between the results could be explained by the different nature of the tasks used and the measured variables. In particular, the hotel task is a relatively simple test as participants are only required to do a little of five different basic tasks, in any order, and without any further instructions. On the contrary, the shopping task places participants in a complex real-life based situation where they have to explore the supermarket in a fast and organized manner, try to remember as many items on the shopping list as possible, inhibit irrelevant stimuli during the task such as non-pertinent items and loud speaker announcements, and continuously shift between tasks and stimuli from the environment. It is thus plausible to hypothesize that the shopping task is closer to a real life multitasking situation and thus makes demands upon more different cognitive functions than the hotel task. In other words, these results indicate that the shopping task is more informative than the hotel task in regard to patients' cognitive and real world functioning. Moreover, Torralva et al. (2012) did not explore the potential relations between performance on the hotel task and certain cognitive functions that may be important for multitasking abilities such as inhibition and planning.

Finally, it is also possible that the discrepancy between the results observed in the present study and Torralva et al. (2012) are related to sample differences. In particular, patients in the present study demonstrated cognitive impairments on a series of measures whereas patients in Torralva et al. showed unimpaired and homogeneous cognitive performances. In particular, performances on standard cognitive tests are characterized by a clear lack of variance, which reduces the likelihood to find some statistically significant results.

Taken together, the present and previous studies suggest that patients diagnosed with bipolar disorder encounter multitasking difficulties. Moreover, results suggested that multitasking abilities are related to processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. Nevertheless, considering the discrepancy between the results across studies, there is a clear need for future studies evaluating multitasking abilities in bipolar disorder and their cognitive underpinnings. More specifically, future studies should assess multitasking abilities with standardized tools that place participants in a complex situation that take into account all the characteristics of multitasking activities (Burgess, 2000). As already stated in the introduction, the hotel task and the shopping task lack some characteristics of multitasking activities (e.g., clear interruptions/unexpected outcomes). Concerning the hospital version of the MET, even though it potentially reflects all the multitasking activities, it clearly lacks standardization which may explain the observed absence of significant correlations between this test and other cognitive measures in Torralva et al. (2012).

Future studies are also required to better characterize the cognitive underpinnings of multitasking abilities. In particular, there is a need to explore the potential implication of other specific cognitive functions that were hypothesized to be related to multitasking abilities such as prospective memory (Burgess, 2000; Burgess et al., 2000; Logie et al., 2011) and source flexibility (Burgess et al., 2007). In fact, the results of the present and previous studies (e.g., Torralva et al., 2012) suggest that multitasking activities rely upon many different cognitive functions, but at the same time, also make demands upon cognitive functions that are not assessed by standard cognitive tests. However, the present results do not allow one to further examine the cognitive underpinnings of multitasking abilities in persons diagnosed with bipolar disorder.

Relations to real world functioning and symptoms

Another aim of the present study was to explore the relations between multitasking abilities and clinical variables including real world functioning and symptoms in patients diagnosed with bipolar disorder. The present results revealed that patients' performance on the shopping task, and in particular the total time taken to complete the task, was significantly and highly correlated with real world functioning (r= -.60). Moreover, the total time taken to complete the task and the mean time spent consulting the shopping list were found to significantly predict 34% (multiple regression analyses) of patients' functioning. These results suggest that the shopping task is tapping into patients' real world functioning. Interestingly, none of the standard cognitive tests significantly predicted any portion of patients' everyday life functioning. In fact, contrary to standard cognitive tests, the shopping task places participants in a multitasking situation that reflects many characteristics of real world activities and which involves a number of different and integrated cognitive processes.

To date, only one previous study (Torralva et al., 2012) has directly explored relations between multitasking abilities and real world functioning in patients diagnosed with bipolar disorder. More specifically, Torralva et al. (2012) found that performance on a modified version of the hotel task, and in particular the number of tasks attempted, was significantly correlated with patients' functioning (r=.55). Moreover, no standard cognitive tests were found to be significantly correlated to patients' everyday life functioning. Unfortunately, the authors did not find any significant correlation between performance on the hospital version of the MET (Knight et al., 2002) and real world functioning. However, as for the lack of significant correlations between the MET and standard cognitive tests, the lack of standardization of the MET could explain this absence of results as participants end up not realizing the same task.

Interestingly, Caletti et al. (2013) also found a significant correlation between performance on an adapted version of the hotel task (Manly et al., 2002; Torralva et al., 2009) and patients' real world functioning. Moreover, contrary to the results of Torralva et al. (2012), the authors showed that performance on the hospital version of the MET (Knight et al. 2002) was significantly related to real world functioning. However, the authors conducted these analyses on a group consisted of patients with bipolar disorder and schizophrenia, and healthy controls. Nevertheless, the fact that the relations between the MET and real world functioning varies across studies represents an additional argument in favor of the influence of the lack of standardization of the MET.

Taken together, such results suggest that multitasking abilities are closely related to patients' real world functioning. Indeed, many everyday life activities are of a multitasking nature, that is, they involve different and integrated cognitive processes and take place in an unstructured context where the person has to initiate, carry out, and alternate between different tasks, define the tasks' targets and face unexpected outcomes (Burgess, 2000). In fact, even if some characteristics of these activities are not represented in the shopping task or the adapted version of the hotel task (e.g., no clear interruption/unexpected outcome), these tasks seem to contain a sufficient number of features to be related to real world functioning, whereas standard cognitive tests do not. However, compared to the hotel task, the shopping task is closer to everyday life activities. It possesses the advantage of providing more information about patients' cognitive and real world functioning.

The observation that standard cognitive tests are not related to real world functioning is consistent with the meta-analysis by Depp et al. (2012) which demonstrated that standard cognitive measures were weakly related to real world functioning in patients diagnosed with bipolar disorder. More specifically, the correlations ranged from .22 (attention) to .29 (working memory). However, the present results demonstrated that the correlation coefficient between the shopping task and real world functioning was twice as large (i.e., .60) compared to the most related cognitive domain in Depp et al. (2012). Similarly, Torralva et al. (2012) also found a correlation of .55 between the hotel task and patients' everyday life functioning.

These results are particularly important for clinical practice for two main reasons. First, they demonstrated that patients diagnosed with bipolar disorder can present multitasking difficulties in the context of preserved performances on standard cognitive tests. Second, multitasking abilities are highly related to real world functioning. Being able to detect cognitive deficits impacting patients' real world functioning is particularly important in order to propose an adapted cognitive remediation program. Moreover, it can be very frustrating for patients who complain about everyday life difficulties to be told that their performances on cognitive tests are normal. Taken together, these results suggest that there is a strong need to systematize the evaluation of multitasking abilities.

Concerning symptomatology, the present study did not reveal any significant correlation between performance on the shopping task and depressive or manic symptoms in persons with bipolar disorder. Moreover, no significant differences were found on the shopping task between patients in a euthymic phase and patients in a depressive, manic, or mixed episode. Such results indicate that multitasking difficulties encountered by patients are independent from symptoms. Unfortunately, no previous study has explored the relations between symptoms and multitasking abilities in bipolar disorder, it is thus not possible to compare the results. Nevertheless, they are consistent with the observation that cognitive impairments are stable across mood states (Martinez-Aran et al., 2004) and that residual symptoms are independent of real world functioning (Martinez-Aran et al., 2007). However, the impact of other symptoms (e.g., positive, negative, or disorganization) was not examined in the present study nor the relations with more specific symptoms (e.g., apathy). It is thus not possible to exclude a possible influence of these symptoms on multitasking abilities. Future studies are required to examine the relations between multitasking abilities and the large range of symptoms in bipolar disorder.

Finally, performance on the shopping task was found to be significantly related to illness duration. In particular, patients who are ill for a long time were found to take a prolonged time to realize the task and to consult the shopping list. Such results could suggest an influence of age as this is a computerized task and older patients could be less familiar with computers. However, controlling for age (partial correlation analyses[7]) did not affect the results, which suggests that the observed relations between the shopping task and illness duration may be due to chronicity. These results are consistent with a review conducted by Robinson and Ferrier (2006) which demonstrated that illness duration was associated with poorer cognitive functioning in patients with bipolar disorder. The authors suggested that patients with greater cognitive impairments encounter more difficulties managing their illness and thus suffer from more frequent relapses. Moreover, the present results are also consistent with studies which found that an early onset of illness was associated with poorer real world functioning (Perlis et al., 2009). In order to explain these results, some authors have suggested that an early onset may disturb personal, interpersonal and professional development of patients (Levy & Manove, 2012).

Summary and perspectives

The present study demonstrated that patients with bipolar disorder presented a poorer performance than healthy controls on the shopping task. In particular, patients took more time to complete the task and spent more time consulting the shopping list. Such results suggest that patients diagnosed with bipolar disorder encounter multitasking difficulties and are consistent with previous studies which found that patients demonstrated poor performances on the MET and the hotel task (Caletti et al., 2013; Torralva et al., 2012). However, whereas the present study only found that patients with bipolar disorder showed a poorer

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[7] These supplementary analyses were conducted for the present discussion and were not included in the published article (Laloyaux et al., 2013).

performance than healthy controls regarding the time-related variables, the studies by Caletti et al. (2013) and Torralva et al. (2012) found that patients also demonstrated impaired performance on variables related to the execution of the task. Such results suggest that performance on the shopping task may be influenced by the familiarity with shopping activities which would make it easier to realize than the MET and the hotel task. There is thus a clear need for future studies to assess multitasking abilities in bipolar disorder using tasks controlling for the familiarity with the evaluated activity.

The present results also demonstrated that multitasking abilities make demands upon several cognitive functions including processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. Interestingly, these relations were not due to a general impairment of processing speed, suggesting that the multitasking abilities rely upon specific cognitive functions. However, the study also suggested that multitasking abilities also make demands upon cognitive functions that are not assessed with standard cognitive tests. On the one hand, these results demonstrate that multitasking abilities rely upon several cognitive functions such as those measured by standard cognitive tests but, on the other hand, that these abilities also make demands upon different cognitive functions. This observation is consistent with previous studies which have suggested that multitasking abilities are supported by three primary constructs: memory (working and episodic memory), planning abilities, and intent (which was hypothesized to mainly reflect prospective memory) (Burgess, 2000; Burgess et al., 2000; Logie et al., 2011). Moreover, the present results are also in accordance with the hypothesis that multitasking abilities rely upon different cognitive functions that are not assessed by standard cognitive tests (Burgess et al., 2009). Unfortunately, the present results do not allow one to further examine the nature of multitasking difficulties in patients diagnosed with bipolar disorder. In particular, the relations between performance of the shopping task and some potentially implicated cognitive functions were not explored (e.g., prospective memory and source flexibility). Moreover, some important characteristics of multitasking activities (Burgess, 2000) are not represented in the shopping task (e.g., clear interruptions and prospective memory instructions) which limits the representativeness of the results. Future studies overcoming these limitations are clearly required in order to further explore the cognitive underpinnings of multitasking abilities in persons diagnosed with bipolar disorder.

Some discrepancies were observed between the present results and the only preexisting study (Torralva et al., 2012) that explored multitasking abilities and their cognitive underpinnings in bipolar patients. Specifically, whereas the present study suggested that performance on the shopping task was related to many cognitive functions (including processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition), Torralva et al. (2012) only found that performance on the hotel task was related to processing speed and cognitive flexibility. Moreover, the hospital version of the MET did not reveal any significant correlations with other cognitive tests. A possible explanation to these differences between studies is related to the different nature of the tasks used. In particular, the MET lacks standardization, and the hotel task is relatively simple, whereas the shopping task is standardized and contains many characteristics of everyday life multitasking activities. There is a need for future studies to assess multitasking abilities with several standardized tools that take into account all the characteristics of multitasking abilities as defined by Burgess (2000).

Interestingly, performance on the shopping task was found to be particularly related to patients' level of real world functioning whereas standard cognitive tests did not reach significance. Taken together, such results underline the importance of evaluating multitasking abilities in persons diagnosed with bipolar disorder in order to better predict patients' real world functioning and identify the cognitive deficits impacting patients' everyday life.

Finally, results revealed no significant correlation between performance on the shopping task and depressive or manic symptoms. Such results indicate that multitasking abilities are independent from symptoms. Nonetheless, the potential impact of other types of symptoms (e.g., positive, negative or disorganization) was not examined in the present study. Future studies are required examining the relations between multitasking abilities and the large range of symptoms in bipolar disorder.

Bipolar disorder versus schizophrenia

Performance on the shopping task and relations to cognitive functioning

Interestingly, the present study on bipolar disorder used the same computerized shopping task as Larøi et al. (2010) did with a sample of persons diagnosed with schizophrenia. It is thus possible to directly compare the results obtained by both clinical populations. However, it is important to underline the fact that bipolar patients presented an older mean age than patients with schizophrenia (respectively 48.95 and 31.13 years); the following comparison should thus be viewed cautiously.

Concerning the performance on the shopping task, Larøi et al. (2010) found that compared to healthy controls, patients diagnosed with schizophrenia took significantly more time to complete the task, bought less correct articles, went more often in the same aisles, visualized more non-pertinent shelves (i.e., number of times participants zoomed on non-pertinent shelves), consulted the shopping list more often and spent more time consulting it. As a reminder, the present study demonstrated that patients diagnosed with bipolar disorder took significantly more time than healthy controls to complete the task and spent a longer mean time consulting the shopping list.

In both studies, time-related variables (i.e., total time taken to complete the task and time spent consulting the shopping list) were found to significantly differentiate patients from heathy controls. Such results suggest that time-related variables are the most sensitive to differentiate patients from healthy controls across clinical populations. This may be due to the fact that these variables reflect a more global aspect of performance whereas the other variables are more specific (e.g., number of correct articles or aisle redundancy). The fact that patients diagnosed with bipolar disorder demonstrated a poorer performance than controls only for these two most sensitive variables whereas patients with schizophrenia also showed difficulties in variables related to the execution of the task (i.e., they bought fewer correct articles, visited more non-pertinent aisles, and went more often in the same aisle) suggests that patients diagnosed with schizophrenia encounter more multitasking difficulties than patients with bipolar disorder. Such results are consistent with the observation that patients with bipolar disorder generally demonstrate better cognitive (Bortolato et al., 2015) and real world functioning (Bowie et al. 2010; WHO, 2008) than patients diagnosed with schizophrenia. Moreover, these results are also in agreement with the only previous study that compared multitasking abilities between patients with schizophrenia and bipolar disorder (Caletti et al., 2013). As a reminder, this study found that patients with schizophrenia encountered more difficulties in realizing an adapted version of the hotel task (Manly et al. 2002; Torralva et al., 2009) than patients with bipolar disorder.

The present study and the study by Larøi et al. (2010) explored the relations between performance on the shopping task and standard cognitive tests. Larøi et al. (2010) demonstrated that performance on the task was significantly correlated with processing speed, episodic memory, cognitive flexibility, planning, inhibition, and verbal fluency. Regarding the present results, performance on the shopping task was related to processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. Taken together, these results suggest that performance on the shopping task was globally related to the same cognitive functions in both clinical populations. However, some differences can be observed when examining the variables individually.

In bipolar disorder, the shopping task variable that was the most related to standard cognitive tests was the total time taken by patients to complete the task. Indeed, this variable was related to tests assessing processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. However, in Larøi et al. (2010), the total time taken by patients to complete the task was only significantly related to cognitive flexibility. Similarly, results of the present study demonstrated that a longer mean time spent consulting the shopping list (i.e., this variable was calculated dividing the total time spent consulting the shopping list by the number of times patients consulted it) was related to poorer performances on tests assessing processing speed and episodic memory. However, Larøi et al. (2010) found that the number of times patients consulted the list was only significantly correlated with processing speed and that the total time spent consulting the shopping list was not related to any cognitive measure. In fact, the variables that were the most related to standard cognitive tests in Larøi et al. were the number of correct articles chosen during the task and the number of times a non-pertinent shelf was visualized. More specifically, the number of correct articles was related to processing speed, episodic memory, planning, inhibition, and verbal fluency. Moreover, the number of times a non-pertinent shelf was visualized was significantly correlated with processing speed, cognitive flexibility, and verbal fluency.

In summary, in persons diagnosed with schizophrenia, performances on standard cognitive tests were found to be mainly correlated with specific variables related to the execution of the task rather than to more general time-related variables. On the contrary, these general time-related variables were found to be primarily related to standard cognitive tests in patients suffering from bipolar disorder. Such a discrepancy between the results is particularly challenging as globally the same cognitive tests and shopping variables were used in both studies. One possible interpretation may be related to the fact that patients diagnosed with schizophrenia encountered more severe difficulties during the shopping task than patients with bipolar disorder. Indeed, whereas patients with bipolar disorder only presented a globally slowed but qualitatively good performance on the shopping task, patients with schizophrenia also encountered difficulties in buying the required items and exploring the supermarket in an organized manner (i.e., more aisle redundancy and visualizations of non-pertinent shelves). Considering the fact that patients diagnosed with schizophrenia generally experience more severe cognitive deficits than patients with bipolar disorder (Bortolato et al., 2015), it is possible that these cognitive deficits engender more difficulties to realize the shopping task. These more severe difficulties would manifest themselves affecting variables related to the execution of the task. In other words, more severe cognitive deficits may have stronger relations with specific variables related to the execution of the task rather than to more general time-related variables.

Indeed, future studies are required to directly examine this hypothesis as it is not possible to directly compare cognitive performances obtained by both patient groups as they differed in terms of age. Moreover, there is also a need to explore the existence of different profiles regarding both performances on cognitive tests and on the shopping task. In particular, one is likely to find different subgroups of patients varying in terms of cognitive and clinical variables. For example, many different reasons could explain why one takes an abnormally long time to complete the shopping task. For instance, one patient can take more time due to severe cognitive deficits, whereas another can present less cognitive deficits but spends a large amount of time double checking what he/she has done. On the contrary, it is also possible for a patient encountering many difficulties to realize the task to rapidly escape the task without having bought the required articles. Such individual differences in the strategy used could influence group analyses and attenuated the observed correlations between performance on the shopping task and standard cognitive tests. There is thus a need to explore the individual profiles in future studies and the strategies used by patients to realize the task.

Concerning the cognitive underpinnings of multitasking abilities, both studies demonstrated that performance on the shopping task was related to several cognitive functions including processing speed, episodic memory, cognitive flexibility, planning, and inhibition. However, some results indicated that the shopping task also makes demands upon cognitive functions that are not measured by standard cognitive tests. In particular, performance on the shopping task was not significantly different between patients with bipolar disorder presenting one or no impaired performance on standard cognitive tests and patients with more than one cognitive deficit. However, compared to healthy controls, the patients with one or no cognitive impairment presented significantly poorer performance on the shopping task. Similarly, Larøi et al. (2010) compared patients with schizophrenia who successfully collected the required items during the shopping task to those who did not in terms of cognitive performance. Results revealed no significant difference between subgroups. Taken together, these results suggest that performance on the shopping task is influenced by other factors. Such results are consistent with the hypothesis that multitasking abilities rely upon different cognitive functions that are not assessed with standard cognitive tests (Burgess et al., 2009). However, in both studies, the potential implication of other more specific cognitive functions was not examined (e.g., prospective memory and source flexibility). There is thus a clear need to further explore the cognitive underpinnings of multitasking abilities.

Relations to real world functioning

In both studies, the relations between performance on the shopping task and real world functioning were explored. In patients with bipolar disorder, the total time taken to complete the task was found to be significantly related to real world functioning. Moreover, the total time taken to complete the task and the mean time spent consulting the shopping list significantly predicted 34% of patients' real world functioning whereas a model including all the cognitive variables did not reach significance. Similarly, Larøi et al. (2010) demonstrated that aisle redundancy as well as the number of times patients consulted the shopping list were correlated with real world functioning in patients diagnosed with schizophrenia. Nonetheless, among the standard cognitive tests, the authors found that only inhibition was related to patients' functioning.

Taken together, such results demonstrate that the shopping task, but not standard cognitive tests (except for measure of inhibition in Larøi et al., 2010), is tapping into patients' level of everyday life functioning. However, the shopping task variables that were demonstrated to be related to real world functioning varied across populations. More specifically, time-related variables were found to be correlated with real world functioning in patients with bipolar disorder but not in patients with schizophrenia. In fact, in patients with schizophrenia, real world functioning was revealed to be correlated with variables related to the execution of the task, namely aisle redundancy and the number of times the shopping list was consulted. These results are similar to the observation that performances on standard cognitive tests were mainly correlated with specific variables related to the execution of the task in persons diagnosed with schizophrenia and to more general time-related variables in bipolar disorder. Taken together, these results underline that the relevance of the shopping variables varies across populations. Indeed, whereas global time-related variables are good indicators of cognitive and real world functioning in bipolar disorder, variables related to the execution of the task seem to be more indicative in patients with schizophrenia.

Another interesting difference between both clinical populations is related to the direction of the observed correlations between performance on the shopping task and real world functioning. In patients diagnosed with bipolar disorder, a longer time taken to complete the task was negatively associated with patents' functioning. In other words, poorer everyday life functioning was associated with longer time taken to complete the task. However, these relations were slightly different in patients diagnosed with schizophrenia. In fact, positive correlations were found between real world functioning and aisle redundancy and the number of times the shopping list was consulted. That is, a better functioning was associated with more aisle redundancy and more list consultations. These results could reflect a coping strategy adopted by patients with schizophrenia—who usually present more cognitive deficits than patients with bipolar disorder (Bortolato et al., 2015)—to deal with the difficulties encountered during the task and more generally during everyday life activities. In particular, patients may have developed the habit of being more conscientious and to carefully double check their realization of everyday tasks. Nevertheless, future studies are required to specifically examine the strategies used by patients to realize multitasking activities.

Summary and perspectives

In summary, the present study and the one by Larøi et al. (2010) demonstrated that the shopping task possesses good sensitivity in its ability to distinguish patients with schizophrenia and bipolar disorder from healthy controls. In particular, both patients with schizophrenia and bipolar disorder presented poorer performance on the task than healthy controls, suggesting that patients encounter multitasking difficulties. Moreover, comparison of both studies revealed that patients with schizophrenia showed a poorer performance than patients with bipolar disorder.

Concerning the cognitive underpinnings of multitasking abilities, results of both studies demonstrated that performance on the shopping task was related to several cognitive functions including processing speed, episodic memory, cognitive flexibility, planning, and inhibition. These results suggest that the same cognitive functions underpin multitasking abilities in both populations. However, the relations between cognitive variables and performance on the task varied across populations. In persons diagnosed with schizophrenia, performances on standard cognitive tests were found to be mainly correlated with specific variables related to the execution of the task rather than with more general time-related variables. On the contrary, these general time-related variables were found to be primarily related to standard cognitive tests in patients suffering from bipolar disorder. A similar pattern of results was found regarding the relations between performance on the shopping task and real world functioning. That is, real world functioning was correlated with time-related variables in patients with bipolar disorder, whereas real world functioning was correlated with variables related to task execution in patients with schizophrenia. Taken together, these results suggest that the relevance of the shopping variables varies across populations.

This discrepancy between the results may be related to the severity of cognitive and real world functioning impairments. In particular, patients with schizophrenia usually demonstrate more cognitive (Bortolato et al., 2015) and real world difficulties (Bowie et al., 2010; WHO, 2008) than patients diagnosed with bipolar disorder. Moreover, in agreement with previous studies (Caletti et al., 2012), the present studies also suggest that patients with schizophrenia encounter more multitasking difficulties than patients with schizophrenia. It is thus possible that more severe cognitive deficits or multitasking difficulties induce a poorer performance on the shopping task as observed by impaired variables related to the execution of the task. These more severe cognitive deficits may have stronger relations with specific variables related to task execution rather than to more general time related variables. Similarly, poorer real world functioning would be specifically related to variables related to task execution.

Another hypothesis explaining the discrepancy between the present study and the one by Larøi et al. (2010) is related to the potential presence of different profiles of patients in terms of strategies used to realize the shopping task. Such individual differences in the used strategies can influence group analyses and attenuate the observed correlations between performance on the shopping task and standard cognitive tests.

There is thus a strong need for future studies that directly compare patients with schizophrenia and patients with bipolar disorder in terms of multitasking abilities, cognitive functioning, and real world functioning. Such comparison is important in order to better understand the common points and differences between these clinical populations. In addition, future studies also need to examine the different strategies used to realize the task and their relations with cognitive deficits. Moreover, as already stated, the shopping task lacks some characteristics of multitasking activities and performance on the task may be influenced by participants' familiarity with shopping activities. Future studies thus need to compare performance of patients with schizophrenia and bipolar disorder on a multitasking task that takes into account all the characteristics of multitasking activities and that controls for the influence of familiarity.

Computerized assessment presents many advantages (e.g., the environment is standardized and many variables can be measured precisely). However, there are obvious differences between a computerized shopping task and shopping in a real supermarket. Regardless of the effort that will be made to create a computerized task as close as possible to real life activities, there will always be differences between a computerized task and the same task realized in a natural environment. Indeed, the environment is perceived as being not real and the interactions are modified (e.g., manipulating a gamepad versus taking a can of soup in hand), the sensorial feedback is different, etc. It is thus legitimate to wonder if one's performance on a computerized task is representative of his/her abilities to shop in a real supermarket. Thus, a necessary addition to the present studies' methodology would be to administer both a real life shopping task and a computerized task to examine the external validity of the computerized shopping task.

Fortunately, a recent study specifically examined the question of the ecological validity of a computerized shopping task in persons diagnosed with schizophrenia (Greenwood et al., 2016). The authors administered an observational shopping task as well as a computerized shopping task to a group of patients diagnosed with schizophrenia. In both tasks, patients were required to shop for a list of 10 articles. Performance on both tasks was represented by the number of correct articles chosen, the total time taken to complete the task, and the number of aisles entered. Correlational analyses revealed that both versions of the shopping tasks were significantly correlated. These results suggest that the virtual shopping task used by the authors presents good ecological validity. Nevertheless, it is interesting to underline the fact that patients were significantly more accurate and faster on the computerized task than on the observational version. The authors explained these results by the fact that the real version of the task contained more food choices, more distractors (e.g., other shoppers), and by the fact that patients had to walk through the supermarket. Taken together, these results suggest that computerized tasks are closely related to the same activity conducted in real life. However, they also underline the importance for computerized tasks to be as closely as possible to the real life activities. In particular, tasks should place participants in a complex environment that reflects all the characteristics of multitasking activities.

Multitasking abilities in schizophrenia

Creation of a new standardized tool designed to assess multitasking abilities

A main aim of the present thesis was to propose a new tool designed to assess multitasking abilities that overcomes as many limitations of existing tasks as possible. To do so, a new multitasking computerized task—the Computerized Meeting Preparation Task (CMPT)—was created and developed across two studies (studies 2 and 3).

In the CMPT, participants first complete a learning phase and, then, complete a meeting preparation phase. The goal of the learning phase is to systematically familiarize participants with the basic actions and functions that are required during the meeting preparation phase such as moving the avatar and carrying objects using the computer mouse. After this learning phase, participants are told that it is 9:30 AM and that a meeting will start in 30 minutes, but that the secretary who is supposed to prepare the meeting room is sick and that the participants must replace her. To do so, participants have access to a list of instructions (containing the required objects, information about the seating plan, and the guests list), and a clock. A main idea behind the development of the CMPT was to create a task that carefully takes into account all the characteristics of multitasking activities as defined by Burgess (2000):

1. Many tasks: a number of different tasks have to be completed (e.g., place the required objects, order objects by phone, read the instructions);
2. Interleaving: the realization of the tasks requires interleaving (e.g., start looking for the missing chair, pick and place some required objects, read the instructions, and start again to look for the chair);
3. One task at a time: due to physical or cognitive constraints, only one task can be performed at a time (e.g., it is impossible to simultaneously place the required objects and read the instructions);
4. Interruptions: unforeseen interruptions can occur (e.g., an interrupting phone call signaling that a guest wants another drink during the meeting);
5. Delayed intentions: the realization of the different tasks requires prospective memory (e.g., remembering to give the camera to an avatar when it comes);

6. Differing task characteristics: the different tasks vary in terms of priority, difficulty, and duration (e.g., placing all the required objects will take more time than ordering the missing chair);
7. Self-determined targets: people defined what constitutes adequate performance (e.g., when the task has been completed);
8. No immediate feedback: there is no minute-by-minute performance feedback. In fact, there is no feedback before the end of the task.

In addition, the CMPT was designed so that the task's level of difficulty can be modulated and it is possible to create parallel versions to use in case of re-test or to integrate in a remediation program. It is thus possible to choose:

- The number of guests attending the meeting: 5, 7, or 9;
- The interruptions and unexpected outcomes: an interrupting phone call signaling that a guest wants another drink during the meeting; an avatar asking participants to call an ambulance; a missing chair; missing bottles of orange juice; an interrupting phone call signaling that a guest will be late for the meeting;
- The prospective memory instructions: participants can be asked to place the coffee on the table at 9:40; to give the camera to an avatar when it comes; to tell the secretary if a guest calls to signal that he/she will be late for the meeting; to tell the boss when the room is ready.

Beside the fact that the CMPT takes into account all the characteristics of multitasking abilities and is modular, the task places participants in a complex, meaningful, and ecological situation that does not contain artificially constraining rules and where participants are free to adopt their own strategy to realize the task. Another main advantage of the CMPT is related to the fact that the task places participants in an unfamiliar situation—a meeting preparation task. Such a feature diminishes the potential influence of a preexisting familiarity with the task which can complicate the interpretation of the results. Indeed, people who are more familiar with an activity will have fewer difficulties performing the task and will not be relying on their executive functions as much in order to perform the task efficiently compared to people who have only rarely done this activity previously.

Moreover, the fact that the task is computerized also offers other advantages. Specifically, the task is standardized as the environment of the task is completely controlled. Thus the exact same task can be administered to all participants. Indeed, this standardization allows comparing between patients or to healthy controls and to establish normative data. Moreover, the computer offers the opportunity to accurately record and compute many variables that may be difficult to measure during an observation-based task (e.g., total distance traveled, total time spent consulting the instructions). Furthermore, a computerized task is also really easy to administer in a clinical setting as it does not require leaving the hospital setting or extra personnel to observe participants. Finally, a last advantage of the CMPT, and of computerized tasks in general, is related to the fact that patients are evaluated in secure and reassuring conditions. More specifically, patients are less likely to be afraid to make an error or to be negatively judged by others compared to an observation-based task where patients are surrounded by people.

Psychometric properties of the CMPT

The CMPT was used in two studies (studies 2 and 3) including patients with schizophrenia. In both studies, the task demonstrated good sensitivity in its ability to distinguish patients from healthy controls. Interestingly, the computerized task was well tolerated by the patients, who reported finding the assessment more entertaining than standard cognitive tests.

In addition, the first study examined the ecological validity of the task by exploring the relations between patients' performance on the CMPT and an observational version of the meeting preparation task. Results demonstrated large correlations between both versions of the task, suggesting that the CMPT possesses good ecological validity.

Finally, the second study also explored the correlations between patients' performance on the CMPT and on another multitasking test (the shortened version of the SET, Wilson et al., 1996). Results showed that both tests were significantly correlated. In particular, the respect of the rules variable of the CMPT was significantly correlated with the global score of the SET. Such results demonstrate that the CMPT possesses good concurrent validity. Furthermore, the CMPT was revealed to be more sensitive than the SET in differentiating between patients and healthy controls (i.e., larger effect sizes). These results could be explained by the fact that contrary to the SET, the CMPT takes into account all the characteristics of multitasking activities and is more ecological. Moreover, compared to the SET, the CMPT possesses the advantage of providing a more detailed evaluation of multitasking abilities. Specifically, as many as eight variables related to different facets of multitasking abilities are calculated, compared to only one for the SET. Thus, the CMPT allows for evaluation of multitasking abilities in a more detailed and specific manner.

Taken together, these results demonstrate that the CMPT is well tolerated by patients, possesses good sensitivity, and good ecological and concurrent validity. Moreover, the CMPT also has the advantage of providing a detailed evaluation of multitasking abilities which reflects the participants' performance on different variables related to different facets of multitasking activities.

Multitasking abilities in schizophrenia

Using this new computerized task—the CMPT—the second main goal of the present thesis was to assess multitasking abilities in persons diagnosed with schizophrenia. To do so, two studies were conducted: (1) a first pilot study including 21 patients diagnosed with schizophrenia and 20 healthy controls, and (2) a second study including 57 patients and 39 healthy controls. It is important to underline the fact that two different versions of the CMPT were used across both studies. In particular, the CMPT used in the first study did not include clear prospective memory instructions and interruptions/unexpected outcomes and thus does not reflect all the characteristics of multitasking activities (Burgess, 2000). The version of the CMPT used in the second study, however, takes into account all these characteristics and thus includes distractors and prospective memory instructions.

Results demonstrated that patients with schizophrenia performed more poorly than healthy controls on the CMPT. More specifically, in both studies, patients took more time to realize the task, presented a lower planning score (e.g., traveled a longer distance, used the cart less, and went into different rooms more often) and respected fewer rules (written instructions). Moreover, the second study also found that patients placed a number of incorrect objects on the table and forgot required items (this variable was also significant in the first study before statistical correction), completed less prospective memory instructions (i.e., they forgot the required objects or did not place them at the appropriate time), presented difficulties in dealing with distractors (i.e., they forgot to order the missing chair and to take into account that a guest wants another drink), and in checking goal achievements (i.e., they did not check the instructions list before leaving the room). Interestingly, these differences observed between groups were not influenced by the level of familiarity with computers/video games.

Results of both studies demonstrate that patients with schizophrenia present multitasking difficulties. Such results are consistent with previous studies that have suggested the presence of multitasking difficulties in persons diagnosed with schizophrenia using the SET (Evans et al., 1997; Katz et al., 2007; van Beilen et al., 2006), the MET (Caletti et al., 2013), computerized shopping tasks (Josman et al., 2009; Larøi et al., 2010) and other observation-based tasks such as cooking (Semkosvka et al., 2004) or preparing a room for a meeting (Levaux et al., 2012).

Specifically, several studies (Evans et al., 1997; Katz et al., 2007; van Beilen et al., 2006) found that patients diagnosed with schizophrenia presented a poorer performance than healthy controls on a shortened version of the SET (Wilson et al., 1996). Unfortunately, performance on the SET is only reflected by one unique global score and therefore is difficult to compare this with the specific variables measured with the CMPT. Similarly, Caletti et al. (2013) showed that patients diagnosed with schizophrenia demonstrated difficulties in realizing the hospital version of the MET (Knight et al., 2002) and a modified version of the hotel task

(Manly et al., 2002; Torralva et al., 2009). In particular, compared to healthy controls, patients presented more task failures, inefficiencies, rule breaks, and interpretation failures during the MET. Concerning the hotel task, patients attempted fewer tasks and made greater time deviations regarding the predefined optimal time to spend on each task. However, these variables are broader than the variables measures by the CMPT. In fact, each variable of the MET could be considered to include several variables of the CMPT. In particular, the interpretation and task failure variables of the MET could be seen as combining three CMPT variables: respect of the rules, number of incorrect and forgotten objects on the table, and prospective memory score. Similarly, two variables of the CMPT, namely the planning score and the checking score, could be related to the number of inefficiencies realized in the MET (i.e., when a better strategy could have been applied, such as entering the same shop more than once). Additionally, the rule breaks variable of the MET shares some similarities with the respect of the rules variable of the CMPT. Concerning the hotel task, the number of tasks attempted variable could be related to the respect of the rules in the CMPT. Finally, the time deviation variable shares similarities with the total time taken to complete the CMPT. Taken together, these results suggest that when confronted with a multitasking situation, patients with schizophrenia present difficulties in respecting the instructions, completing the required tasks, accomplishing prospective memory instructions, organizing the realization of the task, checking goal achievements, and dealing with distractors. Furthermore, these results also demonstrate that the CMPT possesses the advantage of providing more specific variables related to different aspects of multitasking abilities compared to the SET, the hotel task, and the MET.

To date, other authors have also suggested that patients diagnosed with schizophrenia encounter difficulties in completing multitasking tasks based on real world activities. In particular, Semkovska et al. (2004) found that patients with schizophrenia presented a poorer performance than healthy controls on an observation-based meal preparation task. More specifically, patients took more time to prepare the meal, presented difficulties in sequencing and planning their actions, and tended to forget and omit actions or ingredients. Such results are congruent with the present studies, where patients were demonstrated to take more time to complete the CMPT than controls, but also presented difficulties in respecting the rules, placing the required objects on the table, and organizing the realization of the task.

Similarly, Josman et al., (2009) and Larøi et al., (2010) have both demonstrated that patients diagnosed with schizophrenia performed worse than healthy controls for a computerized shopping task. In particular, Josman et al. (2009) found that patients purchased fewer correct articles, realized fewer correct actions (e.g., they proceeded to an unattended checkout counter), and took more time to pay at the checkout. Similarly, Larøi et al., (2010) demonstrated that patients took more time to complete the shopping task, bought fewer correct articles, went more often in the same aisles, visualized more non-pertinent shelves (i.e., number of times participants zoomed on non-pertinent shelves), consulted the shopping list more often and spent more time consulting it. Again, such results are in accordance with the present studies that used the CMPT. In particular, patients were found to take more time to complete the CMPT and to encounter difficulties in respecting the rules, placing the required objects on the table and exploring the environment in an organized manner.

Taken together, previous studies that have explored multitasking abilities in persons diagnosed with schizophrenia using cooking (Semkovska et al., 2004) or shopping tasks (Josman et al., 2009; Larøi et al., 2010) suggest that patients present multitasking difficulties. Indeed, such results are congruent with the present ones which demonstrated that persons diagnosed with schizophrenia performed more poorly than healthy controls for the CMPT. However, the CMPT possesses several advantages compared to the tasks used in previous studies. In particular, compared to the observation-based cooking task (Semkovka et al., 2004), the environment is standardized and reflects all the characteristics of multitasking activities (Burgess, 2000) and thus provides specific additional information about patients' prospective memory and abilities to deal with distractors/interruptions. Similarly, compared to the existing shopping tasks (Josman et al., 2009; Larøi et al., 2010), the CMPT takes into account the characteristics of multitasking activities that are not represented in these tasks, such as clear prospective memory instructions and interruptions/unexpected outcomes. Moreover, compared to the tasks based on everyday life activities, the CMPT offers the opportunity to measure multitasking abilities by placing participants in an unfamiliar context, which limits the influence of preexisting experiences.

In fact, only one previous study has explored multitasking abilities in persons diagnosed with schizophrenia using an unfamiliar task (Levaux et al., 2012). Specifically, as in the CMPT, participants were required to prepare a room for a meeting while respecting a list of instructions. Results revealed that compared to healthy controls, patients made more errors during the task (e.g., placed incorrect objects on the table and forgot required items), achieved fewer goals (i.e., placed fewer required objects), broke more rules regarding the required objects and the seating plan, and presented difficulties in respecting the prospective memory instructions (i.e., pick up the coffee at a certain time). Indeed, such results are really similar to those obtained in the present studies where patients showed difficulties in placing the required objects and respecting the rules and the prospective memory instructions. However, contrary to the CMPT, the task used by Levaux et al. (2012) lacks some characteristics of multitasking activities, such as interruptions/unexpected outcomes. Moreover, as the CMPT is computerized, it offers the possibility to precisely measure more variables and is easy to administer in a clinical setting.

In summary, the present results are consistent with previous studies that have suggested that patients diagnosed with schizophrenia encounter multitasking difficulties. Taken together, these results demonstrate that when confronted with a multitasking situation, patients present difficulties in respecting the instructions, completing the required tasks, organizing the realization of the task, and accomplishing prospective memory instructions. Moreover, results of the CMPT also demonstrated that patients present difficulties in checking goal achievements and dealing with distractors. In fact, compared to preexisting multitasking tools, the CMPT reflects all the characteristics of multitasking activities and places participants in an unfamiliar situation limiting the influence of previous experiences. Moreover, it allows a precise measurement of many variables related to different aspects of the multitasking activity and is easy to administer in a clinical setting.

Cognitive underpinnings

A second aim of the present studies was to explore the cognitive underpinnings of multitasking abilities in persons diagnosed with schizophrenia. To do so, the relations between patients' performance on the CMPT and standard cognitive tests were examined using correlational and regression analyses. Interestingly, results were shown to be similar in both studies, as the cognitive functions that were demonstrated to be related to multitasking abilities in the first study were also found in the second one. However, compared to the first study, the second one also explored the relations between performance on the CMPT and more specific cognitive functions such as prospective memory and source flexibility.

Taken together, results of both studies demonstrated that performance on the CMPT was related to different cognitive domains. In particular, the total time taken to complete the task was found to be related to working and episodic memory, and planning abilities. Indeed, being time-efficient during the task requires maintaining in memory the ongoing actions, remembering as many instructions as possible, and exploring the environment in an organized manner. The ability to respect the rules (i.e., written instructions) was found to be associated with working memory, cognitive, and source flexibility (external to internal), and inhibition. Such results suggest that being able to respect the requirements of the task relies upon the ability to maintain and manipulate information in working memory, to shift back and forth between multiple mental sets or environmental stimuli, to inhibit irrelevant stimuli during the task such as non-pertinent objects, and to switch from the outer world to internal representations (i.e., plan or thoughts). The planning score variable of the CMPT was related to planning abilities. Obviously, exploring the environment and realizing the task in an organized manner make demands upon planning abilities. Number of incorrect and forgotten objects on the table was related to working memory and source flexibility (external to internal). Such results suggest that the ability to place the required objects—and only those—on the table requires one to remember the instructions but also to be able to efficiently switch from the environment to internal representations (e.g., mental representations of instructions). The checking variable which refers to the ability to verify goal achievements was found to be related to working memory. This relation could be explained by the fact that checking goal achievement depends on the ability to maintain these goals in mind during the task. Concerning the prospective memory score, it was found to be related to prospective memory (event-based), planning, and inhibition. Obviously, being able to realize prospective memory instructions during the task makes demands upon prospective memory, but also upon planning abilities and inhibition, as the ongoing action has to be interrupted when the intention needs to be executed. The distractor management variable was found to be related to source flexibility (external to internal). In this context, these results suggest that the ability to deal with interruptions involves creating an internal action plan. Finally, the time taken to consult the instructions list for the first time after the beginning of the task was related to source flexibility (external to internal), cognitive flexibility, and prospective memory (time-based). Thus, rapidly reading the instructions list when the task begins seems to rely upon the ability to switch from the outer world to internal representations, but also between multiple mental sets or environmental stimuli. Moreover, the observed relation with time-based prospective memory may suggest that patients tend to create the intention to read the instructions list after a certain time. However, this relation may also be explained by difficulties in monitoring the action during the CMPT and the prospective memory task.

The present results thus demonstrate that multitasking abilities make demands upon several cognitive functions, including working and episodic memory, cognitive flexibility, inhibition, planning, prospective memory, and source flexibility. Indeed, during the CMPT, as in many activities of the real world, participants are placed in a complex situation where they are required to create an action plan to realize the task (planning), to maintain this plan and related goals in mind throughout the task, and remember as many instructions as possible (episodic and working memory). Moreover, participants also have to create intentions related to actions to realize in the future (prospective memory), to inhibit irrelevant stimuli from the environment and interrupt their ongoing action to realize previously created intentions (inhibition). Participants also need to continuously shift between the different stimuli from the environments and tasks (cognitive flexibility), but also between the environment and internal representations (e.g., internal plan and representations of the instructions) (source flexibility). Finally, participants have to deal with interruptions and unexpected outcomes which requires adapting the internal plan (source flexibility).

A major contribution of the present studies (and in particular the second one) exploring multitasking abilities in persons diagnosed with schizophrenia was to demonstrate the implication of relatively unexplored specific cognitive functions in multitasking activities, namely source flexibility and prospective memory. In particular, the results suggest that difficulties in disengaging from the environment and returning to the internal plan or thoughts are related to poorer multitasking abilities, and in particular to the ability to respect the rules, place the required objects, realize prospective memory instructions, and deal with distractors. Indeed, all these different aspects of the task require creating an internal action plan and consulting mental representations of instructions. However, no significant relation was found between the ability to switch from internal representations to the outer world and variables of the CMPT. This absence of results is quite surprising, as it would have been expected that both facets of source flexibility would be related to multitasking abilities. One possible explanation is related to the fact that patients with schizophrenia revealed more difficulties in switching from the outer world to internal representations than in switching from internal representations to the external world. However, it is also possible that the ability to switch from the external world to internal representations is simply more important in multitasking situations than the ability to switch from internal representations to the outer world. Indeed, multitasking activities require creating an internal action plan which makes demands upon the ability to switch from the external world to internal representations. Future studies are clearly required to reproduce the present results and examine this hypothesis. Nevertheless, the observed relations between multitasking abilities and source flexibility are congruent with the hypothesis that this cognitive mechanism would be particularly related to multitasking activities, as they are likely to trigger internal attending, with the person wondering what to do and plan *("what do I do now?")* (Burgess et al., 2007).

The present results also demonstrated the implication of prospective memory in multitasking activities. In particular, different implications of event-based and time-based prospective memory were found. In fact, the prospective memory variable of the CMPT was found to be related to event-based, but not with time-based prospective memory. Such results could be explained by the fact that event-based prospective memory is more represented in the CMPT than time-based (i.e., there are two event-based prospective memory instructions and one time-based). On the other hand, time-based prospective memory was significantly related to the time elapsed before consulting the instructions list for the first time. This relation may be explained by difficulties in monitoring the actions in both the prospective memory task and the CMPT. Another possibility is related to the fact that patients may create the intention to read the instructions list after a certain time. Nevertheless, such results are in accordance with the assumption that prospective memory may be an important cognitive process implicated in multitasking abilities (Burgess, 2000; Burgess et al., 2000; Logie et al., 2011). Indeed, multitasking activities such as the CMPT require keeping self-generated goals in mind and creating intentions to realize in the future.

Another aim of the present study was to examine whether or not general cognitive factors (such as processing speed and working memory) have a major influence on multitasking abilities in persons diagnosed with schizophrenia. In particular, processing speed (Dickinson et al., 2007; Dickinson et al., 2008) and working memory (Johnson et al., 2013; Silver et al., 2003) have both been demonstrated to be two large deficits in schizophrenia that can impact the performance on tests assessing other cognitive functions. Partial correlation analyses were thus conducted in order to examine if the observed relations between the CMPT variables and standard cognitive tests were due to a general impairment of processing speed or working memory. Results revealed that controlling for either processing speed or working memory did not affect the original correlations. In addition, supplementary analyses[8] also revealed that controlling for processing speed or working memory (ANVOCA) did not change the differences observed between patients and healthy controls. These results thus suggest that multitasking difficulties observed in patients diagnosed with schizophrenia are not due to a general cognitive impairment of processing speed or working memory. Indeed, processing speed and working memory are two main cognitive impairments in patients with schizophrenia (Bortolato et al., 2015). Nonetheless, such deficits are not sufficient to explain the multitasking difficulties encountered by patients. In fact, multitasking activities make demands upon different and integrated cognitive processes and seem to rely upon specific rather than upon general cognitive functions.

To date, only a small number of studies have explored the relations between performance on multitasking tasks and standard cognitive tests in patients diagnosed with schizophrenia. In particular, Semkovska et al. (2004) found that performance on an observation-based cooking task was related to selective attention, episodic memory, cognitive flexibility, verbal fluency, planning, sequential thinking, and inhibition. Similarly, Josman et al. (2009) and Larøi et al. (2010) demonstrated that patients' performance on a computerized shopping task was correlated with cognitive flexibility and planning abilities. Moreover, Larøi et al. (2010) also found that the shopping task was related to processing speed, episodic memory, inhibition, and verbal fluency. Unfortunately, the differences between the tasks used by the authors and the CMPT, and especially

[8] These supplementary analyses were conducted for the present discussion and were not included in the third article.

regarding the computed variables, do not allow for directly comparing the results variable by variable. However, from a general point of view, similar cognitive functions were found to be related to multitasking activities across studies and particularly cognitive flexibility, inhibition, planning, and episodic memory. Such results suggest a major implication of executive functions in multitasking abilities.

It is nevertheless possible to more directly compare the present results with the previous study conducted by Levaux et al. (2012) which examined multitasking abilities in persons diagnosed with schizophrenia using an observation-based meeting preparation task. The authors found that performances on two measured variables during the task were significantly related to standard cognitive tests. Specifically, the number of errors committed during the task (e.g., incorrect and forgotten objects) was related to source flexibility (external to internal), working memory, and processing speed. Similarly, the prospective memory score was related to source flexibility (external to internal). Interestingly, such results are particularly congruent with the results observed in the present studies. In particular, the number of incorrect and forgotten objects on the table was found to be significantly related to working memory and source flexibility (external to internal). Furthermore, the prospective memory score was related to source flexibility (external to internal), planning, and prospective memory. Taken together, the results from Levaux et al. (2012) and the present ones underline the main role of source flexibility in multitasking abilities. Such an observation is congruent with the hypothesis of Burgess et al. (2007).

In summary, the present results demonstrated that multitasking abilities in persons diagnosed with schizophrenia make demands upon several cognitive functions including working and episodic memory, cognitive flexibility, inhibition, planning, prospective memory, and source flexibility. Moreover, the results also suggested that multitasking difficulties are not due to a general cognitive impairment of processing speed or working memory, but are rather related to more specific cognitive functions, such as prospective memory or source flexibility. Such observations are in accordance with previous studies that have explored the cognitive underpinnings of multitasking abilities in brain-injured patients (Burgess et al., 2000) and students (Logie et al., 2011). More specifically, these studies suggested that multitasking abilities are supported by three primary constructs: memory (working and episodic memory), planning abilities, and intent (which was hypothesized to mainly reflect prospective memory). Indeed, performance on the CMPT was found to make demands upon episodic and working memory, planning abilities, and prospective memory. However, the present results also demonstrate the implication of other cognitive functions such as source flexibility, cognitive flexibility, and inhibition.

Heterogeneity and double dissociation

In both the present studies, patients demonstrated heterogeneous performances on the CMPT and on cognitive measures. In particular, no CMPT or cognitive variable was found to be systematically impaired in patients, as they showed heterogeneous profiles with a combination of preserved and impaired variables.

In the first study, compared to healthy controls, 57% of patients demonstrated an impaired planning score, 52% had an increased total time to compete the CMPT, and 38% presented difficulties in respecting the rules. Similarly, patients showed heterogeneous performances on standard cognitive tests. In particular, 47% of them were impaired in terms of processing speed, 43% in episodic memory, 33% in cognitive flexibility, 23% in selective attention, 9% in inhibition, and 4% in working memory. Thereafter, patients who demonstrated an impaired performance on the CMPT were compared to those who did not in terms of cognitive performances and clinical measures (real world functioning and symptoms). The impaired patient subgroup showed poorer planning abilities than the unimpaired subgroup. The other cognitive and clinical measures did not reach significance. In addition, the impaired subgroup on the respect of the rules variable also demonstrated a lower score for real world functioning than the unimpaired subgroup. Indeed, such results are consistent with the observation of strong relations between the CMPT variables and planning abilities. Nevertheless, they also suggest that the CMPT makes demands upon different cognitive functions that are not assessed by standard cognitive tests. Furthermore, the CMPT provides different information about patients' cognitive and real world functioning than standard cognitive tests.

Similarly, the second study also showed that patients' performances on the CMPT and on cognitive tests were heterogeneous. In particular, 56% of them presented impaired abilities in respecting the rules. Fifty-six percent placed a number of incorrect objects on the table and forgot required items. Fifty-four percent also showed impaired abilities in checking goal achievements. In addition, 54% of patients failed to achieve the prospective memory requirements of the CMPT. 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, 40% of patients demonstrated an increased total time to complete the task. In addition, 35% of patients showed impaired abilities in dealing with interruptions and unexpected outcomes. Seventeen percent of patients also presented 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. Finally, 10% of patients took a prolonged time to consult the instructions list for the first time after the beginning of the task. Concerning the cognitive measures, 54% of patients were found to be impaired in processing speed, 50% in cognitive flexibility, 45% in working memory, 43% in planning abilities, 35% in time-based prospective memory, 31% in episodic memory, 31% in event-based prospective memory, 24% in source flexibility-external to internal, 19% in source flexibility-internal to external, and 10% in inhibition.

Taken together, these results demonstrate that multitasking difficulties and cognitive deficits are heterogeneous in patients with schizophrenia. In particular, patients can be specifically impaired in some facets of multitasking abilities but not in others. Moreover, the impaired facets vary from one patient to another. This observation is particularly important for clinical practice as multitasking abilities are usually perceived as being uniformed, whereas the present studies suggest that this is a multifaceted construct. Indeed, these results are congruent with previous studies that demonstrated the inter-individual heterogeneity of cognitive functioning in patients diagnosed with schizophrenia (Kremen et al., 2004; Raffard et al., 2012). These results thus underline the need for an individualized approach to cognitive difficulties in patients diagnosed with schizophrenia. In particular, there is a need to assess patients with an extensive cognitive battery –including multitasking tests– in order to identify the specific cognitive functions and multitasking facets that are impaired in each patient in order to propose an adapted remediation program.

Interestingly, the variables that were impaired in a majority of patients were different between both studies. In the first study, patients were primarily impaired in the planning score and the total time taken to complete the task, whereas the second study found that patients were mostly impaired in the respect of the rules, the number of incorrect and forgotten objects on the table, the checking score, and the prospective memory score. Such differences may be explained by the fact that the version of the CMPT used in the second study is more complex than in the first one and included more aspects of multitasking activities (i.e., prospective memory instructions and interruptions/unexpected outcomes). Results of the second study are of particular interest because they underline that when confronted with a prototypical multitasking situation, many patients show difficulties in respecting the rules, placing the required objects on the table, but also in checking goal achievements and respecting prospective memory instructions. Such deficits seem thus to be the core features of multitasking difficulties encountered by patients with schizophrenia. Moreover, performances on three of these variables (i.e., incorrect and forgotten objects on the table, prospective memory score, and respect of the rules) were related to difficulties in switching from the outer world to internal representations. Such results underline, once again, the main role played by source flexibility in multitasking abilities.

Correlational and regression analyses demonstrated significant relations between the CMPT variables and several cognitive measures. However, it is interesting to underline that the different cognitive measures only predicted between 8% and 39% of each multitasking variable, suggesting the influence of other factors. Moreover, among the eight variables measured during the CMPT, four variables were found to be impaired in the majority of patients. However, among the 10 cognitive tests, only one (measuring processing speed) was found to be impaired in the majority of patients. The above findings lead to three conclusions: (1) patients diagnosed with schizophrenia are highly heterogeneous in terms of multitasking abilities and more generally in terms of cognitive functioning; (2) patients with schizophrenia tend to encounter more difficulties in multitasking situations than in standard cognitive tests; (3) a certain consistency exists between multitasking abilities and cognitive deficits, in that a majority of patients present both impaired performances on standard cognitive tests and on the CMPT. Nonetheless, performance on the CMPT could not be completely predicted by standard cognitive tests, suggesting the influence on other factors.

Regarding this last point, the second study also demonstrated the existence of a double dissociation between multitasking abilities and standard cognitive tests in patients diagnosed with schizophrenia. In particular, three patients showed preserved performances on the cognitive measures but impaired performances on the CMPT. Moreover, these difficulties were found to be heterogeneous as only one patient was impaired in the total time taken to complete the task, one in the respect of the rules, two in the number of incorrect and forgotten objects on the table, one in the planning score, one in the ability to deal with distractors, and two failed to check goal achievements. Inversely, six patients showed the opposite profile, that is, preserved performances on the different CMPT variables, but impaired performances on at least one cognitive measure. Interestingly, these difficulties were not related to one particular cognitive domain, as six patients were demonstrated to be impaired in processing speed, three in working memory, three in episodic memory, two in cognitive flexibility, one in prospective memory (time-based), and one in source flexibility (internal to external).

Such results are consistent with the previous study by Burgess et al. (2009) that described a double dissociation in brain-injured patients between multitasking abilities as measured by a simplified version of the MET (Alderman et al., 2003) and standard cognitive tests assessing processing speed, episodic and working memory, planning abilities, cognitive flexibility, and IQ. Taken together, these results suggest that multitasking abilities make demands upon cognitive functions that are not assessed by standard cognitive tests. Burgess et al. (2009) suggested that this dissociation is related to unexplored cognitive functions sustained by the rostral prefrontal cortex such as source flexibility, prospective memory, and metacognition. Indeed, the present results demonstrated the main role of source flexibility and prospective memory in multitasking abilities. However, not all patients with preserved multitasking abilities presented unimpaired source flexibility or prospective memory. Moreover, regression analyses revealed that source flexibility and prospective memory only partially predicted performance on the CMPT. These results thus suggest the influence of other factors. Future studies are clearly required to further explore the nature of multitasking difficulties. In particular, there is a need to explore the specific strategies used by patients to complete the CMPT. Indeed, it is possible that patients with impaired cognitive performances on standard cognitive tests adopted specific strategies allowing them to cope with these deficits during multitasking activities.

To date, the heterogeneity of multitasking abilities in patients diagnosed with schizophrenia—but also in other populations—has rarely been explored in the literature. In fact, only two previous studies have examined this issue. In particular, Larøi et al. (2010) observed that not all patients demonstrated an impaired qualitative performance on the shopping task. Specifically, the authors found that 53% of patients failed to successfully collect the required articles from the shopping list. Interestingly, the authors compared patients who successfully collected the required items during the shopping task to those who did not in terms of cognitive performances, symptoms, and real world functioning. Results revealed no significant difference between subgroups, suggesting the influence of other factors. Indeed, such results are congruent with the present ones as they suggest that multitasking abilities are heterogeneous in patients diagnosed with schizophrenia, and that multitasking abilities make demands upon other factors that are not assessed by standard cognitive tests.

Similarly, in their study exploring multitasking abilities in patients diagnosed with schizophrenia using an observation-based meeting preparation task, Levaux et al. (2012) found that patients demonstrated heterogeneous performances on both the meeting preparation task and cognitive tests. In particular, no cognitive or meeting task variables were systematically impaired in patients. More specifically, compared to healthy controls, 40% of patients presented difficulties in respecting the prospective memory instructions (i.e., pick up the coffee at a certain time), 37% demonstrated an increased number of errors (e.g., placed incorrect objects on the table and forgot required items), 33% achieved fewer goals (i.e., placed fewer required objects), and 31% broke more rules regarding the required object and the seating plan. Thereafter, the authors examined the consistency between performances on the cognitive measures and on the meeting preparation task. That is, they explored if patients demonstrating impaired performances on standard cognitive measures also showed difficulties in the meeting task and vice versa. From a general point of view, Levaux et al. (2012) found that the majority of patients were equally impaired on both the standard cognitive tests and the meeting task. However, some patients were demonstrated to encounter more difficulties on the multitasking test compared to the cognitive measures and some patients showed the opposite profile. These findings are particularly relevant regarding the present studies that also found multitasking and cognitive performances to be heterogeneous in patients diagnosed with schizophrenia. Moreover, they also suggest that multitasking abilities make demands upon different functions than standard cognitive tests.

In summary, multitasking abilities in persons diagnosed with schizophrenia were found to be heterogeneous as well as their cognitive deficits. In particular, no variable was found to be systematically impaired in patients. Such results underline the need for an individualized approach to the difficulties encountered by patients. In particular, the specific cognitive deficits and impaired multitasking facets need to be identified in order to propose an adapted remediation program. In fact, a certain consistency exists between multitasking abilities and cognitive deficits, in that a majority of patients tend to present both impaired performances on standard cognitive tests and in multitasking abilities. However, standard cognitive tests as well as more specific cognitive functions (e.g., source flexibility and prospective memory) only partially predict multitasking abilities. Moreover, a double dissociation was found between multitasking abilities and both standard and more specific cognitive tests. Taken together, these results suggest that multitasking abilities make demands upon different cognitive functions than those assessed by standard cognitive tests. Nevertheless, the specific nature of multitasking abilities is still poorly understood and future studies are clearly required to further explore this issue.

Multitasking abilities and real world functioning

Another aim of the present studies was to explore the relations between multitasking abilities and real world functioning in patients diagnosed with schizophrenia. In the first study, patients' performance on the CMPT, and in particular for the respect of the rules, was revealed to be highly (r=.69) and significantly correlated with real world functioning (FROGS; Llorca et al., 2009). Moreover, multiple regression analyses demonstrated that the three CMPT variables that significantly differentiated patients from healthy controls (i.e., total time to complete the task, respect of the rules, and planning score) predicted up 50% of the real world functioning (FROGS). Interestingly, none of the standard cognitive tests significantly predicted any portion of patients' everyday life functioning. These results thus suggest that the CMPT is tapping into patients' real world functioning, but not the standard cognitive tests.

However, the second study did not reveal similar results. No significant correlations were found between patients' performance on the CMPT and real world functioning. This absence of results is particularly surprising. Indeed, in the first study, the version of the CMPT used was found to highly predict patients' functioning. However, this version lacks some characteristics of multitasking activities (Burgess, 2000) such as clear prospective memory instructions and interruptions/unexpected outcomes. On the contrary, the version of the CMPT used in the second study reflects all these characteristics. It was thus expected that taking into account all the characteristics of multitasking activities would have increased the ability of the task to predict real world functioning. Yet some elements can help to explain this lack of results.

To begin with, the mean score on the FROGS presents a clear lack of variance in the second study. Compared to the sample of the first study, patients in the second study demonstrated a more homogeneous (Levene's test: $F=3.93$, $p<.05$) and better level of functioning ($U=281.5$, $p<.001$). In fact, a lack of variance reduces the likelihood of finding any statistically significant results. Moreover, the rating of the FROGS was uniquely based on information collected from patients during an interview, which is influenced by confounding factors such as patients' degree of insight and a social desirability bias. In addition, 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. Finally, it could be difficult for a person to verbalize how he/she manages to realize a multitasking activity (e.g., how the person managed to return to the main task after an interruption). Thus, it is possible that by taking into account all the characteristics of multitasking activities, the version of the CMPT used in the second study ends up measuring something that may be difficult to verbalize (especially for patients) and that is different from what is measured with the FROGS (which was not designed to measure multitasking activities).

Interestingly, Bowie et al. (2007) demonstrated, in a large sample of patients diagnosed with schizophrenia, that self-report measures of real world functioning were not significantly correlated with more objective measures, such as caregiver- and observation-based measures. Moreover, they also found that patients who overestimated their level of functioning were more cognitively impaired than those who underestimated it. Furthermore, “overestimators” were also characterized by a lower level of functioning based on caregiver-measure. These results thus suggest the need for objective information in order to rate patients’ 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 ones. In particular, both subgroups were significantly different for the ability to respect the rules ($U = 51$; $p < .05$). Interestingly, in the first study, the respect of the rules was the variable that demonstrated the highest correlation coefficient with real world functioning. In view of these findings, there is a need to explore in more detail the relations between the CMPT and real world functioning, albeit with objective measures such as observation-based approaches and sociodemographic data such as employment status.

Moreover, patients’ real world functioning was evaluated with a scale that is quite general (i.e., FROGS) and that only provides relatively global information about patients’ functioning. In particular, the scale does not reflect the specific complaints reported by patients about their real world or cognitive functioning. Future studies are clearly required to examine this issue and explore specific relations between the different variables of the CMPT and specific complaints.

To date, a small number of studies have examined the relations between multitasking tests and real world functioning in patients diagnosed with schizophrenia. Katz et al. (2007) found that performance on a shortened version of the SET (Wilson et al., 1996) was related to an observation-based measure of real world functioning. However, for their part, Evans et al. (1997) did not find any significant relation between the SET and self and informant evaluations of real world functioning. The fact that performance on the SET was found to be significantly correlated with an objective evaluation of real world functioning (Katz et al., 2007), but not with subjective evaluations (Evans et al., 1997), is in agreement with the results of Bowie et al. (2007) that underlined the need for objective evaluations of real world functioning in patients diagnosed with schizophrenia.

For their part, Caletti et al. (2013) found significant correlations between real world functioning and performance on the hospital version of the MET (Knight et al. 2002) and on an adapted version of the hotel task (Manly et al., 2002; Torralva et al., 2009) in patients diagnosed with bipolar disorder, schizophrenia and healthy controls. However, the authors did not examine these relations in each population as they merged all groups into a single group which complicates the interpretations of the findings. More recently, Bulzacka et al. (2016) also found in a sample of patients diagnosed with schizophrenia that patients' performance on an adapted version of the MET (Shallice & Burgess, 1991) was significantly correlated with a clinician evaluation of real world functioning. Interestingly, standard executive tests were not found to be significantly related to patients' functioning. Finally, Larøi et al. (2010) demonstrated that patients' performance on a computerized shopping task was significantly correlated with real world functioning, whereas standard cognitive tests (except for a measure of inhibition) did not reach significance.

Taken together, results of previous studies and of the present ones suggest that multitasking abilities are highly related to patients' real world functioning, whereas standard cognitive tests do not reveal such relations. Indeed, the fact that standard cognitive tests were not found to be related to real world functioning is consistent with the meta-analysis by Fett et al. (2011) that demonstrated that overall cognition only predicts 6% of real world functioning in patients with schizophrenia. In fact, standard cognitive tests are designed to assess one isolated cognitive function in a quiet and well-structured environment, whereas multitasking situations involve different and integrated cognitive processes and take place in an unstructured context. These results are particularly important for clinical practice, as they demonstrate the need for assessing multitasking abilities in patients diagnosed with schizophrenia in order to better evaluate patients' abilities to realize complex activities of real world.

In summary, in the first present study, performance on the CMPT was found to highly predict patients' real world functioning. Unfortunately, these results were not reproduced in the second study. Nevertheless, some elements can help to explain this discrepancy, such as a lack of variance of the real world functioning scale in the second study, the influence of confounding factors such as patients' degree of insight, and difficulties in verbalizing multitasking abilities. Moreover, previous studies (Bowie et al., 2007) have suggested the need to rate patients' real world functioning with objective measures, as self-reports are not reliable in patients diagnosed with schizophrenia. In accordance with this observation, in the second study, employed patients demonstrated a significantly better performance on the CMPT than the unemployed patients. Moreover, the first study also showed that performance on the CMPT was highly related to an observation-based version of the task. Taken together, such results suggest that performance of the CMPT is highly related to real world functioning. Nonetheless, future studies are clearly required to further explore relations between multitasking abilities and everyday life functioning using objective measures (e.g., employment status and observation-based tests).

To date, previous studies have also found that performance on different multitasking tests (Bulzacka et al., 2016; Caletti et al., 2013; Katz et al., 2007; Larøi et al., 2010) were related to patients' real world functioning. In agreement with the first study, these findings suggest that multitasking abilities are highly related to real world functioning. Nevertheless, the CMPT possesses several advantages compared to tools used in previous studies, such as the shortened version of the SET (Wilson et al., 1996), the MET (Shallice & Burgess, 1991), the hotel task (Manly et al., 2002; Torralva et al., 2009), and the shopping task (Larøi et al., 2010). In particular, the CMPT places participants in a complex and standardized situation that takes into account all the characteristics of multitasking activities (Burgess, 2000). Moreover, the CMPT places participants in an unfamiliar situation that limits the influence of previous experiences. Finally, performance on the CMPT is reflected by many variables that are related to different facets of multitasking activities, such as the ability to realize the task in an organized manner, to complete the requirements, to deal with distractors, and complete prospective memory instructions.

Multitasking abilities and psychotic symptoms

Another aim of the present studies was to explore the relations between multitasking abilities and symptoms in patients diagnosed with schizophrenia. Results of both studies revealed no significant correlation between performance on the CMPT and positive and negative symptoms as measured by the PANSS (Kay et al., 1987). Moreover, the second study did not find any significant relation between the CMPT and a specific measure of apathy (Initiative-Interest Scale; Esposito et al., 2014).

These results, or rather this absence of results, is surprising, considering the fact that several previous studies demonstrated significant correlations between multitasking abilities and symptoms in patients diagnosed with schizophrenia. To begin with, Raffard et al. (2016) found a link between performance on the shortened version of the SET (Wilson et al., 1996) and a dimension of apathy related to interest and self-awareness. Similarly, Semkovska et al. (2004) demonstrated that patients' performance on an observation-based cooking task was significantly correlated with negative symptom severity as measured with the PANSS. Finally, Larøi et al. (2010) and Josman et al. (2009) have both found that performance on a computerized shopping task was related to psychotic symptoms (PANSS). Specifically, the results of Josman et al. (2009) showed significant correlations between performance on a computerized shopping task and negative symptoms. For their part, Larøi et al. (2010) demonstrated significant correlations between the shopping task and both negative and positive symptoms.

In summary, the present studies revealed no significant correlation between psychotic symptoms and performance on the CMPT. On the contrary, several previous studies found that multitasking abilities were related to psychotic symptoms (mainly negative). Yet some elements can help to explain this discrepancy between results. To begin with, it could be argued that the relations between multitasking abilities and symptoms may be influenced by the level of symptom severity in that more severe symptoms may have a stronger impact on multitasking abilities. Indeed, some patient groups demonstrated more severe symptoms than others. For instance, in Josman et al. (2009), patients demonstrated a mean PANSS negative score of 25.23, whereas the first and second of the present studies revealed a mean score of 19.35 and 18.75 respectively. Nonetheless, Larøi et al. (2010) demonstrated an equivalent mean negative score (19.93) but still found significant relations between multitasking abilities and negative symptoms. Thus, the level of symptom severity does not seem to be a plausible explanation for the fact that previous studies found significant relations between multitasking abilities and symptoms but not the present ones.

Another possible explanation is related to the fact that symptoms are not homogenous categories, as they refer to different manifestations and behaviors. For example, the negative subscale of the PANSS groups together symptoms of different nature, such as blunted affect and apathy. Similarly, the positive subscale combines symptoms such as hallucinations, delusions and conceptual disorganization. It is thus possible for two patients to present a similar mean score on the PANSS but to differ in terms of specific symptom severity. In addition, it is possible that certain types of symptoms may be more strongly related to multitasking abilities than others, and in particular to specific facets of these activities.

From a theoretical standpoint, two types of symptoms seem particularly relevant for multitasking abilities, naming disorganization and apathy, as multitasking activities require organizing thinking and initiating goal directed behaviors. In fact, it is possible to hypothesize that disruption of thinking may be particularly linked to facets of multitasking activities related to goal achievement and to the realization of tasks such as the ability to respect the instructions, complete the requirements of tasks, and to the exploration of the environment. The influence of disorganization may help to explain the negative correlations found in Larøi et al. (2010) between the positive subscale of the PANSS and the number of correct articles purchased during the shopping task and the number of times patients consulted the shopping list. In other words, patients who are more disorganized may consult less the shopping list and present more difficulties in buying the required articles. Unfortunately the specific relations between performance on the shopping task and disorganization symptoms were not examined in Larøi et al. (2010) as they authors used the total score of the positive PANSS subscale.

In order to explore potential relations between disorganization symptoms and performance on the CMPT, supplementary analyses were conducted with the data of the second study and the disorganization factor of the PANSS (Stefanovics, Elkis, Zhening, Zhang, & Rosenheck, 2014)[9]. Results revealed no significant

[9] These analyses were conducted for the present discussion.

correlations, suggesting that multitasking abilities are not related to disorganization as measured by the PANSS. Nevertheless, it is important to underline the fact that the disorganization factor of the PANSS (Stefanovics et al., 2014) may lack specificity as it includes three symptoms of different nature (i.e. conceptual disorganization, abstract thinking, and poor attention). In particular, in the Scale for the Assessment of Thought, Language and Communication (TLC; Andreansen, 1986) which assesses different dimensions of thought disorder, conceptual dizorganisation is included in the disorganization factor, whereas poor attention is related to a distratcability factor (Bazin, Lefrere, Passerieux, Sarfati, & Hardy-Baylé, 2002). Future studies are thus required to further examine the relations between specific facets of multitasking abilities and more precise measures of disorganization.

Concerning apathy, it is possible to hypothesize that this symptom may be related to facets of multitasking abilities that particularly involved initiating goal directed behaviors such as the ability to complete the requirements of the task, consult the instructions, or explore the environment. The influence of apathy may help to explain results of previous studies. In particular, Larøi et al. (2010) found that a higher score on the negative subscale of the PANSS was related to fewer correct articles purchased during the shopping task, less aisle redundancy, and fewer consultations of the shopping list. Similarly, Josman et al. (2009) demonstrated that negative symptom severity was significantly correlated with the number of correct articles purchased and the number of correct actions conducted during the shopping task (e.g., proceeding to an attended checkout counter). Finally, Semkovska et al. (2004) found that a higher score on the negative subscale of the PANSS was related to an increased time taken to complete an observation-based cooking task, but also to more difficulties in planning the realization of the different actions and more omissions of actions and ingredients. Taken together, these results make sense in regard to a hypothesized influence of apathy on multitasking abilities as all these variables require initiating goal directed behaviors. Unfortunately, the specific relations between multitasking abilities and apathy were not examined in previous studies as all negative symptoms were grouped together in the negative subscale of the PANSS.

Regarding the present thesis, the relations between performance on the CMPT and a specific measure of apathy were explored in the second study using the Initiative-Interest Scale (Esposito et al., 2014). Surprisingly, no significant correlations were found. However, results of a previous study may help to explain this absence of results. In particular, Raffard et al. (2016) examined the relations between different dimensions of apathy (as measured by the Lille Apathy Rating Scale, Sockeel et al., 2006; Yazbek et al., 2014) and cognitive functioning in patients with schizophrenia. Interestingly, the authors found a link between multitasking abilities, as measured with the shortened version of the SET (Wilson et al., 1996) and a factor of apathy related to interest and self-awareness, but not to the total score of apathy. These results suggest that the relations between a specific symptom and multitasking abilities may vary according to the symptom dimensions and may help to explain why the second study did not find any significant correlation between the CMPT and a specific measure of apathy (Initiative-Interest Scale; Esposito et al., 2014). Indeed, as its name indicated, the Initiative-Interest scale measures patients' interest, however, this scale does not assess the self-awareness dimension of apathy.

In summary, the present studies found no significant correlation between psychotic symptoms and performance on the CMPT. On the contrary, several previous studies (Larøi et al., 2010; Raffard et al.; 2016; Semkovska et al.,2004) found that multitasking abilities were related to psychotic symptoms (mainly negative). This discrepancy between results may be explained by differences in terms of severity of specific symptoms between patients across the different studies. In particular, not only the strength of the relations between symptoms and multitasking abilities may vary according to specific types of symptom, but some results also suggest that the relations may depend on the different dimensions of the same symptoms. In addition, it is hypothesized that the relations between multitasking abilities and psychotic symptoms may also vary according to the specific facets of multitasking abilities. There is thus a clear need for future studies to explore the relations between specific symptoms dimensions —and in particular of apathy and disorganization — and the different facets of multitasking abilities in persons diagnosed with schizophrenia.

Summary and perspectives

A new computerized multitasking task—the Computerized Meeting Preparation Task—was created and developed across two studies. This task was designed so that it takes into account all the characteristics of multitasking activities, but at the same time, places participants in an unfamiliar situation in order to limit the influence of previous experiences.

The CMPT was used in two studies exploring multitasking abilities in patients diagnosed with schizophrenia. Both studies revealed that patients presented a poorer performance than healthy controls on the CMPT, suggesting the presence of multitasking difficulties. In fact, these results are congruent with previous studies which found that patients performed worse than controls for different multitasking tests such as the SET (Evans et al., 1997; Katz et al., 2007; van Beilen et al., 2006), the MET (Caletti et al., 2013), computerized shopping tasks (Josman et al., 2009; Larøi et al., 2010), and other observation-based tasks such as cooking (Semkosvka et al., 2004) or preparing a room for a meeting (Levaux et al., 2012). Taken together, these results suggest that when confronted with a multitasking situation, patients present difficulties in respecting the instructions, completing the required tasks, organizing the realization of the tasks, and accomplishing prospective memory instructions. Moreover, results of the CMPT also demonstrated that patients present difficulties in checking goal achievements and dealing with distractors. In fact, compared to preexisting multitasking tools, the CMPT possesses the advantage of reflecting all the characteristics of multitasking activities and to place participants in an unfamiliar situation, limiting the influence of previous experiences. Moreover, it is possible to precisely measure many variables related to the different aspects of multitasking activities and is easy to administer in a clinical setting.

The present results also demonstrated that, in schizophrenia, multitasking abilities make demands upon several cognitive functions, including working and episodic memory, cognitive flexibility, inhibition, planning, prospective memory, and source flexibility. Additionally, the results also showed that multitasking difficulties in patients with schizophrenia are not due to a general cognitive impairment of processing speed or working memory. Such observations are in accordance with previous studies (Burgess et al., 2000; Logie et al., 2011) which suggested that multitasking abilities are supported by three primary constructs:

memory (working and episodic memory), planning abilities, and intent (which was hypothesized to mainly reflect prospective memory). However, the present results also demonstrated the influence of other cognitive functions such as source flexibility, cognitive flexibility, and inhibition.

Interestingly, with patients diagnosed with schizophrenia, multitasking abilities were found to be heterogeneous, as were performances on standard cognitive tests as well. Moreover, a double dissociation was found between multitasking abilities and standard cognitive tests. Such results are in accordance with a previous study by Burgess et al. (2009) that described a double dissociation in brain-injured patients between multitasking abilities and standard cognitive tests. Burgess et al. (2009) suggested that this dissociation is related to unexplored cognitive functions sustained by the rostral prefrontal cortex such as source flexibility, prospective memory, and metacognition. However, not all patients with preserved multitasking abilities presented unimpaired source flexibility or prospective memory as measured by the specific task used, which suggests the influence of other factors that were not measured. There is a need for future studies to further explore the nature of multitasking difficulties in patients diagnosed with schizophrenia.

In the first study, patients' performance on the CMPT was also found to be highly related to patients' level of real world functioning, whereas standard cognitive tests did not reach significance. Such results are in agreement with previous studies which suggested that performances on different multitasking tests (Bulzacka et al., 2016; Caletti et al.,2013; Katz et al., 2007; Larøi et al., 2010) were related to patients' real world functioning. Taken together, such results demonstrate that multitasking abilities are particularly implicated in real world activities, and underline the importance of evaluating multitasking abilities in order to better evaluate patients' functioning.

Unfortunately, these results were not reproduced in the second study, as no significant correlations were found between the CMPT and everyday life functioning. Nevertheless, some elements can help to explain this discrepancy in results, such as a lack of variance in the real world functioning scale, the influence of confounding factors, and difficulties in verbalizing multitasking abilities. Nonetheless, future studies are clearly required to further explore the relations between multitasking abilities and everyday life functioning. In particular, there is a need to examine the relations between the CMPT and performances on specific multitasking activities of everyday life (e.g., cooking and shopping), but also with the specific complaints made by patients.

Finally, the present studies found no significant correlation between symptoms and performance on the CMPT. On the contrary, several previous studies (Larøi et al., 2010; Raffard et al.; 2016; Semkovska et al.,2004) found that multitasking abilities were related to psychotic symptoms (mainly negative). This discrepancy between the results may be explained by differences in terms of the severity of specific symptoms. In particular, it may be possible that specific symptoms have a stronger impact on multitasking abilities than others. In addition, it is hypothesized that the relations between multitasking abilities and psychotic symptoms may also vary according to the specific facets of multitasking abilities. Future studies need to explore the relations between specific symptom dimensions —and in particular of apathy and disorganization — and the different facets of multitasking abilities in persons diagnosed with schizophrenia.

Shopping task versus Meeting Preparation Task

At this point, it may be interesting to further analyze the common points and differences between the computerized shopping task created by Larøi et al. (2010) and the CMPT developed for the present thesis.

As a reminder, the shopping task (Larøi et al., 2010) requires participants to shop for a list of grocery store items in a virtual supermarket. The task also contains distractors in the presence of other customers, music played in the background, and loud-speaker announcements. In 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. Thus, in both tasks, participants are placed in a complex situation that shares many characteristics with everyday life activities. Specifically, participants are required to realize different tasks, to create an action plan, remember tasks to realize, and deal with non-pertinent stimuli.

In fact, both tasks were revealed to significantly differentiate patients diagnosed with schizophrenia from healthy controls. More specifically, Larøi et al. (2010) found that patients took more time to complete the task, bought fewer correct articles, went more often in the same aisles, visualized more non-pertinent shelves, consulted the shopping list more often and spent more time consulting it. For its part, the CMPT showed that patients took more time to realize the task, presented a lower planning score, respected fewer rules (written instructions), placed a number of incorrect objects on the table and forgot required items, completed less prospective memory instructions, presented difficulties in dealing with distractors, and in checking goal achievements. Taken together, these results suggest that when confronted with a multitasking situation, patients with schizophrenia present difficulties in respecting the instructions, completing the required tasks, accomplishing prospective memory instructions, organizing the realization of the task, checking goal achievements, and dealing with distractors. Indeed, performance on both tasks was found to be related to similar cognitive functions, including cognitive flexibility, inhibition, planning, and episodic memory, suggesting a major implication of executive functions in multitasking abilities. Finally, both tasks were revealed to be highly related to patients' real world functioning, whereas standard cognitive tests did not reach significance in any of the studies.

However, a main difference between the shopping task and the CMPT is that the CMPT reflects all the characteristics of multitasking activities (Burgess, 2000), whereas the shopping task lacks some of them. More specifically, the shopping task does not contain clear prospective memory instructions, whereas the CMPT requires participants to realize both event-based and time-based prospective memory instructions. Moreover, in the CMPT, participants also have to deal with interruptions/unexpected outcomes: an interrupting phone call and a missing chair. In fact, the shopping task contains distractors such as other (virtual) shoppers and loud speaker announcements. However, these distractors do not directly interrupt participants in their ongoing action and do not require realizing additional tasks as in the CMPT, where participants have to pick up the phone and solve the missing chair problem. The CMPT thus shares more characteristics with multitasking real world activities than the shopping task, and provides more information about patients' abilities to realize complex activities.

Performance on the shopping task is reflected by relatively basic variables (e.g., aisle redundancy, number of times the shopping list has been consulted) referring to many cognitive functions such as processing speed, episodic memory, cognitive flexibility, planning, inhibition. On the contrary, the CMPT variables were created to precisely reflect different facets of the activity and are related to more specific cognitive functions. For example, the variables provide information about patients' abilities to plan, respect the rules, deal with distractors, realize prospective memory instructions, and check goal achievement. Thus, from a clinical point of view, variables of the CMPT provide more useful information about patients' functioning than the variables of the shopping task.

Another main difference between the shopping task and the CMPT is related to the nature of the task. Specifically, the shopping task requires participants to realize a familiar activity—a shopping task. On the contrary, the CMPT places participants in an unfamiliar situation. This difference is really important, as performance on the shopping task may be mediated by participants' familiarity with the activity. Thus, people who are more familiar with doing the shopping in everyday life will have fewer difficulties performing the task and will not be relying on their executive functions as much in order to perform the task efficiently, compared to people who have only rarely shopped previously. Such influence complicates the interpretation of the results. For instance, one patient could present a preserved performance on the shopping task due to the fact that he/she is really familiar with this kind of activity but still present difficulties on other less familiar multitasking activities. The fact that the CMPT places participants in an unfamiliar situation limits the influence of previous experiences and thus allows for more direct evaluation of multitasking abilities. Indeed, as the CMPT reflects all the characteristics of real world multitasking activities, patients' performance could be transposed to many other multitasking activities of everyday life.

In addition, the CMPT was designed so that the level of difficulty can be modulated and different scenarios can be created. It is thus possible to choose the number of guests attending the meeting (5, 7, or 9), the interruptions/unexpected outcomes (e.g., interrupting phone calls, missing objects), the prospective memory instructions (e.g., to place coffee on the table at a certain time; give the camera to an avatar when it comes). This modularity of the task offers the possibility to create parallel versions of the task to use in case of re-testing or integration into a remediation program. It is possible to progressively train patients to realize multitasking activities by increasing the difficulty of the task and by varying the demands of the task.

In summary, both the CMPT and the shopping task allow for evaluating patients' abilities to realize complex activities of everyday life. However, compared to the shopping task, the CMPT possesses a number of advantages. In particular, the CMPT reflects all the characteristics of real world multitasking activities (Burgess, 2000) and provides specific variables related to different facets of the activity. In addition, the CMPT allows for evaluating multitasking abilities by placing participants in an unfamiliar situation, which limits the influence of preexisting experiences and facilitates the interpretation of the results. Finally, the CMPT is modular, which allows the creation of parallel versions and for use in remediation programs. Taken together, these different features of the CMPT render the task more relevant than the shopping task to assess patients' multitasking abilities, but also to remediate multitasking difficulties.

Clinical implications

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 where the person has to initiate, carry out, and alternate between different tasks, define the tasks' targets, and face unexpected outcomes (Burgess, 2000). Multitasking abilities are thus essential in order to realize complex activities that are central for independent living, such as shopping, cooking, or maintaining professional activity.

Using two different computerized tasks—the shopping task developed by Larøi et al. (2010) and the CMPT—the present thesis demonstrated that patients diagnosed with bipolar disorder and schizophrenia present multitasking difficulties. Moreover, performance on these tasks was found to be highly related to real world functioning, whereas standard cognitive tests did not reveal significant correlations with patients' everyday life functioning. In fact, multitasking abilities were found to make demands upon several cognitive functions including working and episodic memory, cognitive flexibility, inhibition, and planning. Additionally, one of the present studies on schizophrenia also demonstrated the implication of more specific cognitive functions, including prospective memory and source flexibility. However, besides the obvious links found between standard cognitive tests and multitasking abilities, some results have also suggested that multitasking abilities make demands upon different cognitive functions than those evaluated with standard cognitive tests. In agreement with a previous study on brain-injured patients (Burgess et al., 2009), the second study on schizophrenia found a double dissociation between standard cognitive tests and multitasking abilities. In a related way, the analysis of the individual profiles also revealed that multitasking abilities were particularly heterogeneous in schizophrenia, as patients showed a combination of preserved and impaired variables.

Such findings are particularly important for clinical practice, as they underline the importance of assessing multitasking abilities in patients suffering from different pathologies in order to better evaluate patients' abilities to realize the complex activities of everyday life. Indeed, being able to detect cognitive deficits impacting patients real world functioning is a main goal of clinical practice and is highly valuable. For example, after a hospitalization, performance on tasks such as the CMPT and the shopping task could provide important information in regard to how patients will face multitasking situations. It may also help to assess the functional impact of an intervention and help to design a remediation program. Additionally, it can be very frustrating for patients who complain about everyday life difficulties to be told that their cognitive assessments are normal. Evaluating multitasking abilities may help to avoid such scenarios and provides a better evaluation of patients' real world functioning.

As already stated, the CMPT possesses several advantages compared to the shopping task that makes it a particularly interesting tool to use in clinical practice. Specifically, the CMPT reflects all the characteristics of real world multitasking activities (Burgess, 2000) but, at the same time, places participants in an unfamiliar situation which limits the influence of preexisting experiences and facilitates interpretation of the results. Thus, the CMPT allows for the evaluation of multitasking abilities by placing participants in a prototypical multitasking situation that may reflect participants' abilities to realize other multitasking activities of everyday life. In addition, the CMPT reflects participants' performance with several variables related to different facets of the activity. Such specific variables allow for detecting difficulties related to different aspects of the task, such as prospective memory or distractor management. Indeed, many of these abilities are not assessed by standard cognitive tests, as they are designed to assess one isolated cognitive function in a quiet and well-structured environment. From this point of view, tests assessing multitasking abilities and in particular the CMPT, provide different information about patients' cognitive and real world functioning than standard cognitive tests. Specifically, they inform clinicians about patients' abilities to realize complex tasks that require the same integrated cognitive functions as many real world activities.

In addition, the CMPT was designed so that the task's level of difficulty can be modulated and different scenarios can be created. This modularity offers the possibility to develop parallel versions of the task to use in case of re-test by varying the distractors or prospective memory instructions. In addition, the modularity of the CMPT also allows integrating the task into cognitive remediation programs. In particular, it may be possible to use the different levels of difficulty and scenarios of the CMPT to train patients suffering from multitasking difficulties. It is also possible to focus on an impaired aspect of multitasking abilities, such as the ability to deal with distractors or prospective memory.

Multitasking abilities were found to make demands upon several cognitive functions including working and episodic memory, cognitive flexibility, inhibition, planning, source flexibility, and prospective memory. Such results suggest that it is important to assess such cognitive functions in patients using standard cognitive tests in order to identify potential cognitive deficits that can have an impact on multitasking abilities. Indeed, if such cognitive deficits are observed, there is a need to propose specific cognitive remediation programs specifically designed for these difficulties. In particular, it may be pertinent to remediate such difficulties before training patients in multitasking situations as they make demands upon these cognitive functions. Indeed, future studies are clearly required to assess the effects of a cognitive remediation program integrating the CMPT on patients' real world functioning. Nevertheless, there is also a need to better specify the nature of multitasking difficulties in order to be able to propose more specific remediation programs.

The fact that the CMPT and the shopping task are computerized also offers the advantage of being easily administered in a clinical setting, as it does not require leaving the hospital or extra personnel. Moreover, the environment is completely controlled and standardized, which allows creating normative data to compare patients' performance to healthy controls or to other clinical populations.

The ultimate goal of the CMPT is to be used by clinicians. To do so, a website was created (www.meetingpreparationtask.com) where clinicians can download the task (free of charge) in French and in Dutch. Moreover, normative data were also developed to compare patients' performance with healthy controls. Finally, in order to make the utilization of the task easier by the clinicians, a program was developed that automatically compares the results obtained by a patient to the normative data.

Conceptualizing multitasking abilities

One goal of the present thesis was to explore the cognitive underpinnings of multitasking abilities in patients diagnosed with bipolar disorder and schizophrenia. To do so, the relations between performances on two different multitasking tasks—a computerized shopping task and the Computerized Meeting Preparation Task—and an extensive cognitive battery were examined.

The study on bipolar disorder demonstrated that performance on the shopping task was significantly related to different cognitive functions, including processing speed, episodic memory, planning abilities, cognitive flexibility, and inhibition. Moreover, some results suggested that multitasking abilities also make demands upon cognitive functions that are not assessed by standard cognitive tests. Specifically, performance on the shopping task was not significantly different between patients presenting one or no impaired performance on standard cognitive tests and patients with more than one cognitive deficit. Such results indicate that impaired performance on standard cognitive tests is neither a necessary nor a sufficient condition to present multitasking difficulties.

Concerning schizophrenia, two studies were conducted exploring the cognitive underpinnings of multitasking abilities with a new computerized multitasking task—the CMPT—reflecting all the characteristics of multitasking activities (at least in the second study). Taken together, results of both studies demonstrated that performance on the CMPT was significantly related to different cognitive functions including working and episodic memory, cognitive flexibility, inhibition, planning, prospective memory, and source flexibility. Moreover, a double dissociation was found between multitasking abilities and cognitive tests. More specifically, some patients were found to be impaired on the CMPT, but not on standard cognitive tests and vice versa.

Interestingly, despite their methodological differences, the study on bipolar disorder and the two studies on schizophrenia demonstrated that multitasking abilities were related to similar cognitive functions, including episodic memory, planning, cognitive flexibility, and inhibition. Such results suggest that multitasking abilities make demands upon similar cognitive functions across different populations and tasks. However, the second study conducted with patients diagnosed with schizophrenia also demonstrated the implication of more specific functions: prospective memory and source flexibility.

To date, only two studies have directly examined the cognitive underpinnings of multitasking abilities in the literature: Burgess et al. (2000) in a sample of brain-injured patients using the Greenwich task, and Logie et al (2011) in a sample of students using the Edinburgh Virtual Errands Task (EVET). Both studies proposed that multitasking abilities are supported by three primary constructs: memory (working and episodic), planning abilities, and intent (supposed to mainly reflect prospective memory). Moreover, these latent variables are also related to each other, such that unidirectional paths were described from memory to intent and to planning, and from planning to intent. Such results suggest that the ability to plan depends upon working and episodic memory. Similarly, the ability to perform the task makes demands upon memory and planning abilities.

Nonetheless, as previously mentioned in the introduction, these studies (Burgess et al., 2000; Logie et al., 2011) present several limitations. In both studies, participants were required to follow a specific and sequential method to realize the multitasking tests. Such an imposed method lacks ecological validity and artificially creates unidirectional relations between the cognitive underpinnings. Another limitation is related to the fact that the multitasking tests used in these studies lack some important characteristics of multitasking abilities (Burgess, 2000), such as the presence of interruptions/unexpected outcomes.

Moreover, performance on the multitasking tasks is only represented by one variable. The other measures are related to the performance before (e.g., learning the instructions) or after the task (e.g., recall what has been done). This reverts to an approach whereby specific cognitive functions (e.g., episodic memory) are measured and not the multitasking abilities themselves. Finally, only a limited number of cognitive functions were examined in relation to multitasking abilities.

All these different limitations have been overcome in the third study of this thesis. In particular, the task used—the CMPT—takes into account all the characteristics of multitasking activities (Burgess, 2000). Performance on the CMPT is reflected by several variables that are measured during the realization of the task and not before or after. Moreover, participants were free to adopt their own strategy to realize the task. Finally, many different cognitive functions were explored in relation to performance on the CMPT.

Interestingly, despite the main methodological differences between the study conducted in the present thesis and the studies by Burgess et al. (2000) and Logie et al. (2011), results were revealed to be relatively consistent across studies. Indeed, performance on the CMPT was found to make demands upon episodic and working memory, planning abilities, and prospective memory. However, the present study also demonstrated the implication of other cognitive functions that were not assessed in Burgess et al. (2000) and Logie et al. (2011). Specifically, results revealed that performance on the CMPT was related to source flexibility, cognitive flexibility, and inhibition. Indeed, during multitasking activities, people are placed in a complex situation where they are required to create an action plan (planning), to maintain this plan and related goals in mind throughout the task, and remember as many things to do as possible (episodic and working memory).

Moreover, they also have to create intentions related to actions to realize in the future (prospective memory), to inhibit irrelevant stimuli from the environment, and interrupt their ongoing action in order to realize previously created intentions (inhibition). It is also essential for people to continuously shift between the different stimuli from the environment and tasks (cognitive flexibility), but also between the environment and internal representations (e.g., internal plan and representations of the instructions) (source flexibility). Finally, people also have to deal with interruptions and unexpected outcomes, requiring adapting the internal plan (source flexibility).

Taken together, the present results and those of Burgess et al. (2000) and Logie et al. (2011) demonstrate that multitasking abilities make demands upon several cognitive functions, as measured by standard cognitive tests or similar methods (e.g., asking participants to learn the instructions by heart before conducting the task). However, some results also suggest that multitasking abilities rely upon cognitive functions that are not assessed by standard cognitive tests. In particular, Burgess et al. (2009) described a double dissociation in brain-injured patients between multitasking abilities and standard cognitive tests, assessing processing speed, episodic and working memory, planning abilities, cognitive flexibility, and IQ. Similarly, the third study of the present thesis also found a double dissociation in patients diagnosed with schizophrenia between multitasking abilities and cognitive tests assessing processing speed, working and episodic memory, cognitive flexibility, inhibition, planning, source flexibility, and prospective memory.

This double dissociation is particularly challenging to explain. The fact that some patients present multitasking difficulties in the context of preserved standard cognitive tests could suggest that multitasking tasks are simply more difficult and more multi-determined than standard cognitive tests. However, the fact that some patients demonstrate the opposite profile is not an argument in favor of this hypothesis and rather indicates that multitasking abilities make demands upon factors other than standard cognitive tests.

Burgess et al. (2009) suggested that this dissociation may be related to unexplored cognitive functions sustained by the rostral prefrontal cortex and related to the gateway hypothesis (Burgess et al., 2007), such as source flexibility and prospective memory. Indeed, the present results demonstrated that source flexibility and prospective memory both play a major role in multitasking abilities as they were related to many CMPT variables. However, the third study of this thesis found that not all patients with preserved multitasking abilities presented unimpaired source flexibility or prospective memory as measured by the specific tasks used. Inversely, some patients with preserved cognitive performances on standard cognitive tests—including source flexibility and prospective memory—presented multitasking difficulties.

The fact that source flexibility was found to play a major role in multitasking abilities is in agreement with the gateway hypothesis (Burgess et al., 2005; Burgess et al., 2007). As a reminder, the gateway hypothesis claims that the BA 10 underpins an attentional gateway that allows one to control the degree to which one is engaging in stimulus-independent thoughts (i.e., the thoughts in one’s head) or attending to external stimuli (i.e., environment), and switch between these sources—source flexibility. The authors hypothesized that multitasking situations particularly imply this gateway because they require bearing in mind self-generated goals and task constraints, while interacting with the environment, and are also likely to trigger internal attending with the person wondering what to do and plan *("what do I do now?")*. In fact, this hypothesis was partially confirmed by the present results, as source flexibility was found to be related to many variables of the CMPT. Nonetheless, the double dissociation observed in the present study between multitasking abilities and performance on a source flexibility task suggests that multitasking activities may also make demands upon other cognitive functions. It is, however, also important to underline the fact that source flexibility was only assessed by one laboratory and artificial task. There is thus a need for future studies to confirm these finding using different tasks assessing source flexibility.

One possible explanation for this double dissociation would be the presence of an integrative cognitive process. In particular, Gilbert et al. (2006) suggested that the most rostral part of the BA 10 may support high level guidance and coordination of task performance. This hypothesis is based on the observation of a particular activation (fMRI) of the rostral part of the BA 10 when participants are confronted with the realization of more than one task at a time, for example, during tasks requiring the realization of goals and sub-goals. The coordination of several tasks may provoke a higher level of information processing about the various tasks being performed above processing related to the individual tasks themselves. Similarly, Ramnani and Owen (2004) have suggested that the BA 10 would be engaged in situations involving several cognitive functions that need to be coordinated. In particular, the BA 10 would be implicated in situations requiring the integration and coordination of several separate cognitive operations. According to these authors, the role of the BA 10 would be to coordinate the different related cognitive operations, orchestrating the information processing and information transfer between multiple operations across supramodal cortex in the pursuit of a global goal. An impairment of this integrative and coordinating cognitive process may help to explain why some patients present difficulties in tasks requiring the realization of several cognitive operations, such as in multitasking situations, but preserved performance on standard cognitive tests assessing more isolated cognitive functions. Explaining why some patients present preserved multitasking abilities in the context of impaired performance on standard cognitive tests is more challenging. However, it is possible to hypothesize that a preserved coordinating process may help to compensate for the impact of impaired cognitive functions on multitasking situations by recruiting other cognitive resources. Nevertheless, patients would still present difficulties in standard cognitive tests that would not rely on this coordinating process. Future studies are clearly required to specify and clarify the nature of this hypothesized coordinating function and if it plays a role in multitasking abilities.

Other authors have suggested that the BA 10 would be involved in metacognitive abilities (Burgess & Wu, 2013; Christoff & Gabrieli, 2000). Johnson et al. (2002) demonstrated that this brain region was particularly activated when people have to judge their own cognitive functioning. Similarly, Fleming et al. (2010) found that the gray matter volume in the prefrontal cortex was related to people’s ability to accurately judge their performance on a task. Indeed, the ability to reflect upon one’s own performance may be particularly important in multitasking activities, where people have to define for themselves what constitutes adequate performance, define their own strategy to realize the task, and where the task does not contain feedback. There is thus a need to examine the relations between metacognitive abilities and multitasking abilities. In particular, it is possible that patients who present impaired cognitive performances on standard cognitive tests, but who are well aware of their cognitive functioning, adopt specific and subtle (e.g., consult more the instructions list) strategies allowing them to cope with these deficits during multitasking activities. Such specific strategies may thus help to explain why patients with cognitive deficits may present preserved multitasking abilities.

To date, many studies have suggested that multitasking abilities are underpinned by the BA 10 (e.g., Burgess et al., 2000; Gilbert et al., 2006; Roca et al., 2011). However, little is known about the specific cognitive processes sustained by this brain region. In agreement with the gateway hypothesis (Burgess et al., 2007), results of the present thesis suggest a major implication of source flexibility in multitasking abilities. However, such impairment does not seem sufficient or necessary to induce multitasking difficulties, which suggests the implication of other cognitive processes. Future studies are thus clearly required to further examine the cognitive underpinnings of multitasking abilities and especially regarding the implication of metacognitive abilities and of a coordinating process.

The present thesis examined the relations between multitasking abilities and many different cognitive processes. However, it is possible that multitasking abilities also make demands upon cognitive functions that were not measured in the existing studies. In particular, Burgess (2015) made a distinction between serial multitasking as measures by the CMPT, and concurrent multitasking as in the dual task paradigm. This thesis only focused on serial multitasking; however, Burgess (2015) hypothesized that concurrent multitasking may be embedded in serial multitasking. Of course, characteristics of (serial) multitasking activities

(Burgess, 2000) state that it is not possible to conduct two tasks at the same time. It is not indeed possible to simultaneously realize two main tasks (e.g., it is impossible to simultaneously chop the carrots and peel the potatoes). Nevertheless, multitasking activities also required the realization of many “micro-tasks” and some of them may be realized at the same time (e.g., stirring the cooking carrots and thinking about the organization of the next steps of the recipe). Being able to realize two tasks at the same time may thus facilitate the realization of a serial multitasking activity. Future studies are thus required to examine the relations between serial and concurrent multitasking.

Finally, the impact of psychological factors such as self-efficacy and motivation were not assessed in the present thesis. Nonetheless, some previous studies have suggested that motivation can have an impact on cognitive functioning in patients diagnosed with schizophrenia (Fervaha, Foussias, Agid, & Remington, 2015). Similarly, Kurtz, Olfson, and Rose (2013) found that self-efficacy was related to real world functioning. Such results suggest that such psychological factors may have an impact on multitasking abilities. Such an influence may also help to explain the observed double dissociation between multitasking abilities and standard cognitive tests. For example, multitasking activities, such as the CMPT, could be more motivating and less confronting/stigmatizing than standard cognitive tests. In reaction, patients may get more involved in such tasks than in standard cognitive tests and demonstrate an unimpaired performance.

Directions for future studies

The first study of the present thesis demonstrated that patients diagnosed with bipolar disorder encounter multitasking difficulties as measured by the shopping task developed by Larøi et al. (2010). To date, multitasking abilities have rarely been examined in that population. In fact, only two previous studies (Caletti et al., 2013; Torralva et al., 2012) have explored patients' ability to realize multitasking tasks. Moreover, among these studies, only one has examined the cognitive underpinnings of multitasking abilities (Torralva et al., 2012). Nevertheless, previous studies and the present one suggest that patients diagnosed with bipolar disorder encounter multitasking difficulties and that such impairments are highly related to real world functioning. These results are encouraging and underline the need to continue exploring multitasking abilities in patients with bipolar disorder. In particular, none of these studies has examined patients' multitasking abilities with a task reflecting all the characteristics of multitasking activities. There is thus a need to explore patients' multitasking abilities using tasks such as the CMPT. Future studies are also required to better characterize the cognitive underpinnings of multitasking abilities. In particular, the implication of potentially important cognitive functions (e.g., prospective memory, source flexibility, metacognition, coordinating process) has never been examined.

In the present thesis, multitasking abilities were compared between patients diagnosed with schizophrenia and bipolar disorder. Results suggested that patients diagnosed with schizophrenia encounter more multitasking difficulties than patients with bipolar disorder (i.e. more impaired variables on the shopping task). Indeed, such results are consistent with the fact that patients with bipolar disorder generally demonstrate better cognitive (Bortolato et al., 2015) and real world functioning (Bowie et al. 2010; WHO, 2008) than patients diagnosed with schizophrenia. However, this comparison should be viewed cautiously as both patient groups differed in terms of age. There is thus a need for future studies to directly compare these populations while controlling for age. Such a comparison is important to better understand the common points and differences between these populations in terms of cognitive functioning.

Across the three studies conducted for the present thesis, real world functioning was assessed with scales either completed by a psychiatrist based on his/her knowledge of the patient or by a psychologist during a semi-structured interview with the patient. Nevertheless, these scales provide relatively global information about patients' functioning and do not reflect the specific complaints made by patients. Moreover, these scales are influenced by patients' lack of insight and social desirability bias. Indeed, even if these scales are filled out by a clinician, their completions depend upon what patients agree to say or are able to report. Moreover, Bowie et al. (2007) demonstrated that self-report measures are not reliable in patients diagnosed with schizophrenia and underlined the need for objective information to rate patients' functioning. There is thus a need for future studies to precisely examine the relations between multitasking abilities and (1) the specific complaints made by patients, and (2) objective measures of functioning (e.g., observation-based).

The second study of the present thesis demonstrated that the CMPT was significantly correlated with a real version of the task, pointing to good ecological validity. Nevertheless, there are obvious differences between computerized tasks and activities carried out in real life. In computerized tasks, the environment is perceived as being not real and the interactions are modified (e.g., manipulating a gamepad versus taking a can of soup in hand), the sensorial feedback is different, etc. Moreover, many everyday life activities take place in a social context which can influence patients' performance. For example, patients may be afraid to make an error or to be negatively judged by others. It is indeed possible to add avatars to computerized tasks in order to recreate a social context such as in the computerized shopping task (Larøi et al., 2010). However, these social situations will always be artificial. Thus, a good performance on a computerized task does not guarantee that the same task in a real situation will be as successful due to the presence of other variables not included in the computerized task. The observation leads to two conclusions: (1) computerized tasks need to reflect as many characteristics as possible of real world activities; and (2) as suggested by Larøi and Van der Linden (2013), there is a need for an individualized approach to everyday life difficulties encountered by patients that takes into account various factors that play a significant role in functional outcomes including (but not limited to) cognitive functioning, symptoms, dysfunctional attitudes, insight, metacognition, family attitudes, and stigma. Such an approach is essential in order to identify the specific factors causing the everyday life difficulties encountered by a patient and propose an adapted and personalized remediation program.

The present studies on schizophrenia demonstrated that patients present multitasking difficulties. Moreover, these multitasking difficulties were found to be related to several cognitive functions, including working and episodic memory, cognitive flexibility, inhibition, planning, prospective memory, and source flexibility. A double dissociation was also found between multitasking abilities and all the cognitive measures. The fact that source flexibility was found to play a major role in multitasking abilities is in agreement with the gateway hypothesis (Burgess et al., 2005; Burgess et al., 2007). Nonetheless, the double dissociation observed between multitasking abilities and performance on a source flexibility task suggests that multitasking activities may also make demands upon other cognitive functions. Such results underline the need to continue exploring the cognitive underpinnings of multitasking abilities. Particularly, there is a need to explore the implications of other cognitive functions related to the BA 10, such as metacognitive abilities and a coordinating process. From this point a view, it may also be interesting to conduct fMRI studies exploring the neuronal underpinnings of multitasking abilities, using complex tasks such as the CMPT in order to examine if a particular activation of the BA 10 is found. For example, an fMRI study can be envisioned, comparing the brain activation observed with different versions of the CMPT, which vary in terms of multitasking characteristics and difficulty, to see if the activation of the BA 10 varies as well.

Finally, the present studies demonstrated that multitasking abilities are impaired in patients diagnosed with schizophrenia and bipolar disorder. Such abilities were found to be particularly related to patients’ real world functioning, whereas the standard cognitive tests did not demonstrate such relations. Moreover, the present results also reveal that these abilities can be specifically impaired. Such information is particularly important for clinical practice in order to better evaluate patients’ abilities to realize complex activities of everyday life. Thus there is now an urgent need to develop remediation programs. One possibility would be to use the modularity of the CMPT to progressively train patients to realize multitasking activities. Future studies are needed to assess the effects on real world functioning of such training.

General conclusion

In the present thesis, multitasking abilities were examined in persons diagnosed with bipolar disorder and in schizophrenia. Multitasking abilities were assessed using two different tasks: the computerized shopping task developed by Larøi et al. (2010) and a new computerized task—the Computerized Meeting Preparation Task (CMPT). The CMPT was designed so that it takes into account all the characteristics of multitasking activities but, at the same time, places participants in an unfamiliar situation to limit the influence of previous experiences.

Results suggested the presence of multitasking difficulties in both patients with bipolar disorder and with schizophrenia. Moreover, results demonstrated that multitasking abilities were related to several cognitive domains in both populations, including episodic memory, planning, cognitive flexibility, and inhibition. The second study conducted with patients diagnosed with schizophrenia also demonstrated the implication of more specific functions: prospective memory and source flexibility. Interestingly, results revealed that multitasking difficulties were not due to a general impairment of processing speed (in schizophrenia and bipolar disorder) or working memory (in schizophrenia), suggesting the specificity of multitasking abilities.

Such observations are in accordance with previous studies (Burgess et al., 2000; Logie et al., 2011) which have suggested that multitasking abilities are supported by three primary constructs: memory (working and episodic memory), planning abilities, and intent (which was hypothesized to mainly reflect prospective memory). However, the present results also demonstrated the influence of other cognitive functions that were not examined in previous studies, including source flexibility, cognitive flexibility, and inhibition.

The analyses of individual profiles in patients diagnosed with schizophrenia reveal that multitasking abilities were heterogeneous as well as performance on standard cognitive tests. Specifically, no variable was found to be systematically impaired in patients. Moreover, for the first time in the literature, a double dissociation was found between multitasking abilities and standard cognitive tests in patients diagnosed with schizophrenia. More specifically, some patients were found to be impaired on the CMPT, but not on standard cognitive tests and vice versa. Such results are in accordance with a previous study by Burgess et al. (2009) that described a double dissociation in brain-injured patients between multitasking abilities and standard cognitive tests. Taken together, these results suggest that multitasking abilities make demands upon cognitive functions that are not assessed by standard cognitive tests.

The fact that source flexibility was found to play a major role in multitasking abilities is in agreement with the hypothesis that the ability to switch between environmental stimuli and mental representations may be particularly implicated in multitasking situations (Burgess et al., 2007). Nonetheless, the double dissociation observed in the present thesis between multitasking abilities and performance on a source flexibility task suggests that multitasking activities may also make demands upon other cognitive functions. One possibility would be the presence of an integrative and coordinating cognitive function or the influence of metacognition. Whatever the case may be, the influence of the specific strategies used to realize the task as well as the impact of other psychological factors (e.g., self-efficacy and motivation) need to be examined. Future studies are clearly needed to further explore the cognitive underpinnings of multitasking abilities.

In both populations, multitasking abilities were found to be particularly related to real world functioning, whereas standard cognitive tests did not reveal any significant correlation with functioning. Such results underline the need for assessing multitasking abilities in clinical practice in order to better evaluate and predict patients' real world functioning. From a broader standpoint, these results suggest the need for developing cognitive tests that are more closely related to real world activities.

No significant correlations were found between multitasking abilities and symptoms, suggesting the independence of both phenomena. Nonetheless, future studies are required to explore the relations between multitasking abilities and specific symptoms dimensions (e.g., dimensions of apathy and of disorganization).

The findings of the present thesis are particularly important for clinical practice as they underline the importance of assessing multitasking abilities in patients suffering from different pathologies in order to better evaluate patients' ability to realize complex activities of everyday life. In particular, tests assessing multitasking abilities provide different information about patients' cognitive and real world functioning than standard cognitive tests. More specifically, they inform clinicians about patients' ability to realize complex tasks that require integrated cognitive functions as many real world activities. In addition, the CMPT provides specific variables related to different abilities important for many real world activities, such as the ability to deal with distractors and to realize prospective memory instructions. Indeed, many of these abilities are not assessed by standard cognitive tests, as they are designed to assess one isolated cognitive function in a quiet and well-structured environment.

The CMPT possesses several advantages that make it a particularly interesting tool to use in clinical practice. Specifically, the CMPT reflects all the characteristics of real world multitasking activities (Burgess, 2000) but, at the same time, places participants in an unfamiliar situation which limits the influence of preexisting experiences and facilitates the interpretation of the results. Thus, the CMPT allows for evaluating multitasking abilities by placing participants in a prototypical multitasking situation that may reflect participants' abilities to realize other multitasking activities of everyday life. In addition, the CMPT was designed so that the task's level of difficulty can be modulated and different scenarios can be created. This modularity offers the possibility to develop parallel versions of the task to use in case of re-test or to integrate the task in cognitive remediation programs.

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Annex

Annex 1: Screenshots of the Computerized Meeting Preparation Task

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

Figure 2: The main room where the meeting takes place.

Figure 3: The office material area.

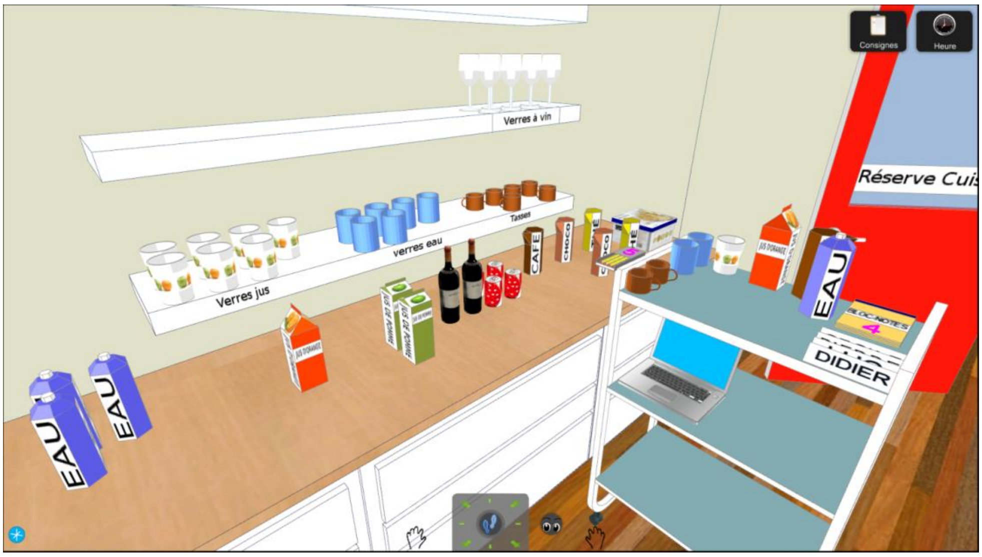

Figure 4: The kitchen area.

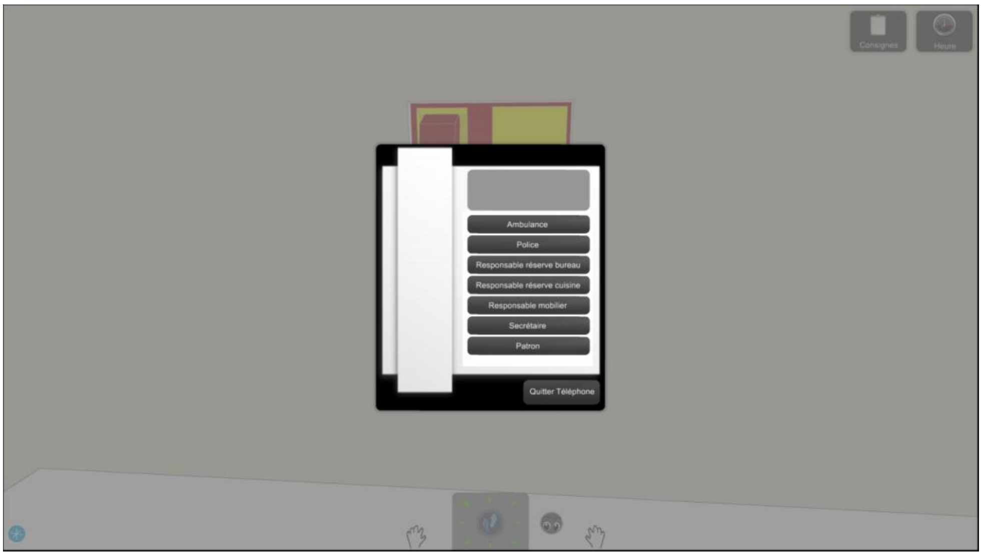

Figure 5: The telephone that can be used to order objects or contact someone.

Figure 6: The avatar that needs the camera.