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Does multitasking mediate the relationships between episodic memory, attention, executive functions and apathetic manifestations in traumatic brain injury?

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ABSTRACT

Apathy is frequently described in patients with traumatic brain injury (TBI); its negative consequences particularly affect functional independence. Among apathetic manifestations, lack of initiative and lack of interest have mainly been associated with cognitive impairments. However, few studies have been conducted to precisely identify the underlying cognitive processes. Our aims were (1) to determine the best predictor of apathy from among several cognitive processes, including episodic memory and attention/ executive mechanisms and multitasking, and (2) to examine to what extent multitasking could mediate the relationships between specific cognitive processes and lack of initiative/ interest. Seventy participants (34 patients with TBI matched with 36 control participants) were given a questionnaire to assess anxio-depressive symptoms, four tasks to assess specific cognitive processes, and one task to assess real-life multitasking. Participants' relatives completed an apathy questionnaire. Multitasking, as assessed by the number of goals not achieved, was the only significant predictor of apathetic manifestations. In addition, the mediation analyses revealed that multitasking performance mediated the relationships between verbal episodic memory and lack of initiative/interest, whereas executive and attentional functions were only indirectly related to lack of initiative/ interest due to their significant impacts on multitasking. These results shed new light on the aetiology of apathetic manifestations in patients with TBI, indicating how specific cognitive deficits are expressed in real-life multitasking, and consequently, how they may lead to the development and/or maintenance of apathetic manifestations.

Apathy is a frequent behavioural consequence of traumatic brain injury (TBI), described in about half of all patients at some stage in the post-TBI period (Arnould, Rochat, Azouvi, & Van der Linden, 2013). Post-TBI apathy has detrimental effects on quality of life (Marsh, Kersel, Havill, & Sleigh, 1998), functional independence (Arnould, Rochat, Azouvi, & Van der Linden, 2015), socio-professional reintegration (Mazaux *et al.,* 1997), and caregivers' well-being (Kelly,

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Brown, Todd, & Kremer, 2008). Because of its negative impact on everyday life, apathy constitutes a challenge for rehabilitation and clinical research. However, there are still some important gaps regarding the identification of the psychological mechanisms involved in the occurrence of this problematic behaviour.

There is some agreement in the literature that disorders of interest, action initiation, and emotional reactivity are all dimensions of apathy (Marin, 1991; Mulin et al., 2011). Recently, however, several studies have revealed that lack of initiative and lack of interest are strongly interrelated (Arnould et al., 2015; Esposito et al., 2014). Conceptually, lack of interest and lack of initiative are considered as the most direct motivational dimensions of apathy (Robert et *al.*, 2006), referring to diminished goal-directed cognition and behaviours. The successful execution of goal-directed behaviours depends on a wide range of psychological processes (Brown & Pluck, 2000). More specifically, most definitions acknowledge that apathy is not a single syndrome but rather a multidimensional concept, which is composed of various manifestations that are themselves underpinned by a variety of psychological processes, including cognitive aspects (e.g., executive functions, memory), motivational aspects (e.g., anticipatory pleasure), affective aspects (e.g., negative mood), and aspects linked to personal identity (e.g., self-esteem) (Arnould et al., 2013; Levy & Dubois, 2006; Stuss, Van Reekum, & Murphy, 2000). As regards cognitive processes, Levy and Dubois (2006) have related apathy to a reduction in goal-directed behaviour due to impairments in the cognitive functions required to formulate a plan of action, namely such executive functions as set-shifting, working memory, rule finding, and planning.

One of the few studies to explore the cognitive processes underlying apathetic manifestations in patients with TBI is the one by Andersson and Bergedalen (2002). Working with a group of 53 patients with severe TBI, these authors showed that apathy was significantly related to impaired performance on acquisition and recall memory (as assessed by the California Verbal Learning Test [CVLT]; Delis, Kramer, Kaplan, & Ober, 1987), executive functions (as assessed by the Wisconsin Card Sorting Test; Heaton, 1993), and psychomotor speed (as assessed by the trail-making test [TMT]; Reitan & Wolfson, 1993). However, some researchers have demonstrated that performance on specific cognitive measures does not always correlate with or capture the behavioural or functional problems often faced following a TBI (Levine, Dawson, Boutet, Schwartz, & Stuss, 2000; Pachalska, Kurzbauer, Talar, &MacQueen, 2002). For instance, Lengenfelder, Arjunan, Chiaravalloti, Smith, and DeLuca (2015) found no significant correlations between the apathy subscale of the Frontal Systems Behaviour Scale (FrSBe; Grace, Stout, & Malloy, 1999) and various measures of cognitive functioning as assessed by laboratory tasks. This may due in part to the limited ecological validity of traditional cognitive function measures (Marcotte, Scott, Kamat, & Heaton, 2010).

More specifically, some authors have emphasized the limited ability of traditional cognitive measures to detect apathetic manifestations because such measures do not take into account an essential characteristic of everyday life, namely 'multitasking' (Reid-Arndt, Nehl, & Hinkebein, 2007). Multitasking means that different tasks with different priorities are initiated and monitored in parallel, tasks are interleaved in order to use time efficiently, and behaviour

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is adjusted to unexpected interruptions or changes (Burgess, 2000). Furthermore, it implies that goals, time, and other task constraints are self-defined and that people flexibly switch between 'foreground' and 'background' actions in a self-initiated manner, thereby accomplishing their delayed intentions (Frisch, Forstl, Legler, Schope, & Goebel, 2012). In this sense, several studies have reported significant relationships between apathy and multitasking. For instance, Muller, Czymmek, Thone-Otto, and Von Cramon (2006) showed that apathetic patients with TBI performed significantly worse on the ecological Behavioural Assessment of Dysexecutive Syndrome battery (Wilson, Alderman, Burgess, Emslie, & Evans, 1996) than non-apathetic patients with TBI. Burgess, Alderman, Evans, Emslie, and Wilson (1998) reported that, in a group of 92 mixed- aetiology neurological patients with a majority of TBI, of the 10 neuropsychological measures of executive function used, only the modified Six-element Task (SET; Burgess *et al.,* 1996) was significantly related to the Dysexecutive Questionnaire intentionality subscore (i.e., a factor assessing everyday deficits in planning and decision-making). Furthermore, Esposito *et al.* (2010) showed that the number of rule breaks on the modified SET was a significant predictor of apathy, and especially of lack of initiative, in patients diagnosed with Alzheimer's disease.

Based on these various findings, it seems that multitasking situations, which are very representative of everyday life, are more sensitive at detecting lack of initiative/interest in patients with TBI than traditional structured laboratory tests. Indeed, several studies have shown that multitasking relies on a number of cognitive competencies such as planning, cognitive flexibility, and episodic memory (Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Logie, Trawley, & Law, 2011; McAlister & Schmitter-Edgecombe, 2013) that are necessary for successful goal-directed activities in everyday life (Esposito *et al.*, 2010; Mackinlay, Charman, & Karmiloff-Smith, 2006). In this context, it might be expected that the cognitive processes underlying multitasking are indirectly involved in the clinical expression of apathetic symptoms. In particular, executive functions that have been widely claimed to be related to multitasking abilities, such as set-shifting between mental sets or tasks, attention, updating, and monitoring working memory contents (Chevignard et al., 2009; Semkovska, Bedard, Godbout, Limoge, & Stip, 2004), may be involved in apathy through its impact on the ability to run multiple tasks simultaneously. For instance, a disturbance that specifically affects the ability to switch from one task to another could compromise the execution of multitasking in complex everyday situations, which may gradually lead to a loss of interest and initiative. Similarly, verbal episodic memory, which has also been widely associated with multitasking abilities due to its central role in prospective memory, namely in maintaining the contents of the intended actions (i.e., the objective, constraints or context) (Jovanovski et al., 2012; Laloyaux et al., 2013), might be involved in apathetic manifestations through its effects on multitasking situations.

The objective of this study was thus to examine the relationships between verbal episodic memory, sustained attention, executive functions (i.e., cognitive flexibility, updating working memory), multitasking, and lack of initiative/interest. We specifically hypothesized that (1) poorer multitasking performance would be related to reduced verbal episodic memory, poorer sustained attention and executive capacities, and greater lack of initiative/interest; (2)

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apathetic manifestations would best be predicted by multitasking rather than the specific cognitive processes assessed by traditional laboratory tasks; and (3) the relationships between verbal episodic memory, sustained attention and executive functions, on the one hand, and lack of initiative/interest, on the other hand, are mediated by multitasking performance. To assess multitasking, we used the meeting preparation task (MPT; Levaux, Van der Linden, Lar0i, & Danion, 2012), which evaluates an unfamiliar real-life multitasking activity. Indeed, several authors have emphasized that executive deficits in daily life may be best assessed by naturalistic assessment measures rather than office-based tests, which are somewhat artificial and do not address the broader demands of multitasking (Chevignard et *al.*, 2008; Lamberts, Evans, & Spikman, 2010). In addition, among real-life activity tasks, the MPT is probably more closely related to executive and mnesic capacities than cooking or shopping tasks, which are generally familiar to individuals (Laloyaux *et al.,* 2014) and therefore require fewer self-initiated behaviours. Apathy was assessed by the Initiative-Interest Scale (IIS; Esposito et al., 2014), which was recently developed specifically to assess lack of initiative and lack of interest. This scale provides a comprehensive assessment of these two apathetic manifestations insofar as it takes into account both the characteristics that are specific to these manifestations and those that are common or closely related to other features, such as curiosity in the case of lack of interest.

Methods

PARTICIPANTS AND PROCEDURE

A total of 70 participants took part in the study. Thirty-four non-consecutive adults with severe TBI (28 men, six women) were recruited from a head trauma rehabilitation unit in France. The patients'ages ranged from 18 to 65 years *(M* = 34.91, *SD* = 13.15) and their years of education from 7 to 21 (M = 13.50, SD = 3.27). Patients had an initial mean Glasgow Coma Scale score of 7.2 (range: 3-14) and a mean post-traumatic amnesia duration of 58.9 days (range: 5-420); time since injury ranged from 4 to 277 months (*M* = 55.68, *SD* = 59.27). Twenty-two patients had sustained their injuries after a motor vehicle accident, 10 after a fall, one after a bicycle accident, and the remaining one had been assaulted. The patients' caregivers completed a questionnaire to assess the patients' premorbid and current apathetic behaviours. Among the relatives who completed the questionnaire, 35% were spouses, 44% were parents, 3% were siblings, 15% were friends, and the remaining 3% were adult children. The control group consisted of 36 participants (29 men, seven women) aged between 18 and 67 years old (*M* = 34.3, *SD* = 12.2). Their educational level ranged from 10 to 20 years of education (*M* = 13.69, *SD* = 2.38). Among the relatives of control participants who completed the current level of apathy questionnaire, 49% were spouses, 20% were siblings, 17% were friends, and the remaining 14% were parents. Control participants were recruited from the general population and matched for age, gender, and years of schooling with the TBI patients.

Participants were excluded if they had any history of pre-injury psychiatric or neurological disease. Each participant was tested in a quiet room. No compensation was given for participation. The study was approved by the local ethics committee (CPP Ile de France VIII),

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and each participant completed an informed consent form.

QUESTIONNAIRES

Initiative-Interest Scale

The IIS (Esposito et al., 2014) is a new apathy rating scale, which was specifically designed to assess lack of initiative and lack of interest. The questionnaire consists of 10 items rated on a 4-point Likert scale (yes, mostly yes, mostly no, no), including six items that measure lack of initiative (e.g., 'He is an active person who takes initiative') and four that measure lack of interest (e.g., 'He is interested in many different things'). Items assessing lack of initiative mainly focus on self-initiated behaviours and on two other aspects of diminished goal-directed behaviour, namely lack of effort and lack of perseverance. To evaluate lack of interest, items assessing curiosity, defined as an active seeking of opportunities for new information and experiences (Kashdan et *al.*, 2009), were included. The questions were answered by a close relative of the participant, who assessed his or her apathetic behaviours both at the pre-injury level (retrospectively) and at the current level. The total score ranges from 10 to 40, with higher scores reflecting more apathetic manifestations. Good psychometric properties (the Cronbach's alpha calculated for a sample of 114 elderly people was .91) have previously been demonstrated (Esposito *et al.,* 2014). In addition, the exploratory factor analysis confirmed the strong relationships between lack of initiative and lack of interest, by showing that these two facets of apathy constitute a single dimension. To assess the structure of this scale in our sample of patients with TBI, we performed an exploratory factor analysis with the maximum-likelihood method on the current level of the scale. The Kaiser-Meyer-Olkin measure was .83 and Bartlett's test of sphericity reached statistical significance ($p < .001$), supporting the factorability of the correlation matrix. A parallel analysis (O'Connor, 2000) indicated that the IIS was unidimensional. The results of the factor analysis revealed the presence of one factor (eigenvalue of 4.93) that accounted for 44.4% of the total variation. Item loadings ranged from 0.24 to 0.80. The Cronbach's α coefficient was .87 for the total 10-item IIS, which indicates a high level of internal consistency.

Hospital Anxiety and Depression Scale

Insofar as apathy and depression frequently coexist in patients with TBI (Andersson, Krogstad, & Finset, 1999), an assessment of anxio-depressive symptoms was included in the study as a control variable. The Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) is a 14-item rating scale that assesses the severity of anxiety and depression symptoms in the previous week. Items are rated on a 4-point scale from 0 (no symptoms) to 3 (severe symptoms). Sum scores are computed for both subscales, ranging from 0 to 21. This scale has been shown to be a reliable, valid measure in individuals with TBI (Schonberger & Ponsford, 2010).

COGNITIVE MEASURES

Meeting preparation task

The MPT (Levaux, Larpi, et al., 2012; Levaux, Van der Linden, et al., 2012) is a real-life activity

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task designed to take into account the complex, multitasking nature of unfamiliar everyday life activities. Participants are required to prepare a room for a meeting that nine people (a manager, a secretary, and seven guests) will attend. The task took place in a room at the hospital that contained a screen, a video projector, a table with 10 chairs, and another table with all the necessary items including a clock and a telephone. Participants had to arrange the places (with name cards), beverages, and materials (glasses, cups, notebooks, pens, laptop, microphone, projector, projection screen), while respecting the beverage list (e.g., 'Patrick wants orange juice and coffee') and a set of six rules (e.g., 'The manager is always seated at the head of the table with his laptop', etc.). Distractor items were also included that were not necessary for the required task (e.g., other beverages, too many glasses or cups, name cards for guests who were not attending). Regarding the microphone, participants were informed that they would receive a phone call from the secretary to confirm whether or not the microphone would be used during the meeting. In addition to involving planning capacities, this task engaged prospective memory (i.e., get coffee from the kitchen 10 min after the beginning of the task) and updating in goal pursuit (i.e., remove the name card, materials, and beverage of a guest who withdrew from the meeting). The updating required reorganizing the places to respect the rule that 'a woman cannot be placed beside another woman'. These two components were controlled as follows: while performing the task, as soon as a participant placed the name cards on the table, there was a phone call announcing that the microphone would not be used and that one guest had decided not to attend the meeting. Instructions were given to participants orally and in writing. Three sheets with the instructions, the list of attendees and their beverages, and the rules were given to participants, who were told that they could refer to them if needed. The task examiner was present during the task and referred participants to the instructions if they had any questions. Participants' performance was recorded on video, and a twofold evaluation was performed by independent examiners. The dependent variables retained were the duration of task execution, the number of inefficiencies (i.e., number of goals/rules that were unachieved/violated), and time deviation on the prospective memory index. Pearson's correlations revealed that the number of inefficiencies in the MPT was significantly associated with both the total number of errors ($r = .42$, $p < .05$) and the total number of points in the SET ($r = —.34$, $p = .05$), a laboratory task designed to assess multitasking (Shallice & Burgess, 1991; French adaptation, Garnier *et al.,* 1998), providing evidence of convergent validity.

Trail Making Test

The TMT consists of two parts (Reitan & Wolfson, 1985). Subjects must first draw lines to connect consecutively numbered circles on one worksheet (part A) and then connect the same number of consecutively numbered and lettered circles on another worksheet by alternating between the two sequences (i.e., numbers and letters; part B). Completion time for parts A and B was taken into account. The dependent variable was the completion time for part B minus the time for part A to further isolate executive functioning from attention (Arbuthnott & Frank, 2000). The TMT has been shown to be sensitive to the presence of brain injury in general and frontal lobe injury in particular (Chan, 2000). In addition, this task has been related to multitasking performance (Jovanovski *et al.*, 2012) and apathetic manifestations (Andersson

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& Bergedalen, 2002) in patients with brain damage.

2-Back ‘working memory" task

Updating in working memory was assessed by the 2-back subtest of the computerized Test for Attentional Performance (TAP; Zimmermann & Fimm, 1995). Numbers were presented on the computer screen at a 1-s rate. Patients were required to press a key when a number matched a number presented two back in the sequence. The measure retained was the number of omissions. Several studies have demonstrated that the ηback paradigm provides a valid measure of working memory updating (Jaeggi, Buschkuehl, Perrig, & Meier, 2010) and is sensitive to deficits after TBI (Perlstein et al., 2004). In addition, this component of working memory has been specifically related to multitasking performance (Rose et al., 2015), and several studies have shown that working memory is involved in apathy(e.g., Esposito, Rochat, Juillerat Van der Linden, & Van der Linden, 2012).

California Verbal Learning Test

The CVLT (Delis, Kramer, Kaplan, & Ober, 2000; Delis et al., 1987) is a widely used clinical test of verbal episodic memory, which consists of a 16-item word list (List A), with four words from each of four semantic categories (fruits, spices, clothes, and tools). The administration procedure involves the oral presentation and recall of List A over five learning trials, a single presentation of a 16-item distractor word list (List B), short- and long-delay recall trials of List A (free and semantically cued), and a recognition trial of List A. The authors report excellent internal consistency and adequate alternate form reliability. The selected outcome measures were the four factors identified by DeJong and Donders (2009), who examined the latent structure of the CVLT in a clinical sample of 223 persons with TBI. The factors and their related variables are as follows: attention span (List A trial 1, List B), learning efficiency (List A trial 5, semantic clustering, recall consistency), delayed memory (short-delay free recall, short-delay cued recall, long-delay free recall, long-delay cued recall, recognition hits), and inaccurate memory (total intrusions, recognition false positives). Studies have shown significant relationships between this episodic memory task and multitasking (e.g., Jovanovski *et al.,* 2012), as well as apathetic manifestations (e.g., Andersson & Bergedalen, 2002).

Simple reaction task

The Simple reaction task (SRT; Volle, Gonen-Yaacovi, Costello Ade, Gilbert, & Burgess, 2011) was designed to assess sensorimotor reaction times (RTs). Participants were shown pictures and words, and had to press the space bar as soon as the next item appeared. One hundred and twenty items were presented, with three possible pseudo-randomly ordered interstimulus intervals: 0.5 s (40 times), 1 s (40 times), and 2 s (40 times). Stimulus duration was self-paced. The variable retained was the intra-individual coefficient of variation (ICV; see Stuss, Murphy, Binns, & Alexander, 2003) of RTs, computed by dividing the standard deviation by the mean RT, as a measure of sustained attention. Sustained attention difficulties have recently been associated with a central aspect of diminished goal-directed behaviour, namely lack of perseverance (Rochat, Billieux, et *al.*, 2013).

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STATISTICAL ANALYSES

First, exploratory analyses of each variable were conducted to explore the distribution of the data. T-tests were then performed to appraise the changes between the pre-injury scores and current scores for apathy and to compare the performance of patients with TBI and control participants on the neuropsychological tests and questionnaires. Pearson's correlations were used to evaluate the relationships between specific cognitive measures and apathy in the patient group. Principal component analyses (PCAs) were performed to investigate whether the specific cognitive data could be reduced, and then, Pearson's correlations were used to explore the relationships between these cognitive components, apathy and multitasking variables. Note that all correlation, regression, and mediation analyses used the z-scores of patients with TBI relative to control participants. Multiple regression analyses were performed to find out which components best predicted apathy. Finally, a product-of-coefficient test for mediation analyses was performed using bootstrapping procedures, a nonparametric re-sampling technique to test for indirect effects (Preacher & Hayes, 2008), in order to test our principal hypothesis that multitasking operates as a mediator between specific cognitive mechanisms and apathy. Bootstrapping involves estimating the indirect effect in thousands of re-sampled observations within the data set. It calculates an approximation of the distribution of the indirect effect, together with the confidence intervals (CIs) around the effect. CIs are used to test whether the distribution of the indirect effect is significantly different from zero. This method tends to be more robust for small samples than alternative methods, such as the Sobel test. Indeed, bootstrapping has been found not to inflate Type I and Type II error rates and to have higher power (Fritz & MacKinnon, 2007). In addition, bootstrapping does not assume multivariate normality. The significance of the mediation effect is determined when the 95% bias-corrected CIs do not contain zero. Mediation analyses were performed using MEDIATE, a software developed by Hayes and Preacher (2014).

Results

PRELIMINARY ANALYSES

Skewness and kurtosis of each variable revealed that the majority of the data did not strongly deviate from normality, considering that absolute values for skewness and kurtosis >3 and 20, respectively, are judged to be extreme (Weston & Gore, 2006). Specifically, the results showed that skewness ranged from —0.98 to 2.51 and kurtosis from —1.27 to 8.34.

COMPARISON ANALYSES

Comparison between premorbid and current levels of patients' apathetic behaviour

The paired-samples t-test, performed to appraise apathy changes between the pre-injury and current conditions on the IIS scale completed by the relatives, highlighted a significant increase in apathy from the pre-injury (M = 17.09, SD = 5.32) to the current condition (M = 23.31, SD = 6.43, $t(33) = -5.38$, $p < .001$).

COMPARISON BETWEEN TBI PATIENTS AND CONTROL PARTICIPANTS

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A series of t-tests for independent samples indicated that patients with TBI and control participants did not differ significantly in age, $t(68) = 0.19$, $p = .85$, or education level, $t\,(68) = —0.29$, $p = .78$. Group comparisons on the clinical and cognitive data are reported in Table 1. The results revealed significant group differences on all the measures, except the TMT, for which we observed a trend towards significance, and the inaccurate memory variable of the CVLT. More specifically, compared to control participants, patients with TBI scored significantly higher for current apathy, depression, and anxiety. As for the specific cognitive measures, patients scored significantly below the matched controls on all recalls of the CVLT, had more variable RTs on the SRT, and made more omissions on the TAP 2-back. Finally, regarding the MPT, group comparisons indicated that the duration of task execution, the number of inefficiencies, and the time deviation on the prospective memory index were significantly greater in the TBI group than in the controls. Cohen's effect size values were moderate to large (ranging from $d = 0.34$ to $d = 1.68$).

Table 1. *Means, standard deviations, and results of group comparisons on clinical and cognitive measures for patients and control participants (t-tests for independent sample)*

	TBI patients *M (SD)*	Control participants *M (SD)*	*t*	*p*-Value	*d*
IIS	*23.31* (6.43)	14.60 (3.52)	6.76	.001**	1.68
HADS anxiety	8.21 (4.87)	5.74 (2.79)	2.59	.012*	0.62
HADS depression	6.09 (4.11)	3.46 (2.56)	3.19	.002**	0.77
TMT (time B minus A)	50.71 (30.03)	40.11 (32.63)	1.41	.16	0.34
SRTICV	0.26 (0.10)	0.22 (0.08)	2.12	.037*	0.51
TAP 2-back (omissions)	2.68 (2.52)	1.28 (1.91)	2.63	.011*	0.63
MPT time	878.21 (384.37)	592.94 (93.34)	4.26	.001**	1.02
Inefficiency	1.32 (1.36)	0.63 (0.65)	2.72	.008**	0.65
Prospective memory	2.27 (1.33)	2.94(1.30)	-2.10	.04*	0.51
CVLT attention span	6.15 (1.96)	7.54(1.75)	-3.14	.002**	0.75
Learning efficiency	32.60 (4.12)	34.49 (3.62)	-2.04	.045*	0.49
Delayed memory	11.15 (3.40)	13.43 (2.03)	-3.43	.001**	0.82
Inaccurate memory	3.81 (4.07)	2.32 (3.10)	1.73	.09	0.41

Note. IIS = Initiative-Interest Scale; HADS = Hospital Anxiety and Depression Scale; TMT = Trail Making Test; SRT = Simple Reaction Time; ICV = intra-individual coefficient of variation; TAP = Test for Attentional Performance; MPT = meeting preparation task; CVLT = California Verbal LearningTest; TBI = traumatic brain injury.

$^*p < .05$, $^{**}p < .01$.

CORRELATION ANALYSES

In the TBI group, Pearson's correlations were computed between apathy, cognitive measures,

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and the demographic and clinical data. The analyses revealed that apathy was (1) negatively related to the learning efficiency (r = —.37, p < .05) and delay memory (r = —.46, p < .01) factors of the CVLT, and (2) positively related to the number of inefficiencies in the MPT (r = .47, p < .01). In addition, the number of inefficiencies in the MPT was significantly associated with time difference on the TMT (r = .36, p < .05) and related to three factors of the CVLT: attention span (r = —.40, p < .05), delayed memory (r = —.44, p = .01), and inaccurate memory (r = .34, p = .05). As regards the demographic data (age, education level, time since injury, and severity of trauma), a significant correlation was observed between educational level and the number of inefficiencies in the MPT (r = —.38, p < .05). No other correlations reached statistical significance.

FACTOR *ANALYSIS OF THE VARIOUS SPECIFIC COGNITIVE MEASURES*

We performed a PCA (with varimax rotation) on the set of specific cognitive measures to extract processing components and then examined the relations between these processing components, the multitasking variables, and apathy. Specifically, the TMT Part B minus Part A, the ICV derived from the SRT, the TAP 2-back (number of omissions), and the four factors of the CVLT were included in the analysis. The results of the PCA revealed the presence of two components with eigenvalues exceeding 1, which explained 35.9% and 22.6% of the variance, respectively. The first factor consisted of four variables representing episodic memory (variables related to the CVLT), and the second factor was composed of the other three variables, which are more representative of executive and attentional functions (variables related to TMT, TAP 2-back and SRT). Component loading for the episodic memory factor and the executive/attentional factor are presented in Table 2. The Kaiser-Meyer-Olkin measure was .59, Bartlett's test of sphericity reached statistical significance (p < .001), and the correlation between the two components was not significant (r = .01, p = .99).

Table 2. *Component loadings for the episodic memory factor and the executive/attentional factor*

	Episodic memory factor	Executive and attentional factor
CVLT delayed memory	0.89	-
Learning efficiency	0.82	-
Inaccurate memory	-0.77	-
Attention span	0.61	-
SRT ICV	-	0.81
TMT (time B minus A)	-	0.74
TAP 2-back (omissions)	-	0.31

Note. TMT = Trail Making Test; SRT = Simple Reaction Time; ICV = intra-individual coefficient of variation; TAP = Test for Attentional Performance; CVLT = California Verbal Learning Test.

Finally, the correlation analyses showed that the episodic memory factor was negatively related to apathy (r = —.45, p < .01) and to the number of inefficiencies in the MPT (r = —.39, p

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< .05), indicating that the better episodic memory performance was, the lower the number of inefficiencies and the lack of initiative and interest score were. In addition, the results revealed that the executive/attentional factor was positively related to performance on the MPT, namely the duration of task execution ($r = .36$, $p < .05$) and the number of inefficiencies ($r = .39$, $p < .05$): the greater the executive/attentional capacity, the better the MPT performance. No other correlations reached statistical significance.

REGRESSION ANALYSIS

A regression analysis was performed to find out which components among the specific cognitive processes and multitasking performances best predicted lack of initiative and interest.

Table 3. *Multiple regressions for lack of initiative and interest*

Dependent variable	Predictor variable	*B*	*SE*	*t*	*p-value*	β
IIS	(Intercept)	21.42	1.42	15.08	.001*	-
	Episodic memory factor	-1.80	1.11	-1.63	.11	-.28
	Executive and attentional factor	-0.71	1.17	-0.61	.55	-.11
	MPT time	0.21	0.26	0.79	.44	.13
	MPT inefficiency	1.17	0.56	2.08	.047*	.38

Note. MPT = meeting preparation task; IIS = Initiative-Interest Scale.

*p < .05.

Insofar as the prospective memory index of the MPT was not correlated with apathy and cognitive measures, we did not include this variable in the regression model. We therefore computed a multiple linear regression using the number of inefficiencies and the duration of task execution in the MPT, with the episodic memory factor and the executive/attentional factor as predictors, and the lack of initiative and interest score as the dependent variable (see Table 3). There was no multicollinearity, and the results showed that the number of inefficiencies in the MPT was the only significant predictor of lack of initiative and interest, adjusted $R^2 = .224$, $F(4, 29) = 3.38$, $p < .05$. In order to precisely determine the direction of the relationship between apathy and multitasking, we also performed a regression analysis to examine the potential predictive role of apathetic manifestations on multitasking. More specifically, the lack of initiative and interest score, the episodic memory factor, and the executive/attentional factor were included as predictors and the number of inefficiencies in the MPT as the dependent variable (see Table 4). There was no multicollinearity, and the results showed that the episodic memory factor was the only significant predictor of the number of inefficiencies in the MPT, while the lack of initiative and interest score showed a strong tendency towards statistical significance, adjusted $R2 = .328$, $F(3, 30) = 6.36$, $p < .01$.

MEDIATION ANALYSES

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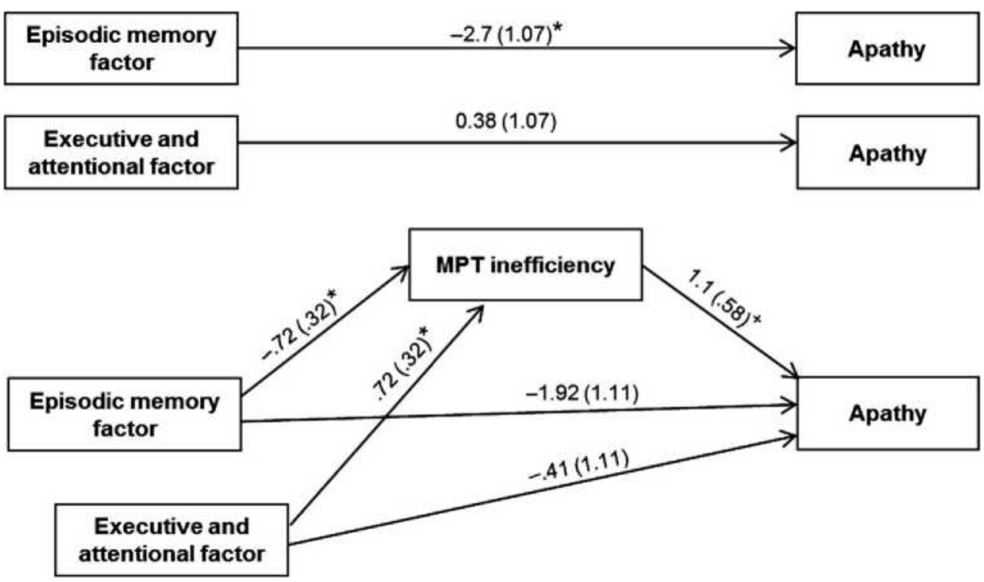
We had hypothesized that multitasking as assessed by the MPT should be a mediating variable between specific cognitive processes (episodic memory, executive, and attentional functions) and apathy. Given the significant correlation observed between MPT inefficiency and educational level, we entered the latter variable as a covariate into the mediation models. As depicted in Figure 1, the mediation analysis points in the same direction as our hypothesis, showing that multitasking mediates the effect of episodic memory on apathy. Specifically, the results showed that: (1) the episodic memory factor was significantly related to MPT inefficiency (b = —0.72, t = —2.23, $p < .05$); (2) a trend between MPT inefficiency and apathy was observed (b = 1.10, t = 1.88, p = .07); and (3) the significant relationship between the episodic memory factor and apathy (b = —2.7, t = -2.53, $p < .05$) was reduced when MPT inefficiency was included in the regression equation (b = —1.92, t = —1.73, p = .10). The 95% CI from the bootstrap analysis for indirect effects did not include zero (CI = —1.85 to —0.03), indicating a mediation effect. As for the executive/attentional factor, the results revealed only a significant indirect effect on apathy through MPT inefficiency.

Table 4. *Multiple regressions for the number of inefficiencies in the MPT*

Dependent variable	Predictor variable	*B*	*SE*	*t*	p-value	β
MPT inefficiency	(Intercept)	-1.42	1.26	-1.12	.27	-
	Episodic memory factor	0.77	0.30	2.52	.017*	.36
	Executive and attentional factor	-0.52	0.34	-1.53	.14	-.25
	IIS	0.11	0.05	2.03	.051^{f}	.33

*Note. MPT = meeting preparation task; IIS = Initiative-Interest Scale. *p < .05, §p < .10.*

Figure I. *Mediation of the episodic memory factor-apathy relationship and the executive/attentional factor-apathy relationship by MPT inefficiency after controlling for educational level. Note. Path values represent unstandardized regression coefficients. Standard errors are in parentheses. $^{+}$p < .10, *p < .05.*



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Indeed, the total effect of the executive/ attentional factor on apathy was not significant, but a significant indirect effect through MPT inefficiency was found ($b = 0.72$, $t = 2.24$, $p < .05$), with a 95% CI from the bootstrap analysis for indirect effects that did not include zero (point estimate = 0.79, *SE* = 0.58; CI = 0.03-1.85). Finally, no significant effect of educational level on MPT inefficiency ($b = —0.14$, $t = —1.41$, $p = .17$) or apathy ($b = —0.23$, $t = —0.68$, $p = .50$) was observed. The R^2 value indicated that the overall model explains 20.9% of the variance of apathy.

Discussion

The objective of the study was to examine the relationships between verbal episodic memory, sustained attention, executive functions (i.e., cognitive flexibility, updating working memory), multitasking, and lack of initiative/interest in patients with TBI. The main findings were the following: (1) patients had higher scores on lack of initiative/ interest after the TBI and greater apathy than control participants; (2) multitasking performance as assessed by the number of inefficiencies in the MPT was significantly related to the lack of initiative/interest, executive/attentional, and episodic memory factors; (3) multitasking was the only significant predictor of apathetic manifestations; (4) multitasking performance mediated the relationship between episodic memory capacities and lack of initiative/interest; and (5) the executive and attentional factor had an indirect effect on lack of initiative/interest due to its impact on multitasking performance.

These findings confirmed that TBI is frequently associated with lack of initiative and lack of interest. Indeed, the comparison analyses showed that patients displayed a significant increase in these apathetic manifestations from their pre-injury condition and also that current levels of lack of initiative/interest were significantly higher in patients with TBI than in the control participants according to their respective relatives. Moreover, our results are in line with previous findings showing that lack of initiative and interest was specifically related to poorer psychosocial functioning, namely independent living skills, occupational activities, and interpersonal relationships in patients with TBI (Arnould *et al.,* 2015). Indeed, the strong association observed between lack of initiative/interest and multitasking, which is reported to be the most representative and predictive measure of real-life functioning (Burgess *et al.*, 2000), underscored the functional disabilities related to these apathy manifestations.

More specifically, as regards multitasking performance, the only variable significantly related to apathy, episodic memory, and executive/attentional factors was the number of inefficiencies, which corresponds to the number of goals and rules not achieved or not respected. This result corroborates previous studies showing that patients with brain damage were particularly impaired on these variables compared to control participants. For instance, a study by Chevignard *et al.* (2008) showed that more than half of a group of 45 patients with TBI did not achieve the goal during a cooking task. Furthermore, Laloyaux et *al.* (2014) demonstrated that respect of the rules was the main predictor of real-world functioning in patients with schizophrenia performing a computerized version of the MPT. Consequently, our

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findings revealed that lack of initiative/interest is not associated with mere cognitive slowing or non-optimal organization leading to an increase in completion time, but rather with a real inability to run multiple tasks simultaneously, due to specific cognitive deficits affecting episodic memory or set-shifting. As well, it should be noted that the MPT prospective memory index was not correlated with any cognitive and behavioural variables in our study. Given the substantial effect of verbal episodic memory on prospective memory according to the literature (Burgess *et al.*, 2000; Schmitter- Edgecombe & Wright, 2004), the lack of relationship between these two variables is surprising. However, it is possible that the prospective memory index of the MPT was not sufficiently sensitive. Indeed, the retrieval of this time-based prospective intention ('get coffee from the kitchen 10 min after the beginning of the task') may be facilitated by the context and especially by the time when participants serve the beverages. Further studies are needed to explore the relationships between episodic memory, apathy, and timebased prospective memory, which is reported to involve a high degree of self-initiated processes (Einstein & McDaniel, 1990).

To the best of our knowledge, this is the first study to show that multitasking performance as assessed by the number of goals unachieved tends to mediate the relationship between episodic memory deficits and lack of initiative/interest in patients with TBI. In other words, patients who have episodic memory difficulties are likely to fail to memorize or to forget the constraints or goals of real-life activities and thus not to perform them, which may in turn lead, at a behavioural level, to a lack of initiative and interest. Our findings are in accordance with several studies conducted in patients with brain damage that showed significant relationships between episodic memory and multitasking performance as assessed by the number of omissions or rule violations (Rempfer, Hamera, Brown, & Cromwell, 2003; Scott *et al.,* 2011); between these multitasking variables and apathetic manifestations (Burgess *et al.*, 1998; Esposito *et al.*, 2010); and between apathetic manifestations and episodic memory (Andersson & Bergedalen, 2002; Baudic et *al.*, 2006). In addition, our results point in the same direction as those of Burgess et *al.* (2000), who tested the ability of patients with frontal lobe lesions to learn task rules before the beginning of a multitasking assessment and showed that retrospective memory demands (i.e., rule learning and remembering) constituted a significant construct supporting the ability to run multiple tasks simultaneously. More specifically, the authors stressed the central role of retrospective memory in multitasking compared to planning and prospective memory, which largely depend on efficient learning and memory for the rules governing the task. Note that, in our study, participants had the list of instructions available to them at all times during the task. Despite this, they exhibited mnesic difficulties impacting multitasking performance, which could be explained by a failure to use the list often enough to compensate for their memory problems due to their unawareness of these impairments (Knight, Titov, & Crawford, 2006).

Furthermore, the results also indicated that the occurrence of apathetic manifestations was not directly related to the executive/attentional dysfunctions as such but rather to the expression of these dysfunctions in real-life multitasking situations. Consequently, these results clearly highlighted the limited ability of specific executive measures to identify apathetic manifestations in the TBI population. In addition, our findings are consistent with

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studies conducted in patients with TBI that showed that specific executive and attentional functions are significantly involved in multitasking (Chevignard *et al.,* 2009; Jovanovski et al., 2012). More specifically, the results revealed that cognitive inflexibility was particularly closely related to MPT inefficiencies. In this sense, Semkovska et al. (2004) showed that, of the various executive functions, cognitive flexibility was the best predictor of the number of goals achieved during a meal cooking test in patients with schizophrenia. The authors reported that patients exhibited inefficient and redundant shifting between the macro-steps, which resulted in a tendency to shift from one dish to another, without completing the preparation of any of them. Overall, our study suggests that shifting impairments lead to an inability to meet all the targets set during a multitasking situation, which may result in a lack of initiative and interest in patients with TBI. It is noteworthy that we focused only on certain executive processes, but other functions such as inhibition and planning have also been related to the emergence of goal- directed behaviour in patients with brain damage (Andersson & Bergedalen, 2002; Liemburg et al., 2015).

Other aspects of our results should be discussed. First, as regards the direction of the relationship between apathy and multitasking, the regression analyses showed that lack of initiative and interest tends to be associated with the number of inefficiencies in the MPT. Thus, although several results converge to suggest that multitasking ability plays a specific role in apathetic manifestations - namely the facts that the only significant predictor of apathy was the number of inefficiencies in the MPT and the best predictor of inefficiencies in the MPT was the episodic memory factor - it is possible that apathetic manifestations may gradually lead to or exacerbate multitasking difficulties. Indeed, as mentioned previously, apathy is related to a variety of psychological mechanisms, including not only cognitive impairments such as multitasking but also motivational, affective, and/or personal identity disturbances (Arnould et *al.*, 2013). Consequently, it could be expected that low self-efficacy beliefs, poor effort mobilization, or poor reward sensitivity lead to apathetic manifestations (Dumont, Gervais, Fougeyrollas, & Bertrand, 2004; Rochat, Van der Linden, *et al.,* 2013), which in turn gradually compromise the execution of multitasking. For instance, faced with a complex everyday situation, people with low self-efficacy beliefs regarding their cognitive abilities may be passive and use avoidance coping because the goal appears unreachable (Finset & Andersson, 2000); this behaviour may then lead to poor performance in a multitasking situation. Further studies are clearly needed to clarify the directionality of the relationship between the lack of initiative and lack of interest dimensions of apathy and multitasking ability, by increasing the sample size and using longitudinal designs. Second, concerning the anxio-depressive symptoms, which were included in the study as control variables, the results showed that patients with TBI had more symptoms than control participants, but no significant correlation was observed between these symptoms and lack of initiative and interest, which corroborates previous studies (Kirsch-Darrow, Fernandez, Marsiske, Okun, & Bowers, 2006; Levy et *al.*, 1998). However, it should be noted that this lack of association could also be due to the nature of the assessment of the two constructs (self-report for anxiety and depression vs. hetero-report for apathy). Thus, further studies are needed to better understand the relationships between anxiety, depression, and apathy, as well as their underlying processes.

To conclude, the main result of this study showed that multitasking ability is a key variable affecting the relationships between, on the one hand, episodic memory, sustained attention and executive functions and, on the other hand, lack of initiative and interest in patients with TBI. Further studies are needed to confirm these results and to explore the involvement of other psychological factors in apathy (e.g., inhibition, self-esteem, self-efficacy), through their impacts on multitasking performance. Longitudinal studies are also required to investigate the predictive role of multitasking competencies and their related processes in the occurrence of apathetic manifestations. Such findings will be very valuable for management strategies as they will allow us to determine how specific psychological deficits are expressed in real-life situations and how they lead to the emergence and persistence of apathetic manifestations. Finally, as regards the apathy scale, the IIS appeared to be reliable in patients with TBI, but further studies are needed to confirm its validation in this population.

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