Just do it! How performing an action enhances remembering in transient global amnesia.

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Mathieu Hainselin[1,2,3,4], Peggy Quinette[1,2,3,4], Aurelija Juskenaite[1,2,3,4], Béatrice Desgranges[1,2,3,4], Olivier Martinaud[6], Vincent de La Sayette[1,2,3,5], Didier Hannequin[6,7], Fausto Viader[1,2,3,5], and Francis Eustache[1,2,3,4]

[1] Inserm, U1077, Caen, France

[2] Université de Caen Basse-Normandie, UMR-S1077, Caen, France

[3] Ecole Pratique des Hautes Etudes, UMR-S1077, Caen, France

[4] CHU de Caen, U1077, Caen, France

[5] CHU de Caen, Service de Neurologie, Caen, France

[6] CHU de Rouen, Rouen, France

[7] Inserm, U1079, Rouen, France

Correspondence to: Francis Eustache

Inserm - EPHE - Université de Caen Basse-Normandie, Unité de recherche U1077

"Neuropsychologie et neuroanatomie fonctionnelle de la mémoire humaine"

CHU, Avenue de la Côte de Nacre, 14033 Caen Cedex 09, France

Tel.: +33(0)2 31 06 51 97

Fax: + 33(0)2 31 06 51 98

E-mail: neuropsycho@chu-caen.fr

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Abstract: Transient global amnesia is a clinical syndrome characterized by the sudden onset of a massive episodic memory deficit that spares other cognitive functions. As such, it provides a unique human amnesia model for testing the enactment effect (i.e., better memory for performed actions than for verbally encoded sentences). Our main aim was to test whether the enactment effect is preserved in TGA patients, both tohave a better understanding and to test the robustness of this effect in a massive amnesia.

Object-action pairs were encoded under four conditions: verbal, experimenter-performed, and two enacted conditions (self-performed and self-performed with choice). We tested object-action pair retrieval using cued recall and recognition tasks, and source memory using a free recall task. We also assessed binding, executive functions, short-term memory, episodic memory, anxiety and mood. We run correlations to control for their putative effects on memory for action. Data were collected from 24 patients, 16 of whom were examined during the acute phase and eight the day after, as well as from 18 healthy controls.

The memory performances of the patients in the acute phase improved for both the i) cued recall score, between the verbal, experimenter-performed and self-performed with choice conditions, and ii) the total recognition score, between the verbal condition and the two enacted conditions. Correlations were found between self-performed task enhancement and both the binding and anxiety.

In spite of their severely impaired episodic memory, patients with TGA benefit from the enactment effect. These results are discussed in relation to the role of motor components and episodic integration in memory for actions. We suggest that enactment effect can be used in clinical practice and rehabilitation, possible even for patients with a massive memory impairment.

Key words: transient global amnesia; enactment effect; self-performed task; binding; memory for action

1. Introduction

Transient global amnesia (TGA) is a neurological syndrome that occurs in middle age and lasts up to 24 hours. Its aetiology remains elusive, despite recent evidence of transient focal abnormalities in the CA1 hippocampal region(Bartsch et al., 2008). This amnesia is characterized by the sudden onset of massive anterograde amnesia with no attendant neurological or cognitive impairments(Quinette et al., 2006a). During the acute phase, patients also display increased anxiety and a deterioration in mood, which have a deleterious impact on episodic memory functioning(Noël et al., 2008).

Despite the massiveness of the episodic memory deficit, which is present whatever the types of materials that have to be memorizedand whatever the encoding and retrieval conditions, TGA patients have been shown to be capable of acquiring new skills in procedural memory(Eustache et al., 1997), the perceptual representation system(Kazui and Tanabe, 1995), and semantic memory(Beauregard et al., 1997; Guillery et al., 2001), using priming effects. No study, however, has ever investigated whether TGA patients can improve their episodic memoryperformance during the amnesic episode.

In the past three decades, many studies have focused on memory for actions(for a review, see Engelkamp, 1998; Nilsson, 2000), a particular form of episodic memory(Tulving, 2002; Zimmer et al., 2001).Most of them focused on enactment effect, an improvement of recall and recognition scores for action phrases (e.g., "put on a glove", "move the pen to the right") when participants perform the actions (subject-performed task or SPT) during encoding compared with classic condition under which participants merely listen to or read the phrases (verbal task or VT).

Of the few studies that have explored this memory for actions in pathological conditions(for review, see Hainselin et al., 2013), the majority havedemonstrated the

robustness of the enactment effect inchildren with autistic spectrum disorders, Parkinson's disease and frontal lobe syndrome and Korsakoff's syndrome while only a little benefit was observed in schizophrenia and sometimes in Alzheimer's disease, and in rats (Thompson, 1959). However, a patient with developmental amnesia (Gardiner et al., 2006) showed no enactment benefit, suggesting other functions than episodic memory might contribute to this effect.

Although the enactment effect has frequently been studied since the 1980's, there is still no consensus on how it enhances memory(for review, see Madan and Singhal, 2012), including if it is supported by episodic memory. There are two main schools of thought: according to Engelkamp(2001), participants first have to plan the action, involving motor and visual information. This multimodal theory is supported by the advantage of SPTs over experimenter-performed tasks (EPTs), when healthy participants simply observe somebody else performing the action. The planning component does, however, seem to be essential, but needs to be more extensively studied, for example by letting participants choose which actions to perform with the different objects. According to Kormi-Nouriand Nilsson (2001), enactment enhances episodic integration, binding the action verbs and object nouns together. This "glue" theory has mostly been studied by comparing well-integrated ("put the money in the wallet") and poorly integrated ("put the money in the napkin") actions (Mangels and Heinberg, 2006). Although this second hypothesis is a very important topic of discussion, binding itself had never been assessed with a specific task.

Thus, the main aim of our study was to assess whether the enactment effect is sufficiently robust for it to be observed during a massive amnesia episode such as TGA. Our second objective was to gain a better understanding of how enactment enhances memory byinvestigating the functions that sustain the enactment effect on patients. To this end, we chose to assess binding with a specific task to test the "glue" theory. Inhibition and shifting

(as patients have to perform different actions and shift from one to the other), short-term memory and episodic memory itself, thought to influence enactment effect, were also assessed. Given the impact of patients' emotional state on memory, especially during TGA, we also wondered whether anxietyand mood might diminish the enactment effect.

2. Methods

2.1. Participants

Twenty-four TGA patients admitted to the emergency departments of Caen and Rouen University Hospitals between June 2010 and March 2012 were included in the study. Of these patients, 16 were in the acute phase (*acute*) and eight in the post-acute phase (*day-after*). Descriptive data are reported in Tab. 1. Eight of them (six acute and two day-after) were drawn from the cohort of a previously published study of awareness of memory failure(Hainselin et al., 2012). The control group consisted of 18 healthy individuals. All participants gave their written informed consent to the study, which was approved by the local ethics committee.

All patients met the standard clinical criteria for the diagnosis of TGA published by Hodges and Warlow(1990). The 16 acute patients were examined during the TGA episode itself, and the eight day-after patients were assessed at the end of the episode. For all patients, a follow-up examination was carried out two months later (mean interval = 69.59 days, *SD* = 9.13). By that stage, none of the patients exhibited any memory impairment. Finally, at the first test session, patients and controls underwent an assessment of two potentially confounding factors, namely visuoconstructive abilities(Signoret et al., 1989) and apraxia(Peigneux and Van der Linden, 2000). No impairment was found (data not shown). The acute patients were matched with healthy controls for sex, age and level of education.

[Tab. 1]

2.2. Memory for action task

Participants incidentally encoded 48 object-action sentences (see Tab. 2 for an example ofa complete list of items) under four conditions: verbal task (VT), experimenter-performed task (EPT), self-performed task (SPT) and self-performed task with choice (SPTc; see Fig. 1 for the general design and task details).

Immediate retrieval was assessed for each object-action sentence via cued recall, recognition and source memory (free recall) tasks. We collected and analysed the cued recall and total recall (correct responses on cued recall + recognition) scores. For correctly recalled or recognized items, we collected and analysed R/K/G and source memory scores to assess the participants' subjective experience.

[Tab. 2]

[Fig. 1]

2.3. Complementary cognitive assessment

The neuropsychological protocol was designed to assess binding, executive functions, short-term memory and episodic memory.Due to the specific nature of TGA, the cognitive assessment was modular and could be applied to the patients in the form of short sequences interleaved with medical examinations.

Binding, a process thought to take place in the episodic buffer, was assessed using a verbal and visuospatial association task (for complete description, see Quinette et al., 2013, 2006b) (see supplementary material).

Episodic memory was assessed with the Encoding – Storage – Retrieval (ESR) test, to which we added a *Remember/Know/Guess*(R/K/G; Gardiner et al., 1998) paradigm (the R, K and G scores are expressed as percentages in the statistical analysis). This has been used and described in previous studies of TGA(Hainselin et al., 2011; Quinette et al., 2006b).

We investigated two executive functions, namely inhibition and shifting, using the Stroop test and the Trail Making Test, respectively(Godefroy, 2008). Forward digit and forward visuospatial span tasks(Wechsler, 1991)were used to probe short-term memory.

2.4. Anxiety and mood assessments

State and trait anxiety was assessed by means of the State-Trait Anxiety Inventory(STAI: Spielberger, 1983). Mood state was evaluated by means of the Beck Depression Inventory (BDI; Beck et al., 1974) and the Befindlichkeits-Skala adjective mood scale(Bf-S Von Zerssen et al., 1970).

Total duration for all tests administered was about 3 hours.

2.5. Statistical methodology

The statistical analysis of the memory for action task scores was carried out using a repeated-measures ANOVA, with Group (acute TGA, day-after TGA, healthy controls) as the between-participants factor and Condition (VT, EPT, SPT, SPTc) as the within-participants

factor. The remaining data were analysed using a one-way ANOVA, with Group as a between-participants factor. Post hoc Tukey tests were used to carry out paired comparisons.

Pearson correlation coefficients were conducted on the acute TGA groupto determine which processes were involved in the enactment effect. To this end, we calculated two *improvement by action* indices (we deliberately chose not to use the expression *enactment effect*to avoid confusion between these indices and the differences between the SPT and VT conditions in the memory for action task described above). The *classic action improvement* index (SPT/VT) was calculated by dividing the total score in the SPT condition by the total score in the VT condition. The *chosen action improvement* index (SPTc/VT) was calculated by dividing the total score in the SPTc condition by the total score in the VT condition.

3. Results

3.1. Memory for action task

For the cued recall score, we found a main effect of Group, $F(2, 39) = 128.09$, $p< .0001$, and Condition, $F(3, 39) = 36.40$, $p< .0001$, but no Group × Condition interaction, $F(6, 117) = 1.79$, $p = .11$. Results are set out in Tab. 3.

[Tab. 3]

Analyses of the total score (cued recall + recognition) showed a main effect of Group, $F(2, 39) = 30.72$, $p< .0001$, and Condition, $F(3, 39) = 20.67$, $p< .0001$, but no Group × Condition interaction, $F(6, 117) = .85$, $p = .54$.Results are set out in Tab. 4.

In this condition, we observed the classic enactment effect (SPT > VT), as well as the chosen enactment effect (SPTc > VT), both for acute patients and for healthy controls. Post

hoc Tukey tests also revealed better performances under the SPTc condition than under the EPT one by the acute patient group. No difference was found between the conditions within the day-after group.

The acute group performed more poorly than the healthy controls in all four conditions, and more poorly than the day-after group in the VT and SPT conditions.

[Tab. 4]

Regarding the R/K/G paradigm, we found a main effect of Condition, $F(2, 39) = 27.46$, $p< .0001$, a trend towards a Group effect, $F(2, 39) = 2.96$, $p = .065$, and a Group × Condition interaction, $F(4, 68) = 8.80$, $p< .0001$. Post hoc Tukey tests showed that patients in the acute phase of TGA gave more %G answers than %R or %K answers. We also found that acute patients gave fewer %K answers and more %G answers than the healthy controls did.

Concerning the source memory score, we found a significant main effect of Group, $F(2, 39) = 16.64$, $p< .0001$, and Condition, $F(3, 39) = 2.80$, $p< .05$, but no Group × Condition interaction, $F(6, 117) = .98$, $p = .45$. Post hoc analyses revealed that healthy controls had better source memory performances in the SPT condition compared with the acute patients, and better performances in the EPT condition compared with the day-after patients. Intragroup comparisons did not reach statistical significance for any of the three groups (see supplementary material).

3.2. Complementary cognitive assessment

The detailed scores for cognitive and anxiety assessments are set out in Tab.5.

As expected, a significant effect of Group was found in ESR for the immediate cued recall, $F(2, 39) = 3.78$, $p< .05$, free recall, $F(2, 39) = 21.96$, $p<.0001$, and recognition scores $F(2, 39) = 15.40$, $p< .0001$ (Tab.3), with poorer performances for acute patients. The analysis of R/K/G paradigm performances revealed a significant effect of Group on the %R, $F(2, 39) = 21.19$, $p<.0001$, and %G scores, $F(2, 39) = 787$, $p = .02$, but not on the %K scores, $F(2, 39) = 13.30$, $p = .46$, with lower %R and higher %G scores for acute patients than the other groups.

No statistical difference was found between the three groups in performances on the binding task, Stroop interference test, Part B of the TMT, forward digit span or forward visuospatial span.

3.3. Anxiety and mood assessments

Unlike trait-STAI, we found a significant difference between groups in scores on the state-STAI, $F(2, 39) = 13.51$, $p< .0001$, BDI, $F(2, 39) = 3.36$, $p< .05$, and Bf-S, $F(2, 39) = 10.24$, $p< .001$. Post hoc analyses showed that the acute patients scored more highly on the state-STAI, BDI and Bf-S than the healthy controls.

[Tab. 5]

3.4. Correlations

For acute patients, regarding the SPT/VT action improvement index, negative correlations ($p< .05$) were found with incorrect responses on the binding task ($r = -.73$; i.e., the fewer incorrect responses provided by patients in the binding task, the more their memory was enhanced in the SPT condition) and state anxiety ($r = -.94$; i.e., the less anxious patients

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were, the more their memory was enhanced in the SPT condition). Moreover, a correlation was found between the SPTc/VT action improvement index and the forward visuospatial span score ($r = .90$). No other significant correlations were found(see Tab. 6).

[Tab. 6]

4. Discussion

The results of the present study show that, despite their severe episodic memory impairment, TGA patients can still benefit from the enactment effect. This is the first time that this effect has been demonstrated in a sample of patients with such a pure and massive episodic memory deficit. We also highlighted links between the enactment effect and binding. We discuss below the implications of these results at both theoretical and clinical levels.

The first aim of this study was to assess the enactment effect in TGA (i.e., better recall for actions that are actually performed rather for ones that are just verbally encoded). The main finding was that TGA patients in the acute phase can benefit from self-performed task conditions just as much as healthy controls, even if they still do not perform normally. We labelled this enactment effect (SPT > VT) *classic*, to distinguish it from the *chosen* enactment effect (SPTc > VT) discussed below. Our results confirm that this classic enactment effect is present in amnesia, consistent with findings from Korsakoff patients(Mimura et al., 1998), allowing us to conclude that it is not impaired by amnesia per se. In our study, we went one step further, as this is the first time that the enactment effect has been found in a very pure, nonpermanent amnesia without any cognitive reorganization.

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In addition to the classic enactment effect (SPT > VT), we observed a chosen enactment effect (SPTc > VT) in the acute patients, even for cued recall. However, this chosen enactment effect may also have been due to the very high rate of typicalactions, which are known to be well integrated(Mangels and Heinberg, 2006) and more familiar. Future studies will need to address this issue by distinguishing between typical or well integrated and poorly integrated actions, as well as the self-reference effect, in the new SPTc condition proposed here. We thereforeonly discuss the *classic* enactment effect below, from the perspective of their underlying cognitive functions.

Our second objective was to gain a better understanding of the cognitive functions that sustain memory enhancement in the enactment effect. First, we highlighted a link between a specific binding task and the classic enactment effect (assessed with the SPT/VT action improvement index). This result suggests the involvement of the episodic buffer in the enactment effect and is consistent with the episodic integration view discussed below(Kormi-Nouri and Nilsson, 1998).

The classic enactment effect (SPT > VT) found in the acute patients and the healthy control group, added to the absence of any significant improvement between the VT and EPT conditions for any of the groups, is consistent with the hypothesis that the enactment effect has a motor component(Engelkamp, 2001), even in the absence of any improvement between the EPT and SPT conditions(Feyereisen, 2009). Regarding glue theory, which assumes that enactment encoding cements actions and objects together(Kormi-Nouri and Nilsson, 2001), the close correlation found between binding scores and the SPT/VT action improvement index is consistent with the notion that binding plays a role in the enhancement of memory for actions in TGA patients. Thus, we suggest that both the motor control component and episodic integration processes (binding) contribute to the classic enactment effect seen in TGA

patients. Our results support the idea of a spared episodic buffer(Quinette et al., 2006b) for the classic enactment effect to occur.

By contrast, spared episodic memory may not be required for enactment effect. In the acute group, we did not observeany link between episodic memory scores and the action improvement indices nor improvement in source memorybetween VT and SPT. We suggest that, instead of stemming from a genuine episodic improvement, the enactment effect is sustained by implicit mechanisms, consistent with massive episodic memory impairment and implicit memory preservation in TGA(Eustache et al., 1997), or by semantic memory (Beauregard et al., 1997; Guillery et al., 2001). Nevertheless Jon, with spared semantic memory (Gardiner et al., 2006),did not benefit from enactment effect for action phrases (without object) recognition. Those results suggest that enactment effect needsepisodic buffer, but can occur independently of, or is only sparsely influenced by, episodic memory. The role of semantic memory and implicit mechanisms need to be explored in future researches.

Moreover, we found a negative correlation between the SPT/VT action improvement index and state-anxiety score. This suggests an influence of state-anxiety on enactment effect, with a more important effect for the less anxious patients, although every patient showed better performances for SPT compared to VT. Besides supporting the importance of state-anxiety level on memory performances during TGA (Hainselin et al., 2011; Noël et al., 2008), it reinforces the robustness of enactment effect, which can be found even in anxious (and amnesic) patients.

In conclusion, the present experiment demonstrated that the enactment effect is robust enough to be found during a TGA episode. Our newly designed paradigm, featuring an original condition and a source memory assessment, in addition to a neuropsychological assessment, helped us to refine current understanding of the enactment effect. Further studies

are now needed to 1) undertake a more in-depth exploration of enactment effect and its links with cognitive and emotional factors, and 2) integrate these very robust effects into clinical practice and rehabilitation, possible even for patients with a massive memory impairment.

Conflict of interest

There is no competing interest.

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TABLES & FIGURES

Table 1. Clinical and Demographic Characteristics of Individuals with TGA and Controls

	Acute TGA **(*n* = 16)**	**Day-after TGA** **(*n* = 8)**	**Healthy controls** **(*n* = 18)**
Sex: women/men	13/3	4/4	13/5
Age in years: mean (*SD*)	60.56 (5.42)	68.3*†† (6.45)	61.00 (6.48)
Level of education in years: mean (*SD*)	11.56 (2.99)	10.00 (3.51)	10.56 (2.20)
Duration of TGA in hours: mean (*SD*)	4.96 (3.37)	3.81 (2.5)	/
No. recurrent patients	2 (second episode)	1 (second episode)	/

* Significant difference from healthy control group.

†† Significant difference from acute TGA group.

A comparison of the three groups showed an effect of Group on age, $F(2, 39) = 5.05$, $p< .05$.

A post hoc Tukey test showed this was due to the presence of older patients in the day-after group compared with the acute and healthy control groups.
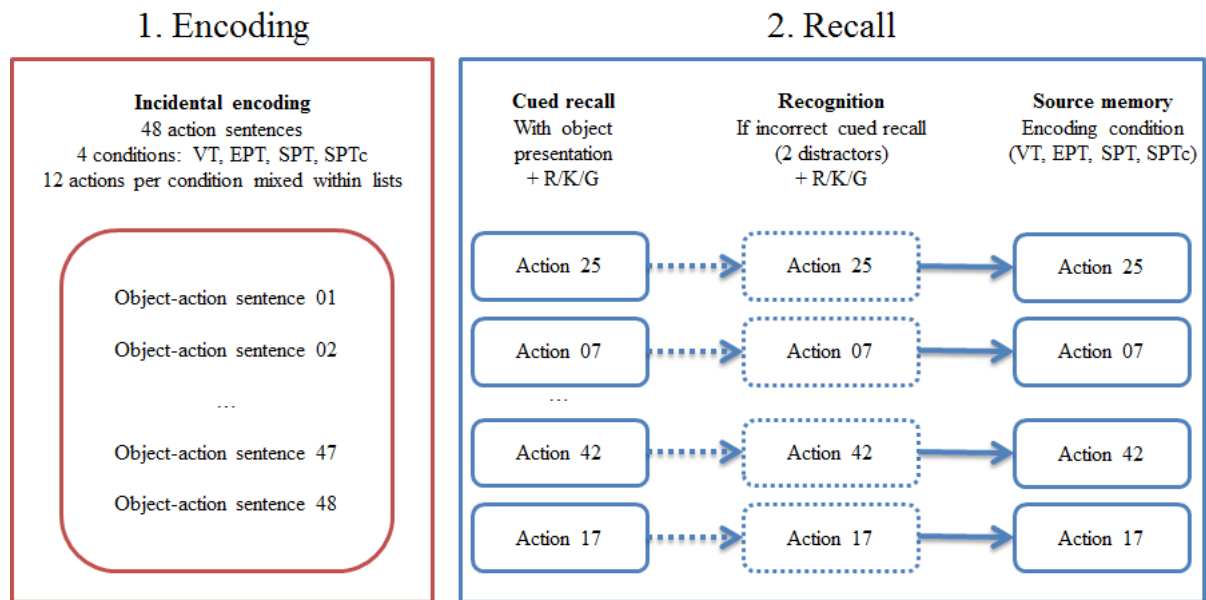
1. Encoding

Incidental encoding
48 action sentences
4 conditions: VT, EPT, SPT, SPTc
12 actions per condition mixed within lists

Object-action sentence 01

Object-action sentence 02

...

Object-action sentence 47

Object-action sentence 48

2. Recall

Cued recall	Recognition	Source memory
With object presentation + R/K/G	If incorrect cued recall (2 distractors) + R/K/G	Encoding condition (VT, EPT, SPT, SPTc)
Action 25	Action 25	Action 25
Action 07	Action 07	Action 07
...		
Action 42	Action 42	Action 42
Action 17	Action 17	Action 17

Fig. 1. General design of the memory for action task. Forty-eight action verbs and 48 objects were used in this task, paired in a semi-random way so as to avoid typical/well-integrated ("write with the pen"), dangerous ("throw the hammer in the air") or impossible ("twist the cell phone") utilisations of each item. We created 20 different lists of 48 object-action sentences, randomly attributed to each participant. Four extra object-action sentences (one for each condition described below) were used for training prior to the task to check that the participants understood the instructions. To ensure incidental encoding, participants were not aware they had to remember either actions or objects. During the encoding phase, an object was placed on a table in front of the participant and a sentence describing the relevant object-action pair was shown on a computer screen for 5 seconds, using E-Prime software. The design included four encoding conditions (mixed within each list). In the verbal task (VT) condition, participants read aloud the sentence displayed on the computer (no action performed), and in the experimenter-performed task (EPT) condition, they watched the experimenter performing the action displayed on the screen. In the self-performed task (SPT) condition, however, participants actually performed the action displayed on the computer, and in the self-performed task with choice (SPTc) condition, they both chose and performed an action with each item named on the computer screen. We expected the latter condition to

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enhance the effect, in line with Engelkamp's (2001) theory on action planning. Immediately after the 48 trials, all the objects were brought out again and their names were displayed on the computer, one after the other (in a different random order from that of the encoding phase to avoid an order effect). In this cued recall phase, participants had to remember the action associated with each object. In the case of a wrong answer, the correct sentence was displayed on the screen, along with two nonstudied distractor sentences, and participants had to select the right one (recognition). Immediately after each correctly recalled or recognized item, we assessed the participants' source memory by asking them to recall the encoding context of each sentence (read: VT; seen: EPT; self-performed: SPT; or self-performed with choice: SPTc). Their scores were expressed as a percentage of the maximum possible score. For each correctly recalled or recognized item (in cued recall or recognition), we also administered a Remember/Know/Guess (R/K/G) paradigm to assess the participants' subjective experience of the retrieval process (the R, K and G scores for all tasks are expressed as percentages in the statistical analysis).

Table 2. Example of an entire list of 48 object-action sentences used for the enactment effect task

French	English translation
Déplacer le déodorant derrière l'ordinateur	Move the deodorant behind the computer
Déplacer l'allumette à droite	Move the match to the right
Prendre le marteau entre le pouce et l'index	Grab the hammer with the thumb and forefinger
Serrer la boucle d'oreille dans la main	Tighten the earring in the hand
Une action de votre choix avec l'élastique	An action you choose with the elastic
Frotter le taille-crayon	Rub the pencil sharpener
Une action de votre choix avec le niveau	An action you choose with the spirit level
Caresser la balle de ping-pong	Caress the ping pong ball
Essuyer le bonbon	Wipe the candy
Soupeser le thermomètre	Heft the thermometer
Tordre le filtre à café	Twist the coffee filter
Appuyer sur le couteau avec l'index	Press the knife with the forefinger
Lancer le trombone en l'air	Toss the paperclip
Une action de votre choix avec les ciseaux	An action you choose with the scissors
Tourner le mètre dans le sens antihoraire	Turn the ruler counterclockwise
Une action de votre choix avec la cassette	An action you choose with the tape
Pincer la clé	Pinch the key
Retourner la pince	Upturn the pliers
Une action de votre choix avec l'éponge	An action you choose with the sponge
Ecraser la gomme avec la main	Crush the eraser with the hand

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French	English translation
Une action de votre choix avec la pile	An action you choose with the battery
Taper sur le bureau avec le crayon de couleur	Thump the desk with the colored pencil
Plier la carte	Bend the card
Passer la cuillère d'une main à l'autre	Pass the spoon from one hand to the other
Souffler sur le tube de dentifrice	Blow on the toothpaste tube
Une action de votre choix avec le gant	An action you choose with the glove
Une action de votre choix avec le bouton	An action you choose with the button
Déplacer les lunettes à gauche	Move the glasses to the left
Jeter la craie par terre	Throw the chalk on the floor
Mettre le bonnet dans la main	Put the bonnet in the hand
Une action de votre choix avec la brosse à dents	An action you choose with the toothbrush
Poser le peigne par terre	Put the comb on the floor
Poser le coton tige sur la chaise	Put the swab on the chair
Palper la lime à ongles	Palpate the nail file
Donner le rasoir à la personne en face	Give the razor to the person in front of you
Ramener le savon vers soi	Take the soap back to oneself
Tapoter le collier	Tap the necklace
Visser avec la bague	Screw with the ring
Une action de votre choix avec l'agrafeuse	An action you choose with the stapler
Secouer le cahier	Shake the notebook
Gratter la louche	Scratch the ladle
Cacher le tournevis	Hide the screwdiver

French	English translation
Pousser le téléphone	Push the phone
Une action de votre choix avec la bougie	An action you choose with the candle
Faire rouler la fourchette	Make the fork roll
Tourner le pinceau dans le sens horaire	Turn the paintbrush clockwise
Une action de votre choix avec le bracelet	An action you choose with the bracelet
Poser le gobelet sur la main	Put the cup on your hand

Table 3. Cued recall (CR) scores of patients and healthy controls in all memory for action conditions

	Acute TGA (*n* = 16)	Day-after TGA (*n* = 8)	Healthy controls (*n* = 18)
Verbal task (VT): number of correct responses (*SD*)	0.81*†(0,46)	3.75* (0.99)	7.69 (0.85)
Experimenter-performed task (EPT): number of correct responses (*SD*)	0.69*† (0.35)	5.25* (1.58)	9.31 (0.80)
Self-performed task (SPT): number of correct responses (*SD*)	1.94*† (1.06)	5.38* (1.28)	10.46♦ (0.53)
Self-performed task with choice (SPT): number of correct responses (*SD*)	4.06*†♦❖● (1.20)	7.38*♦ (1.00)	11.23♦❖ (0.55)

* Significant difference from healthy control group in the same condition.

† Significant difference from day-after group in the same condition.

♦Significant difference with VT condition within the same group (enactment effect).

❖ Significant difference with EPT condition within the same group.

● Significant difference with SPT condition within the same group.

Table 4. Total scores (cued recall + recognition scores, CR+R) of patients and healthy controls in all memory for action conditions

	Acute TGA (*n* = 16)	Day-after TGA (*n* = 8)	Healthy controls (*n* = 18)
Verbal task (VT): number of correct responses (*SD*)	4.25*† (0.85)	7.88 (0.68)	8.46 (1.01)
Experimenter-performed task (EPT): number of correct responses (*SD*)	5.06*† (1.09)	8.63 (0.46)	9.77 (0.55)
Self-performed task (SPT): number of correct responses (*SD*)	6.75*♦ (1.50)	9.38 (0.96)	10.77♦ (0.51)
Self-performed task with choice (SPT): number of correct responses (*SD*)	7.81*♦❖ (1.51)	9.75 (0.88)	11.31♦ (0.43)

* Significant difference from healthy control group in the same condition.

† Significant difference from day-after group in the same condition.

♦Significant difference with VT condition within the same group (enactment effect).

❖ Significant difference with EPT condition within the same group.

Table 5. Participants' Neuropsychological Results Expressed as Means (SD)

|	Acute TGA (*n* = 16)	Day-after TGA (*n* = 8)	Healthy controls (*n* = 18)
Binding: incorrect answers	5.20 (4.84)	5.13 (4.02)	6.36 (3.41)
Stroop interference: time	133.06 (24.73)	135.00 (32.01)	122.85 (36.96)
Stroop interference: errors	2.50 (1.93)	2.38 (1.51)	3.31 (2.87)
TMT B: time	105.13 (27.14)	117.13 (59.08)	93.85 (34.30)
TMT B: errors	0.60 (0.74)	0.75 (0.89)	0.38 (0.65)
Forward digit span	5.06 (1.24)	5.71 (1.11)	5.46 (0.77)
Forward visuospatial span	5 (0.63)	5.29 (2.92)	5.15 (0.98)
ESR cued recall	12.94* (3.19)	14.63 (1.30)	15.85 (0.38)
ESR free recall	3.19*† (2.70)	6* (1.86)	8.85 (1.9)
ESR recognition	9.56*† (4.77)	14.38 (1.30)	15.92 (0.27)
ESR %R	25.38*† (33.18)	64.66* (22.87)	71.36 (22.45)
ESR %K	34.03 (19.23)	23.58 (22.92)	23.44 (12.74)
ESR %G	40.59*† (45,55)	11.76 (13.39)	6.20 (3.22)
Trait-STAI	43.5 (6.23)	39.63 (8.73)	37.54 (6.64)
State-STAI	49.75* (13.85)	41.50* (10.74)	28 (7.07)
BDI	5.69* (3.91)	4.38 (1.85)	2.46 (3.23)
Bf-S adjective mood scale	28.73* (10.09)	22.00 (7.40)	8.38 (7.39)

* Significant difference from healthy control group.

† Significant difference from day-after group.

Table 6. Correlations between action improvement index (SPT/VT), neuropsychological scores, anxiety and mood scales in patients during TGA (r Values)

	SPT/VT index	SPTc/VT index
Binding: incorrect answers	-0.73 [a]	-0.47
Stroop interference: time	-0.10	-0.28
Stroop interference: errors	0.75	0.20
TMT B: time	0.33	0.51
TMT B: errors	-0.33	-0.03
Forward digit span	-0.25	-0.74
Forward visuospatial span	0.30	0.90[a]
ESR cued recall	0.66	0.01
ESR free recall	0.52	0.53
ESR recognition	-0.58	-0.26
Trait-STAI	-0.30	-0.58
State-STAI	-0.94 [a]	-0.77
BDI	0.08	-0.65
Bf-S adjective mood scale	0.24	0.27

[a] *Significant correlation p < .05*
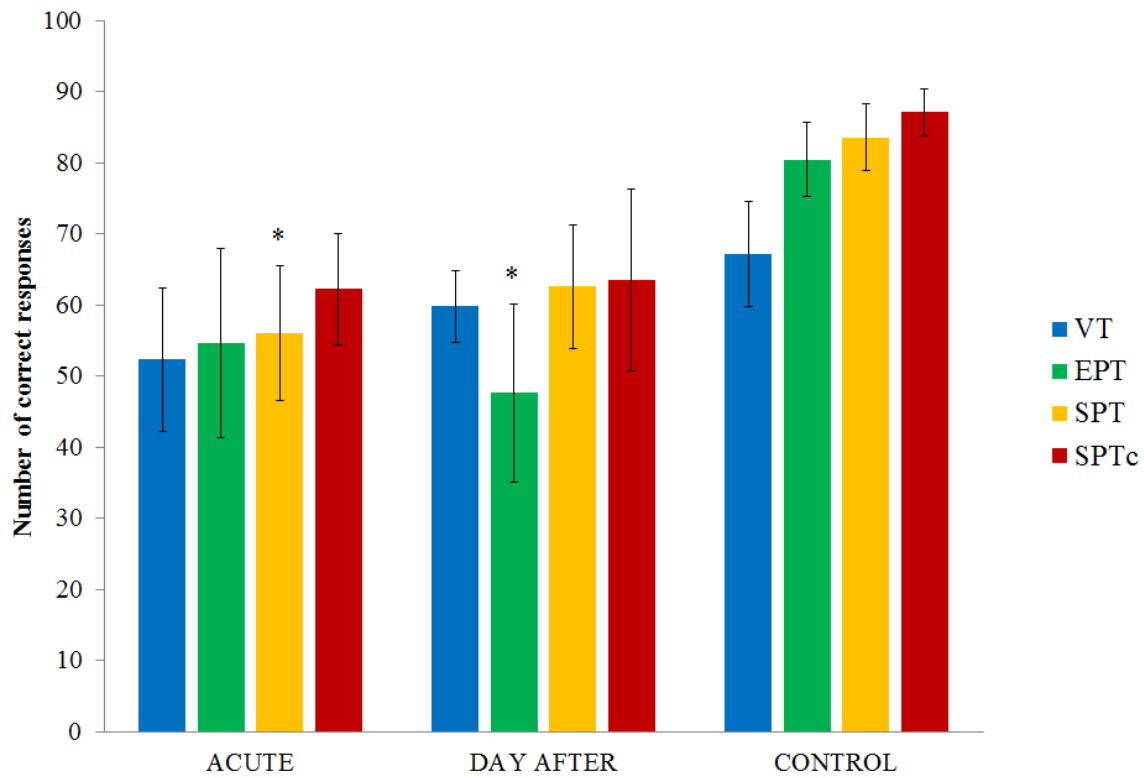
Supplementary Figure1: Source memory scores (expressed as percentages) of the patients and healthy controls in all conditions of the memory for action task (verbal task: VT; experimenter-performed task: EPT; self-performed task: SPT; self-performed task with choice: SPTc).

* Significant difference from the healthy control group in the same condition.
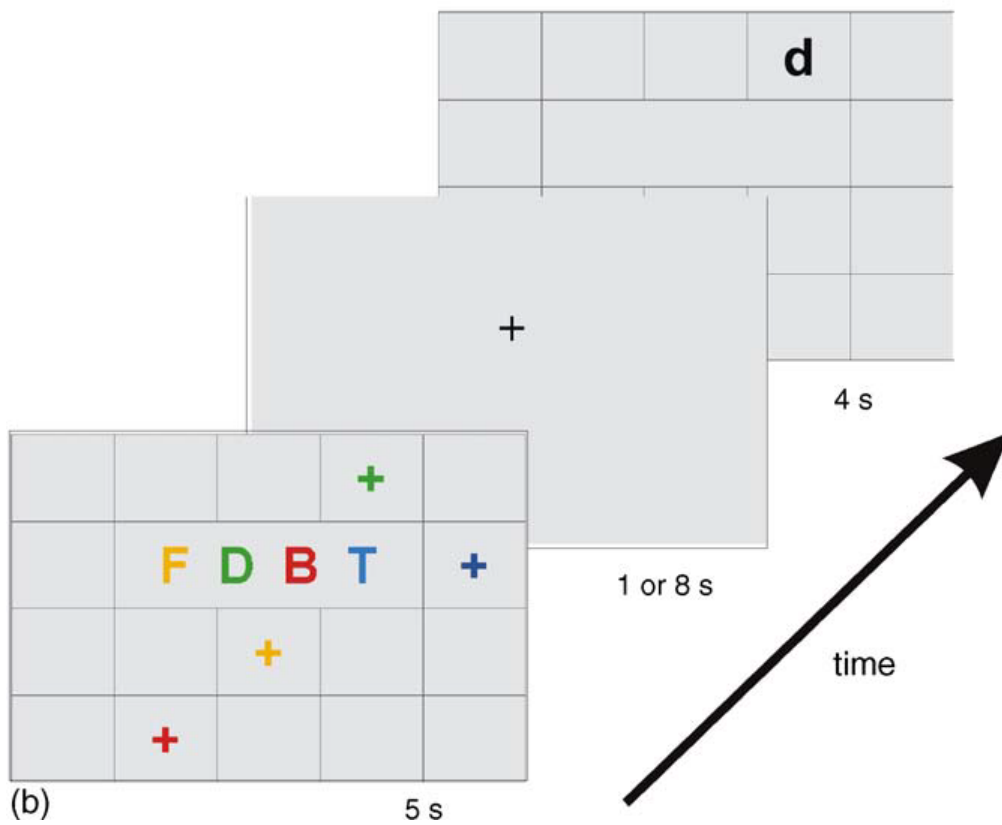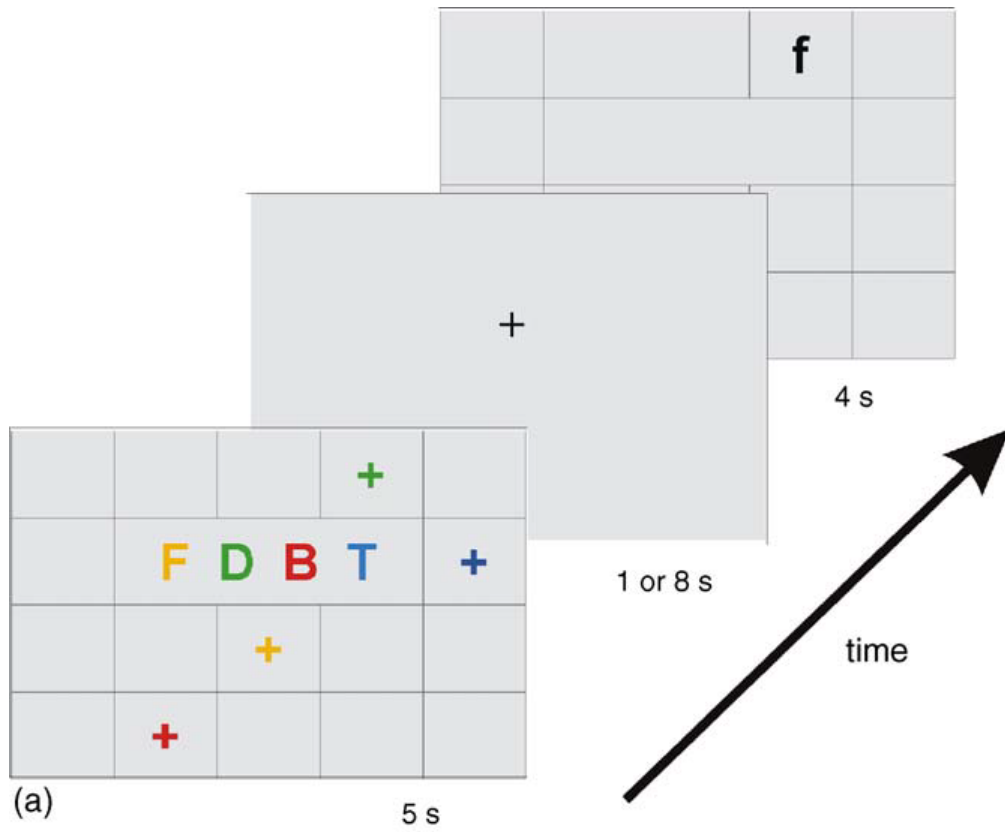
Supplementary Figure 2: Diagram of the binding task. This task consists in matching

four consonants with four locations marked by four crosses on a 5 x 4 grid, according to their

colour. After the binding processing (matching letter with location according to colour), patients had to memorize the integrated information. During the test phase, a grid is provided with a single black letter inside one of the squares. Participants have to determine whether it corresponds to the initial matching. We recorded the numbers of correct and incorrect responses. Two types of stimuli were presented: the target type (a), when the letter was in the wrong location, or the lure type (b), when the letter was in the right. We used the 1 second cross presentation.