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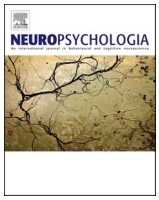

Follow the script: the role of vmPFC in the reinstatement and instantiation of event schemata during event construction

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A B S T R A C T

Previous evidence has shown that the ventromedial prefrontal cortex (vmPFC) has a role in schematic processing and event construction. Here, we tested whether vmPFC mediates the activation of event schemata (scripts; i.e. *reinstatement*), or their *instantiation* during event construction. vmPFC patients and healthy and brain-damaged controls performed (1) a script production task and (2) an event generation task in three experimental conditions: in one condition the to be imagined events did not obey a script (non-scripted condition), in one condition they obeyed a script (scripted condition), and in one condition they obeyed a script that served as an external cue for event generation (cued-scripted condition). At the script production task, vmPFC patients showed accurate knowledge of the main structure of scripts, but insufficient knowledge of their finer details, suggesting impaired script reinstatement. In line with previous studies, vmPFC patients' event construction performance was impaired in the non-scripted and scripted condition; however, it significantly improved when the script of the to be constructed events was externally cued during event generation, suggesting preserved schema instantiation. These findings indicate that vmPFC integrity is crucial for the reinstatement of scripts, but not for their instantiation when externally provided.

1. Introduction

A schema is an associative network of knowledge extracted over multiple similar experiences (Ghosh and Gilboa, 2014). For example, having attended many conferences, we know registration is the first step, and then lectures, talks, posters, and hopefully some good catering will follow. Schemata play a crucial role in shaping the structural organization of learning, memory, and behavior (Ghosh et al., 2014; Spalding et al., 2015). They influence memory formation and retrieval, facilitating or biasing perception, encoding and recollection of information and events (Bartlett, 1932; Wagner et al., 1998; Wang et al., 2012; Robin and Moscovitch, 2017). The term 'schema' has been used to describe a wide variety of cognitive structures that facilitate memory encoding and retrieval, such as the beginnings of narratives, multisensory object representations, and perceptual statistical regularities (Durrant et al., 2011; Van Kesteren et al., 2010). Narrowing the definition (Ghosh and Gilboa, 2014), proposed that schemata are characterized by four essential features: (1) an associative network structure, (2) grounding in multiple episodes, (3) a lack of unit-level detail, and (4) adaptability. The definition of schema proposed by Ghosh and Gilboa (2014) clearly sets boundaries between the construct of schema and different (yet related) concepts, such as semantic categories and event gist (see Gilboa and Marlatte, 2017; Giuliano et al., 2021). For example, people schemata, including the self-schema - the articulated set of beliefs about oneself generally deriving from the repeated categorization and subsequent evaluation of one's behavior (Markus, 1977) - obey the definition proposed by Ghosh and Gilboa (2014). As well, scripts -the structured, stereotypical sequences of actions that capture familiar situations (Schank and Abelson, 1977) - can be considered as event schemata (see Baldassano et al., 2018; Giuliano et al., 2021).

Despite their significance, the neural mechanisms underlying schemata are not fully understood. Recent evidence points to medial prefrontal regions as having a prominent role in schema-mediated cognition (for a review, see Gilboa and Marlatte, 2017). fMRI studies have consistently implicated mPFC in schematic processing. For example, mPFC exhibits patterns of activity tracking the structure of specific schemata during event perception (Baldassano et al., 2017). Moreover, the congruency effect in memory (*i.e.* the mnemonic superiority of information consistent with prior knowledge) has been convincingly linked to mPFC (Van Kesteren et al., 2013; Spalding et al., 2015). Even the self-schema has been shown to be strongly supported by the ventral mPFC (vmPFC; for a review, see Wagner et al., 2012). Indeed, a damage

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to vmPFC causes the disappearance of the self-reference effect, *i.e.* the mnemonic advantage for items related to the self (Rogers et al., 1977; Stendardi et al., 2021), and leads to inconsistency in judgments regarding one's own preferred activities, habits, and characteristics (Stendardi et al., 2023). Sirigu et al. (1995) compared patients with lesions in the frontal and posterior cortices with healthy controls in a script production task, and showed a tendency, in frontal patients, to commit more errors in sequencing the actions composing the script, in detecting the scripts' boundaries (initial and final) actions, and to make deviant estimates of action importance within a script (see also Godbout and Doyon, 1995; Allain et al., 1999; Godbout et al., 2004; Wood et al., 2005). More recently, Ghosh et al. (2014) tested whether vmPFC patients were able to correctly classify actions' belonginess to schemata (*e.g.*, supermarket schema), and found a striking difference in performance between non-confabulating and (prior or present) confabulating vmPFC patients, with the latter failing at correctly pairing actions and schemata and rejecting lure actions coherent with previously activated schemata (see also Giuliano et al., 2021).

mPFC is also heavily involved in scene- and event-construction (Addis et al., 2007; Bahk and Choi, 2018). Indeed, mPFC, as part of the brain default network, is consistently activated during autobiographical memory retrieval (Gilboa, 2004; McCormick et al., 2020) as well as episodic future thinking (Atance and O'Neill, 2001; Buckner et al., 2008; Schacter et al., 2007). It has been suggested that an interplay between vmPFC and the hippocampus is at the core of event construction (Ciaramelli et al., 2019; McCormick et al., 2018; Moscovitch et al., 2016; Ryom et al., 2024). Episodic memory and future thinking are indeed severely hindered by hippocampal damage (Hassabis et al., 2007; Hassabis and Maguire, 2007). The event generation deficit of vmPFC patients is also well documented (Bertossi et al., 2017; McCormick et al., 2020). When asked to construct specific past and future events, patients with vmPFC damage produce less detailed accounts than healthy and brain-damaged controls (Bertossi et al., 2016a, 2016b), an impairment that cannot simply be ascribed to poor working memory (see Bertossi et al., 2017; Ciaramelli et al., 2021a). Interestingly, whereas hippocampal damage results in a selective deficit in producing spatial details in imagined scenes, vmPFC damage results in a pervasive impairment in producing even the entities present in the scenes, suggesting a more basic role of vmPFC in scene construction (De Luca et al., 2018). For this reason, Ciaramelli et al. (2019) have proposed that during event construction vmPFC activates the relevant schemata that drive the collection of schema-congruent details to be collated into cohesive events by the hippocampus.

The (re)construction of personal events can depend heavily on the engagement of the self-schema and of event schemata as sources of information that is relevant to conceive personally-relevant activities. Thus, an impoverishment of the self- or of event-schemata can result in impaired event construction. Considering vmPFC patients' impairment in event construction (Bertossi et al., 2017, 2016a; 2016b; De Luca et al., 2018), we have previously hypothesized and found a degradation of the self-schema in vmPFC patients (Stendardi et al., 2021, 2023). Here we focus on event schemata (scripts). In a previous study on problem-solving, Peters et al. (2017) investigated vmPFC patients' ability to conceive effective solutions to open-ended, life-like problems. Open-ended problems do not follow a script: they do not have a set path to a predefined solution. The authors found that vmPFC patients generated fewer relevant means to solve the problems than healthy controls and patients with lesions in other frontal regions, particularly for socially relevant problems. Sheldon et al. (2011) and Vandermorris et al. (2013) have shown that episodic simulation plays a key role in solving open-ended problems such as those explored with the Means-End Problem Solving Task (MEPS; Platt and Spivack, 1975). It is possible, therefore, that impaired episodic simulation in vmPFC patients (see Bertossi et al., 2016a, 2017; De Luca et al., 2018) contributed to their problem solving deficits in open-ended, life-like problems (Peters et al., 2017). The extent to which episodic simulation deficits in vmPFC patients depend on a failure in activating or using relevant event schemata, however, remains to be explored.

Here we investigated whether vmPFC is necessary to mediate schematic processing and its interplay with event construction, and whether vmPFC is more concerned with the activation (reinstatement) or the use (instantiation) of schemata. To study the role of vmPFC in script reinstatement, we had vmPFC patients and healthy and brain-damaged controls engage in a script production task requiring to list the series of action composing over-learned events (*e.g.*, going to the supermarket). Moreover, to test the role of script processing in event construction, we investigated whether vmPFC patients' event construction deficits change as a function of the availability of schematic event knowledge during event construction. To this aim, we tested participants in an event construction task in three conditions: when the to be imagined events do not obey an underlying script (non-scripted condition), when the to be imagined events obey an underlying script (scripted condition), and when the to be imagined events obey an underlying script that is externally provided during event construction. First, we hypothesize that vmPFC patients would be poor at producing scripts of common events, consistent with a deficit in schema reinstatement. Next, we hypothesize that vmPFC patients' poor schematic knowledge would contribute to their event generation deficits, making them less sensitive to the script structure underlying well-known events. Finally, if vmPFC is necessary for the endogenous activation (reinstatement) of scripts, vmPFC patients should be capable to instantiate scripts during event construction if these are externally provided.

2. Methods

2.1. Preliminary phase: selection of scripted events and script extraction

A group of 34 healthy young adults (15 M; mean age = 22.5 years; mean education = 16 years) not involved in the main experiment were presented with 28 short headlines indexing events that would normally last for a day or less through the platform Qualtrics (Qualtrics, 2020 http://www.qualtrics.com). Events were preselected to either obey a script (N = 14, *e.g.*, going to a restaurant, taking a shower) or not obey a script (N = 14; *e.g.*, looking for a lost watch, getting to know new neighbours; see Appendix 1). To preselect events not obeying a script we adapted open-ended activities from the MEPS task (N = 5; Platt and Spivack, 1975; see also Sheldon et al., 2011) or created new ones (N = 9; *e.g.*, entertain kids while babysitting, retrieve a ball stuck on a tree). The preliminary experiment served to confirm whether the preselected events did in fact obey a script (or not).

After reading the headline relative to each of the 28 events (*e.g.*, taking your dog for a stroll), participants had to list the 10 actions most likely to constitute that event, that is, which most people would perform while engaging in that activity, while avoiding idiosyncratic actions referring specifically to their own experience. The initial and final actions of each event were specified in parentheses beside the headline. For each action, we calculated the frequency with which participants mentioned it, regardless of the order it appeared in participants' lists. We defined major actions those that were mentioned by at least 65 % of participants, minor actions those that were mentioned by 45–64 % of participants, and trivial actions those mentioned by 25–44 % of participants (see also Godbout and Doyon, 1995, 2000). Actions that were described with different words but referred to the same activity (*e.g.* "writing down the shopping list" and "taking note of what to buy at the grocery shop") were considered as the same action. Cases of ambiguity were solved through discussion. We then selected 12 events that contained $\geq$5 major actions (mean and SD: 6.6 $\pm$ 1.4) to serve as the scripted events, and 4 events that contained $\leq$2 major actions (mean and SD: 1 $\pm$ 1.2) to serve as the non-scripted events. The complete list of non-scripted and scripted events, along with their major, minor and trivial actions, are reported in Appendix 1.

2.2. Experimental phase

2.2.1. Participants

The study involved 8 patients with lesions to the vmPFC (6 M, mean age = 58 ± 5.9 years, range = 50–65; mean education = 10.6 ± 3.2 years, range = 5–14), 11 patients with lesions not including vmPFC (9 M, mean age = 55.8 ± 12.4 years, range = 34–68; mean education = 13.3 ± 3.1 years, range = 8–19), and 46 healthy participants (32 M, mean age = 58.2 ± 6.5 years, range = 40–68; mean education = 11.5 ± 3.3 years, range = 5–18). Patients were recruited at the Centre for Studies and Research in Cognitive Neuroscience of the University of Bologna, Cesena Campus. The three groups were matched for gender balance ($\chi^2_2 = 0.7$, p = 0.7), age ($F_{2,62} = 0.4$ p = 0.7), and education ($F_{2,62} = 1.8$, p = 0.2). Included patients were in the stable phase of recovery (at least 3 months postmorbid). vmPFC patients' lesions resulted from a ruptured aneurysm of the anterior communicating artery (AcoA) in all cases. Six vmPFC patients had bilateral lesions, while the other two had unilateral lesions (right in one case, left in the other). Control patients' lesions were caused by ischemic (3 cases) or haemorrhagic stroke (3 cases), or tumor resection (5 cases). Eight patients presented with right brain lesions and two with left brain lesions. Lesions affected the right temporal lobe in four cases, the right fronto-temporal cortex in two cases, the right temporo-parietal cortex in one case, the right occipito-temporal cortex in one case, the left temporal lobe in one case, and the left occipital cortex in one case. The remaining patient had subcortical lesions. The regions of maximal overlap for control patients were BA 20 (8.9 cc, SD = 28), BA 21 (6.3 cc, SD = 19), BA 37 (3.6 cc, SD = 11.4), and BA 38 (3.6 cc, SD = 11.5). The 2 patients with lesions encroaching the frontal lobe had damage in a small portion of the ventrolateral prefrontal cortex (BA 47; patient 1 = 2.4 cc, patient 2 = 5.3 cc). Lesion size did not differ significantly between vmPFC and control patients (vmPFC patients: 48.7 cc vs. Control patients: 52.7 cc, p = 0.42).

vmPFC and control patients underwent a brief standardized neuropsychological battery (with the exception of one control patient who was no longer available for testing; see Table 1 for individual vmPFC patients' data), which showed that their performance was comparable in terms of attention (attentional matrices: 49.1 vs 45.4, $t_{16} = 1.1$, p = 0.3; Spinnler and Tognoni, 1987), verbal and visuo-spatial short-term memory (digit span: 5.25 vs 5.8, $t_{16} = 0.8$, p = 0.4; Corsi tapping test: 4.6 vs 4.5, $t_{16} = 0.3$, p = 0.7; Spinnler and Tognoni, 1987), and verbal fluency (phonemic fluency: 30.1 vs 36.8, $t_{16} = 1.5$, p = 0.2; semantic fluency: 40.6 vs 53.1, $t_{16} = 1.6$, p = 0.1; Spinnler and Tognoni, 1987). All participants provided informed consent in compliance with the Declaration of Helsinki (International Committee of Medical Journal, 1991) and the departmental ethical committee's guidelines.

2.3. Lesion analysis

Individual patients' lesions, extracted from the most recent MRI or computed tomography scans, were manually drawn by two trained neuroscientists on each slice of the normalized T1-weighted template MRI scan provided by the Montreal Neurological Institute with MRIcro software (Rorden and Brett, 2000). This template aligns approximately with Talairach space (Talairach and Tournoux, 1988). Overlaying the lesion of each patient onto the standard brain allowed us to calculate the overall brain lesion volume (in cc). Lesion overlap images for all vmPFC patients were generated using the MRIcro software and are displayed in Fig. 1. Brodmann's areas (BA) affected in vmPFC patients were areas BA 10, BA 11, BA 24, BA 25, BA 32, BA 46, BA 47, with the region of maximal overlap occurring in BA 11 (M = 19.16 cc, SD = 10.27), BA 10 (M = 10.08 cc, SD = 7.04), and BA 32 (M = 6.58 cc, SD = 5.61).

2.4. Materials and procedure

The 12 headlines of scripted events were divided into three sets of four events each. The three sets had an average number of major actions of 6.75 (group A) and 6.5 (groups B and C). The three sets of scripted events were allocated to three tasks (counterbalanced: script production task, scripted event generation task, and cued-scripted event generation task). The set of 4 non-scripted events served for the non-scripted event generation task.

Participants were tested individually in two separate sessions, approximately a week apart. Participants were tested at the lab or through a video-call with the experimenter (healthy participants, N = 14/46; vmPFC patients, N = 4/8; Control patients, N = 7/11). Sessions were audio-recorded in all cases. All participants completed a script production task and three event generation tasks: an event generation task for non-scripted events (non-scripted event generation task), an event generation task for scripted events (scripted event generation task), and an event generation task for scripted events in which the script of the event was externally cued (cued-scripted event generation task). Preliminary analyses show that the testing method (in person, online) had no effect on our main variables, and, therefore, the data were collapsed across in person and online testing.

2.4.1. Event generation task

In all three conditions of the event generation tasks, upon reading the headline (*e.g.*, imagine attending a wedding), participants were asked to imagine in as much detail as possible an event that could plausibly happen to them in a similar situation one year in the future. A fixed one-year time frame was chosen based on previous studies showing future thinking deficits in vmPFC patients (Bertossi et al., 2016a, 2016b, 2017) and to encourage the adoption of the same time frame while constructing events across participants, avoiding potential differences in the quality of constructed events due to temporal construal effects (Rosenbaum et al., 2023; Trope and Liberman, 2003). Participants then answered a series of questions about their imagination experience (perceived difficulty, perceived vividness and detailedness, sense of presence, and similarity to a memory) on a Likert scale from 1 to 5. For each event, we also calculated a Spatial Coherence Index (SCI), following the procedure of Hassabis et al. (2007). Participants had to evaluate the veracity of 12 individual statements describing the event they imagined. Eight statements related to a rich and vivid imagination

Table 1
The table reports, for each vmPFC patient (p), neuropsychological scores corrected for age, education and sex according to normative samples (Spinnler and Tognoni, 1987). An impaired performance is signalled by an *, while a borderline performance is signalled by a °.

vmPFC patients								
	p. 1	p. 2	p. 3	p. 4	p. 5	p. 6	p. 7	p.8
Sex	M	M	F	M	F	M	M	M
Age (years)	55	63	65	53	50	61	64	53
Education (years)	13	8	13	10	5	13	9	14
Phonemic Fluency (cut-off = 17)	45	27	24	17°	19	32	23	41
Semantic Fluency (cut-off = 25)	45	37	62	31	28	35	52	35
Short term memory - Digit span (cut-off = 3.75)	6.75	5.00	4.75	4.75	4.25	5.75	5.25	5.50
Short term memory – Corsi Tapping (cut-off = 3.75)	4.75	5.00	4.87	3.50*	3.75°	3.50*	6.00	5.50
Attentional matrices (cut-off = 31)	49.5	48.50	53.75	49.50	49.00	49.50	52.75	40.25

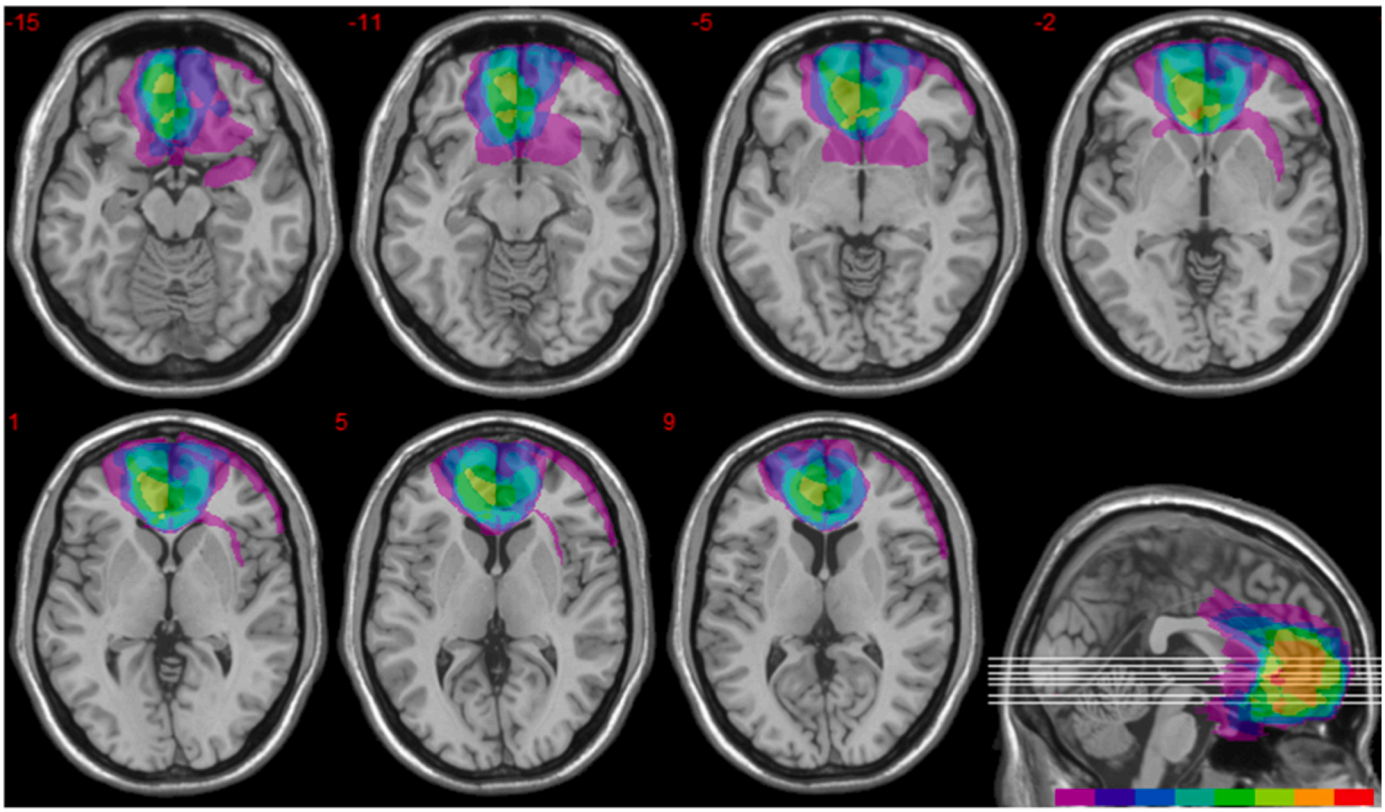

Fig. 1. Location and overlap of vmPFC patients' brain lesions. Lesions are projected on the same axial slices and on the mesial view of the standard Montreal Neurological Institute brain. The level of the axial slices is indicated by white horizontal lines on the mesial view of the brain, and by *z*-coordinates. The color bar represents the number of overlapping lesions.

experience (*e.g.* "I could see the scene in color"), whereas the other 4 described a fragmented and more "distant" scene (*e.g.* "It was more a collection of separate images rather than a scene"). Each flagged positive statement received a +1, and each negative one received a −1. We then subtracted two points from the SCI score, so that its range of values would be centered on 0 (from −6 to +6).

The three event generation conditions differed in terms of types of stimuli (headlines) given to participants, and specifically.

- *Non scripted event generation.* Participants were presented with the 4 headlines of non-scripted events selected in the Preliminary phase.
- *Scripted event generation.* Participants were presented with 4 of the headlines of scripted events selected in the Preliminary phase (counterbalanced).
- *Cued-scripted event generation.* Participants were presented with the headlines of the other 4 scripted events selected in the Preliminary phase (counterbalanced). In addition, in this condition the major actions of the underlying script (as determined in the Preliminary phase) were made available to the participants during the event construction task, by having them shown on the screen for the entire duration of the trial. Participants could use the script actions while imagining the event, though they did not have to.

2.4.2. Script production task

In the script production task, we presented 4 headlines of scripted events, one at a time, and asked participants to list the series of actions they thought was most likely to constitute the event, with the starting and ending point of each script specified in parenthesis. We made it clear that participants should list the actions that the event would entail for most people in our culture, rather than the actions that they themselves used to do in that situation. The experimental tasks were administered in two separate sessions, lasting approximately 1 h each. Participants always completed the non-scripted and scripted event generation tasks (in random order; blocked) in the first session. This was done to avoid cueing participants with event scripts before the event-construction task, as this might have led them to believe that following a script was a necessary requirement of event construction. In the second session, they were first administered the script production task, and then the cued-scripted event generation task. The script production task preceded the cued-scripted event generation task to prevent learning effects. For example, participants might have tended to produce scripts of the same length as those provided in the cued-scripted event generation task.

2.5. Scoring

Event generation task (non-scripted, scripted, cued-scripted events). All stories were transcribed and scored according to the Autobiographical Interview (AI) protocol developed by Levine et al. (2002). First, the text was segmented into details, which denote unique bits of information. These were then categorized as internal or external. Internal details are contextual details pertaining to the main event (the event described in the headline), including event, perceptual, temporal, and emotional information. External details involve events diverging from the main event (external event details), factual information (sematic details), repetitions, and other comments, remarks, or hesitations (other details; *e.g.* "I don't know", "Let me think"; see Levine et al., 2002). For the cued event generation task, details that corresponded to an externally provided major action were not counted as produced by the participant.

Script production task. Actions mentioned by participants were assessed through a scoring procedure that allowed us to investigate the semantic aspect of a script (core), along with different possible types of errors (see Bower et al., 1979; Godbout et al., 2004; Godbout and Doyon, 1995, 2000; Lynch et al., 2020; Roman et al., 1987; St-Laurent et al., 2009). First, we counted the total number of actions produced by

participants. All actions of a given script were compared with those detected in the preliminary experiment; all matches with major, minor and trivial actions were classified as such. When a major action was hyper-segmented, *i.e.* broken down into two or more actions (*e.g.* "take products" and "put them in the shopping trolley" instead of "shop"), it was counted as one major action; the two original activities however affected the total number of actions uttered by the participant. The remaining actions mentioned could be assigned to one of three error categories: idiosyncratic errors, relevant intrusions and irrelevant intrusions. An error was considered idiosyncratic when it described an action that was specific for that participant, and not generalizable to most people within the culture (*e.g.* "order steak" instead of "order food" at the restaurant script; see also Lynch et al., 2020). Actions that were mentioned by less than 25 % of participants of the preliminary phase were scored as intrusions; when an action was appropriate in the script's context (*e.g.* "starting the car to go home" in the shopping for groceries script) it was scored as a relevant intrusion; otherwise, it was counted as an irrelevant intrusion (*e.g.* "going for a pizza after the movie" in the cinema script; see also Scott et al., 2011; Godbout and Doyon, 2000). When the difference between idiosyncratic errors and intrusions was subtle (*e.g.*, 'going for a pizza after a movie' in the cinema script), we adopted a rule of considering an action an idiosyncratic error if the participant stated explicitly that was their own usual way of acting out the given script (*e.g.* "I always go for pizza after a movie", or "As I did yesterday"). On the contrary, when participants gave some indication that they did not usually perform that script (*e.g.* "I never go to the cinema"), or gave no information, the action was scored as an intrusion. The additional distinction between relevant and irrelevant intrusions was based on whether the action was relevant in the script's context. Boundary errors referred to an incorrect start and/or end of the script (which were given in the headline, but not always respected by participants). Sequencing errors described the occurrence of an impossible or not natural sequence of events (*e.g.* "take your keys" after "leave your house"; see also Lynch et al., 2020; Scott et al., 2011). Author DS and coauthors NC, EBR, and EM (blind to the study's hypotheses) jointly established the scoring method based on prior literature (see Godbout and Doyon, 2000; Lynch et al., 2020; Scott et al., 2011) and scored the first 10 participants together. The remaining data were divided evenly. Any scoring uncertainty was flagged, brought to the attention of the other scorers, and resolved through discussion.

3. Results

3.1. Script production

We first conducted a one-way ANOVA on the total number of actions with Group (Healthy participants, vmPFC patients, Control patients) as predictor, and confirmed that the three groups listed a comparable total number of actions ($F_{2,62} = 2.4$, $p = 0.1$). Then, for each action category (major, minor, trivial) and participant, we computed the percentage of actions correctly stated, by dividing the number of actions from that category stated correctly by the participant by the number of actions of that same category present in the 4 scripts. We conducted a repeated measure ANOVA on the percentage of actions, with Action Type (Major, Minor, Trivial) and Group (Healthy, Control Patients, vmPFC Patients) as predictors. The main effect of Group was significant ($F_{2,62} = 3.6$, $p = 0.03$, $\eta^2_p = 0.1$), indicating that vmPFC patients produced fewer actions than the control groups, with no difference between the control groups (vmPFC patients, M = 0.31; Healthy Controls, M = 0.44; Control Patients, M = 0.42). The effect of Action Type was also significant ($F_{2,124} = 99.9$, $p < 0.0001$, $\eta^2_p = 0.62$), revealing that participants produced more major (M = 0.63) compared to minor (M = 0.36) or trivial actions (M = 0.26). The interaction Type of action*Group was not significant ($p = 0.3$). This was likely due to reduced statistical power, as visual inspection of averages suggests that the Group difference was driven by minor and trivial actions. To explore this possibility, we conducted three separate ANOVAs on major, minor, and trivial actions, with Group as predictor. The ANOVA on major actions did not unveil a significant effect of Group ($F_{2,62} = 0.7$, $p = 0.5$). The ANOVA on minor actions revealed a significant effect of Group ($F_{2,62} = 4.2$, $p = 0.02$, $\eta^2_p = 0.12$), with post-hoc Fisher tests showing that vmPFC patients mentioned fewer minor actions as compared to both healthy controls (0.22 vs 0.39, $p = 0.005$) and control patients (0.22 vs 0.36, $p = 0.04$), and no difference between the control groups (0.39 vs 0.36, $p = 0.7$). Similarly, a significant effect of Group was present in the ANOVA on trivial actions ($F_{2,62} = 3.2$, $p = 0.048$, $\eta^2_p = 0.09$). Post-hoc Fisher's tests again highlighted fewer trivial actions in vmPFC patients than both healthy controls (0.13 vs 0.27, $p = 0.02$) and control patients (0.13 vs 0.29, $p = 0.03$), and no differences between control groups (0.27 vs 0.29, $p = 0.7$, Fig. 2; **see** Supplementary materials for an analysis on the role of education on script production). We note that (vmPFC and control patients') lesion size did not correlate with the number of major, minor, or trivial actions, with Pearson's correlation coefficients ranging between $r = 0.02$ and $r = 0.19$, all non-significant (ps > 0.4). None of the ANOVAs on the number of errors (sequencing errors, idiosyncratic errors, relevant and irrelevant intrusions, boundary errors) revealed Group effects (all ps > 0.2).

This first set of analyses shows that vmPFC patients tended to retain accurate knowledge of the important, or "core" aspects of scripts (major actions) and did not show any systematic tendency towards error. However, they failed to provide as many minor and trivial actions as the control groups, suggesting a loss of the finer aspects of scripts.

3.2. Event generation

3.2.1. Internal and external details

We ran a repeated-measures ANOVA on the number of details with Group as the between-subject factor, and Condition (non-scripted, scripted, cued-scripted) and Type of detail (internal, external) as within-subject factors (see Fig. 3). The main effect of Group, the interaction Group*Condition, and the interaction Condition*Type of Details were not significant (all ps > 0.1). There were significant main effects of Condition ($F_{2,124} = 3.8$, $p = 0.02$, $\eta^2_p = 0.06$), and of Type of detail ($F_{1,62} = 44.6$, $p < 0.0001$, $\eta^2_p = 0.42$), a significant Group*Type of detail interaction ($F_{2,62} = 5$, $p < 0.01$, $\eta^2_p = 0.14$), and a significant Group*Condition*Type of detail interaction ($F_{4,124} = 3.2$, $p = 0.02$, $\eta^2_p = 0.09$). We first report intra-condition post-hoc tests, looking at differences among groups between types of details (Internal and External) in the three experimental conditions separately. Then, we focus on intra-group differences, which indicate changes in internal and external details across conditions. Lastly, we report changes in the number of internal vs external details for the three groups across conditions.

Non-scripted condition. Post-hoc Fisher tests revealed that in the non-scripted condition vmPFC patients produced fewer internal details than both healthy ($p = 0.002$) and brain damaged controls ($p = 0.02$), with no difference between the control groups ($p = 0.7$), and a comparable number of external details than the control groups (vmPFC vs Healthy, $p = 0.3$; vmPFC vs Control Patients, $p = 0.5$).

Scripted condition. In the scripted condition, vmPFC patients were still poor in event generation: they produced significantly fewer internal details than control patients ($p = 0.007$) and (only numerically) fewer internal details than healthy controls ($p = 0.09$). The difference in internal details between the control groups was marginally significant ($p = 0.06$). There were no group differences in external details ($p > 0.3$ in all cases).

Cued-scripted condition. Importantly, group differences in event generation were eliminated in the cued-scripted condition: vmPFC patients did not differ from the control groups in either internal or external details (all ps > 0.1).

Non-scripted vs scripted condition. Compared to the non-scripted condition, in the scripted condition healthy controls produced more external details ($p = 0.004$), whereas control patients produced more internal details ($p = 0.02$). In vmPFC patients neither internal nor

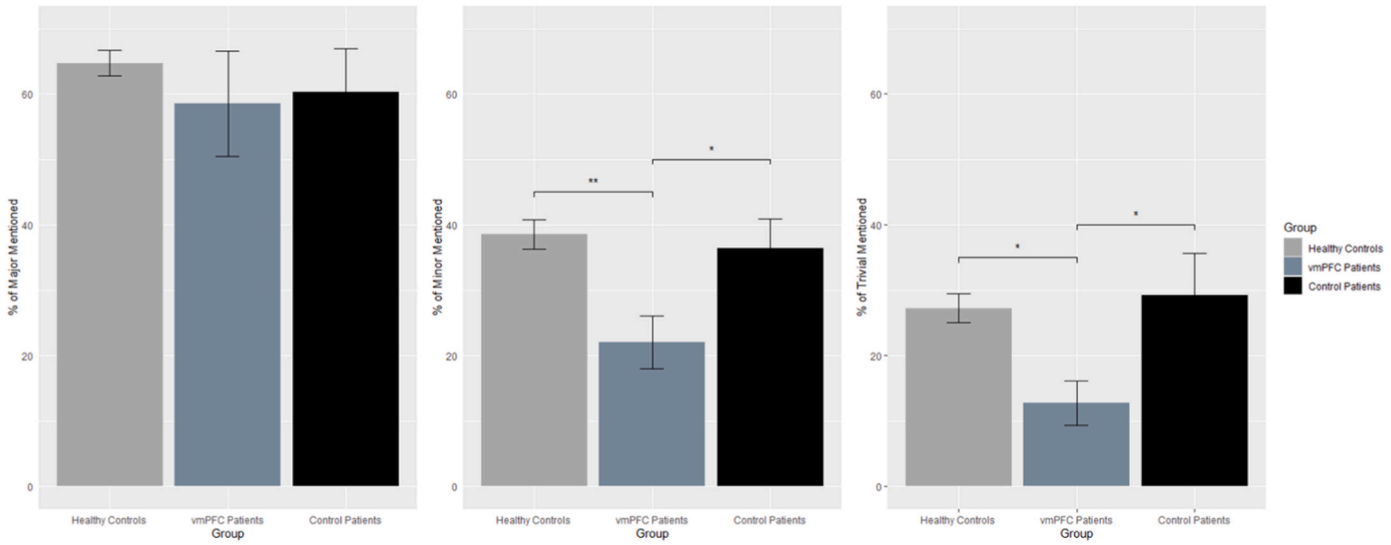

Fig. 2. Percentages of major, minor and trivial actions correctly produced by participant groups.

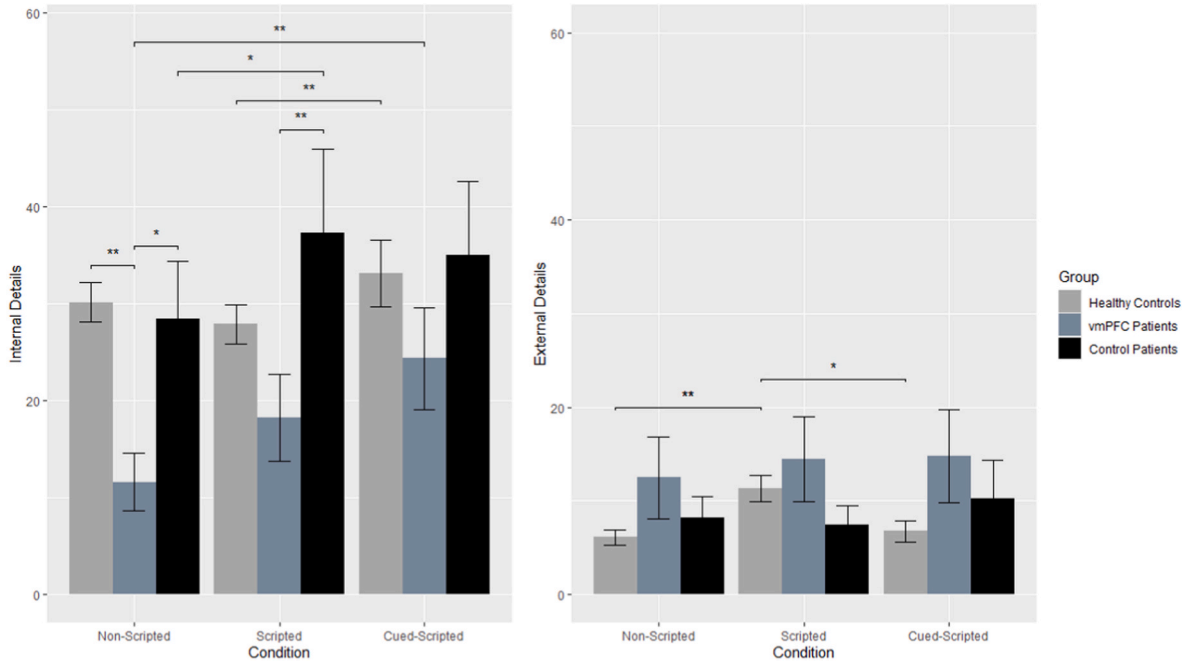

Fig. 3. Average number of internal (left panel) and external (right panel) details produced during event construction by participant group and experimental condition. **Single asterisks indicate p < 0.01, double asterisks indicate p < 0.001.**

external details increased significantly (all ps > 0.1).

Scripted vs cued-scripted condition. Compared to the scripted condition, in the cued-scripted condition healthy controls produced more internal details (p = 0.004), but fewer external details (p = 0.01). In control patients no significant change was observed from the scripted to the cued-scripted condition in either internal (p = 0.5) or external details (p = 0.45). Finally, in vmPFC patients internal details increased numerically but not significantly (p = 0.16), whereas external details did not change across the two conditions (p = 0.9).

Non scripted vs cued-scripted condition. Internal details in vmPFC patients were significantly more in the cued-scripted compared to the non-scripted condition (p = 0.003), which was not the case for control patients (p = 0.07), or healthy controls (p = 0.09). External details did not vary from the non-scripted to the cued-scripted condition in any group (all ps > 0.6).

Internal vs external details across conditions. Whereas the control groups consistently generated events characterized by more internal than external details across conditions (all ps < 0.0001), for vmPFC patients this was the case only in the cued-scripted condition (24.4 vs 14.8, p = 0.03), while in the non-scripted condition and in the scripted condition they generated events poor in episodic content and characterized by a similar number of internal and external details (non-scripted: 11.6 vs 12.5, p = 0.8; scripted: 18.3 vs 14.5, p = 0.4, Fig. 3; see Supplementary materials for an analysis on the role of education on event generation). We note that (vmPFC and control patients') lesion size was not a reliable predictor of the number of internal details (collapsed across conditions; r = 0.12, p = 0.6). This lack of association remained even when the three conditions were analyzed separately (all ps > 0.1).

This second set of analyses shows an impairment in event generation

in vmPFC patients in the non-scripted condition; event generation performance improves but the deficit is still visible in the scripted condition, when a detailed script must be reinstated and instantiated. By contrast, in the cued-scripted condition, when the script is externally provided (bypassing schema reinstatement), vmPFC patients' event generation performance improves to the level of the control groups'.

3.2.2. Quality of internal and external details

To qualify what type of information participants provided when producing internal details, we ran repeated measure ANOVA on the average number of internal details, with Group (Healthy, vmPFC Patients, Control Patients), Type of Detail (Event, Place, Time, Perceptual, Emotional/Thought), and Condition (Non scripted, Scripted, Cued-scripted) as predictors (see Fig. 4, left panel). The ANOVA yielded a main effect of Condition ($F_{8,123} = 8.3$, $p < 0.001$, $\eta_p^2 = 0.12$), a main effect of Type of Detail ($F_{4,248} = 114.6$, $p < 0.001$, $\eta_p^2 = 0.65$), and a Condition*Type of Detail interaction ($F_{8,496} = 13.8$, $p < 0.001$, $\eta_p^2 = 0.18$). Post-hoc comparisons revealed that perceptual details were more in the scripted vs non-scripted condition ($p = 0.04$), without significant differences between the scripted and cued-scripted, or the non-scripted and cued-scripted conditions (all ps > 0.1). Event details, on the other hand, increased in the cued-scripted conditions as compared to the other conditions (all ps < 0.01), with no difference between non-scripted and scripted conditions ($p = 0.6$). No difference across conditions were detected for Place, Time, and Emotional/Thought details (all ps > 0.05). The effect of Group, the interaction Group*Condition, and Group*Type of Detail were not significant (all ps > 0.08).

We then ran the same ANOVA on the average number of external details, with Group (Healthy, vmPFC Patients, Control Patients), Type of Detail (Event, Semantic, Repetition, Other), and Condition (Non scripted, Scripted, Cued-scripted) as predictors (see Fig. 4, right panel). The analysis unveiled a significant main effect of Type of Detail ($F_{3,186} = 46.2$, $p < 0.00001$, $\eta_p^2 = 0.42$) and a significant Type of Detail*Condition interaction ($F_{6,372} = 3.7$, $p = 0.001$, $\eta_p^2 = 0.06$). Post-hoc comparisons indicated that more semantic details were produced in both the scripted and cued-scripted condition compared to the non-scripted (all ps < 0.0001), with no differences between the scripted and cued-scripted conditions ($p = 0.08$), confirming that scripts facilitate access to factual information while conceiving events (see Fig. 4). External event details were more in the scripted condition compared to the cued-scripted condition ($p = 0.009$), possibly indicating that participants tended to recast past events compatible with the scripts, but this recasting occurred less in the cued-scripted condition, which promoted the production of a story that obeyed a fixed series of steps. Repetitions and 'other' details remained stable across conditions (all ps > 0.33).

3.2.3. Adherence of constructed events to the scripts' steps

We investigated whether constructed events tended to explicitly incorporate the steps of the underlying scripts. We counted the number of major actions mentioned in each constructed event, and divided them by the total number of major actions present in the relative script, separately for the scripted and cued-scripted conditions. We then ran a repeated measure ANOVA on the frequency of major actions mentioned in the events, with Condition (Scripted, Cued-Scripted) and Group (Healthy, Control Patients, vmPFC Patients) as predictors. The effect of Group was not significant ($F_{2,62} = 2.3$, $p = 0.1$), but there were significant main effects of Condition ($F_{1,62} = 190$, $p < 0.00001$, $\eta_p^2 = 0.75$), and a significant Group*Condition interaction ($F_{2,62} = 3.6$, $p = 0.03$, $\eta_p^2 = 0.1$). Post-hoc Fisher tests showed that the three groups mentioned major actions with comparable frequency in the scripted condition (all ps > 0.1). However, in the cued-scripted condition, vmPFC patients mentioned fewer major actions than healthy controls (0.70 vs 0.86, $p = 0.004$). There was no significant difference between vmPFC patients and control patients (0.70 vs 0.82, $p = 0.09$) and between control patients and healthy controls ($p = 0.35$).

3.2.4. Self-reported ratings

We ran a series of repeated measures ANOVAs on self-reported ratings, with Group and Condition (Non-Scripted, Scripted, Cued-Scripted) as factors. The ANOVAs on perceived detailedness, perceived vividness, similarity to memory and sense of presence all revealed Condition as the only significant effect (all ps < 0.0001). Specifically, participants rated the constructed experience in the non-scripted condition as less detailed, less vivid, less similar to a memory, end evoking a weaker sense of presence compared to that in the scripted and cued-scripted condition (all ps < 0.0001), with the scripted and cued-scripted conditions being

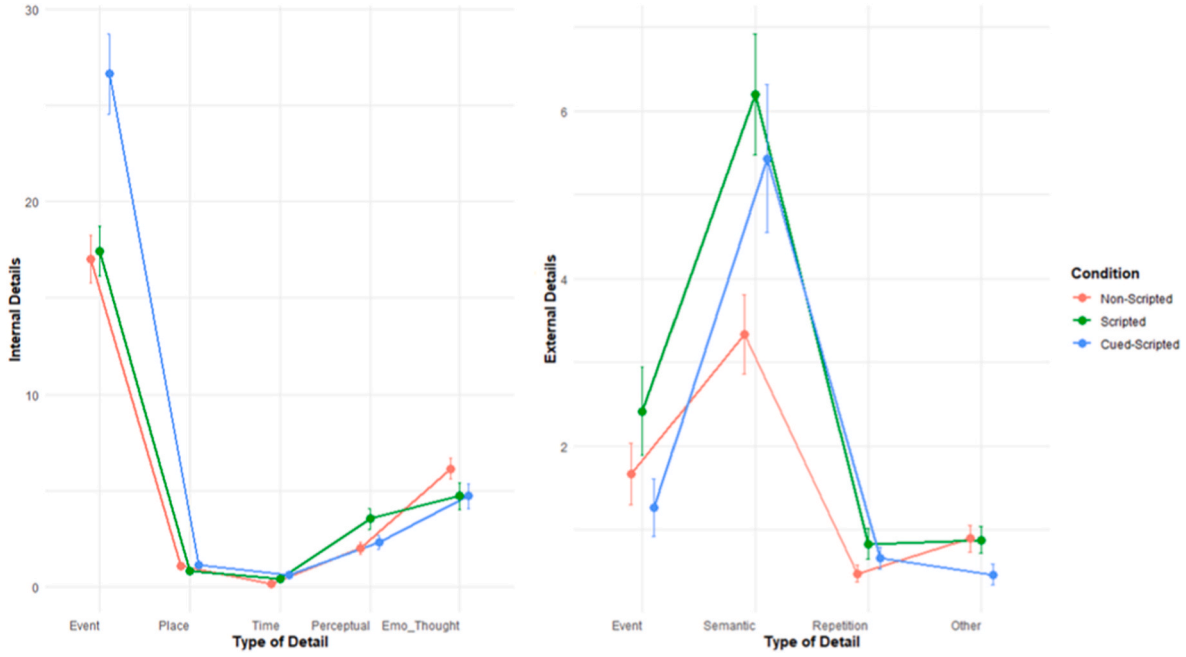

Fig. 4. Average number of internal (left panel) and external (right panel) details produced during event construction by Detail category (Event, Place, Time, Perceptual, Emotional/Thought for internal details, and Event, Semantic, Repetition, Other for external details).

judged similarly across types of qualitative rating (all ps > 0.09).

The analysis on the Spatial Coherence Index (SCI) highlighted a significant effect of Condition ($F_{2,124} = 13.7$, $p < 0.0001$, $\eta_p^2 = 0.18$) and a Group*Condition interaction ($F_{4,124} = 2.6$, $p = 0.04$, $\eta_p^2 = 0.08$), which was driven by control patients exhibiting a different SCI trend than the other groups. Specifically, Fisher tests showed that healthy controls and vmPFC patients had lower SCIs in the non-scripted compared to the scripted and cued-scripted conditions (all ps < 0.01), but this was not the case for control patients, who had comparable scores across conditions (all ps > 0.4). There were no significant differences in SCI among participant groups across conditions (all ps > 0.3).

Similarly, the ANOVA on perceived difficulty revealed an effect of Condition ($F_{2,124} = 13.2$, $p < 0.0001$, $\eta_p^2 = 0.18$) and a Group*Condition interaction ($F_{4,124} = 3.3$, $p = 0.01$, $\eta_p^2 = 0.1$), with post-hoc comparisons showing that healthy controls and vmPFC patients rated the non-scripted condition as more difficult than the scripted and cued-scripted conditions (all ps < 0.01), and gave similar ratings between the scripted and cued-scripted conditions (all ps > 0.5). However, control patients gave similar ratings across conditions (all ps > 0.6). Perceived difficulty was comparable across groups in the scripted and cued-scripted condition (p > 0.28 in all cases), but control patients perceived the non-scripted condition as easier than the other groups (all ps < 0.048).

3.2.5. Exploratory correlations

Major, minor, trivial actions and internal details. To investigate whether vmPFC patients' impoverished knowledge of the finer aspect of event scripts (*i.e.* minor and trivial actions) was related to their poor event generation performance (see also Bertossi et al., 2016a,b) we ran a repeated measures ANOVA on the number of internal details, with Condition (non-scripted, scripted, cued-scripted), and the frequency of major, minor and trivial actions as predictors, including all possible two-way interaction terms. The only significant predictor was the frequency of trivial actions ($F_{1,61} = 14.3$, $p < 0.001$, $\eta_p^2 = 0.19$), indicating that few trivial actions in the script production task predicted few internal details in the event generation task. All interactions involving the variable Condition were not significant.

Internal details and self-reported ratings. We explored whether the number of internal details in the different experimental conditions (non-scripted, scripted, cued-scripted) could be determinants of self-reported ratings. To do so, we ran 5 repeated measure ANOVAs, one for each self-reported rating (difficulty, sense of presence, similarity to memory, vividness, detailedness), with the number of internal details and Condition as predictors. The number of internal details was significantly and positively related perceived vividness, detailedness, and sense of presence (all ps < 0.048), while it did not influence ratings of difficulty and similarity to memory (p > 0.2 in both cases). We also obtained a significant main effect of Condition in all 5 ANOVAs (all ps < 0.008; see section 3.2.4). The interaction between the number of internal details and Condition was not significant in any of the 5 ANOVAs (all ps > 0.1).

4. Discussion

In the present study, we investigated the role of vmPFC in the reinstatement and instantiation of event schemata (scripts). Script reinstatement was assessed through a script production task, in which vmPFC patients and healthy and brain-damaged controls were asked to generate scripts of everyday activities. Script instantiation was evaluated with an event-generation task for non-scripted events, scripted events, and scripted events cued by their underlying scripts during event generation.

At the script production task, we found a significant deficit in the reinstatement of scripts in vmPFC patients. vmPFC patients, however, tended to have adequate knowledge of the "backbone" of scripts, namely, the (major) actions that mostly characterize a specific script, which they were also able to incorporate in their mental constructions of scripted events. However, they failed to enumerate a sufficient number of actions that make up the finer details of a script (*i.e.* minor and trivial actions), indicating that the scripts they reinstate are impoverished compared to the controls'. Interestingly, vmPFC patients did not make more errors than healthy and brain-damaged controls, contrary to previous studies on patients with diffuse lesions to the frontal lobe who exhibited frequent failures to close scripts, errors in ordering actions within a script, and choice of irrelevant actions as part of scripts (Allain et al., 1999; Godbout and Doyon, 1995; Sirigu et al., 1995; Wood et al., 2005). Our results agree with the proposal that vmPFC patients do activate schemata, but these are broad, "nebulous", suggesting a degraded schema reinstatement following vmPFC damage (Giuliano et al., 2021; see also Ghosh et al., 2014; Shallice and Cooper, 2012). These results are also consistent with the study by Ghosh et al. (2014) that examined vmPFC patients' ability to categorize actions within their appropriate schema, and found that vmPFC patients with present or prior confabulation were impaired in classifying the stimulus belongingness to a schema and in rejecting lures. The "protective" role of vmPFC damage against intrusion errors at the Deese-Roediger-McDermott paradigm also suggests a role of the vmPFC in supporting the reinstatement of schemata that then drive the erroneous endorsement of schema-congruent words at recognition (Melo et al., 1999; Warren et al., 2014). Our finding of degraded event scripts in vmPFC patients aligns with previous evidence from our group indicating a degradation of the self-schema following vmPFC damage. In particular, Stendardi et al. (2021) found that vmPFC damage causes the disappearance of a mnemonic advantage for trait items encoded with respect to the self, compared to another individual (self-reference effect; see also Philippi et al., 2012). Moreover, Stendardi et al. (2023) found that vmPFC patients, contrary to healthy and brain lesioned controls, were not more consistent between sessions when answering questions about their own preferences compared to those of a close other.

At event generation, in the non-scripted condition, when there is not a specific, strong script to follow, vmPFC patients produced significantly fewer internal details than the control groups, together with a similar number of external details, replicating findings of impaired episodic simulation in vmPFC patients under standard conditions (Bertossi et al., 2016a, 2016b, 2017; McCormick et al., 2018). The present finding also makes contact with the results of Peters et al. (2017), who investigated life-like problem-solving in vmPFC patients using scenarios akin to those in our non-scripted condition. The authors reported that vmPFC patients were impaired in generating effective solutions, particularly to social problems, possibly due to a failure in retrieving relevant schemata to drive the search for potential behavioral options (Peters et al., 2017). Although we did not investigate problem solving, the fact that vmPFC patients were impaired in imagining non-scripted scenarios is in line with their poor problem solving performance in such scenarios (Peters et al., 2017), as the number of internal details while imagining open-ended situations and the number of relevant means produced to solve the same situations are correlated (Sheldon et al., 2011).

What happened when participants were given the possibility to base the generated event on a specific, unique script? Self-ratings showed that all groups, including vmPFC patients, perceived scripted compared to non-scripted events as 'less similar to memories', meaning they were sensitive to some extent to the different nature (non-scripted vs. scripted) of the events to be constructed. Consistently, all groups produced more semantic details while producing scripted compared to non-scripted events. However, vmPFC patients were not able to reinstate fully the scripts underlying the events to improve event generation significantly. Indeed, passing from the non-scripted to the scripted event generation condition, we observed an increase in internal details in control patients but not in vmPFC patients. In healthy controls, internal details did not increase further from the non-scripted to the scripted condition; rather, we observed an increase in external details, suggesting that individuals narrated events with a strong underlying script directly mentioning aspects of the script, or their habitual way to accomplish the

activities. vmPFC patients did not seem to benefit significantly from the presence of a strong script underlying the event to be narrated, as if they were not sufficiently receptive to the scripted nature of the events. Indeed, no significant change in internal or external details was observed from the non-scripted to the scripted condition in vmPFC patients. As a result, vmPFC patients' event generation performance in this condition (internal details) was still poor compared to that of control groups.

vmPFC patients' performance clearly improved compared to the non-scripted condition only in the cued-scripted condition, that is, when the scripts underlying the to be constructed events were made available to the participants during event generation, bypassing schema reinstatement. In this condition, group differences were eliminated: vmPFC patients produced a similar number of internal and external details compared to both healthy and brain-damaged controls. Moreover, vmPFC patients' constructed events appeared as episodically rich as those of the controls. Indeed, whereas healthy and brain damaged controls produced events with more internal than external details across experimental conditions, vmPFC patients were capable to construct events richer in internal than external detail only when they had the script of events available during event construction (cued-scripted condition). Notably, these findings were not merely due to a tendency, on the vmPFC patients' part, to directly utter the externally provided scripts steps, as this tendency was instead stronger in healthy controls. The results show that when a script was externally provided, thus reducing the demands on schema reinstatement, vmPFC patients were able to use it to guide event generation, suggesting that schema reinstatement but not schema instantiation is impaired in these patients.

Our interpretation is in line with previous evidence that vmPFC is crucial for the endogenous but not the exogenous activation of mental contents and processes. For example, vmPFC patients have steep delay discounting of future rewards but are capable to upregulate their valuation of future rewards if they are externally prompted to imagine future scenarios (Ciaramelli et al., 2021b). In addition, inhibition of medial prefrontal cortex with transcranial direct current stimulation inhibits endogenously generated but not externally triggered forms of mind-wandering (Giacometti Giordani et al., 2023). Our results are not perfectly in agreement with previous studies of schema reinstatement and instantiation, but the operationalization of these processes is not always perfectly aligned across tasks. For example, Giuliano et al. (2021) investigated the temporal dynamics of reinstatement and instantiation in healthy controls and vmPFC patients while they classified words according to a given schema (or semantic category). They reported sustained theta desynchronization resulting from the interaction between vmPFC and posterior cortical regions immediately prior to word presentation (*i.e.* when only the schema or category was known to participants), supporting schema reinstatement (Gilboa and Moscovitch, 2017; Hebscher et al., 2019). vmPFC patients showed the least amount of such interregional desynchronization (see also Gilboa and Marlatte, 2017), in accordance with our finding of a degradation of the reinstatement process after vmPFC damage. The authors also reported that schema instantiation was associated with post-stimulus desynchronization in the alpha and beta frequency ranges while participants had read the word and were about to classify it, reflecting interactions between vmPFC and the lateral temporal cortex (LTC). Our results suggest a preserved ability to instantiate schematic knowledge in vmPFC patients, since their performance during event construction was comparable to the controls' when scripts did not need be reinstated but only instantiated to guide event construction (cued-scripted condition).

Previous studies of event construction have led to the hypothesis that vmPFC would be responsible for the activation of schematic knowledge in neocortex, which is used by the hippocampus to construct a sketch of a rudimentary scene, and then vmPFC would engage in feedback loops with the hippocampus to monitor the retrieval of schema-congruent details to fill the unfolding event (McCormick et al., 2021; Pisani et al., 2025). This hypothesis is supported by neuropsychological evidence that patients with lesion to the hippocampus produce fewer spatial details during scene construction, while patients with vmPFC lesions construct scenes that are devoid of multiple types of detail, including sensory details, entities present and actions, suggesting that vmPFC plays a superordinate role than the hippocampus in event construction (De Luca et al., 2018). Indeed, MEG studies have shown that vmPFC activity precedes that of the hippocampus during scene construction (Barry et al., 2019; Monk et al., 2021). The present findings support this hypothesis because we found that vmPFC damage causes the reinstatement of poor schemata that are insufficient to drive event construction. Indeed, our vmPFC patients were mostly capable to reinstate the 'backbone' of scripts (major actions), while exploratory analyses showed that the capability to construct events (internal details) is in fact related to the ability to conjure up the finer aspects of the scripts (trivial actions). Future studies should investigate if probing vmPFC patients with trivial actions of scripts is even more effective in enriching event construction performance, as the number of internal details proved an important determinant of the subjective experience of constructed events, in terms of perceived vividness, detailedness, and sense of presence across groups.

To conclude, we have shown that vmPFC damage causes an impairment in schema reinstatement, leading to the activation, on the vmPFC patients' part, of incomplete, broad scripts that are mainly characterized by major actions, while they have lost finer details that appear conducive to the construction of script-congruent, context-rich events. When scripts are externally provided, however, vmPFC patients were capable to use them to efficiently drive event construction. We propose, therefore, that vmPFC integrity is crucial for the reinstatement of scripts. However, the instantiation of scripts can be preserved following vmPFC damage when these are externally provided, reducing the demands on script reinstatement.

CRediT authorship contribution statement

Debora Stendardi: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Nicola Ciavatti:** Methodology, Investigation, Data curation. **Eloisa Bianchi Rossi:** Methodology, Investigation, Data curation. **Erida Meminaj:** Methodology, Investigation, Data curation. **Luana Valeri:** Methodology, Investigation, Data curation. **Elena Mengoli:** Methodology, Investigation, Data curation. **Davide Braghittoni:** Resources, Investigation. **Elisa Ciaramelli:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.neuropsychologia.2025.109249.

Appendix 1

Non-scripted events

- Finding your lost watch – from the moment you realize you have lost it to when you find it;
- Making friends in your new neighbourhood – from moving to a new neighbourhood to making at least a friend there;
- Entertain and baby-sit three children aged 4, 7 and 11 for a few hours – from when a relative of yours brings them to you, until s/he collects them;
- Retrieve a soccer ball that your niece/nephew threw on a tree – from when you realize the ball is stuck, to when you successfully retrieve it.

Scripted events

1. Going out for dinner with friends – from the decision to go out, to coming back home.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Make a reservation/call the restaurant; Get ready to go out; Go to the restaurant; Order food; Eat; Pay; Return home.	Decide to go out for dinner; Choose the restaurant. Take your wallet/key/phone;	Call/invite your friends; Leave the house; Meet up with your friends; Enter the restaurant; Sit at your table.

2. Going to the movies – from the decision to go, to coming back home

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Choose the movie Get ready to go out; Get snacks; Get the tickets; Look for the cinema hall/enter the hall; Watch the movie; Return home.	Decide to go to the movies; Take your wallet/key/phone; Meet up with your friends; Go to the cinema; Sit down in the hall.	Choose a time for the movie; Leave the house; Enter the building; Exit the cinema hall; Take your car to go home.

3. Attend a wedding – from getting ready, to coming back home.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Get ready/get dressed; Go to the venue; Attend the ceremony; Go to the restaurant; Eat/attend the lunch or dinner; Return home.	Take your wallet/purse/wedding gift; Leave the house; Party/dance.	Meet up/greet friends; Congratulate the bride and groom; Say goodbye.

4. Shop for groceries – from the decision to go, to coming back home.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Write down a shopping list; Go to the grocery store; Get a shopping trolley; Shop/choose the products; Get in the check out line/queue; Pay; Return home.	Decide to go grocery shopping; Look in fridge/pantry to see what you need; Take your wallet/key/phone; Leave the house; Enter the grocery store; Put your shopping in shopping bags.	Get ready to go out; Take your shopping bags; Park your car; Wander the aisles; Place your shop on the conveyor belt; Put your shopping in the car; Exit the grocery store; Put the trolley back in its place.

5. Going to the doctors – from when you book the appointment, to coming back home.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Book an appointment; Go to the doctor's office; Sit in the waiting room/wait for your turn; Have the check-up/get examined; Return home.	Call your doctor; Get ready to go out; Leave the house; Leave the doctor's office.	Take your wallet/key/phone; Enter the doctor's office; Check-in at the doctor's office; Talk to the doctor/list your symptoms; Get a diagnosis/get medication; Pay; Say goodbye when leaving.

6. Taking a shower – from the decision to have a shower, to when you are dressed.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Decide to shower; Turn the water on; Undress; Enter the shower; Wash yourself up/soap and rinse; Exit the shower; Use the bathrobe/towel; Dry yourself; Dry your hair; Get dressed.	Go in the bathroom; Wait for hot water; Wash your hair/shampoo and rinse.	Get wet; Turn the water off.

7. Christmas day – from waking up to going to sleep.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Wake up; Have breakfast; Open presents; Have lunch; Go to sleep.	Get ready to go out/get dressed; Exchange Christmas greetings; Have dinner.	Cook; Go to the family Christmas lunch; Play bingo/play games; Say goodbye to relatives; Return home.

8. Get ready for work/school – from waking up to arriving at work/school.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Wake up/get up; Wash up/wash your face/brush your teeth; Have breakfast; Get dressed; Leave the house; Arrive at work/school.	Go to the bathroom; Take your wallet/key/phone.	Hear the alarm clock; Sit down at your desk.

9. Shop for clothes – from the decision to go, to coming back home.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Decide to go shopping; Try the clothes on; Check-out/queue at the check-out line; Pay; Return home.	Take your wallet/key/phone; Leave the house; Go to the shops; Enter the shop; Choose clothes to try on; Exit the shop.	Get dressed (to go out); Wander around different shops; Look at the clothes; Look for your size; Go to the dressing rooms; Look at your reflection/see whether the clothes fit well; Choose which clothes to buy.

10. Going a day at the swimming pool - from the decision to go, to coming back home.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Decide to go to the swimming pool; Take your swimming bag/towels/swim cap/key/wallet; Leave the house; Get changed/put swimsuit on; Go to the pool; Swim/do laps; Have a shower before leaving the pool; Return home.	Dive/get in the water; Get out the water; Get dry and dressed after swimming.	Get dressed (to go out); Pay at the entrance; Enter the building; Sunbathe/relax on the deckchair.

11. Go to the hairdresser/barber – from the decision to go, to coming back home.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Decide to go to the hairdresser/barber; Set an appointment; Get to the salon; Get a haircut/wash/hair dye; Pay; Return home.	Call the salon; Get ready to go out; Leave the house; Enter the salon; Wait for your turn; Explain/request a haircut/blow-dry/hair dye.	Take your key/wallet/phone; Exit the salon.

12. Have a minor car accident (*e.g.* a rear ending) – from the collision to when you drive away after having dealt with the other person involved.

Major (≥65 %)	Minor (45–64 %)	Trivial (25–44 %)
Be rear-ended; Get out your car; Assess the damage; Reach an agreement with the other person; Fill insurance documents (italian "CID"); Get back in your car; Drive away.	Stop/pull over; Make sure nobody is injured; Exchange personal info with the other driver.	Get the documents to fill; Talk with the other driver.

Data availability

Data will be made available on request.

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