Elevated perseveration errors on a verbal fluency task in frequent nightmare recallers: a replication

MICHELLE CARR[1,2], KADIA SAINT-ONGE[1,3], CLOÉ BLANCHETTE-CARRIÈRE[1,3], TYNA PAQUETTE[1] and TORE NIELSEN[1,4]

[1]Dream and Nightmare Laboratory, Center for Advanced Research in Sleep Medicine, CIUSSS-NÎM - Hôpital du Sacré-Coeur de Montréal, Montréal, Québec, Canada; [2]Swansea University Sleep Laboratory, Department of Psychology, Swansea University, Swansea, UK; [3]Department of Psychology, Université de Montréal, Montréal, Québec, Canada; [4]Department of Psychiatry, Université de Montréal, Montréal, Québec, Canada

Keywords
executive dysfunction, neurocognitive model, nightmares, perseveration, verbal fluency

Correspondence
Tore Nielsen, PhD, Center for Advanced Research in Sleep Medicine, CIUSSS-NÎM – Hôpital du Sacré-Coeur de Montréal, 5400 Boulevard, Gouin West, Montreal, Quebec, Canada H4J 1C5.
Tel.: 514-338-2222x3350;
fax: 514-338-2531;
e-mail: tore.nielsen@umontreal.ca

Accepted in revised form 30 October 2017; received 18 July 2017

DOI: 10.1111/jsr.12644

SUMMARY

A recent study reported that individuals recalling frequent idiopathic nightmares (NM) produced more perseveration errors on a verbal fluency task than did control participants (CTL), while not differing in overall verbal fluency. Elevated scores on perseveration errors, an index of executive dysfunction, suggest a cognitive inhibitory control deficit in NM participants. The present study sought to replicate these results using a French-speaking cohort and French language verbal fluency tasks. A phonetic verbal fluency task using three stimulus letters (P, R, V) and a semantic verbal fluency task using two stimulus categories (female and male French first names) were administered to 23 participants with frequent recall of NM (≥2 NM per week, mean age = 24.4 ± 4.0 years), and to 16 CTL participants with few recalled NM (≤ 1 NM per month, mean age = 24.5 ± 3.8 years). All participants were French-speaking since birth and self-declared to be in good mental and physical health apart from their NM. As expected, groups did not differ in overall verbal fluency, i.e. total number of correct words produced in response to stimulus letters or categories ($P = 0.97$). Furthermore, groups exhibited a difference in fluency perseveration errors, with the NM group having higher perseveration than the CTL group ($P = 0.03$, Cohen's $d = 0.745$). This replication suggests that frequent NM recallers have executive inhibitory dysfunction during a cognitive association task and supports a neurocognitive model which posits fronto-limbic impairment as a neural correlate of disturbed dreaming.

INTRODUCTION

Idiopathic nightmares (NM) are distinguished from other types of NM, such as post-traumatic or medication-induced NM, in having no immediately known medical aetiology. They are vivid dreams, usually arising from rapid eye movement (REM) sleep (American Academy of Sleep Medicine, 2005; American Psychiatric Association, 2013; Fisher *et al.*, 1970) that are marked by intense dysphoric emotions such as fear, anger or sadness, and often end in abrupt awakenings.

Approximately 5% (Nielsen and Zadra, 2000) of the general population recall NM at a clinically significant frequency of one or more times per week (American Academy of Sleep Medicine, 2005), although this percentage varies from 0.9 to 6.8% of individuals (see review in Sandman *et al.*, 2013). Occasional NM are much more common, with up to 85% of adults recalling at least one NM per year (Levin and Nielsen, 2007). NM frequency has been linked to genetic factors (Hublin *et al.*, 1999) and to certain personality traits, particularly neuroticism (Levin and Nielsen, 2007). They often arise in childhood and, when they persist into adulthood (Kales *et al.*, 1980; Nielsen and Zadra, 2000), may be associated with disturbances such as avoidance behaviours (Haynes and Mooney, 1975; Schredl and Pallmer, 1998), diminished sleep hygiene (Krakow *et al.*, 2000), psychological distress and insomnia (Levin and Nielsen, 2007).

Affective network dysfunction (AND) model of nightmares

A neurocognitive model of NM—the affective network dysfunction (AND) model—proposes that nightmares arise due

to a failure in emotional memory processing, particularly during NM themselves (Nielsen and Levin, 2007). According to the model, normal dreaming is proposed to facilitate fear memory extinction according to currently accepted notions of fear memory acquisition and extinction. Fear extinction memories are presumed to be created or maintained when dreams associate, on one hand, an element that has been conditioned previously to elicit a fear response (e.g. a stranger in a dark alley evoking fear) to, on the other hand, one or more neutral contexts (e.g. the same stranger on a sunny beach no longer evoking fear). This process of extinction memory formation is postulated to operate according to the principles of extinction in classical conditioning (Pavlov, 2003). This notion is consistent with the finding that REM sleep may be particularly important in the consolidation of fear extinction memories (Fu *et al.*, 2007; see review in Pace-Schott *et al.*, 2015).

The AND model thus builds upon the notion that dreaming is hyperassociative (Hartmann, 1996), in that fear extinction requires that memories between distant elements be associated during dreaming. There is increasing evidence that associative mechanisms are broader during REM sleep than they are during non-REM (NREM) sleep or waking. First, participants awakened from REM sleep display broader associative responses on an associative task with priming than do those experiencing a period of wake or NREM (Carr and Nielsen, 2015). Secondly, increased breadth of associative processing is suggested by better scores on anagram solutions after REM but not NREM sleep (Walker *et al.*, 2002). Thirdly, REM, but not NREM, sleep is followed by improved performance on the remote associates task (Cai *et al.*, 2009). The increased breadth of associative mechanisms during REM sleep may be implicated in the formation of dream content, and particularly in allowing for novel memory elements to be associated with fear memories and thus extinguished.

According to the AND model, nightmares result from a failure in creating and maintaining fear-extinction memories during dreaming. This dysfunction is related to impairments in the ventromedial prefrontal and anterior cingulate cortex, which lead to a failure of fear extinction processes that are normally active during dreaming. In particular, dysfunctional executive processing during REM sleep may limit or block hyperassociativity and thus prevent the production of new fear-extinction memories. Without neutral or positively toned spatiotemporal contexts with which to associate anxiogenic elements that are normally brought up during dreaming, fear extinction cannot occur and disturbed dreaming may prevail (Nielsen and Levin, 2007). Presumably, this process failure is tied to neuronal changes; namely, to dysfunction in specific regions in the prefrontal cortex (e.g. medial prefrontal cortex) and fronto-limbic system (e.g. amygdala, hippocampus) that support higher-order executive functions and emotional processing.

In line with the cross-state continuity assumption of this theory, if frequent NM recallers exhibit impaired prefrontal or fronto-limbic functions during REM sleep dreaming they should also manifest deficits in executive function during waking cognitive performance. Tasks of executive function that rely upon prefrontal and fronto-limbic functions could, therefore, reveal deficits among NM-prone individuals.

One such task, the verbal fluency task (VFT), was used to test the AND model and found that NM recallers and controls did, in fact, differ (Simor *et al.*, 2012). The VFT is used widely and validated in both research and clinical settings to assess executive functioning (Crawford and Henry, 2005; Gierski and Ergis, 2004). It requires that participants name as many words as possible—without repetitions—that either start with a specific letter or that belong to a specific category within a given time (generally 60 s). Fluency is defined as the number of correct words given (higher scores indicate higher fluency), whereas perseveration is defined as erroneous response repetition (higher scores indicate higher perseveration). The task is thought to engage several cognitive processes, including working memory, cognitive flexibility and inhibitory control (Baldo and Shimamura, 1998), and performance has been related to both the frontal and the temporal cortex (Baldo *et al.*, 2006; Schwartz *et al.*, 2003). Verbal fluency requires semantic search and retrieval of lexical memory elements and is correlated with language and working memory abilities (Levelt *et al.*, 1999; Shao *et al.*, 2014), whereas avoiding perseveration requires inhibitory control, which is more reliant upon executive function. Further, although the letter and category fluency tasks are similar, they differ in subtle ways: category fluency requires semantically associated responses, whereas phonemic fluency does not. Because of this, disorders marked by impaired access to semantic information may be associated with relatively worse performance on the category than on the letter fluency task, e.g. in Alzheimer's disease (Laws *et al.*, 2010). Nevertheless, populations that are not marked by semantic deficits, presumed to be the case in NM, are not likely to differ in performance on the two types of fluency.

Implications for nightmare aetiology

Consistent with the AND model, and suggestive of dysfunction in prefrontal executive processes, Simor *et al.* (2012) found NM participants to have higher VFT perseveration scores when compared to control participants. As the first demonstration of an executive dysfunction in NM, the finding by Simor *et al.* (2012) warrants replication. Replication would confirm the utility of a VFT as a widely available, easily administered test for accessing an executive dysfunction inherent to NM. Further, the findings would contribute to clarification of the underlying mechanisms by which frequent idiopathic NM may be produced and, thus, may be helpful in further understanding their aetiology and eventual treatment.

Goals and hypotheses of the study

The goal of this work was to replicate the Simor *et al.* (2012) findings with a VFT adapted specifically to a French-speaking

NM-prone sample. Accordingly, we hypothesized that frequent NM recallers would produce more perseveration errors on a VFT than would healthy participants.

MATERIALS AND METHODS

Participants

Research took place at the Dream and Nightmare Laboratory of the CIUSSS-NÎM—Hôpital du Sacré-Coeur de Montréal, an affiliate to the Université de Montréal. Ethics approval was obtained by the CIUSSS-NÎM—Hôpital du Sacré-Coeur de Montréal Research ethics committee. All participants gave written informed consent.

Forty-seven participants were recruited using advertisements and posters placed at the Université de Montréal, on the laboratory's website and by word of mouth. A standard telephone interview confirmed inclusion criteria and screened for major sleep dysfunction, medical or psychiatric conditions (except for depression and anxiety, which were controlled for); excessive intake of alcohol, recreational drugs, nicotine or caffeine; intake of medication affecting sleep, trauma or death in family or friends during the last 6 months and night-shift or time-change during the last 3 months. Candidates were required to be self-declared mentally and physically healthy, aged 18–50 years, have French as a first language, remember two or more dreams per week on average and have a good ability to sleep during daytime naps. Five candidates withdrew after initial contact. NM candidates (n = 24) were required to report recalling at least two NM (with awakenings) or bad dreams (BD; without awakenings) per week during the last 6 months. The control group (CTL; n = 18) candidates were required to report recalling no more than one NM per month on average during the last 5 years. One participant reported an unsatisfactorily low nightmare frequency on the dream and sleep questionnaires and was excluded; two participants were removed from analyses: one presented a medical condition affecting sleep and the other presented too many missing values for dependent variables analyses. Thus, a total of 39 participants (23 NM; 16 CTL) were included in the final sample. Participants received $100 plus travel expenses and lunch as compensation.

Procedure

Participants arrived for the laboratory visit at approximately 08:00 h and completed questionnaires. They were then administered the VFT (see Fig. 1) prior to taking a nap (sleep results not reported here).

Materials

Questionnaires

Demographic characteristics. An in-house standard laboratory questionnaire was used to collect demographic information, including age, education and employment status.

State–Trait Anxiety Inventory (STAI). This widely used 40-item, 1–4 response scale (1 = not at all to 4 = very much so) questionnaire includes two 20-item subscales: the STAI-S assesses state anxiety, i.e. transient feelings of apprehension, tension, nervousness and worry experienced at testing time; the STAI-T evaluates general feelings of anxiety as a stable trait (Spielberger *et al.*, 1970).

Beck Depression Inventory (BDI-II). This 21-item questionnaire uses 0–3 response scales (0 = not depressive to 3 = depressive) to measure levels of depressive symptoms (Beck *et al.*, 1996).

Nightmare Distress Questionnaire (NDQ). This 13-item questionnaire uses 0–4 response scales (0 = never to 4 = always) to measure the degree of distress experienced

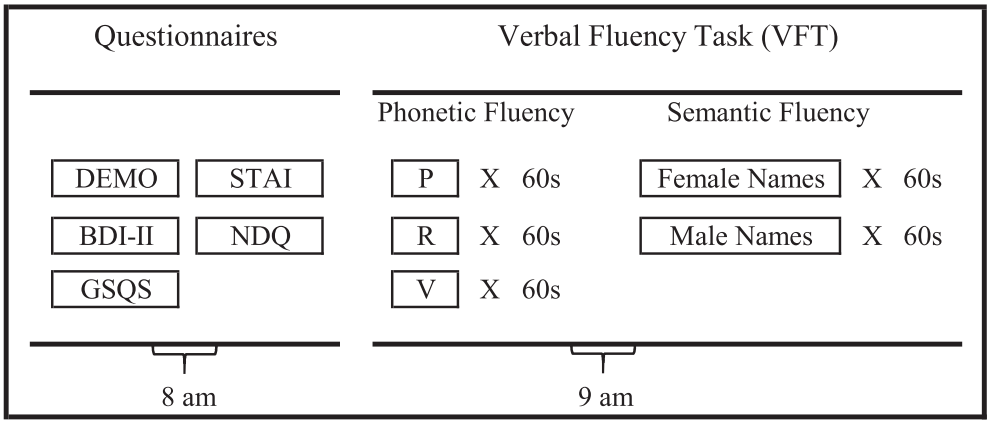

Figure 1. Study protocol. Participants arrived at the laboratory at approximately 08:00 h and completed questionnaires concerning demographic characteristics (DEMO), anxiety [State–Trait Anxiety Inventory (STAI)], depression [Beck Depression Inventory (BDI-II)], nightmare distress [Nightmare Distress Questionnaire (NDQ)] and sleep quality [Groningen Sleep Quality Scale (GSQS)]. They then completed the verbal fluency task (VFT).

in relation to nightmares during both sleep and wakefulness. The sum of items gives a total score indicating degree of distress, from 0 = very low to 52 = very high (Belicki, 1992).

Groningen Sleep Quality Scale (GSQS). This 14-item true-or-false questionnaire, measuring subjective sleep quality during the previous night's sleep (Meijman *et al.*, 1988), was meant to control for the impact of the degree of sleep fragmentation on verbal fluency performance.

Verbal fluency task. Each administration consisted of a phonetic fluency component and a semantic fluency component presented in the same order for all participants. For both components, participants were instructed to produce as many associated words as possible in 60 s that either started with the given letter (phonetic fluency) or belonged to the given category (semantic fluency), while avoiding repetitions and words with the same root. For the phonetic fluency component, previously validated French letter sets were selected, i.e. the letters P, R and V (Cardebat *et al.*, 1990). For the semantic fluency component, French word stimuli were selected to mirror the Hungarian category stimuli used in the Simor *et al.* (2012) study, i.e. female and male first names (in French). In the case of names, participants were instructed to avoid hyphenated names, same-root names and repetitions of the same name. In the case of phonetic fluency, participants were instructed to avoid proper names which were counted as errors. Participants' associates were handwritten by the experimenter and recorded digitally for later verification. Two trained independent blind raters computed the numbers of valid words, repetitions and errors given in each phonetic and semantic fluency administration.

Fluency was computed as the sum of valid words given for all three letters on the phonetic fluency portion and both categories on the semantic fluency portion combined. Perseveration was computed as the sum of repetitions divided by the total number of words produced (repetitions/valid + repetitions + errors) (Simor *et al.*, 2012).

Statistical analysis

Student *t*-tests ($P < 0.05$) were used to compare groups on demographic and psychological measures and VFT performance. Effect size for all comparisons was calculated as Cohen's d = [mean $(M)_2$–M_1)/standard deviation (SD_{pooled}, where $SD_{pooled} = \sqrt{[(SD_1{}^2 + SD_2{}^2)/2]}$. We conducted analyses of covariance (ANCOVAS) to compare groups on VFT performance while controlling for trait anxiety and sleep quality. Pearson correlations were used to assess within-group associations between VFT performance and demographic, psychological and dream frequency characteristics. Alpha correction for multiple testing of $P < 0.001$ was used for correlations (determined by 0.05/40 multiple correlations). All analyses were completed using SPSS version 22.0. One NM participant's State anxiety questionnaire was incomplete and therefore his scores were replaced by the NM group's mean.

RESULTS

Demographic characteristics

Sixteen participants comprised the CTL group (12 females, four males), reporting low weekly recall of BD and NM ($M_{BD} = 0.35 \pm 0.7$ per week, $M_{NM} = 0.06 \pm 0.3$ per week); 23 participants comprised the NM group (18 females, five males), reporting more frequent BD and NM ($M_{BD} = 3.21 \pm 1.9$ per week, $M_{NM} = 2.5 \pm 1.6$ per week; see Table 1). Groups did not differ in age ($t_{(37)} = 0.05$, $P = 0.96$), in completed years of education ($t_{(37)} = 0.61$, $P = 0.55$) or in dreams recalled per week ($t_{(37)} = -1.12$, $P = -0.63$).

Psychological characteristics

NM participants reported higher state anxiety ($P = 0.04$), trait anxiety ($P = 0.048$), depression symptoms ($P = 0.006$), NM

Table 1 Demographic characteristics for the study groups

	CTL	*NM*	*Group comparison*	*Cohen's* d
Total *N*	16	23	–	
Age (years; mean ± SD)	24.50 ± 3.8	24.43 ± 4.0	$t_{(37)} = 0.05$, $P = 0.96$	0.018
Sex			$\chi^2 = 0.08$, $P = 1.00$	
Male	4	5	–	
Female	12	18	–	
Occupation			$\chi^2 = 0.02$, $P = 0.88$	
Student	13	17	–	
Other	3	6	–	
Education (years; mean ± SD)	15.38 ± 2.0	14.87 ± 2.9	$t_{(37)} = 0.61$, $P = 0.55$	0.205
No. of dreams per week (mean ± SD)	4.00 ± 2.0	4.63 ± 1.5	$t_{(37)} = -1.12$, $P = 0.63$	0.356
BD per week (mean ± SD)	0.35 ± 0.7	3.21 ± 1.9	$t_{(37)} = -5.66$, $P < 0.001$*	1.998
No. of NM per week (mean ± SD)	0.06 ± 0.3	0.82 ± 0.7	$t_{(37)} = -4.21$, $P < 0.001$*	1.411

BD: bad dreams: dysphoric dreams without abrupt awakenings; NM: nightmares: dysphoric dreams with awakenings; SD: standard deviation.

Table 2 Psychological characteristics of the control (CTL) and nightmare (NM) groups; SD: standard deviation

	*CTL (*n = *16) mean ± SD*	*NM (*n = *23) mean ± SD*	*Test*	*Cohen's* d
State anxiety	27.50 ± 5.81	32.87 ± 8.64	$t(37) = -2.16$, $P = 0.040$*	0.729
Trait anxiety	32.06 ± 9.67	38.30 ± 9.18	$t(37) = -2.04$, $P = 0.048$*	0.662
Depression	3.25 ± 3.61	9.91 ± 8.68	$t(37) = -2.89$, $P = 0.006$*	1.002
Nightmare distress	24.06 ± 4.88	34.57 ± 8.34	$t(37) = -4.52$, $P = 0.0001$*	1.538
Sleep quality	2.94 ± 1.69	5.70 ± 3.13	$t(37) = 3.21$, $P = 0.003$*	1.097

Table 3 Verbal fluency task scores of control (CTL) and nightmare (NM) groups in the current and original study

Current study					*Simor* et al. *(2012)*†		
	*CTL (*n = *16) mean ± SD*	*NM (*n = *23) mean ± SD*	*Test*	*Cohen's* d	*CTL (*n = *35) mean ± SD*	*NM (*n = *35) mean ± SD*	*Cohen's* d
Total words	80.94 ± 11.90	82.22 ± 14.84	$t_{(37)} = -0.29$, $P = 0.78$	0.095			
Repetitions	1.94 ± 2.02	3.57 ± 2.19	$t_{(37)} = -2.36$, $P = 0.02$*	0.774			
Errors	0.69 ± 1.49	0.52 ± 0.90	$t_{(37)} = 0.43$, $P = 0.67$	0.138			
Fluency	78.31 ± 12.50	78.13 ± 14.13	$t_{(37)} = -0.04$, $P = 0.97$	0.013	74.14 ± 12.8	73.57 ± 11.7	0.046
Perseveration	0.024 ± 0.025	0.043 ± 0.026	$t_{(37)} = -2.30$, $P = 0.03$*	0.745	0.018 ± 0.023	0.040 ± 0.032	0.790*

†The fluency data were provided through a personal communication with Simor.
SD: standard deviation.

distress ($P = 0.0001$) and lower sleep quality ($P = 0.003$) than did CTLs (see Table 2).

Group differences on VFT

Groups did not differ on total words produced ($t_{(37)} = -0.29$, $P = 0.78$), number of errors ($t_{(37)} = 0.43$, $P = 0.67$) or fluency score ($t_{(37)} = -0.04$, $P = 0.97$) (Table 3). NM recallers had significantly higher repetitions ($t_{(37)} = 2.36$, $P = 0.02$) and perseveration scores ($t_{(37)} = 2.30$, $P = 0.03$) than did CTL participants (see Table 3).

ANCOVAs revealed that there was no effect of group on fluency after controlling for trait anxiety ($F_{(1,36)} = 0.32$, $P = 0.56$) or sleep quality ($F_{(1,36)} = 0.03$, $P = 0.86$). The group effect for perseveration scores remained after controlling for both trait anxiety ($F_{(1,36)} = 8.34$, $P = 0.007$) and sleep quality ($F_{(1,36)} = 6.79$, $P = 0.01$). We further conducted ANCOVAs for additional psychological characteristics and found, similarly, no effect of group on fluency after controlling for state anxiety ($F_{(1,36)} = 0.27$, $P = 0.61$), depression ($F_{(1,36)} = 0.01$, $P = 0.86$) or NM-distress ($F_{(1,36)} = 0.01$, $P = 0.93$). The perseveration effect remained after controlling for depression ($F_{(1,36)} = 6.46$, $P = 0.02$) and NM-distress ($F_{(1,36)} = 6.38$, $P = 0.02$), but was reduced to a trend after controlling for state anxiety ($F_{(1,36)} = 3.88$, $P = 0.06$).

Within-group correlations between verbal fluency performance and other measures

Within the CTL group, only one significant correlation was found, between number of dreams recalled per week and fluency score ($r = 0.82$, $P = 0.0001$); no correlations between any other demographic, psychological or dream measures were found (see Table 4). Within the NM group, perseveration scores correlated positively with nightmares recalled per week ($r = 0.44$, $P = 0.04$), but this did not survive the strict $P < 0.001$ cut-off controlling for multiple comparisons; no other correlations with demographic, psychological or dream measures were found.

DISCUSSION

The AND neurocognitive model of disturbed dreaming (Nielsen and Levin, 2007) provides testable hypotheses concerning neurocognitive–emotional deficits underlying chronic NM recall; specifically, impaired prefrontal and fronto-limbic functions that interfere with emotion regulation. Simor *et al.* (2012) demonstrated that a prefrontal deficit among NM-prone individuals characterizes performance during a waking state executive function task. The present results replicate this finding of increased perseveration errors on a VFT in frequent NM recallers compared to CTLs. In fact, our values constitute a clear—almost exact—replication of the Simor *et al.* (2012) results (see Fig. 2).

The close similarity between our two sets of findings is striking in that the perseveration effects were elicited using stimuli in two different languages. Hungarian (Simor *et al.*, 2012), a Uralic language affiliated with Finnish and Estonian, is not even part of the Indo-European family of languages from which French (current study) derives. Thus, the parallel differences point to a dysfunction that may be independent of language type. Further, the phonetic fluency stimuli administered were different in nature, being chosen to represent letters of the alphabet for which there is a large number of

Table 4 Pearson's correlations between verbal fluency and demographic, psychological and dream characteristics

	CTL (n = 16)				*NM (n = 23)*			
	Fluency		*Perseveration*		*Fluency*		*Perseveration*	
	R	*Sig.*	R	*Sig.*	R	*Sig.*	R	*Sig.*
Age	−0.47	0.07	−0.18	0.52	−0.27	0.22	0.05	0.82
Education	0.42	0.11	−0.23	0.40	0.20	0.36	−0.25	0.24
State anxiety	0.03	0.90	−0.01	0.96	0.31	0.15	0.13	0.55
Trait anxiety	0.18	0.51	−0.19	0.48	0.32	0.13	−0.39	0.06
Depression	−0.20	0.45	−0.09	0.74	0.09	0.69	−0.21	0.33
NM distress	−0.11	0.69	−0.20	0.46	0.06	0.79	−0.19	0.39
Sleep quality	−0.10	0.71	−0.30	0.26	0.10	0.64	−0.17	0.44
No. of dreams per week	**0.82**	**0.0001***	−0.27	0.32	−0.11	0.63	0.12	0.58
No. of BD per week	0.37	0.16	−0.04	0.88	−0.07	0.74	0.12	0.58
No. of NM per week	0.40	0.13	−0.04	0.89	−0.32	0.14	**0.44**	**0.04**

*Conservative alpha of $P < 0.001$ used to correct for multiple comparisons.
BD: bad dreams; CTL: control; NM: nightmares; Sig.: significance.

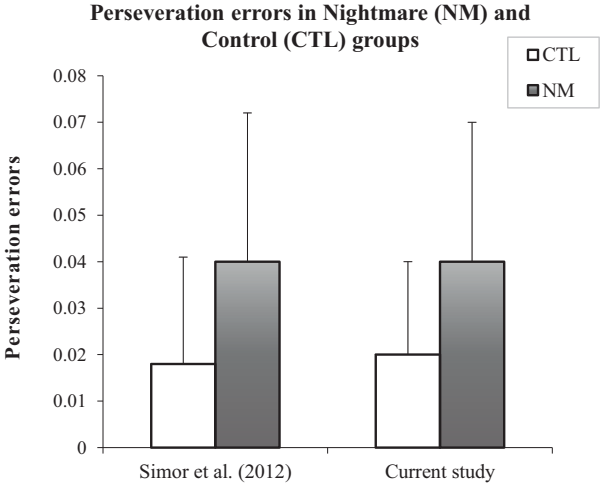

Figure 2. Perseveration errors in nightmare (NM) and control (CTL) groups in Simor *et al.* (2012) and the current study.

available words in each participant's native language (Cardebat *et al.*, 1990; Gierski and Ergis, 2004). The Hungarian stimuli in Simor *et al.* (2012) used the letter-set F, A and Sz (equal to S in English), whereas the present study used a previously validated French letter-set (P, R, V; Cardebat *et al.*, 1990). Although we know of no studies comparing these letter-sets in their respective populations, the similarity of results in our two studies suggests that the tests had largely equivalent degrees of difficulty despite differences in their phonetic characteristics.

However, whereas the original study detected slight group differences in fluency performance ($P = 0.07$) only after controlling trait anxiety and sleep quality, our groups performed similarly on this measure and did not exhibit an association between fluency performance and general anxiety. The fluency–anxiety correlation led Simor *et al.* (2012) to propose that fluency is affected by subclinical levels of trait anxiety, particularly by performance anxiety and the surprising difficulty of the task observed during its execution. Although we also noted that participants often expressed their difficulty with the task, we did not find a significant correlation between fluency and either trait or state anxiety. One possibility for this difference between studies is the higher trait anxiety levels of the original NM cohort (mean = 49.2 ± 9.1) than that in the present cohort (mean = 38.3 ± 9.2); the lower anxiety severity of our NM cohort may have reduced the variability of this measure to such an extent that no correlation was visible. Nevertheless, our results are more consistent with a prior study that found that, while anxiety disorders were associated with deficits in executive functioning, they were not associated with impaired verbal fluency (Airaksinen *et al.*, 2005).

We also assessed several other affective symptoms in our NM group, which scored consistently higher in depression, state anxiety, NM-distress and poor sleep quality than did the CTL group, suggesting a significant level of pathology in the sample. These characteristics are congruent with several studies with similar NM cohorts (Nielsen and Zadra, 2011; Schredl, 2003). The fact that we found no correlations between any psychological characteristics and either fluency or perseveration supports the conclusion that there is a link between NM pathology and executive deficits that is independent of comorbid affective pathologies. Nevertheless, while the AND model stipulates that impaired prefrontal function underlies production of nightmares and waking executive dysfunction, it is possible that other correlates of frequent nightmares are at play, such as impaired sleep quality and fragmentation.

Finally, we discovered an unexpected and highly positive correlation between dream recall frequency and verbal fluency in our CTL group ($r = 0.82$, $P = 0.0001$). This relationship reinforces the notion that aspects of verbal fluency performance share a unique relationship with

mechanisms of dream production or recall. There are a couple of possible explanations for this relationship. First, fluency scores are considered good indicators of lexical access, which is the ability to retrieve grammatical representations from the mental lexicon (Levelt *et al*., 1999). This process of mapping conceptual representations onto experience may similarly underlie the ability to retrieve a dream. In fact, prior studies have found that alexithymia, a disorder marked by word finding difficulty, is associated with a cessation of dream recall (externally orientated thinking subtype; Lumley and Bazydlo, 2000). Remembering a dream may depend upon access to categorical/lexical footholds with which to remember them by. However, prior empirical work has not supported a relationship between dream recall and verbal intelligence (Tonay, 1993) or narrative memory (Blagrove and Akehurst, 2000).

A second possibility is that 'updating'—the ability to store and update information—serves as a common mechanism underlying fluency performance and dream recall. One recent study found that performance on an updating (operation span) task, but not on either vocabulary or lexical access, predicted verbal fluency performance (Shao *et al*., 2014). This feature of working memory may similarly be critical for remembering a dream. Support for this claim is that increased cortical activation is a prerequisite for dream recall; in particular, theta (5–8 Hz) electroencephalograph (EEG) oscillations on frontal regions (Scarpelli *et al*., 2015), along with decreased delta over frontal and temporo-parietal areas (Scarpelli *et al*., 2017) in pre-awakening sleep, are predictive of dream recall. These findings parallel the relationship between theta activity and working memory during wake (Sauseng *et al*., 2010), and although these observations have been interpreted as state-dependent factors in dream recall, our present verbal fluency findings support a trait-like influence of working memory capacity on dream recall.

CONCLUSION

Our replication of the Simor *et al.* (2012) finding that frequent NM recallers produce more perseveration errors on a VFT than do CTLs, despite intact verbal fluency, supports the general notion of a frontal, executive dysfunction in the NM group, and the more specific suggestion of an impairment of associational processes. These findings are consistent with claims of the AND model (Nielsen and Levin, 2007), which postulates that nightmares are produced in part by a cognitive deficit that lessens the efficacy of associating fear-inducing memory elements with fear-extinction memory elements during dreaming.

The main limitation of the current study is that it is correlational. While the findings fit with the theoretical assumptions of the AND model, it remains to be seen whether executive dysfunction plays a causal role in nightmare production or whether the waking cognitive deficits result from nightmares. Future research is necessary to elucidate other personality and physiological factors that may influence the neurocognitive make-up of the nightmare-prone individual (Carr and Nielsen, 2017).

ACKNOWLEDGEMENTS

This study was supported by Canadian Institutes of Health Research grant (TN), a Natural Sciences and Engineering Research Council of Canada grant (TN) and DreamScience Foundation Research Grant (KSO).

CONFLICT OF INTEREST

No conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

Study design, data analysis/interpretation, manuscript writing: MC, KSO, TP and TN; data collection/entry: KSO and CB-C.

REFERENCES

Airaksinen, E., Larsson, M. and Forsell, Y. Neuropsychological functions in anxiety disorders in population-based samples: evidence of episodic memory dysfunction. *J. Psychiatr. Res*., 2005, 39: 207–214.

American Academy of Sleep Medicine. *International Classification of Sleep Disorders*. American Academy of Sleep Medicine, Chicago, IL, 2005.

American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders: DSM 5*. American Psychiatric Association, Washington, DC, 2013.

Baldo, J. V. and Shimamura, A. P. Letter and category fluency in patients with frontal lobe lesions. *Neuropsychology*, 1998, 12: 259–267.

Baldo, J. V., Schwartz, S., Wilkins, D. and Dronkers, N. F. Role of frontal versus temporal cortex in verbal fluency as revealed by voxel-based lesion symptom mapping. *J. Int. Neuropsychol. Soc*., 2006, 12: 896–900.

Beck, A., Steer, R. and Brown, G. *Manual for the Beck Depression Inventory*. The Psychological Corporation, San Antonio, TX, 1996.

Belicki, K. The relationship of nightmare frequency to nightmare suffering with implications for treatment and research. *Dreaming*, 1992, 2: 143–148.

Blagrove, M. and Akehurst, L. Personality and dream recall frequency: further negative findings. *Dreaming*, 2000, 2000: 139–148.

Cai, D. J., Mednick, S. A., Harrison, E. M., Kanady, J. C. and Mednick, S. C. REM, not incubation, improves creativity by priming associative networks. *Proc. Nat. Acad. Sci*., 2009, 106: 10130–10134.

Cardebat, D., Doyon, B., Puel, M., Goulet, P. and Joanette, Y. Formal and semantic lexical evocation in normal subjects. Performance and dynamics of production as a function of sex, age and educational level. *Acta Neurol. Belg*., 1990, 90: 207–217.

Carr, M. and Nielsen, T. A novel differential susceptibility framework for the study of nightmares: Evidence for trait sensory processing sensitivity. *Clinical Psychology Review*, 2017, 58: 86–96.

Carr, M. and Nielsen, T. Morning REM sleep naps facilitate broad access to emotional semantic networks. *Sleep*, 2015, 38: 433–443.

Crawford, J. R. and Henry, J. D. Assessment of executive dysfunction. In: P. W. Halligan and D. T. Wade (Eds) *Effectiveness of*

Rehabilitation for Cognitive Deficits. Oxford University Press, New York, NY, 2005: 233–245.

Fisher, C., Byrne, J., Edwards, A. and Kahn, E. A psychophysiological study of nightmares. *J. Am. Psychoanal. Assoc.*, 1970, 18: 747–782.

Fu, J., Li, P., Ouyang, X. *et al.* Rapid eye movement sleep deprivation selectively impairs recall of fear extinction in hippocampus-independent tasks in rats. *Neuroscience*, 2007, 144: 1186–1192.

Gierski, F. and Ergis, A. M. Les fluences verbales: aspects théoriques et nouvelles approches [Verbal fluency: theoretical aspects and new approaches]. *L'année Psychol.*, 2004, 104: 331–359.

Hartmann, E. Outline for a theory on the nature and functions of dreaming. *Dreaming*, 1996, 6: 147–170.

Haynes, S. N. and Mooney, D. K. Nightmares: etiological, theoretical, and behavioral treatment considerations. *Psychol. Record*, 1975, 25: 225–236.

Hublin, C., Kaprio, J., Partinen, M. and Koskenvuo, M. Nightmares: familial aggregation and association with psychiatric disorders in a nationwide twin cohort. *Am. J. Med. Genet.*, 1999, 88: 329–336.

Kales, A., Soldatos, C. R., Caldwell, A. B. *et al.* Nightmares: clinical characteristics and personality patterns. *Am. J. Psychiatry*, 1980, 137: 1197–1201.

Krakow, B., Hollifield, M., Schrader, R. *et al.* A controlled study of imagery rehearsal for chronic nightmares in sexual assault survivors with PTSD: a preliminary report. *J. Trauma. Stress*, 2000, 13: 589–609.

Levelt, W. J., Roelofs, A. and Meyer, A. S. A theory of lexical access in speech production. *Behav. Brain Sci.*, 1999, 22: 1–38.

Levin, R. and Nielsen, T. Disturbed dreaming, posttraumatic stress disorder, and affect distress: a review and neurocognitive model. *Psychol. Bull.*, 2007, 133: 482–528.

Lumley, M. A. and Bazydlo, R. A. The relationship of alexithymia characteristics to dreaming. *J. Psychosom. Res.*, 2000, 48: 561–567.

Meijman, T., deVries-Griever, A., De Vries, G. and Kampman, R. *The Evaluation of the Groningen sleep Quality Scale. The Construction and Evaluation of a One-Dimensional Scale Measuring Subjective Sleep Quality*. Heijmans Bulletins Psychologische Instituten, University of Groningen, Groningen, 1988.

Nielsen, T. and Levin, R. Nightmares: A new neurocognitive model. *Sleep Medicine Reviews*, 2007, 11(4): 295–310.

Nielsen, T. and Zadra, A. Dreaming disorders. In: M. Kryger, T. Roth and W. C. Dement (Eds) *Principles and Practices of Sleep Medicine*. WB Saunders, Philidelphia, PA, 2000.

Nielsen, T. and Zadra, A. Idiopathic nightmares and dream disturbances associated with sleep–wake transitions. In: M. Kryger, T. Roth and W. C. Dement (Eds) *Principles and Practice of Sleep Medicine*. Elsevier, New York, 2011: 1106–1115.

Pace-Schott, E. F., Germain, A. and Milad, M. R. Effects of sleep on memory for conditioned fear and fear extinction. *Psychol. Bull.*, 2015, 141: 835–857.

Pavlov, I. P. *Conditioned Reflexes*. Courier Dover Publications, New York, NY, 2003.

Sandman, N., Valli, K., Kronholm, E. *et al.* Nightmares: prevalence among the Finnish general adult population and war veterans during 1972–2007. *Sleep*, 2013, 36: 1041–1050.

Sauseng, P., Griesmayr, B., Freunberger, R. and Klimesch, W. Control mechanisms in working memory: a possible function of EEG theta oscillations. *Neurosci. Biobehav. Rev.*, 2010, 34: 1015–1022.

Scarpelli, S., D'Atri, A., Gorgoni, M., Ferrara, M. and De Gennaro, L. EEG oscillations during sleep and dream recall: state-or trait-like individual differences? *Front. Psychol.*, 2015, 6: 605–605.

Scarpelli, S., D'Atri, A., Mangiaruga, A. *et al.* Predicting dream recall: EEG activation during NREM sleep or shared mechanisms with wakefulness? *Brain Topogr.*, 2017, 30: 629–638.

Schredl, M. Effects of state and trait factors on nightmare frequency. *Eur. Arch. Psychiatry Clin. Neurosci.*, 2003, 253: 241–247.

Schredl, M. and Pallmer, R. Sex-specific differences of nightmares in students. *Prax. Kinderpsychol. Kinderpsychiatr.*, 1998, 47: 463–476.

Schwartz, S., Baldo, J., Graves, R. E. and Brugger, P. Pervasive influence of semantics in letter and category fluency: a multidimensional approach. *Brain Lang.*, 2003, 87: 400–411.

Shao, Z., Janse, E., Visser, K. and Meyer, A. S. What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Front. Psychol.*, 2014, 5: 772.

Simor, P., Pajkossy, P., Horváth, K. and Bódizs, R. Impaired executive functions in subjects with frequent nightmares as reflected by performance in different neuropsychological tasks. [published erratum in: *Brain Cogn.,* 2016, 109: 130–130]. *Brain Cogn.*, 2012, 78: 274–283.

Spielberger, C. D., Gorsuch, R. L. and Lushene, R. E. *The State-Trait Anxiety Inventory (Self-Evaluation Questionnaire)*. Consulting Psychologists Press, Palo Alto, CA, 1970.

Tonay, V. K. Personality correlates of dream recall: who remembers? *Dreaming*, 1993, 3: 1–8.

Walker, M. P., Liston, C., Hobson, J. A. and Stickgold, R. Cognitive flexibility across the sleep–wake cycle: REM-sleep enhancement of anagram problem solving. *Cogn. Brain Res.*, 2002, 14: 317–324.