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Running title: Creativity in narcolepsy

Abstract

Some studies suggest a link between creativity and rapid eye movement sleep. Narcolepsy is characterised by falling asleep directly into rapid eye movement sleep, states of dissociated wakefulness and rapid eye movement sleep (cataplexy, hypnagogic hallucinations, sleep paralysis, rapid eye movement sleep behaviour disorder and lucid dreaming) and a high dream recall frequency. Lucid dreaming (the awareness of dreaming while dreaming) has been correlated with creativity. Given their life-long privileged access to rapid eye movement sleep and dreams, we hypothesised that subjects with narcolepsy may have developed high creative abilities. To test this assumption, 185 subjects with narcolepsy and 126 healthy controls were evaluated for their level of creativity with two questionnaires, the Test of Creative Profile and the Creativity Achievement Questionnaire. Creativity was also objectively tested in 30 controls and 30 subjects with narcolepsy using the Evaluation of Creative Potential, which measures divergent and convergent modes of creative thinking in the graphic and verbal domains, using concrete and abstract problems. Subjects with narcolepsy obtained higher scores than controls on the Test of Creative Profile (58.9 ± 9.6 [mean ± SD] vs. 55.1 ± 10, P = 0.001), in the three creative profiles (Innovative, Imaginative and Researcher) and on the Creative Achievement Questionnaire (10.4 ± 25.7 vs. 6.4 ± 7.6, P = 0.047). They also performed better than controls on the objective test of creative performance (4.3 ± 1.5 vs. 3.7 ± 1.4; P = 0.009). Most symptoms of narcolepsy (including sleepiness, hypnagogic hallucinations, sleep paralysis, lucid dreaming, and rapid eye movement sleep behaviour disorder, but not cataplexy) were associated with higher scores on the Test of Creative Profile. These results highlight a higher creative potential in subjects with narcolepsy and further support a role of rapid eye movement sleep in creativity.

Keywords: narcolepsy, creativity, lucid dreaming

Abbreviations: CAQ = Creative Achievement Questionnaire; EPoC = Evaluation of Creative Potential; REM = rapid eye movement; SOREM = Sleep Onset in REM sleep period; TCP = Test of Creative Profile.

Introduction

The poet Saint-Pol-Roux used to hang on his bedroom's door every night a sign that read "Do not disturb: Poet at work" (Breton, 1924). Giving credit to his empiric conception of sleep as a creative muse, Wagner *et al.* (2004) demonstrated that sleep helps gain insight (i.e., the sudden discovery of a solution). Among the sleep stages, rapid eye movement (REM) sleep is the most frequently associated with dreaming (Nir and Tononi, 2010). The link between creativity and dreaming has been a topic of intense speculation (Stickgold and Walker, 2004), mainly based on anecdotal reports of artistic and scientific discoveries made while dreaming, such as the periodic table of Mendeleyev (Strathern, 2000). Notably, both dream recall frequency (Schredl, 1995, Schredl, 2000, Schredl and Erlacher, 2007) and complexity (Sladeczek and Domino, 1985) have been correlated with a higher creativity. Plus, participants asked to 'incubate' a problem in their dreams frequently dreamed a solution useful to solve their problem (Barrett, 1993). Theoretical accounts propose that, instead of purely consolidating newly existing memories, a process that takes place during non-REM sleep via neuronal replays (O'Neill *et al.*, 2010; Born and Wilhelm, 2012), REM sleep would allow these mnesic traces to mingle and associate with already-stored memories in novel and abstract ways (Stickgold *et al.*, 2001). REM sleep dreaming could be seen as a process that detects elements of similar meanings in past events and fuses them together to reflect specific experiential patterns (Llewellyn, 2016). Consistent with this theory, only 1-2% of dream reports are faithful copies of previous experiences (Fosse *et al.*, 2003). Most of them rather hyper-associate different memories (Malinowski and Horton, 2015), resulting in fictional bizarre memories. In line with this assumption, a few studies demonstrated that REM sleep might favour spreading activation of a memory trace within cortical regions. This would lead to a reorganization of associative networks and an expansion of the problem space, which would help forming non-obvious associations and reaching new solutions. In a seminal work (Stickgold *et al.*, 1999), showed that participants awakened from REM sleep (vs. non-REM sleep) were faster at recognising target words when they were preceded by a weakly related prime (e.g., thief-wrong) than a strongly related prime (e.g., hot-cold). Moreover, REM sleep had a beneficial role on anagram solving (Walker *et al.*, 2002) and on creative problem solving that required the integration of loosely associated information (Cai *et al.*, 2009). Neuroimaging data suggest that functional connectivity of higher order brain associative areas during REM sleep favours associations between distant memories (Chow *et al.*, 2013). Beyond these studies, the literature linking REM sleep (and their accompanying dreams) and creativity remains sparse. Moreover, most studies are based on simple associative tests but do not directly evaluate creativity *per se* as defined by Sternberg and Lubart (1999), namely, the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints).

It is unlikely that creativity *per se* is instantaneously achieved in a nap. Rather, the development of creativity probably stretches over years, including numerous sleep periods. If this is true, how can the role of REM sleep over such a long timescale be examined? Our solution is to call upon REM sleep and dream experts: subjects with narcolepsy. Subjects with narcolepsy experience excessive daytime sleepiness often accompanied by direct transitions from wakefulness to REM sleep, named sleep onset in REM periods, SOREMs (American Academy of Sleep Medicine, 2014). They have repeated naps (often containing REM sleep), in contrast with healthy controls who have only occasional naps and rarely reach REM sleep during daytime. They present symptoms of a dissociated REM sleep, including cataplexy (sudden loss of muscular tone with clear consciousness), sleep paralysis, hypnagogic hallucinations, REM sleep behaviour disorder and lucid dreaming. Indeed, subjects with narcolepsy are more potent lucid dreamers than controls, meaning that they are more often conscious of dreaming when dreaming in REM sleep than controls are (Dodet *et al.*, 2015; Rak *et al.*, 2015). They also have a higher dream recall frequency and complexity than normal controls (Fosse, 2000) and a more fragmented REM sleep. Consequently, patients with narcolepsy exhibit a privileged access to sleep (particularly REM sleep) and dreams. Interestingly, lucid dreaming has been positively linked with creativity (Blagrove and Hartnell, 2000; Zink and Pietrowksy, 2013), as confirmed by anecdotal reports in our subjects with narcolepsy who used naps to solve real-life problems. For all these reasons, subjects with narcolepsy might have developed higher creative abilities. However, given their massive level of tiredness, one may expect that their cognitive abilities (including creativity) could be impaired. We postulated that they would score higher on creativity tests compared to controls. To test this assumption, we compared the creative abilities in subjects with narcolepsy vs. matched controls using self-administered questionnaires and a formal test of creative potential.

Materials and methods

Subjects

The study was performed in two National Reference Centres for narcolepsy, in the Pitié-Salpêtrière University Hospital in Paris (France) and in the University Hospital of Bologna (Italy). Over the course of six months, all consecutive adult subjects with narcolepsy visiting the centres for routine yearly follow-up were invited to complete two self-administered questionnaires on creativity. A subgroup (unselected) had formal tests of creativity during a day spent in the hospital in the French centre. Subjects had to meet the international criteria for narcolepsy (American Academy of Sleep, 2014), including excessive daytime sleepiness occurring daily for more than three months, a mean sleep latency lower than 8 minutes on the multiple sleep latency test, two or more sleep-onset REM periods and no other causes for these findings (including acute and chronic sleep deprivation, shift work disorder, depression, sleep apnoea syndrome, circadian sleep disorders, and recent withdrawal of an antidepressant, all reasons that had been carefully excluded in the two reference centres). They were classified as suffering from narcolepsy type 1 if they had frank cataplexies and/or were hypocretin-1 deficient (as measured in the cerebrospinal fluid) and from narcolepsy type 2 if it was not the case. Most patients with narcolepsy had a brain MRI at time of diagnosis, which was normal, as expected in narcolepsy. No brain MRI was performed in controls. The same questionnaires were given to healthy controls recruited by word of mouth and matched for age, sex and laterality with the narcolepsy groups in each country. Healthy controls had normal daytime sleepiness as assessed by the Epworth sleepiness scale (Johns, 1991), reported no history of sleep disorders and had no anxiety or depressive symptoms, as assessed using the Hospital Anxiety and Depression Scale (Zigmond and Snaith, 1983). Thirty healthy controls (included in the general control group), matched for age, sex, laterality and education, performed the formal creativity test in France.

The protocol was approved by both local ethical committees, and all participants signed an informed consent form. No participant was paid for the study, except the healthy controls having completed the formal creativity test, who received a monetary compensation of 20€. Subjects with narcolepsy performed the formal test when present in the sleep laboratory for a follow-up clinical examination and were not paid for their participation.

Demographic and clinical measures

In addition to the collection of information on age, sex, laterality and education level (Schneider, 2013), the participants completed at the same time as the creativity tests, a questionnaire reporting the presence of cataplexy, hypnagogic hallucinations, sleep paralysis, enacted dream behaviour evocative of clinical REM sleep behaviour disorder (Postuma *et al.*, 2012) and lucid dreaming. They completed the Epworth sleepiness scale and the Hospital Anxiety and Depression Rating scale. The treating physician reported the results of the multiple sleep latency test at the time of diagnosis and the current treatment.

Creativity questionnaires

Participants completed two questionnaires of creativity, including the Test of Creative Profile (Sellier, 1977) and the Creative Achievement Questionnaire (Carson *et al.*, 2005). The Test of Creative Profile contains 57 yes/no questions, examining three different types of creativity, including “Innovative”, “Imaginative” and “Researcher” profiles. An Innovative person tries to change situations into better ones and typically scores positively on this sentence: “In general, when you want to achieve something, you only rely on yourself: no one is able to solve your personal problems”. Subjects with an Imaginative profile are not directly concerned by down-to-earth problems but are more those with a poetic soul who score typically positively on this question: “At one point or another of your existence, you were taken by the itch to write (or to create a work of art), if only for your personal pleasure”. The Researcher profile generally consists of scientists or inventors guided by a specific subject. Contrary to Innovative persons, they have no ideas to propose on every topic but only on a long-term mature one, and contrary to the Imaginative profile, they remain down-to-earth, their work being subjected to the evaluation of a rigorous scientific method and experimentation. Each positive answer for each profile was summed and normalised on a 100-point scale to enable comparisons between the three profiles.

The Creative Achievement Questionnaire (Carson *et al.*, 2005; Silvia *et al.*, 2012) is a reliable self-reported assessment of creative achievement across ten domains (visual arts, music, dance, architectural design, creative writing, humour, inventions, scientific discovery, theatre/film and culinary arts). Each domain is scored by the subject between 0 and 8, including 0 (“I have no training or recognised talent in this area”), 1 (“I have taken lessons in this area”), and six additional scores for ascending achievement (i.e., “I have won a national prize in the fields of science or medicine”). For the scores selected, subjects indicated how many times each achievement was earned. The summation of all scores resulted in the total creative achievement score. By asking about significant, observable accomplishments, the score at the Creative Achievement Questionnaire is inherently skewed (Beghetto and Kaufman, 2007; Kaufman and Beghetto, 2009), aiming to capture those rare individuals with eminent creativity or with professional expertise in a creative area.

Formal test of creativity

The Evaluation of Creative Potential (EPoC) test battery is an objective test evaluating creative abilities (Lubart *et al.*, 2011). It contains eight subtests that assess the two key modes of creative thinking, including divergent-exploratory thinking (i.e., finding the greatest number of solutions based on a given stimulus) and convergent-integrative thinking (i.e., integrating several elements into a coherent synthesis) on two different domains of expression (graphic and verbal). With its ability to capture the multidimensionality of creativity, this test contrasts markedly with the past decades of research on creativity, which was mainly based on single indicators of creative potential, mainly divergent thinking tasks (Barbot *et al.*, 2016).

In divergent-exploratory tasks, participants were asked to generate as many ideas as possible based on a single stimulus, such as inventing as many different endings of one story (verbal) or generating as many drawings as possible incorporating one shape (graphic). The convergent-integrative tests consist of incorporating multiple elements to form a unique production, such as inventing an entire story that incorporates three main imposed characters (verbal) or producing one original drawing that incorporates a set of forms (either abstract or concrete). For details on the timeline and on the eight tasks of this test, please refer to the Supplementary material, Figure S1). Participants were asked to name their productions and to offer original solutions (different from what others may propose). They had a time constraint of 10 to 15 minutes depending on the task. The full Evaluation of Creative Potential test lasted two and a half hours in total (which included a thirty-minute break during which 6/30 subjects per group slept).

Two independent scorers (CL, OD) blind to the group (control or narcolepsy) scored the data following established guidelines (Lubart *et al.*, 2011). They later met to discuss points of disagreement to converge to a consensual score. The Evaluation of Creative Potential test was originally designed for children, and there are no existing norms for adults with a large age range. For each of the eight tests, all productions from the 60 participants were mixed and then scored for creativity relative to each other. Among them, the measures for two tasks of verbal divergent thinking were removed from the analysis in five subjects (two controls and three subjects with narcolepsy) due to a misunderstanding of the instruction.

For the divergent-graphic tasks (both abstract and concrete), the raw score corresponded to the fluency (i.e., the number of drawings produced). Fluency has been highly correlated with originality (r = 0.80) in various studies (Mouchiroud and Lubart, 2001). If two subjects obtained the same score, the originality of their stories/drawings was further taken into account to disentangle them. Originality scores were judged relative to the participants' performance. For the divergent-verbal tasks, three factors were taken into account, including the fluency (i.e., the number of beginnings or endings of the story imagined), the elaboration of the story (i.e., the number of words) and the originality. There was an excellent inter-scorer agreement for scoring the divergent-exploratory dimension (Cohen's K = 0.923).

The convergent tasks (both graphic and verbal) were initially scored following the manual guidelines (Lubart *et al.*, 2011). However, due to inter-rater agreement issues, we built a 5-factor model encompassing the main criteria of creativity and scored productions using this rubric to reduce subjectivity. The five factors included (in decreasing order of priority) the originality of the production (judged relative to one another), the integration of the elements altogether, the coherence of the story/drawing (i.e., digressions from the main storyline), the respect of the constraint (e.g., number of elements used), and the elaboration of the production (i.e., details). The first criterion (i.e., originality) was weighted by 5, the second by 4 and so on to obtain a final score of creativity. These weights were attributed based on the instructions given to the subjects (‘integrate these elements into a single original and coherent production’), and coupled with the objective criteria of creativity (Lubart *et al.*, 2011). There was a good inter-scorer agreement for scoring the convergent-integrative based on the 5-factor model ($r = 0.715$, $P < 0.0001$).

As recommended in the Evaluation of Creative Potential manual (Lubart *et al.*, 2011), the raw scores of the eight tests were then transformed into standard scores on a 7-point Likert scale that fit a Gaussian distribution amongst participants. Thus, 4.75% of the productions obtained a score of 1, 11.1% a score of 2, 21.2% a score of 3, 25.9% a score of 4, 21.2% a score of 5, 11.1% a score of 6, and 4.75% a score of 7. Importantly, raw scores highly correlated with standard scores for each of the four divergent tests ($r = 0.97$-0.98, $P<0.001$, Supplementary material, Table S4). Therefore, this transformation allows comparison of scores amongst different creative dimensions without modifying or discarding information. Examples of ratings for the graphic divergent and convergent tests are provided in Figure 1.

Statistical analysis

Chi-squared tests were used to test relationships between categorical variables. Linear mixed model analyses were performed using R (R Core Team, 2017) and the package lme4 to test the relationship between independent variables of interest (i.e., narcolepsy) and creativity. Subjects were entered as a random effect to take variability between subjects into account. Student’s t-tests were performed as a parametric measure of the difference between two means when required and for small sample sizes (<30), and Z-tests were performed for large sample sizes (>30). Spearman correlations were used as a nonparametric measure of the correlations between the measures of creativity (Evaluation of Creative Potential test vs. questionnaires), and Pearson correlations were used to compare parametric measures (scores on the creativity questionnaires) with continuous measures of symptoms (e.g., sleep latency, anxiety and depressive symptoms). Inter-test Spearman correlations and principal component analysis with varimax rotation were additionally conducted with the eight variables measured by the Evaluation of Creative Potential test to determine the appropriate number of factors to be retained in our model. Interjudge agreement was evaluated with the Cohen's K test.

The data that support the findings of this study are openly available at https://figshare.com/articles/Increased_creative_thinking_in_narcolepsy/7795805.

Results

Characteristics of the samples

A total of 185 subjects with narcolepsy were included (71% with narcolepsy type 1 and 29% with narcolepsy type 2), including 118 subjects in Paris (aged 37.0 ± 15.3, 59% female) and 67 subjects (aged 34.8 ± 17.0, 52% female) in Bologna. As indicated in Table 1, the 126 healthy controls were matched for age, gender, and laterality with the subjects from the narcolepsy group. The education level was lower on average in the narcolepsy group than in the control group. As expected by the disorder, subjects with narcolepsy had more severe daytime sleepiness, more frequent sleep and depressive symptoms, and took stimulants and anti-cataplectic drugs (including antidepressants and sodium oxybate) more frequently than controls (Table 1). They did not differ on anxiety symptoms. The subgroups of 30 subjects with narcolepsy and 30 healthy controls who performed the Evaluation of Creative Potential test did not differ in age, gender, laterality and education level, or anxiety symptoms. Subjects with narcolepsy had, on average, higher levels of daytime sleepiness, more frequent sleep and depressive symptoms and took stimulants and anti-cataplectic drugs more frequently than controls (Supplementary material, Table S1).

Self-reported assessments of creativity in subjects with narcolepsy and controls

The subjects with narcolepsy scored higher than controls on the total score of the Test of Creative Profile (mean = 58.9 in narcolepsy vs. 55.1 in control, z(308) = -3.32; P = 0.001) and on all three different creative profiles, namely, Innovative (z(308) = -2.06; P = 0.039), Imaginative (z(308) = -2.79; P = 0.005) and Researcher (z(308) = -2.8; P = 0.005) (Figure 2A). Similarly, subjects with narcolepsy had higher scores on the Creative Achievement Questionnaire (Figure 2B; mean = 10.4 in narcolepsy vs. 6.4 in control, z(308) = -1.99; P = 0.047). Of note, the medians were not different between the two groups (median = 4 for both groups), as expected by the skewed nature of the Creative Achievement Questionnaire. When looking separately at the two cohorts (Supplementary Figure S2), French subjects with narcolepsy scored higher than controls both on the Test of Creative Profile and on the Creative Achievement Questionnaire. When restricting analysis to type 1 narcolepsy only, subjects with narcolepsy also scored higher than controls on both questionnaires (Test of Creative Profile: z(143) = -3.19; P = 0.001; Creative Achievement Questionnaire: z(143) = -2.12; P = 0.034). Italian subjects with narcolepsy scored higher than controls on the Test of Creative Profile but not on the Creative Achievement Questionnaire. As the Creative Achievement Questionnaire is designed to provide highly skewed data and to give the highest weight to the fewest individuals with higher levels of achievement (the outliers) to capture the so-called 'Big-C' creativity that is by definition uncommon (Beghetto and Kaufman, 2007; Kaufman and Beghetto, 2009), we performed a Z-test rather than a non-parametric test that would eliminate our data of interest. The difference between subjects with narcolepsy and controls was mostly driven by these outliers (score on the Creative Achievement Questionnaire higher than 28, i.e., maximum score for each domain), which represented 6.5% of subjects with narcolepsy and 3.2% of controls (P = 0.30; Figure 2B).

Associations between self-reported creativity and sleep characteristics

In the narcolepsy group, subjects with hallucinations, sleep paralysis, clinical REM sleep behaviour disorder and lucid dreaming had higher scores on the Test of Creative Profile (Table 2). Lucid dreaming was associated with higher scores on the Imaginative profile (F(1,306) = 8.40; P = 0.004) and tended to be associated with the Innovative profile (F(1,306) = 3.214; P = 0.074) but not with the Researcher profile (F(1,306) = 2.052; P = 0.15). In contrast, cataplexy did not influence creativity, as measured with the total score on the Test of Creative Profile. Higher sleepiness and depression scores correlated (to a mild degree) with higher scores on the Test of Creative Profile (Table 3). There was no difference or correlation between the score on the Creative Achievement Questionnaire and symptoms of narcolepsy and sleep measures (Tables 2 and 3). The use of stimulants and anti-cataplectic drugs (including venlafaxin and sodium oxybate) had no impact on the scores of the Test of Creative Profile and of the Creative Achievement Questionnaire (Table 2 and Table S2 for detailed comparisons between each drug prescribed for narcolepsy and scores on the questionnaires).

As our two groups differed in terms of educational level, we additionally evaluated the influence of educational level on both scores. There was no significant correlation between educational level and the total score of the Test of Creative Profile (r = 0.40; P = 0.49), but a higher educational level was associated with higher scores on the Creative Achievement Questionnaire (r = 0.22; P = 0.0001).

Objective creative production: Analysis of principal factors

Before comparing objective performance between narcolepsy and control groups, we evaluated the correlations between the eight subtests of the Evaluation of Creative Potential to verify whether they were independent and to offer a view of its internal structure.

A principal component analysis with varimax rotation was conducted with these eight variables measured by the Evaluation of Creative Potential test to determine the appropriate number of factors to retain. The analysis yielded two factors that explained 58.7% of the variance for the entire set of variables (Figure 3A). The first factor (comprising the graphic and verbal divergent tasks) explained 38.6% of the variance and was labelled “Divergent”. The second factor (comprising the graphic and verbal convergent tasks) explained 20.1% of the variance and was labelled “Convergent”. For interpretation of the two factors, the varimax orthogonal rotation showed a grouping of items similar to that of the cluster analysis, where the first factor was Divergent and the second factor was Convergent. Consequently, this two-factorial model (Divergent and Convergent creative thinking) will be used to present the results.

Objective assessment of creative production in subjects with narcolepsy versus healthy controls

Based on the principal component analysis, we thus combined all scores from the four divergent tests (i.e., Divergent) and from the four convergent tests (i.e., Convergent). Linear mixed model analyses (with subjects entered as a random effect) revealed that subjects with narcolepsy obtained an overall score at the EPoC test significantly higher than controls ($t(57.88) = 2.7$; $P = 0.009$; Figure 3B). When looking separately at both modes of creative thinking, we found that the narcolepsy group scored higher than the control group on the Convergent mode of creative thinking ($t(58) = 2.7$; $P = 0.008$; Figure 3C) and tended to score higher on the Divergent dimension ($t(57.97) = 1.7$; $P = 0.09$; Figure 3D). Examples of performances in the graphical divergent and convergent dimensions of this test can be found in Figure 1 and results for the four main creative dimensions are displayed in Supplementary Figure S3. Of note, the Divergent dimension had an incomplete sample, as 5/60 subjects had to be removed from the analysis on the verbal divergence creativity because of a misunderstanding of the instructions. This likely explains why a stronger effect was observed for the convergent rather than the divergent mode of creative thinking. The homogeneity of performance within subjects was additionally assessed by calculating the prevalence of performance heterogeneity, which represents the percentage of subjects with more than 3 points (two times the standard deviation, with standard deviation = 1.46) of difference in the scores between two tests in each dimension. The mean percentage of heterogeneity in the four subtests was 1.67% for both convergent and divergent creative thinking. Thus, the subjects had consistent performance along the eight tests of the Evaluation of Creative Potential test, meaning that a high score in one test predicted a high score for all the other tests, whether verbal or graphical. In addition, the five factors (originality, integration, coherence, constraint and elaboration) used to generate the score of convergence were separately analysed (Supplementary Figure S4A). Subjects with narcolepsy scored higher on the factors of originality, elaboration and with a trend on the integration factor (P = 0.08). There were also good between-factors correlations (Supplementary Figure S4B), including with the 'coherence' factor suggesting that it does assess a part of creativity (although not a prominent one). No difference between both groups was observed for the 'constraint' factor and it did not correlate well with the remaining factors. This was expected as this variable only took into account whether subjects fully respected the instructions, which most subjects did. Nonetheless, this penalty factor was necessary in the analyses as the respect of the instructions is part of the definition of creativity we based our work on. Additionally, these subscales correlated well with the scores at the questionnaires of creativity (Figure S4B). Overall, these analyses supported the validity of our multifactorial model in evaluating convergent creative thinking. They also demonstrated that patients with narcolepsy did not sacrifice integration and elaboration for originality. On the contrary, they created both more original and more integrated productions, including many details.

Associations between creative performance and sleep characteristics

In the narcolepsy group, no sleep symptoms (including lucid dreaming) and sleep latency measures influenced creative performance (Supplementary Table S3). Importantly, subjects with narcolepsy type 1 and type 2 had similar creative performance ($F(1,57) = 2.48$; $P = 0.12$). A higher educational level predicted higher creative performance ($r = 0.45$; $P = 0.003$). Gender ($t(58) = 0.38$; $P = 0.71$) and laterality ($F(3, 56) = 1.40$; $P = 0.25$) had no impact on creative performance, whereas older age tended to be associated with lower performance ($r = -0.236$, $P = 0.07$).

Correlation between questionnaires and objective tests of creativity

As shown in Figure 3E, higher scores on the Test of Creative Profile correlated with higher convergent ($r = 0.27$; $P = 0.036$) but not with divergent thinking scores ($r = - 0.02$; $P = 0.87$). Higher scores on the Creative Achievement Questionnaire correlated with higher convergent ($r = 0.46$; $P = 0.0002$) and divergent ($r = 0.26$; $P = 0.04$) thinking scores. The scores on these two questionnaires correlated with each other ($r = 0.32$; $P = 0.012$).

Discussion

The main result here is that subjects with narcolepsy have a higher creative potential than controls, as assessed using creativity profile and achievement questionnaires in a large sample (including subjects from two different countries) and by testing objective creative performance. The high creative potential in narcolepsy extended to all modes of creative thinking analysed here, except for Divergent creative thinking (but $P = 0.09$). Indeed, subjects with narcolepsy scored higher on average and in all the different creative profiles (Imaginative, Innovative and Researcher) assessed by the Test of Creative Profile and were consistent in their performances on the subtests (divergent, convergent, verbal, graphic, abstract, concrete) of the Evaluation of Creative Potential test. The study was not restricted to narcolepsy type 1 (which is caused by hypocretin-1 deficiency) but included also patients with narcolepsy type 2 (a less stable SOREM phenotype with yet unknown pathophysiology). Of interest, the creativity was similarly increased in each type of narcolepsy, suggesting that a complete hypocretin-1 deficiency is not necessary *per se* to increase creativity.

Rather, other factors, such as lucid dreaming (which is as frequent in narcolepsy type 1 and type 2, Dodet *et al.*, 2015) may explain the creative effect.

Starting with disadvantages, subjects with narcolepsy scored higher than controls

These results are strengthened by the fact that the subjects with narcolepsy who completed the self-administered questionnaires had a lower educational level than controls, a bias that should be detrimental to their creative scores, because lower educational level was correlated with lower creativity scores in the Creative Achievement Questionnaire and in the Evaluation of Creative Potential test. They were also more tired than controls, constantly fighting the urge to sleep, and some might have attention deficits (Naumann *et al.*, 2006), although attention was not tested here. Because of these disadvantages, one could havse predicted impaired high-level cognitive skills (including creativity) in subjects with narcolepsy. In contrast, subjects with narcolepsy scored higher than controls on most creative dimensions. Moreover, a higher sleepiness propensity (measured by the Epworth sleepiness scale, but not by the mean sleep latency test) mildly correlated with a higher creativity score on the Test of Creative Profile. One may wonder whether the frequent sleep bouts that subjects with narcolepsy perform in passive conditions offer them the opportunity to mind wander and incubate complex problems.

With this higher creative potential, subjects with narcolepsy scored higher than controls on the Creative Achievement Questionnaire, but only a minority took advantage of this higher creative potential to generate professional creative products (i.e., creative achievement), be it a novel, musical composition, or a sculpture. This limited achievement despite a higher creative potential may have several causes, including difficulties in implementing novel ideas because of sleepiness, tiredness, apathy, emotional blunting (as a way to avoid cataplexy), difficulty in running a business, and lack of support. This study offers clinicians the opportunity to inform their patients of this hidden creative potential and encourage them to exploit their full potential.

One may now imagine that stimulants prescribed for narcolepsy (including modafinil, methylphenidate and pitolisant) could increase creative thinking, as they increase attention and are often regarded as cognitive enhancers (Turner *et al.*, 2003). However, modafinil has rather negative consequences on creativity, as healthy high creative subjects have lower scores on divergent and on convergent creativity when taking modafinil compared to placebo (Müller *et al.*, 2013; Mohamed, 2014). Thus, the stimulants in narcolepsy could be detrimental to their creativity. In addition, subjects with narcolepsy scored similarly on the creative tests, whether they were or not treated with stimulants, suggesting that the stimulants did not play a major role here. Moreover, the anti-cataplectic drugs (and especially sodium oxybate) had a rather negative effect on creativity as assessed with the questionnaires (Table S2). Sodium oxybate decreases the dream recall frequency (Rak *et al.*, 2015), which may result in a decreased creative potential. In any case, the higher creative potential observed in subjects with narcolepsy cannot be attributed to their treatments, which have no or a deleterious impact on creativity.

The role of dissociated REM sleep in creativity

This higher creative potential in narcolepsy is consistent with our initial prediction of the specific role of REM sleep in creativity. Indeed, subjects with narcolepsy have privileged access to REM sleep and to dreams. They often fall asleep directly into REM sleep, a phenomenon that occurs rarely in controls. Many symptoms (cataplexy, sleep paralysis, hypnagogic hallucinations, lucid dreaming and REM sleep behaviour disorder) indicate that the normal boundary between wakefulness and REM sleep is blurred in narcolepsy. Of interest, these symptoms (except cataplexy) were associated with higher scores on the Test of Creative Profile in the narcolepsy group. Notably, 43% of the 185 subjects with narcolepsy were frequent lucid dreamers according to the questionnaire, compared to 3% of the 126 normal controls, supporting further, with a larger sample in the present study, the higher percentage of lucid dreamers previously reported in three cohorts of subjects with narcolepsy (Dodet *et al.*, 2015; Rak *et al.*, 2015; Oudiette *et al.*, 2018). Here, in accordance with previous studies in normal subjects (Blagrove and Hartnell, 2000; Zink and Pietrowksy, 2013), lucid dreaming had a positive impact *per se* (in the whole sample) on subjective measures of creativity. Lucid dreaming was not associated with higher objective performances in the Evaluation of Creative Potential, but this may be due to a smaller sample. Whether lucid dreaming is the cause or consequence of creativity remains an open question (Zink and Pietrowksy, 2013). Similar to previous reports in healthy lucid dreamers (Schädlich and Erlacher, 2012), some of our subjects reported using lucid dreams to come up with novel and creative ideas and to solve problems. This observation would suggest the direction of causation going from lucid dreaming to creativity. Moreover, subjects with narcolepsy recall their dreams much more (3 to 4 times more often) than normal subjects do (Rak *et al.*, 2015). This ability may explain their higher creative potential, as in healthy subjects (Schredl and Erlacher, 2007), high dream recall frequency predicts a high frequency of creative dreams (i.e., dreams that stimulate waking-life creativity). Being able to access and remember one's dreams could provide a higher pool of ideas from which drawing creative inspirations. This is particularly relevant to the hypothesised importance of REM sleep in the increased creativity observed in patients with narcolepsy, as REM sleep dreams often contain unusual, bizarre elements, compared to NREM dreams that display more common replay of mundane experiences (Foulkes, 1962). These two processes (increased dream recall frequency and unusual dreams) precisely correspond to the two criteria (i.e., fluency and originality) used for evaluating divergent-exploratory creative thinking. Conversely, the hyper-association of distinct elements from different memories found in dreams (Malinowski and Horton, 2015) resembles that of convergent-integrative thinking, when different elements need to be combined to form a single original production. The ability to recall these hyper-associated dreams may thus constitute a template from which to learn how to use these ‘building blocks’ in an original way. This high creative potential should naturally result in self-reported higher creative profiles and accomplishments, which is what we observed with the two questionnaires of creativity. These results can also be discussed in the framework of a recent neuronal network model (Hobson and Friston, 2012), which views REM sleep and dreams as an opportunity for optimising a generative model that predicts the world by minimizing redundancy or complexity. To be able to generate a great diversity of scenarios that the person will encounter during waking, the sleeping brain would need to rehearse fictional scenarios and explore new possibilities that could be experienced during wakefulness. This idea is reminiscent of the relationship between dreams and creativity, as the latter is precisely defined as the ability to explore new possibilities within a constrained context.

Limitations

This study has several limitations. Creativity was assessed using a subset of psychometric measurements (57 questions about creativity, 10 domains of achievement, plus 8 formal creativity tests). Whereas one may want to extend the evaluation of achievement in domains such as economy or administration, as well as formally test creativity in three-dimension creations, we chose to use here validated questionnaires and tests for this first study in narcolepsy. Potential confounding factors such as social or cultural influences were not directly examined. However, our two groups are unlikely to differ on these variables as most cases of narcolepsy are sporadic (Nishino, 2007) and indeed there is no indication in the literature and in our clinical experience that patients with narcolepsy belong to a specific social or cultural environment. Patients with narcolepsy also had on average lower educational level than controls, which should rather be a disadvantage for creativity. In contrast, it is more likely that their sleep characteristics (their most notable difference with controls) are responsible for our findings. This hypothesis is supported by the positive correlations between patients’ symptoms and scores of the Test of Creative Profiles.

To directly assess this assumption, longitudinal studies are needed to further examine within-subject relationships between disease onset and creativity. Moreover, many patients with narcolepsy (68% for the questionnaires and 72% for the EPoC test) were treated with stimulants at the time of the creativity tests. However, their creativity scores did not differ from those of untreated patients. It would be interesting to formally test the creative performances in a large group of untreated patients. Also, we did not replicate the finding of a higher score on the Creative Achievement Questionnaire in the Italian cohort. This may be attributed to the smaller sample size and to the fact that they were on average younger than the French cohort, thus reducing the likelihood of attaining professional expertise in a creative field. Additionally, the narcolepsy group did not score significantly higher than controls on the divergent mode of creative thinking, but a trend was present ($P = 0.09$) and would likely reach significance with more statistical power (we had to remove five subjects from the analyses). Moreover, the results from this dimension highly correlated with both convergent creative thinking and the Creative Achievement Questionnaire, and performances of subjects across all the creative dimensions of the EPoC test were homogeneous. We did not directly assess the role of REM sleep in creativity because we decided to study process acquired over the long term that could not be evaluated by comparison of a performance before vs. after a period of REM sleep. Another limitation of this study may concern the choice of creativity questionnaires. Indeed, the Test of Creative Profile is less often used in this research field. However, we selected it as a way to differentiate creative profiles. The Creative Achievement Questionnaire provides skewed data but simultaneously provides the opportunity to evaluate concrete creative achievement and capture eminent creativity. That being said, both questionnaires correlated with the objective measures of creative performance, further supporting their reliability as measures of creativity.

In conclusion, we highlight here that subjects with narcolepsy show higher creative thinking than controls. Sleepiness and dissociated states of REM sleep and wakefulness have a positive impact on the creative profile. We suggest that this higher performance may be due to more frequent opportunities to incubate and associate ideas during sleep (and especially during REM sleep) and to remember them upon awakening. These positive results could be used in clinical settings to encourage subjects with narcolepsy to exploit their full creative potential, thus providing a silver lining when facing the difficulties associated with this disastrous sleep disorder.

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Competing interests

The authors report no competing interests.

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Table 1 - Demographic and clinical characteristics of controls and subjects with narcolepsy

Group	Narcolepsy	Control	P
Number of subjects	185	126	
Age, y	36.2 ± 15.9	33.6 ± 15.2	0.14
Education level, 1-7	5.9 ± 1.3	6.4 ± 0.9	<0.001
Female gender, N (%)	104/185 (56.2)	65/126 (51.6)	0.42

Right-handed, N (%)	154/185 (83.1)	115/126 (91.5)	0.10
Narcolepsy symptoms			
Epworth sleepiness score (treated), 0-24	12.7 ± 5	6.1 ± 2.7	<0.0001
Cataplexy, N (%)	113/178 (63.5)	0/126 (0)	<0.0001
Sleep paralysis, N (%)	66/178 (37.1)	1/126 (0.8)	<0.0001
Hypnagogic hallucinations, N (%)	76/178 (42.7)	1/126 (0.8)	<0.0001
Clinical REM sleep behaviour disorder, N (%)	53/177 (29.9)	1/126 (0.8)	<0.0001
Lucid dreaming, N (%)	80/184 (43.5)	4/126 (3.2)	<0.0001
Hospital Anxiety and Depression Rating Scale			
Depression score, 0-21	5.8 ± 3.9	4 ± 3	0.004
Anxiety score, 0-21	7.3 ± 4.2	6.5 ± 2.6	0.18
Multiple sleep latency tests			
Mean sleep latency, min	3.8 ± 2.4	Not done	NA
Sleep onset in REM periods, 0-5	3.6 ± 1.4	Not done	NA
Medical treatments			
Treated patients, N (%)	138/168 (82.1)	1/82 (1.2)	<0.0001
Stimulants, N (%)	114/168 (67.9)	1/82 (1.2)	<0.0001
Anti-cataplectic drugs, N (%)	52/168 (30.1)	0/82 (0)	<0.0001
Sodium oxybate only, N (%)	44/168 (23.8)	0/82 (0)	<0.0001

Measures are presented as the mean ± standard deviation or N (%). NA: not applicable.

Table 2 - Impact of narcolepsy symptoms and medical treatments on the scores of the creativity questionnaires in subjects with narcolepsy

Scores	**Test of Creative Profile (0-100)**			**Creative Achievement Questionnaire**		
Patients	With	Without	P	With	Without	P
Cataplexy	58.7 ± 9.3	59.6 ± 10.1	0.51	10.1 ± 25	8.3 ± 15.5	0.59
Hallucinations	60.8 ± 8	57.7 ± 10.5	0.03	8.3 ± 14.4	10.3 ± 26.3	0.56
Sleep paralysis	62.1 ± 8.4	57.2 ± 9.8	<0.001	9.4 ± 15.2	9.5 ± 25.1	0.97
Clinical REM sleep behaviour disorder	61.8 ± 8	57.8 ± 10.1	0.01	10.5 ± 22.2	9 ± 8	0.69
Lucid dreaming	61 ± 0.9	57.3 ± 1	0.009	13.6 ± 29.8	8 ± 22	0.09
Medical treatments*						
Stimulant drugs	59.6 ± 9.6	59.9 ± 10.1	0.87	8.6 ± 15.6	17 ± 41.3	0.08
Anti-cataplectic drugs	56.7 ± 9.9	59.9 ± 10.1	0.17	5.8 ± 12.3	17 ± 41.3	0.07

Measures are presented as the mean ± standard deviation. * Comparison with untreated patients (control, N = 30).

Table 3 - Correlations between measures of sleepiness, depressive and anxiety symptoms, and the scores on the creativity questionnaires in subjects with narcolepsy

Correlation with	Test of Creative Profile	P	Creative Achievement Questionnaire	P
Hospital Anxiety and Depression Scale				
Depression score, 0-21	0.23	0.03	0.11	0.30
Anxiety score, 0-21	0.16	0.13	0.03	0.8
Measures of sleepiness				
Epworth sleepiness score, 0-24	0.19	0.01	0.12	0.11
Mean daytime sleep latency, 0-20 min	0.15	0.08	0.10	0.26
Sleep onset in REM periods, 0-5	-0.001	0.99	0.08	0.33

Correlations are Pearson's correlation coefficients.

Figure Legends

Figure 1 - Templates and examples of scored results for the divergent and convergent graphic tasks on the Evaluation of Creative Potential. Using a given template (left panel), the subjects had to draw as many drawings as possible by using this shape for divergent-graphic tasks (abstract or concrete). For the convergent-graphic tasks, they had to use at least four of the presented items (abstract or concrete) into a single original production. Examples of drawings judged as non-creative (middle panel) because participants frequently made these particular drawings (divergent) or because there were only reproductions of the elements without any sense to them (convergent, scored 1 on a 7-point scale). Examples of drawings judged as creative (right panel) because the subjects never/rarely made them (divergent) or because they integrated all elements into coherent, original story-based drawings (convergent, scored 5 and 6, respectively, on a 7-point scale). Templates are protected by copyright@Hogrefe.

Figure 2 - Self-reported assessments of creativity in healthy controls and in subjects with narcolepsy. (**A)** Boxplots of the scores of controls (pink) and subjects with narcolepsy (blue) on the Test of Creative Profile (total score, followed by the three associated creative profiles). On each box, the central thick line indicates the median, the cross represents the mean, and the bottom and top edges of the box indicate the 25th and 75th percentiles, respectively. The whiskers extend to the most extreme data points not considered outliers and the outliers are plotted individually using circles. (**B)** Distribution of the scores obtained on the Creative Achievement Questionnaire for both groups. Note the skewed distribution of the data with a higher proportion of outliers (i.e., individuals with high levels of creative achievement) in the narcolepsy group compared to the control group. N = 126 for control and N = 185 for narcolepsy. **P <0.01 and *P <0.05 for between group differences (Z-test).

Figure 3 - Evaluation of Creative Potential test in healthy controls and in subjects with narcolepsy. (**A)** Correlation circle of the principal component analysis on the eight variables of the Evaluation of Creative Potential test. Histograms showing the distribution of data for the total score of the EPoC test **(B)**, score of convergent **(C)** and divergent **(D)** creative thinking in control and narcolepsy groups. Note that each dimension comprises four subtests. For better visibility, black curves graphically represent each data distribution. The vertical black bar represents the median, and the horizontal black bar on top of each graph represents the mean ± SD. To highlight the difference between groups, the distribution' curves of control and narcolepsy groups were additionally superposed at the lower part of each graph (B, C and D). N = 30 for both control and narcolepsy groups. ** $P < 0.01$; the exact P value is displayed if $P > 0.05$, for between-group differences obtained with linear mixed model analyses. **(E)** Spearman correlation matrix between the creativity and achievement questionnaires and the divergent and convergent scores. ***$P < 0.001$; ** $P < 0.01$; *$P < 0.05$ for correlations between variables. CAQ: Creativity Achievement Questionnaire; TCP: Test of Creative Profile (total score).

Supplementary material

Supplementary methods

Details on the timeline of the Evaluation of Creative Potential test (EPoC) and on the eight tasks are depicted in **Figure S1**. The test is composed of eight subtests evaluating two modes of thinking (divergent-exploratory and convergent-integrative) with two fields of expression (graphic and verbal).

Figure S1 - Timeline of the Evaluation of Creative Potential (EPoC) test. (A) First session of the EPoC test. Divergent graphic (abstract): Participants were first asked to make as many drawings as possible incorporating an abstract form shown on a sheet in 10 minutes. **Divergent verbal (story endings):** Subjects were given the beginning of a story and had to invent as many endings as possible in 10 minutes. **Convergent graphic (abstract):** Subjects were given a sheet with eight abstract forms on it and had to incorporate at least four of them into an original, coherent drawing. They had 15 minutes to do so. **Convergent verbal (story with given title):** Subjects had to invent an entire story for the given title in 10 minutes. Once this latter task was completed, subjects had a break of 30 minutes before starting the second session of the test. (**B) Second session of the EPoC test. Divergent graphic (concrete):** Similar to divergent graphic (abstract) but the drawings had to integrate a concrete object in 10 minutes. **Divergent verbal (story beginnings):** Similar to the divergent verbal (story endings) but participants were given the ending of a story and had to invent as many beginnings as possible in 10 minutes. **Convergent graphic (concrete):** Similar to convergent graphic (abstract) but with 8 concrete objects. **Convergent verbal (story with characters):** Subjects were asked to invent a story in 10 minutes in which there were three imposed main characters. For each test, subjects received the instruction to name their work and to try to produce original drawings/stories, different from what the others could have produced.

Supplementary figures

Figure S2 - Self-reported assessments of creativity in controls and subjects with narcolepsy in two different countries. (A) French group: Mean scores ± SD of controls and subjects with narcolepsy on the Test of Creative Profile (total and its three associated creative profiles, **left panel**) and on the Creative Achievement Questionnaire (CAQ, **right panel**). For clarity, error bars of the CAQ were not displayed on the graph as the scores were highly skewed with SD = 8.55 in 83 controls and SD = 31.78 in 110 subjects with narcolepsy type 1 and type 2. **(B) Italian group:** Same legend as **A**. Note that SD = 4.03 in 43 controls and SD = 9.84 in 64 subjects with narcolepsy type 1. **P < 0.01, * P < 0.05, and ns, non-significant for a difference between control and narcolepsy groups with the Z-test.

Figure S3 - Evaluation of Creative Potential test in control and narcolepsy groups. Mean scores ± SD for divergent (graphic and verbal) and convergent (graphic and verbal) creative thinking. Note that each dimension comprises two subtests. N = 30 for both control and narcolepsy groups. **P<0.01, *P<0.05, and exact P values are displayed if P > 0.05, for differences between control and narcolepsy groups obtained with linear mixed model analyses.

Figure S4 – A closer look at the five factors used to evaluate convergent creative thinking. (A) Mean scores ± SE of controls and subjects with narcolepsy on all the convergent tasks for each of the five factors. **(B)** Spearman correlation matrix between the five factors (orange dotted line) and between the five factors and the questionnaires of creativity (white dotted line). **P<0.01, *P<0.05, and exact P values are displayed if P > 0.05, for differences between the variables of interest obtained with linear mixed model analyses.

Supplementary Tables

Table S1 - Demographic and clinical characteristics of the subjects with narcolepsy and of the healthy controls having completed the Evaluation of Creative Potential test

Group	Narcolepsy	Control	P-value
No.	30	30	NA
Age, y	38.9 ± 14.8	39.5 ± 16.2	0.88
Education level, 1-7	6.5 ± 1	6.2 ± 1.2	0.30
Female gender, N (%)	14/30 (46.7)	17/30 (56.7)	0.51
Right-handed, N (%)	25/30 (83.3)	27/29 (93.1)	0.37
Narcolepsy symptoms			
Epworth sleepiness score, 0-24	13.9 ± 5.4	6.7 ± 2.7	<0.0001
Cataplexy, N (%)	16/30 (53.3)	0/30 (0)	<0.0001
Sleep paralysis, N (%)	11/30 (36.7)	1/30 (3.3)	0.004
Hypnagogic hallucinations, N (%)	15/30 (50)	1/30 (3.3)	<0.001
Clinical REM sleep behaviour disorder, N (%)	8/30 (26.7)	1/30 (3.3)	0.009
Lucid dreaming, N (%)	16/30 (53.3)	3/30 (10)	<0.001
Hospital Anxiety and Depression Rating Scale			
Depression score, 0-21	6.7 ± 3.3	4.7 ± 3.0	0.013
Anxiety score, 0-21	8.0 ± 3.9	6.8 ± 2.9	0.14
Multiple sleep latency tests			
Mean sleep latency, min	5.9 ± 3	Not done	NA
Sleep onset in REM periods, 0-5	3.2 ± 1.1	Not done	NA
Treatments			
Treated patients, N (%)	26/29 (89.7)	0/30 (0)	<0.0001

Stimulants, N (%)	21/29 (72.4)	0/30 (0)	<0.0001
Anti-cataplectic drugs, N (%)	4/29 (13.8)	0/30 (0)	0.035

Data are presented as the mean ± SD or N (%).

Table S2 - Comparisons of the scores on the questionnaires of creativity in untreated patients vs. patients treated with drugs prescribed for narcolepsy.

	Number of patients concerned	Test of Creative Profile (0-100)	P*	Creative Achievement Questionnaire	P*
Untreated patients	30	59.9 ± 10.1	NA	17 ± 41.3	NA
Treated patients	138	59 ± 9.7	0.66	8.2 ± 15.6	0.054
Stimulant (all)	114	59.6 ± 9.6	0.87	8.6 ± 15.6	0.08
Methylphenidate	29	61.5 ± 8.3	0.51	9.6 ± 11.2	0.36
Modafinil	68	58.6 ±10.3	0.56	7.3 ± 14.1	0.09
Pitolisant	18	61.1 ± 6.7	0.65	12.2 ± 24.8	0.66
Anti-cataplectic drugs (all)	52	56.7 ± 9.9	0.17	5.8 ± 12.3	0.07
Sodium oxybate	44	55.7 ± 10	0. 08	5.9 ± 13.2	0.10

Antidepressants	13	64 ± 7.8	0.20	10.1 ± 11.9	0.56

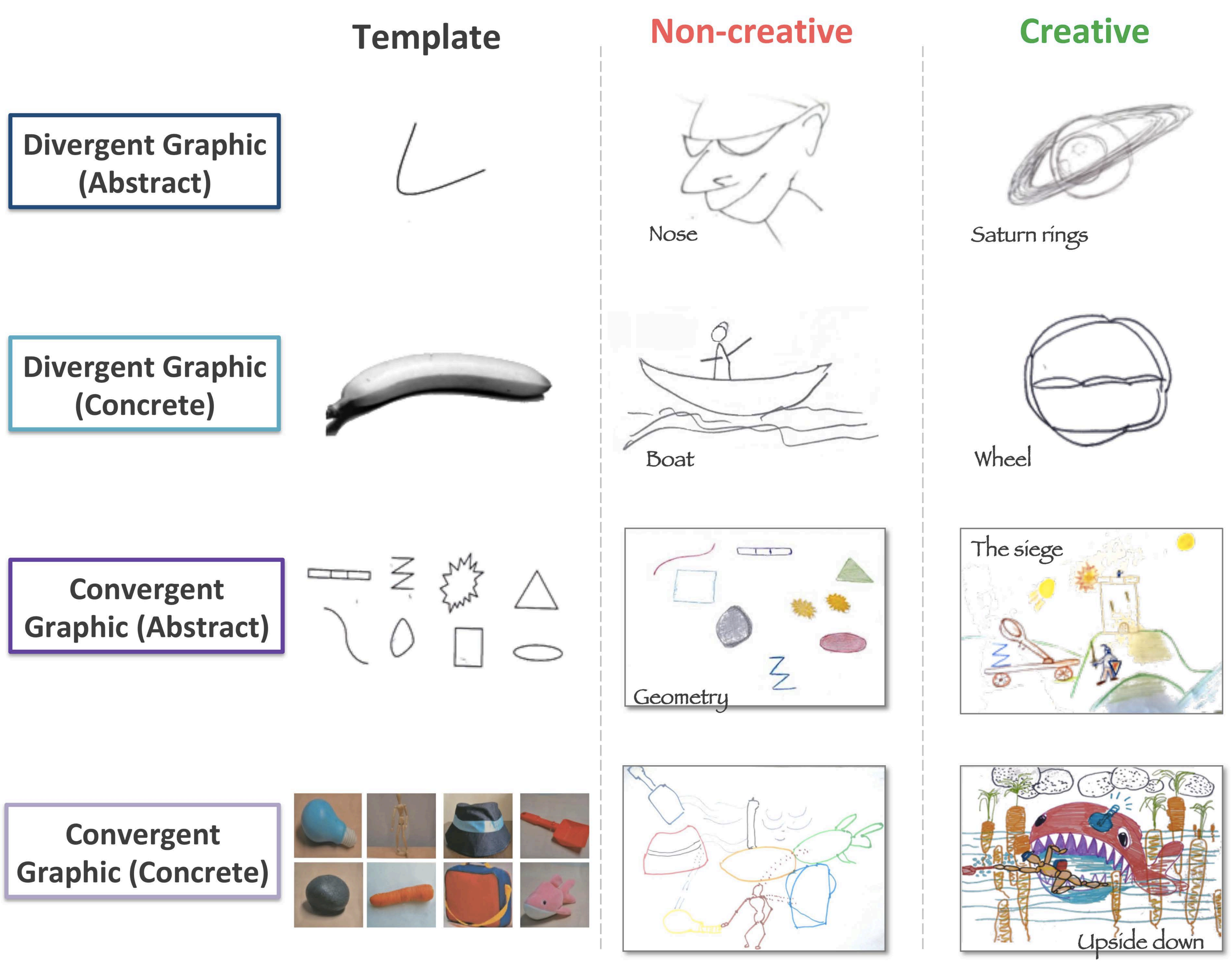
Data are presented as the mean ± SD. * Comparison with untreated patients (control).

Table S3 - Association between narcolepsy symptoms and sleep measures and the mean score of the Evaluation of Creative Potential test in subjects with narcolepsy

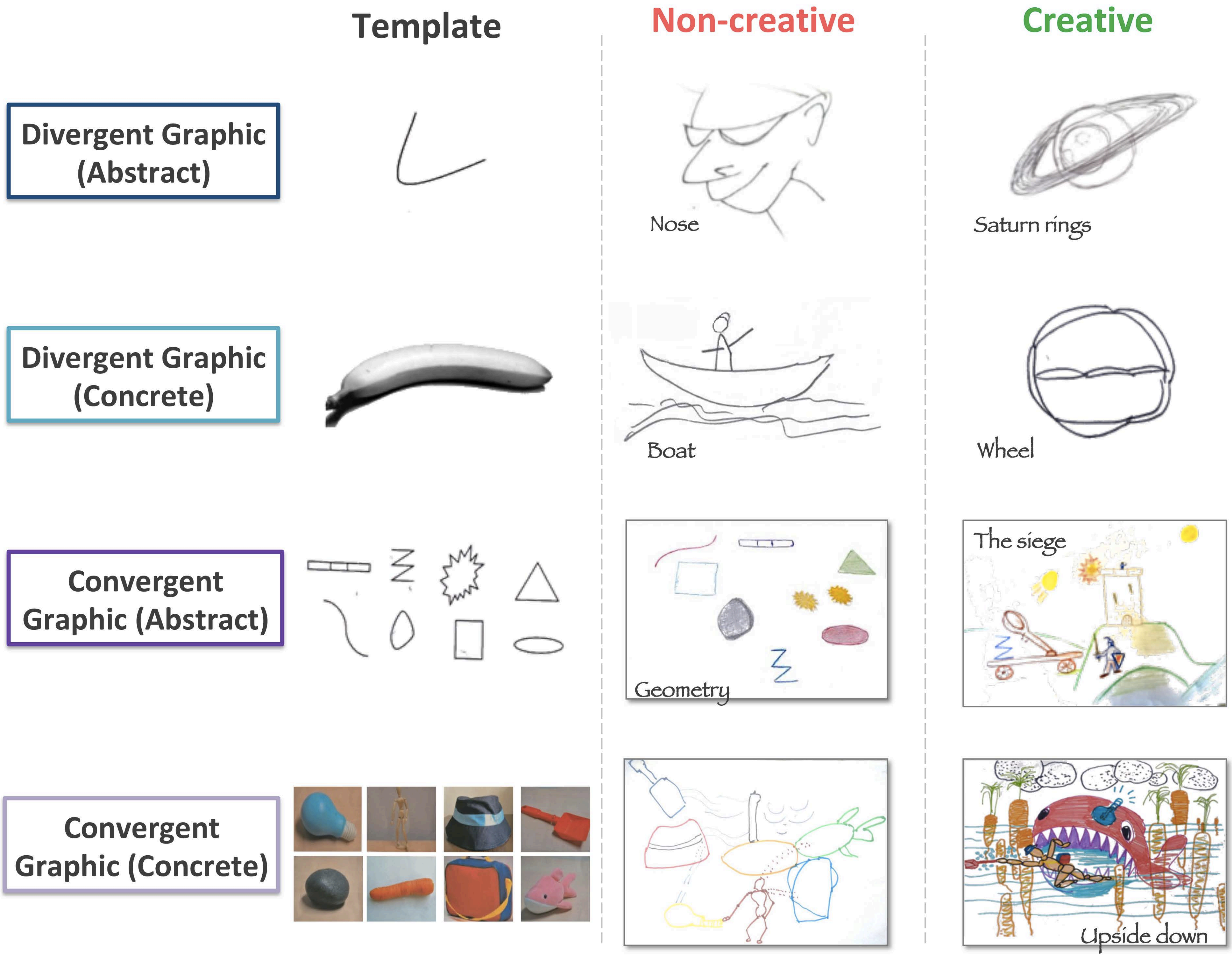
	Score on the Evaluation of Creative Potential test (1-7)		T-test	P
Patients	With	Without		
Cataplexy	4.5 ± 0.9	4.0 ± 0.9	-1.51	0.14
Hallucinations	4.2 ± 1.0	4.4 ± 0.9	0.44	0.66
Sleep paralysis	4.4 ± 1.1	4.2 ± 0.8	-0.54	0.59
Clinical REM sleep behaviour disorder	4.5 ± 0.7	4.2 ± 1.0	-0.64	0.53
Lucid dreaming	4.3 ± 1.1	4.3 ± 0.8	-0.009	0.99
			Correlations coefficient	**P**
Hospital Anxiety and Depression Scale				
Depression score, 0-21			0.01	0.94
Anxiety score, 0-21			0.21	0.29
Epworth sleepiness score, 0-24			0.08	0.67
Mean daytime sleep latency, 0-20 min			-0.15	0.45
Sleep onset in REM periods, 0-5			-0.31	0.10

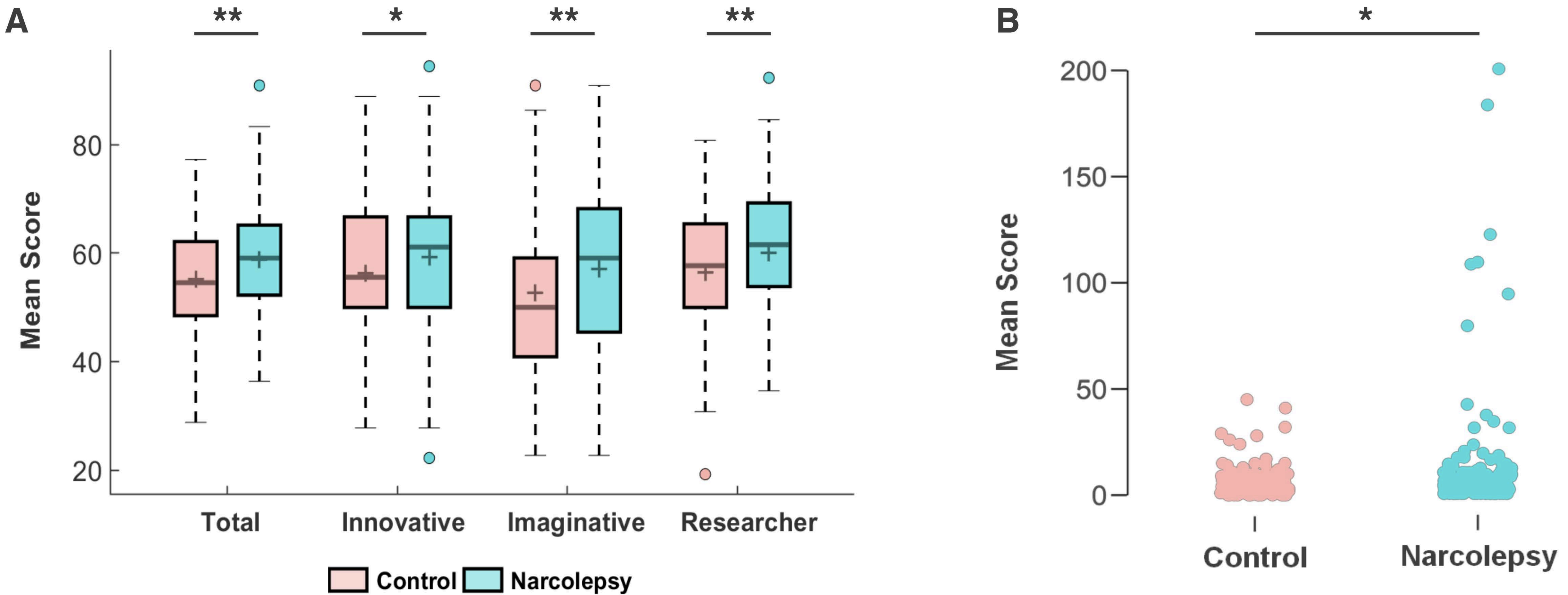
Table S4 - Correlations between raw scores for each of the four divergent subtests of the EPoC and their standard scores on the Likert (7-point) scale

	Spearman Rho	**P**
Divergent		
Graphic (abstract)	0.98	<0.001
Graphic (concrete)	0.97	<0.001
Verbal (story beginnings)	0.97	<0.001
Verbal (story endings)	0.98	<0.001

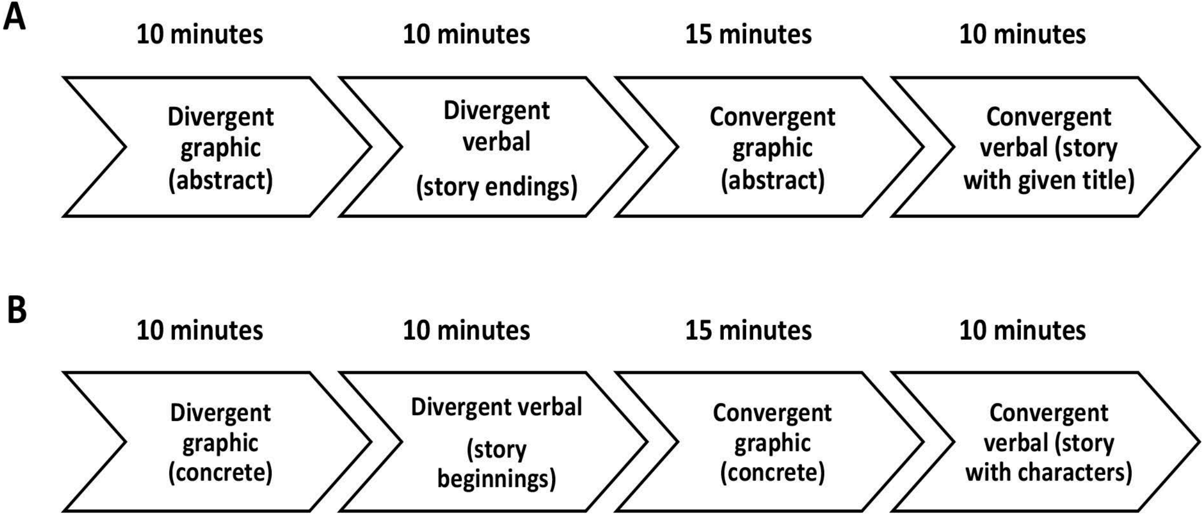


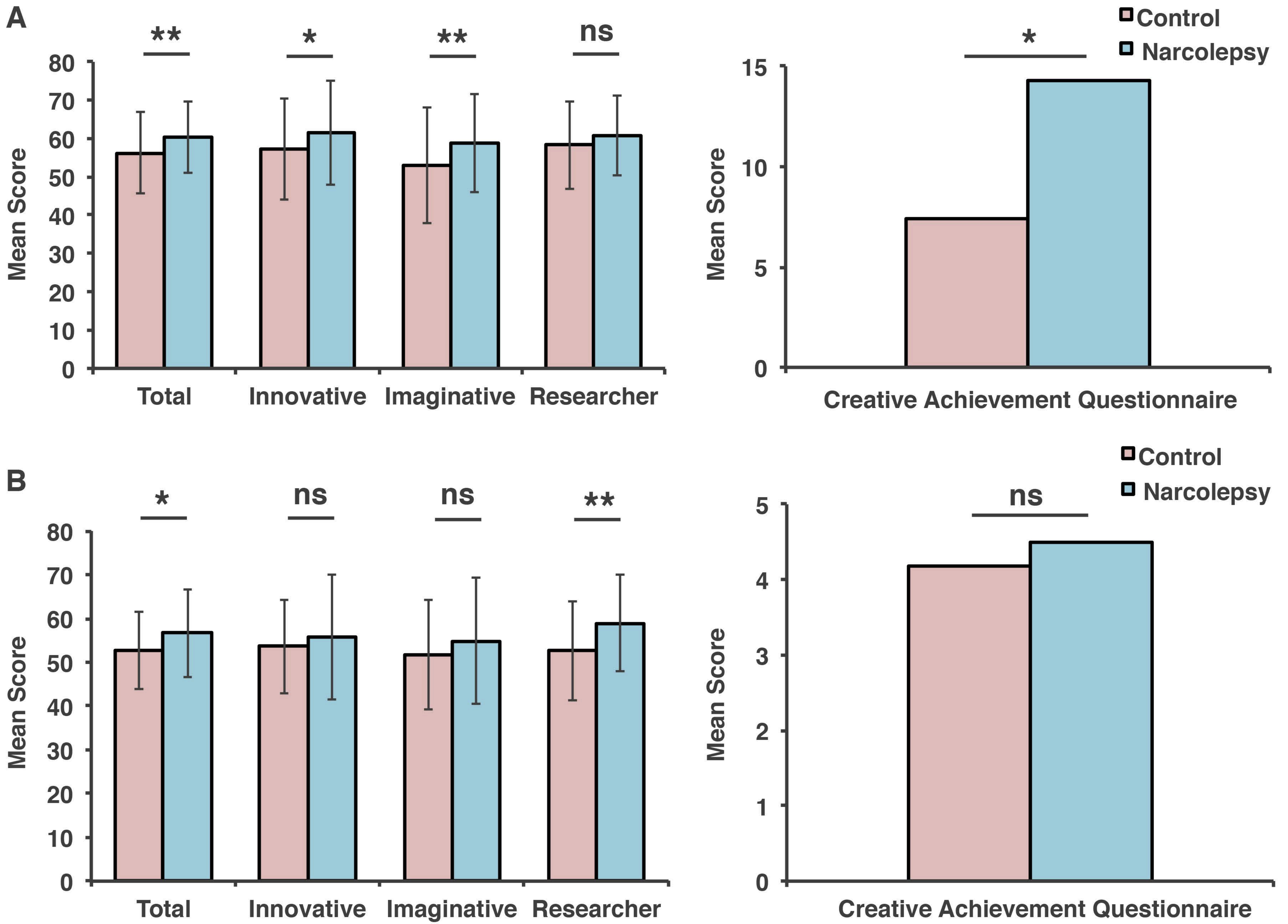
Template
Non-creative
Creative
Divergent Graphic (Abstract)
Nose
Saturn rings
Divergent Graphic (Concrete)
Boat
Wheel
Convergent Graphic (Abstract)
Geometry
The siege
Convergent Graphic (Concrete)
Upside down


Template
Non-creative
Creative
Divergent Graphic (Abstract)
Nose
Saturn rings
Divergent Graphic (Concrete)
Boat
Wheel
Convergent Graphic (Abstract)
Geometry
The siege
Convergent Graphic (Concrete)
Upside down

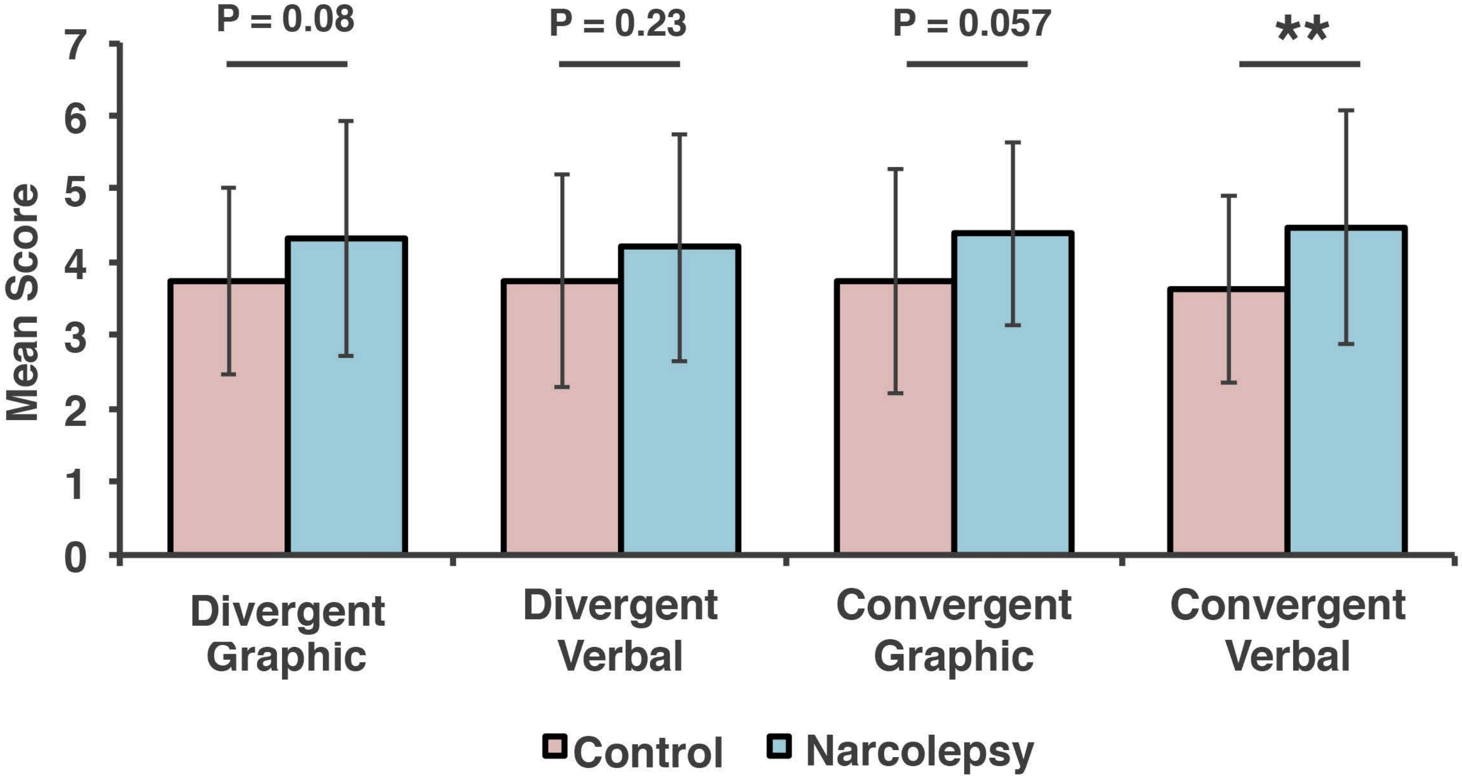

A
B
**
*
**
**
*
Mean Score
80
60
40
20
Total
Innovative
Imaginative
Researcher
Control
Narcolepsy
200
150
100
50
0
Control
Narcolepsy

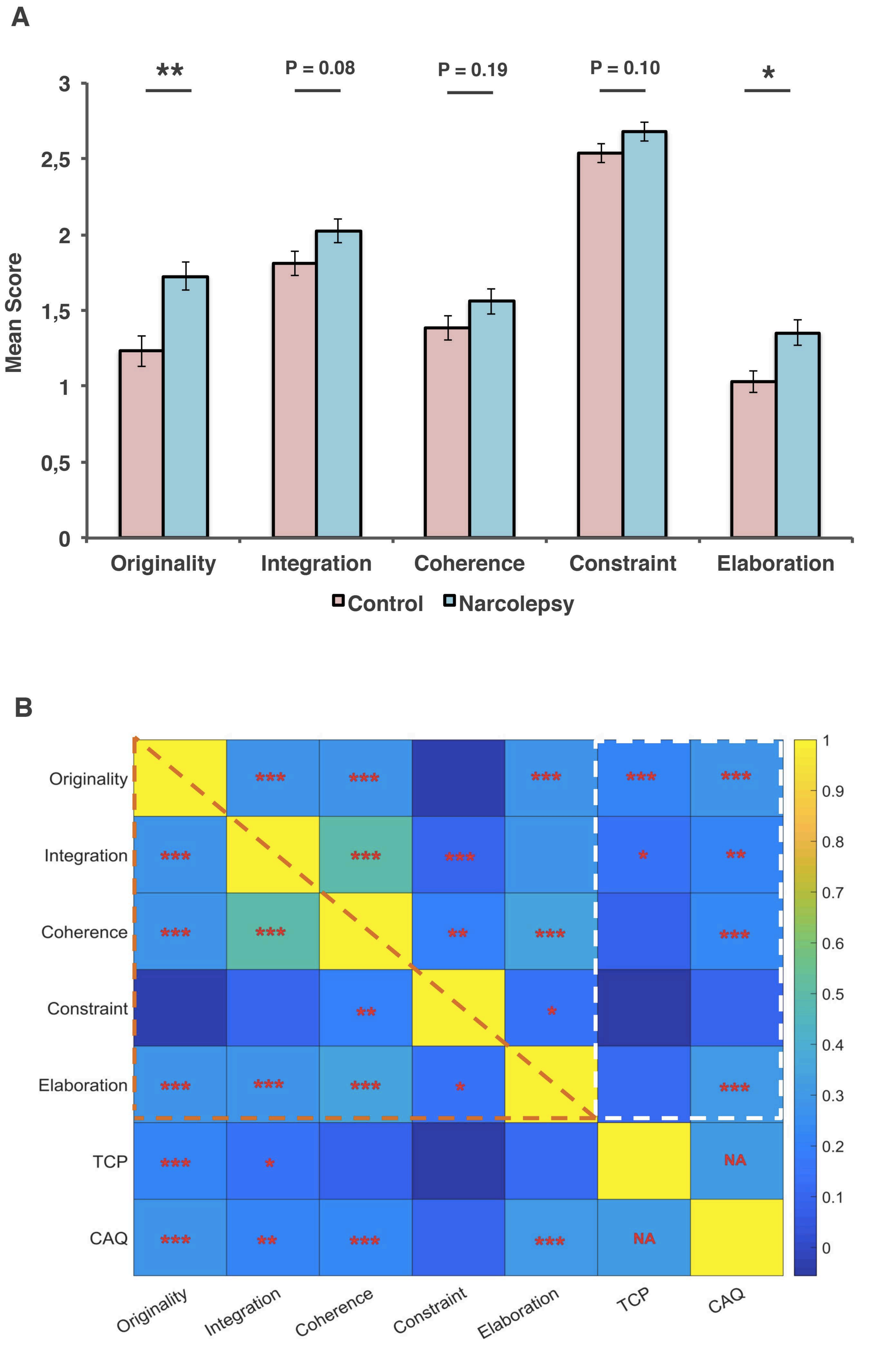

A
Variables (axes Divergent & Convergent: 58.73%)
CGc
CGa
CVc
CVt
DGc
DVe
DGa
DVs
Convergent (20.10%)
Divergent (38.62%)
B
Total
C
Convergent
D
Divergent
Control
Narcolepsy
Proportion
**
P = 0.09
Control
Narcolepsy
Total score
Convergent score
Divergent score
E
TCP
CAQ
Divergent
Convergent


A
10 minutes
10 minutes
15 minutes
10 minutes
Divergent graphic (abstract)
Divergent verbal (story endings)
Convergent graphic (abstract)
Convergent verbal (story with given title)
B
10 minutes
10 minutes
15 minutes
10 minutes
Divergent graphic (concrete)
Divergent verbal (story beginnings)
Convergent graphic (concrete)
Convergent verbal (story with characters)



A
**
*
**
ns
Mean Score
80
70
60
50
40
30
20
10
0
Total
Innovative
Imaginative
Researcher
Control
Narcolepsy
*
15
10
5
0
Mean Score
Creative Achievement Questionnaire
B
*
ns
ns
**
Mean Score
80
70
60
50
40
30
20
10
0
Total
Innovative
Imaginative
Researcher
Control
Narcolepsy
ns
5
4
3
2
1
0
Mean Score
Creative Achievement Questionnaire


P = 0.08
P = 0.23
P = 0.057
**
Mean Score
7
6
5
4
3
2
1
0
Divergent Graphic
Divergent Verbal
Convergent Graphic
Convergent Verbal
Control
Narcolepsy


A
**
P = 0.08
P = 0.19
P = 0.10
*
Mean Score
3
2,5
2
1,5
1
0,5
0
Originality
Integration
Coherence
Constraint
Elaboration
Control
Narcolepsy
B
Originality
Integration
Coherence
Constraint
Elaboration
TCP
CAQ
NA
NA
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0