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A meta-analysis of imagery rehearsal for post-trauma nightmares: Effects on nightmare frequency, sleep quality, and posttraumatic stress

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HIGHLIGHTS

- IR improves nightmare frequency, sleep quality, and PTSD symptoms.
- The benefits of IR are sustained for 6 to 12 months following treatment completion.
- Direct comparisons of IR and established PTSD interventions are warranted.

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ABSTRACT

This meta-analysis evaluates the efficacy of imagery rehearsal as a treatment for nightmares, general sleep disturbance, and symptoms of post-traumatic stress. Bibliographic databases and cited references were searched to identify clinical trials of imagery rehearsal in individuals with post-trauma nightmares. Thirteen studies met inclusion criteria and reported sleep and post-traumatic stress outcomes in sufficient detail to calculate effect sizes. Results indicate that imagery rehearsal had large effects on nightmare frequency, sleep quality, and PTSD symptoms from the initial to post-treatment assessments. These effects were sustained through 6 to 12 months follow-up. Furthermore, interventions that included both imagery rehearsal and cognitive behavioral therapy for insomnia resulted in greater treatment-related improvement in sleep quality than imagery rehearsal alone. Combined treatment did not improve outcomes for PTSD or nightmares. Notably, effect sizes were small in the single study that included an active-treatment control condition. Future research should identify necessary and sufficient components of interventions for trauma-related sleep disturbance and post-traumatic stress (e.g., exposure, cognitive reappraisal, sleep and circadian regulation).

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Abbreviations: BG, between group; C, control group; CAPS, Clinician Administered PTSD Scale; CBTI, Cognitive Behavioral Therapy for Insomnia; Civ, civilian; ERRT, Exposure, Relaxation, and Rescripting Therapy; I, insomnia symptoms; Indiv, individual; IR, imagery rehearsal; IR[a], imagery rehearsal adapted from the protocol by Thompson, Hamilton, and West (1995); IR[b], imagery rehearsal adapted from the protocols by Forbes et al. (2003), Krakow and Zadra (2006), and Thompson et al. (1995); IRET, Imagery Rescripting and Exposure Therapy; IRT, Imagery Rehearsal Therapy; IRT[a], Imagery Rehearsal Therapy with exposure to the original nightmare narrative; IRT[b], Imagery Rehearsal Therapy without exposure to the original nightmare narrative; Mil, active-duty military; NM, nightmares; pre, pre-treatment assessment; post, post-treatment assessment; PSQI, Pittsburgh Sleep Quality Index; PSS, Posttraumatic Stress Scale; PTSD, posttraumatic stress disorder; SDT, Sleep Dynamic Therapy; SIP, Sleep Intervention for PTSD; Sleep edu, sleep education; T, treatment group; TAU, treatment as usual; TE, traumatic event; Vet, military veteran; W, wrote nightmare narrative; W+RA, wrote nightmare narrative and read narrative aloud to therapist or treatment group; W+RD, wrote nightmare narrative and read narrative daily; WG, within group; WL, wait-list control.

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1. Introduction

Sleep disturbance is a core feature of posttraumatic stress disorder (PTSD; Brett & Ostroff, 1985; Ross, Ball, Sullivan, & Caroff, 1989). Up to 72% of individuals with PTSD report posttraumatic nightmares (Leskin, Woodward, Young, & Sheikh, 2002), and up to 91% report problems maintaining sleep (Neylan et al., 1998). Posttraumatic sleep disturbance also predicts PTSD onset and severity (Harvey & Bryant, 1998; Koren, Arnon, Lavie, & Klein, 2002; Mellman, David, Bustamante, Torres, & Fins, 2001), and is independently associated with daytime distress and functional impairment (Clum, Nishith, & Resick, 2001; Krakow et al., 2002b).

Recurrent posttraumatic nightmares and difficulty maintaining sleep can be conceptualized as symptoms of PTSD or independent sleep disorders (American Psychiatric Association, 2000; World Health Organization, 2007). While treatments for PTSD appear to improve nightmares, insomnia, and perceived sleep quality (Belleville, Cousineau, Levrier, St Pierre, & Marchand, 2010), these sleep disturbances often persist at clinically significant levels following reductions in other PTSD symptoms (Belleville, Guay, & Marchand, 2011; Galovski, Monson, Bruce, & Resick, 2009; Zayfert & DeViva, 2004). This has led to the suggestion that posttraumatic nightmares and insomnia should be conceptualized and treated as independent sleep disorders (Germain, 2009; Harvey, 2008; Krakow & Zadra, 2006; Spoormaker & Montgomery, 2008). In fact, some investigators (Davis & Wright, 2007; Krakow et al., 2001a) argue that cognitive-behavioral interventions for nightmares could be stand-alone treatments for individuals with posttraumatic nightmares rather than supplementary treatment options.

Imagery rehearsal (IR) therapies are some of the most commonly-used and well-supported cognitive-behavioral interventions for posttraumatic nightmares. Krakow et al. (2000) were the first to publish a randomized controlled trial demonstrating that IR is an effective treatment for nightmares in individuals with PTSD, and there are now a number of IR treatment protocols available (e.g., Exposure, Relaxation, and Rescripting Therapy; ERRT; Davis, 2009; Imagery Rehearsal Therapy; IRT; Krakow & Zadra, 2006; Imagery Rehearsal and Exposure Therapy; IRET; Long et al., 2011). While there are differences between treatment protocols, the basic components of IR include: 1) sleep education, 2) writing a dream narrative that includes a change to some aspect of a selected nightmare, and 3) daily imaginal rehearsal of the new dream narrative. In addition to these three basic components, some IR protocols include direct exposure to the original nightmare (e.g., ERRT; Davis, 2009; IRET; Long et al., 2011). Exposure may include writing a narrative account of the nightmare and reading the written account aloud to the therapist and/or therapy group members. Furthermore, IR is often combined with components of cognitive-behavioral therapy for insomnia (CBTI; e.g., Krakow et al., 2002b; Swanson, Favorite, Horin, & Arnedt, 2009; Ulmer, Edinger, & Calhoun, 2011). The major components of CBTI include sleep restriction (improving sleep efficiency through consistent bed- and wake-times and restricting time-in-bed to total sleep time), stimulus control (extinguishing learned stimulus–response associations that interfere with sleep), and sleep hygiene (eliminating sleep-interfering behaviors) (Morin, 1993). The wide variety of IR treatment protocols reflects differences between theoretical models of posttraumatic sleep disturbance. The proposed mechanisms of action in IR include habituation, emotional catharsis/abreaction, mastery, cognitive reappraisal, competitive retrieval, and improved sleep regulation (Harvey, Jones, & Schmidt, 2003; Long & Quevillon, 2009; Phelps, Forbes, & Creamer, 2008).

Research on IR has grown over the past decade. However, evidence to support the use of IR as a stand-alone intervention for PTSD symptoms remains very limited. There are currently no randomized controlled trials that directly compare the efficacy of IR for nightmares to established treatments for PTSD. Furthermore, while there are several published reviews that discuss the evidence supporting IR as a treatment for posttraumatic nightmares (e.g., Lamarche & De Koninck, 2007; Nappi, Drummond, & Hall, 2012; Wittmann, Schredl, & Kramer, 2007), there are as yet no quantitative syntheses of treatment outcomes from IR trials. It is also difficult to determine whether one IR protocol is more efficacious than others because the incremental benefit of variations to the treatment protocol (e.g., the inclusion of nightmare exposure or CBTI) has not been systematically explored.

The intent of this meta-analysis is to evaluate the efficacy of nightmare-directed IR as an intervention for nightmares, overall sleep quality, and PTSD symptoms. This will determine: 1) the magnitude of IR treatment effects across multiple labs and treatment-approaches, and 2) whether IR is an effective approach for PTSD symptoms as well as nightmares and general sleep quality. Furthermore, both immediate and long-term treatment outcomes are examined to determine whether the effects of IR persist through 6 to 12 months follow-up. Finally, mixed effects analyses are performed to determine whether the efficacy of IR is moderated by the inclusion of CBTI, exposure to the content of the original nightmare, or implementation with civilian versus veteran samples.

2. Method

2.1. Search

Studies were identified using four search strategies. First, bibliographic databases (i.e., Medline, PsycInfo, PILOTS, Proquest Dissertations and Theses, Cochrane Library) were searched using the following command: (treatment OR therapy) AND (sleep OR insomnia OR nightmares) AND ("stress disorder" OR PTSD) AND English[Language]. Second, reference lists were examined from articles that met inclusion criteria for the meta-analysis. Third, the reference list of a recent qualitative review of sleep treatment in PTSD was reviewed (Nappi et al., 2012). Fourth, authors of articles included in the meta-analysis were contacted to locate unpublished data or reports that were not identified through database or reference searches. Searches were limited to studies of human participants reported in journals, theses, dissertations, and technical reports. Each study author (MDC, LMS) independently reviewed the study titles and abstracts for all reports, as well as full-texts for studies that were not excluded during abstract review.

2.2. Inclusion criteria

Studies were included in the meta-analysis if they constituted an IR treatment outcome study, examined participants with a history of trauma and post-trauma nightmares, reported outcomes for at least one measure of sleep (e.g., nightmare frequency, sleep quality) and one measure of post-traumatic stress symptom severity with enough detail to calculate effect sizes, were written in English, and

were published or in press by July 30, 2011. Studies with fewer than 10 participants in each group were excluded from the meta-analysis based on evidence that effect sizes smaller than 1.5 are reasonably accurate when there are at least 10 participants (Hedges & Olkin, 1985). If there were multiple reports for the same participant sample, data from the most complete report were included in the meta-analysis and preliminary or supplemental reports were excluded. For the purpose of this meta-analysis, interventions were classified as IR for nightmares if they included: 1) scripting a new dream with a change to a selected nightmare, and 2) repeated imaginal rehearsal of the new dream.

2.3. Coding

The following information was extracted from each study included in the meta-analysis: (a) study identification, i.e., author(s), year of publication, journal; (b) sample characteristics, i.e., sample size, percentage females, race, age (mean and SD), civilian or veteran sample, symptoms required for inclusion, percentage of participants diagnosed with PTSD, study attrition, IR treatment attrition; (c) treatment methodology, i.e., treatment approach, number of treatment sessions, duration of treatment sessions, intervention format, treatment manual, randomization, comparison condition, inclusion of CBTI, type of nightmare exposure; (d) measures, i.e., measures of nightmares, sleep quality, and posttraumatic stress; and, (e) quantitative data for calculating effect sizes, i.e., means and standard deviations for each measure at pre- and post-treatment. Studies were coded independently by each study author to ensure data accuracy.

2.4. Effect size calculation

Pre-treatment versus post-treatment (within group; *WG*) effect sizes were calculated using the formula recommended by Lipsey and Wilson (2001),

$$ES_{WG} = w\left[\frac{\left(M_{pre} - M_{post}\right)}{SD_{p,WG}}\right],$$

where the pooled standard deviation was defined as

$$SD_{p,WG} = \sqrt{\frac{\left(SD_{pre}^2 + SD_{post}^2\right)}{2}},$$

the sample size bias adjustment was defined as

$$w_{WG} = \frac{2n}{4(1-r) + ES^2},$$

pre denotes pre-treatment values, *post* denotes post-treatment values, *r* is the correlation between the Time 1 and Time 2 scores, and *ES* is the unweighted effect size. The correlation between the Time 1 and Time 2 scores was not provided in any of the articles included in the meta-analysis. However, Krakow et al. (2001a) provided adequate information to compute pre- to post-test correlations for nightmare frequency (i.e., nights/week with nightmares, nightmares per week), sleep quality (i.e., Pittsburgh Sleep Quality Index; PSQI; Buysse, Reynolds, Monk, & Berman, 1989), and PTSD symptoms (i.e., Clinician Administered PTSD Scale; CAPS; Blake, Weathers, Nagy, & Kaloupek, 1995; Posttraumatic Stress Scale; PSS; Foa, Riggs, Dancu, & Rothbaum, 1993) using the formula provided by Morris and DeShon (2002),

$$r = \frac{SD_{pre}^2 + SD_{post}^2 - SD_D^2}{(2)\left(SD_{pre}\right)\left(SD_{post}\right)}.$$

Correlation coefficients for each measure were incorporated into the corresponding effect size estimate whenever possible. When this was not possible (i.e., when the test–retest correlation coefficients for a particular measure were not reported by Krakow et al., 2001a), correlation coefficients for the most comparable measure were incorporated into the effect size estimate. For example, the correlation coefficient for the PSS was incorporated into effect size estimates for all PTSD self-report measures. Correlation coefficients from validation papers for each measure were not used because these reports examined retest reliability within days or weeks rather than the more representative three-month time window used by Krakow et al. (2001a). Furthermore, the study sample in Krakow et al. (2001a) appeared representative of the other samples included in the meta-analysis (i.e., trauma-exposed individuals with sleep disturbance and PTSD symptoms).

Experimental versus control group (between group; *BG*) effect sizes were calculated using the formula recommended by Morris (2008),

$$ES_{BG} = w\left[\frac{\left(M_{pre,T} - M_{post,T}\right) - \left(M_{pre,C} - M_{post,C}\right)}{SD_{p,BG}}\right],$$

where the pooled standard deviation was defined as

$$SD_{p,BG} = \sqrt{\frac{(n_T - 1)SD_{pre,T}^2 + (n_C - 1)SD_{pre,C}^2}{n_T + n_C - 2}},$$

the sample size bias adjustment was defined as

$$w_{BG} = 1 - \frac{3}{4(n_T + n_C - 2) - 1},$$

T denotes the treatment group, and *C* denotes the control group. Morris (2008) demonstrated that this effect size calculation provides the most unbiased, precise, and robust estimate of treatment effects in pretest–posttest-control group designs.

Meta-analyses generally include one effect size per construct per study. In the present meta-analysis, nightmare frequency, sleep quality (which was always assessed with the PSQI), and PTSD symptoms were considered separate constructs.[1] Therefore, effect sizes were calculated for each of these three measures. In addition, effect sizes were generated for both immediate and long-term treatment outcomes. Immediate treatment effects were based on the first assessment following treatment completion. Long-term treatment effects were based on assessments conducted between 6 and 12 months following treatment completion. Effect sizes for each measure were calculated so that positive effects represent a reduction in symptoms. Because data for treatment completers was available for all studies and many reports did not include results for the intent-to-treat sample, effect sizes were always calculated from treatment completer data to facilitate comparison between studies.

[1] Other constructs were considered for inclusion in the meta-analysis (e.g., nightmare severity, insomnia, total sleep time). However, these outcomes were ultimately omitted from the meta-analysis because they were reported by a small sample of studies ($N \leq 6$).

2.5. Analysis

Computation of mean effect sizes, 95% confidence intervals, and *z*-scores employed SPSS macros provided by Lipsey and Wilson (2001). Statistically significant effect sizes ($p<.05$) have confidence intervals that do not include zero and *z*-scores that are larger than 1.96. Random effects models were applied to mean effect size calculations. The magnitude of the effect sizes was characterized according to the guidelines developed by Lipsey and Wilson (2001, p. 147): effect sizes ≥.67 were considered large and effect sizes ≤.30 were considered small.

Effect size heterogeneity was measured through the *Q*- and I^2-statistics (Higgins, Thompson, Deeks, & Altman, 2003; Lipsey & Wilson, 2001). *Q*-values follow a chi-square distribution where the assumption of effect size homogeneity was rejected if the *Q*-value was statistically significant at $p<.05$. I^2 indicates the percentage of variance in the effect sizes that can be attributed to between-study differences. I^2 values below 25% indicate a small degree of effect size heterogeneity and values above 75% indicate a large degree of effect size heterogeneity.

Calculation of Orwin's fail-safe *N* followed the procedure outlined by Lipsey and Wilson (2001). The fail-safe *N* indicates the number of studies with an effect size of zero required to reduce the mean treatment- or between-group effect size to the corresponding effect size in the control group. Publication bias was also examined through funnel-plots of sample size by effect size. Publication bias is indicated when there are few small-sample studies with relatively small effects. In addition, histograms of the effect sizes were plotted to identify outliers.

Three mixed effects models were performed to evaluate the effect of treatment approach and sample characteristics on treatment efficacy (Lipsey & Wilson, 2001, pp. 134–142). Mixed effects models assume that variance in effect sizes can be attributed to a combination of systematic and random effects. A significant moderation effect is indicated when the between groups *Q*-statistic (Q_B) exceeds the critical value in a chi-square distribution at $p<.05$. The first model compared the efficacy of IR interventions to interventions that combined IR with components of CBTI (e.g., stimulus control, sleep restriction). The second model compared studies with an explicit exposure component (i.e., written or spoken exposure to the original nightmare) to those without direct exposure to the original nightmare narrative. The third model compared studies with civilian samples to those with veteran/military samples. Tests of moderation were underpowered and are therefore exploratory.

3. Results

3.1. Search results

Bibliographic database searches identified 926 reports. Review of reference lists from studies that met inclusion criteria for the meta-analysis identified 12 additional reports for review. Eight of 10 investigators responded to email requests for study information. This resulted in identification of one additional study (Davis et al., 2011). Dr. Davis provided supplementary data to allow effect sizes to be computed for treatment completers rather than the intent-to-treat sample for Davis et al. (2011). In addition, Dr. Krakow provided raw data for one study (Moore & Krakow, 2007) to allow effect size statistics to be computed from group means and standard deviations.

The vast majority of studies were excluded from the meta-analysis because they did not report treatment outcomes from interventions that included IR for nightmares ($n=896$). Thirty-two of the remaining studies were excluded because they reported treatment outcomes for individuals without a history of trauma ($n=9$), included fewer than 10 participants per treatment condition ($n=13$), or reported data from samples included in other studies ($n=7$). One study (Krakow et al., 2001a) reported six month follow-up data from a previously reported sample (Krakow et al., 2000) and was included only for analyses of long-term treatment effects. This resulted in 13 independent studies that met all inclusion criteria for the meta-analysis. Study review conducted independently by each study author resulted in 100% agreement for inclusion–exclusion. Coding conducted independently by each study author was concordant for 92% of the coded study data. All discordance was resolved through study review and discussion.

3.2. Sample characteristics

Table 1 presents descriptive characteristics for each study included in the meta-analysis. The total number of participants included in the meta-analysis (sum of all study participants represented by at least one outcome at post-treatment assessment) was 511. All of the studies included adult samples; no studies with children met inclusion criteria for the meta-analysis. Based on the 12 studies that reported basic information about the race of participants, approximately 61% of participants (306/500) were White. Race/ethnicity for non-Whites was not reported consistently across studies and could not be easily summarized. Study samples included civilians ($n=286$), military veterans ($n=214$), and active-duty military personnel ($n=11$). Though the study with active-duty military personnel is unique, the effect sizes for this study were within the distribution of effect sizes for the other studies and were therefore included in the meta-analysis. Eighty-six percent of participants were diagnosed with PTSD across the 11 studies that provided diagnostic information. One of the studies that did not report diagnostic information included veterans who were enrolled in a PTSD treatment program within a VA hospital (Long et al., 2011). Presumably, most if not all of these veterans carried a PTSD diagnosis. The study with active-duty military also omitted diagnostic information; it included soldiers who endorsed at least one traumatic event within 30 days of initial assessment and reported nightmares and other sleep complaints subsequent to the event (Moore & Krakow, 2007).

The 13 studies included in the meta-analysis ranged in quality. Five studies, representing 277 participants, were randomized controlled trials. Only one study, with a sample of 101 participants, included an active control condition (Cook et al., 2010). All 13 studies reported treatment outcomes for PTSD severity and nightmare frequency. Nine studies, representing 389 participants, reported treatment outcomes for sleep quality. Six studies, representing 309 participants, included assessment results obtained either 6 or 12 months after treatment completion. The average sample attrition across the ten studies that reported sample sizes at study enrollment and completion was 20%. The average rate of attrition from the IR treatment condition was 26%.

Studies included in the meta-analysis also varied in treatment approach. There were eight identifiable variants of IR used across the 13 included studies: ERRT (Davis, 2009); IR[a] adapted by Forbes et al. (2003) from the protocol of Thompson, Hamilton, and West (1995); IR[b] adapted by Nappi et al. (2010) from the protocols of Forbes et al. (2003), Thompson et al. (1995), and Krakow and Zadra (2006); IRT[a], which includes written exposure to the original nightmare narrative (Krakow et al., 2000); IRT[b] which omits direct exposure to the original nightmare narrative (Krakow & Zadra, 2006); IRET adapted by Long et al. (2011) from ERRT; Sleep Intervention for PTSD (SIP; Ulmer et al., 2011); and, Sleep Dynamic Therapy (SDT; Krakow et al., 2002). Out of all of the studies included in the meta-analysis, three omitted exposure, two included writing a nightmare narrative, six included writing a nightmare narrative and reading it aloud to the therapist or treatment group, and one (Long et al., 2011) included writing a nightmare narrative and reading it daily for a week (see Table 1). Studies also varied in their inclusion of CBTI. Seven studies included major components of CBTI (e.g., stimulus control, sleep restriction) in the treatment approach. However, the degree of emphasis on CBTI varied within these studies: three included at least three sessions of CBTI before beginning IR for

Table 1
Study characteristics.

	Cook et al. (2010)	Davis et al. (2011)	Davis and Wright (2007)	Forbes et al. (2003)	Krakow et al. (2000)	Krakow et al. (2001b)	Krakow et al. (2002a)	Long et al. (2011)	Lu, Wagner, Van Male, Whitehead, and Boehnlein (2009)	Moore and Krakow (2007)	Nappi et al. (2010)	Swanson et al. (2009)	Ulmer et al. (2011)
Sample													
Sample size	101	35	32	12	91	62	66	33	15	11	25	10	18
% Female	0	75	82	0	100	84	61	0	0	–	16	0	32
Mean age (SD)	59 (4)	47 (38)	40 (12)	48 (2)	37 (11)	40 (12)	52 (14)	62 (4)	55 (12)	–	50 (15)	59 (4)	46 (11)
Population	Vet	Civ	Civ	Vet	Civ	Civ	Civ	Vet	Vet	Mil	Vet	Vet	Vet
Symptom criteria	PTSD + NM	TE + NM	TE + NM	PTSD + NM	TE + NM + I	TE + NM + I	TE + NM/I	TE + NM	PTSD + NM	TE + NM	TE + NM	PTSD + NM + I	PTSD + NM + I
% with PTSD	100	53	67	100	95	100	56	–	100	–	79	100	100
% Treatment attrition	36	29	19	–	43	–	4	11	29	–	40	20	33
Treatment													
Treatment approach	IR[a]	ERRT*	ERRT*	IR[a]	IRT[a]	CBTI+IRT[b,*]	SDT*	IRET*	IR[a]	IRT[b]	IR[b]	CBTI + ERRT*	SIP*
NM exposure	W+RA	W+RA	W+RA	W+RA	W	None	W	W+RD	W+RA	–	None	W+RA	None
Number of sessions	6	3	3	6	3	3	6	6	6	4	5	10	6
Session length (min)	90	120	120	90	60–180	200	90	90	90	60	60–120	90	60
Session format	Group	Group/Indiv	Group/ Indiv	Group	Group	Group	Group	Group	Group	–	Group/Indiv	Group	Indiv
Treatment manual	Yes	Yes	Yes	–	Yes	Yes	Yes	–	No	No	Yes (group)	No	–
Comparison condition	Sleep edu	WL	WL	None	WL	None	None	None	None	None	None	None	TAU

Note. Sample sizes indicate the number of participants represented by at least one outcome measure at post-treatment assessment. Percent treatment attrition indicates the percentage of participants who dropped out of IR before treatment completion. CBTI = Cognitive Behavioral Therapy for Insomnia; Civ = civilian; ERRT = Exposure, Relaxation, and Rescripting Therapy; I = insomnia symptoms; Indiv = individual; IR[a] = imagery rehearsal adapted from the protocol by Thompson, Hamilton, and West (1995); IR[b] = imagery rehearsal adapted from the protocols by Forbes et al. (2003), Krakow and Zadra (2006), and Thompson et al. (1995); IRET = Imagery Rescripting and Exposure Therapy; IRT[a] = Imagery Rehearsal Therapy with exposure to the original nightmare narrative; IRT[b] = Imagery Rehearsal Therapy without direct exposure to the original nightmare narrative; Mil = active-duty military; NM = nightmares; PTSD = post-traumatic stress disorder; SDT = Sleep Dynamic Therapy; SIP = Sleep Intervention for PTSD; Sleep edu = sleep education; TAU = treatment as usual; TE = traumatic event; Vet = military veteran; W = wrote nightmare narrative; W+RA = wrote nightmare narrative and read narrative aloud to therapist or treatment group; W+RD = wrote nightmare narrative and read narrative daily; WL = wait-list control; * includes components of cognitive behavioral therapy for insomnia (e.g., stimulus control, sleep restriction); "–" = data not reported.

Table 2
Immediate post-treatment assessment effect sizes, confidence intervals, and *z*-scores for nightmare frequency, sleep quality, and PTSD symptoms.

Study	Within treatment group			Within control group			Between treatment and control groups		
	ES	*95% CI*	*z*	*ES*	*95% CI*	*z*	*ES*	*95% CI*	*z*
Nightmare frequency									
Cook et al. (2010)	0.29	0.04–0.55	2.26	0.14	−0.07–0.36	1.29	0.07	−0.26–0.40	0.43
Davis et al. (2011)	0.64	0.19–1.09	2.81	0.01	−0.35–0.38	0.07	0.64	0.08–1.19	2.23
Davis and Wright (2007)	0.80	0.34–1.27	3.38	0.26	−0.14–0.67	1.27	0.41	−0.16–0.98	1.42
Forbes et al. (2003)	0.73	0.17–1.29	2.54						
Krakow et al. (2000)	1.12	0.78–1.46	6.53	0.03	−0.19–0.26	0.30	1.01	0.65–1.37	5.53
Krakow et al. (2001b)	0.74	0.50–0.97	6.13						
Krakow et al. (2002a)	0.84	0.39–1.29	3.66						
Long et al. (2011)	1.33	0.90–1.77	6.01						
Lu et al. (2009)	0.18	−0.22–0.58	0.90						
Moore and Krakow (2007)	0.54	−0.01–1.09	1.92						
Nappi et al. (2010)	0.47	0.07–0.87	2.32						
Swanson et al. (2009)	0.57	−0.02–1.15	1.91						
Ulmer et al. (2011)	0.75	0.05–1.44	2.11	−0.07	−0.62–0.49	−0.24	0.97	0.06–1.88	2.10
Combined	**0.69**	**0.50–0.88**	**7.14**	**0.09**	**−0.05–0.22**	**1.28**	**0.59**	**0.15–1.02**	**2.65**
Sleep quality									
Cook et al. (2010)	0.23	−0.08–0.53	1.46	0.32	0.05–0.59	2.29	−0.08	−0.48–0.32	−0.40
Davis et al. (2011)	1.44	0.77–2.12	4.19	0.11	−0.35–0.58	0.48	1.24	0.51–1.97	3.31
Davis and Wright (2007)	0.92	0.37–1.47	3.27	0.36	−0.14–0.86	1.40	0.56	−0.13–1.25	1.60
Krakow et al. (2000)	0.73	0.40–1.05	4.38	0.33	0.05–0.61	2.33	0.38	−0.02–0.78	1.86
Krakow et al. (2001b)	1.01	0.71–1.31	6.66						
Lu et al. (2009)	0.27	−0.22–0.77	1.09						
Nappi et al. (2010)	−0.31	−0.79–0.17	−1.26						
Swanson et al. (2009)	0.83	0.14–1.53	2.34						
Ulmer et al. (2011)	1.57	0.61–2.53	3.21	−0.07	−0.70–0.56	−0.22	1.78	0.66–2.90	3.11
Combined	**0.68**	**0.34–1.03**	**3.86**	**0.28**	**0.11–0.44**	**3.31**	**0.64**	**0.10–1.18**	**2.33**
PTSD symptoms									
Cook et al. (2010)	0.47	0.19–0.76	3.28	0.35	0.11–0.59	2.90	0.16	−0.19–0.51	0.87
Davis et al. (2011)	0.83	0.35–1.31	3.37	0.15	−0.23–0.54	0.78	0.66	0.08–1.23	2.25
Davis and Wright (2007)	0.48	0.08–0.87	2.36	−0.10	−0.49–0.28	−0.53	0.58	0.03–1.14	2.06
Forbes et al. (2003)	0.74	0.22–1.27	2.79						
Krakow et al. (2000)	1.20	0.85–1.56	6.71	0.28	0.05–0.51	2.38	0.79	0.44–1.14	4.46
Krakow et al. (2001b)	0.71	0.48–0.94	6.14						
Krakow et al. (2002a)	0.50	0.30–0.71	4.86						
Long et al. (2011)	1.00	0.63–1.37	5.34						
Lu et al. (2009)	0.13	−0.25–0.52	0.68						
Moore and Krakow (2007)	0.93	0.34–1.53	3.07						
Nappi et al. (2010)	1.06	0.63–1.48	4.85						
Swanson et al. (2009)	0.43	−0.08–0.94	1.66						
Ulmer et al. (2011)	1.38	0.57–2.20	3.35	−0.27	−0.78–0.25	−1.02	1.72	0.76–2.69	3.50
Combined	**0.72**	**0.54–0.89**	**8.07**	**0.15**	**−0.05–0.35**	**1.47**	**0.67**	**0.27–1.06**	**3.33**

Note. Individual study effect sizes are standardized and unweighted. Combined values are based on random effects models. *ES* = effect size; *CI* = confidence interval; *z* = *z*-score.

nightmares (e.g., Krakow et al., 2002a; Swanson et al., 2009; Ulmer et al., 2011), while other protocols introduced components of CBTI within IR treatment sessions (e.g., Davis & Wright, 2007; Davis et al., 2011; Krakow et al., 2001b; Long et al., 2011). None of these studies attempted to dissociate the effects of IR from CBTI. Treatments were generally conducted in group format; only four studies offered individual treatment. The number of treatment sessions ranged from 3 to 10.

3.3. Effect sizes

There was significant heterogeneity in the treatment group effect sizes for nightmare frequency, $Q(12) = 32.64$, $p < .01$, sleep quality, $Q(8) = 40.42$, $p < .001$, and PTSD, $Q(12) = 33.10$, $p < .001$. I^2 values indicated that between-study differences accounted for most of the heterogeneity in treatment group effect sizes for each measure (63% for nightmare frequency, 80% for sleep quality, 64% for PTSD). Therefore, mean effect sizes for both within- and between-group effects are based on random effects models. Random effects models assume that variation in effect sizes beyond subject-level sampling error can be attributed to random differences between studies.

Table 2 presents effect size statistics for each of the studies included in the meta-analysis at immediate post-treatment assessment, as well as the combined effect size for each outcome. The magnitude of the mean treatment group effect size was large for nightmare frequency ($ES_{WG} = 0.69$), sleep quality ($ES_{WG} = 0.68$), and PTSD ($ES_{WG} = 0.72$). The magnitude of the mean between-group effect size was moderate for nightmare frequency ($ES_{BG} = 0.59$) and sleep quality ($ES_{BG} = 0.64$), and large for PTSD ($ES_{BG} = 0.67$).

Table 3 presents individual and combined effect size statistics for long-term treatment outcomes. The magnitude of the mean treatment group effect size was large for nightmare frequency ($ES_{WG} = 0.72$) and PTSD $ES_{WG} = 0.93$, and moderate for sleep quality ($ES_{WG} = 0.62$). Control- and between-group effect sizes are not presented for 6 to 12 month treatment outcomes because control group data were not available in four of the six studies with long-term follow-up.

The treatment group fail-safe *N*, which indicates the number of studies with an effect size of zero required to reduce the mean within-treatment-group effect size to the mean within-control-group effect size, was 87 for nightmare frequency, 13 for sleep quality, and 49 for PTSD. The between group fail-safe *N*, which indicates the number of studies with an effect size of zero required to reduce the

Table 3
Six to 12 month follow-up assessment effect sizes, confidence intervals, and z-scores for nightmare frequency, sleep quality, and PTSD symptoms.

Study	*ES*	*95% CI*	*z*
Nightmare Frequency			
Cook et al. (2010)	0.10	−0.15–0.35	0.79
Davis et al. (2011)	0.79	0.42–1.17	4.13
Davis and Wright (2007)	0.94	0.47–1.40	3.96
Forbes et al. (2003)	1.10	0.45–1.75	3.31
Krakow et al. (2001a)	1.07	0.77–1.36	7.15
Lu et al. (2009)	0.44	0.01–1.09	1.99
Combined	**0.72**	**0.33–1.10**	**3.67**
Sleep Quality			
Cook et al. (2010)	0.26	−0.05–0.57	1.63
Davis et al. (2011)	0.88	0.44–1.31	3.91
Davis and Wright (2007)	1.20	0.63–1.78	4.09
Krakow et al. (2001a)	0.71	0.42–1.00	4.79
Lu et al. (2009)	0.17	−0.32–0.66	0.68
Combined	**0.62**	**0.29–0.95**	**3.64**
PTSD Symptoms			
Davis et al. (2011)	1.01	0.59–1.42	4.71
Davis and Wright (2007)	0.82	0.39–1.25	3.72
Forbes et al. (2003)	0.80	0.26–1.33	2.91
Krakow et al. (2001a)	1.31	0.98–1.64	7.79
Lu et al. (2009)	0.58	0.14–1.03	2.60
Combined	**0.93**	**0.66–1.20**	**6.82**

Note. Individual study effect sizes are standardized and unweighted. Combined values are based on random effects models for within-treatment group effects. *ES* = effect size; *CI* = confidence interval; *z* = *z*-score.

mean between-group effect size to the corresponding effect size in the control group, was 28 for nightmare frequency, 6 for sleep quality, and 17 for PTSD. Publication bias was undetectable from funnel-plots for each outcome. No outliers were identified in histograms of the effect sizes for nightmare frequency, sleep quality, or PTSD.

3.4. Moderation analyses

Table 4 presents combined effect size statistics within study samples that received IR alone compared to samples treated with a combination of IR and CBTI. CBTI had a significant effect on the degree of improvement in sleep quality from initial assessment to post-treatment, $Q_B(1) = 11.20$, $p < .001$. Samples treated with CBTI + IR reported more improvement in sleep quality at post-test than samples treated with IR alone. CBTI did not have a significant effect on the degree of improvement in nightmare frequency, $Q_B(1) = 2.26$, $p = .13$, or PTSD symptoms, $Q_B(1) = 0.03$, $p = .87$. Mixed model analysis of exposure as a moderator of treatment outcome indicated that writing and/or reading the original nightmare narrative did not have a significant effect on treatment group effect sizes for nightmares $Q_B(1) = 0.07$, $p = .79$, sleep quality, $Q_B(1) = 0.01$, $p = .92$, or PTSD symptoms, $Q_B(1) = 1.82$, $p = .18$. Mixed model analysis of population (civilian versus veteran/military) as a moderator of treatment outcome indicated that civilian samples demonstrated more improvement in sleep quality at post-test than veteran samples, $Q_B(1) = 5.45$, $p < .05$. Patient population did not have a significant effect on the degree of improvement in nightmare frequency, $Q_B(1) = 2.14$, $p = .14$, or PTSD symptoms, $Q_B(1) = 0.01$, $p = .92$.

Table 4
Mean effect sizes, confidence intervals, and *z*-scores for nightmare frequency, sleep quality, and PTSD symptoms within samples treated with IR compared to CBTI + IR.

Treatment approach	*n*	*ES*	*95% CI*	*z*
Nightmare frequency				
IR	6	0.55	0.29–0.80	4.20
CBTI + IR	7	0.82	0.57–1.07	6.45
Sleep quality				
IR	4	0.27	−0.07–0.60	1.57
CBTI + IR	5	1.09	0.73–1.45	6.03
PTSD symptoms				
IR	6	0.74	0.46–1.01	5.31
CBTI + IR	7	0.71	0.46–0.95	5.57

Note. Values are based on mixed effects models for within-treatment group effects. *ES* = effect size; CBTI + IR = cognitive behavioral therapy for insomnia plus imagery rehearsal; *CI* = confidence interval; IR = imagery rehearsal; *n* = number of studies; *z* = *z*-score.

Differences in the efficacy of IR compared to CBTI + IR, or between civilians and veterans, may reflect baseline differences in sleep quality between study samples. Therefore, post-hoc analyses examined pre-treatment PSQI scores in samples treated with IR compared to samples treated with CBTI + IR, and civilian samples compared to veteran/military samples. Pre-treatment PSQI scores did not differ significantly between samples receiving IR alone ($M = 12.76$, $SD = 3.53$) and those receiving the combined intervention ($M = 14.37$, $SD = 3.46$), $ES_{BG=} 1.61$, *%95 CI* = −3.59–6.82, $z = 0.61$. Pre-treatment PSQI scores also did not differ significantly between civilian ($M = 13.30$, $SD = 3.58$) and veteran/military samples ($M = 14.02$, $SD = 3.35$), $ES_{BG=} 0.72$, *%95 CI* = −5.87–4.43, $z = 0.27$.

4. Discussion

The results from this meta-analysis indicate that IR improves sleep and reduces PTSD symptoms across a diverse range of samples and treatment protocols. As expected, both nightmare frequency and general sleep quality improve with treatment. Perhaps less expected, IR produces large decreases in PTSD symptoms even though global PTSD symptoms are not directly targeted by this treatment. Furthermore, analysis of long-term treatment outcomes indicated that the benefits of IR for both sleep and PTSD symptoms were sustained for 6 to 12 months following treatment completion. An important caveat is that only five of the 13 studies included in the meta-analysis were randomized controlled trials, and only one study compared IR treatment outcomes to an active treatment control condition.

Though preliminary, these results also suggest that sleep outcomes from IR compare favorably to cognitive-behavioral therapies that target the full range of PTSD symptoms. In their recent meta-analysis, Belleville et al. (2010) reported that the combined effect size of PTSD-directed cognitive-behavioral treatments on sleep disturbance was 0.40 (*95% CI* = 0.23–0.57). None of these PTSD interventions directly addressed sleep difficulties, yet they resulted in moderate sleep improvements across the combined sample of 637 participants. Notably, differences in the study samples and treatment formats make it difficult to make direct comparisons between the present meta-analysis and that of Belleville et al. (2010). For example, only one of the studies included in the meta-analysis by Belleville et al. (2010) explicitly stated that individuals with sleep difficulties were included in the sample. Most individuals with PTSD report some form of sleep disturbance (Leskin et al., 2002). Therefore, it is probable that most of the sample described by Belleville et al. (2010) includes individuals with nightmares and other sleep complaints. However, the sample in the present meta-analysis included individuals for whom sleep was a primary complaint. Another related concern is that sleep data were reported in only 2% of the 1205 intervention trials reviewed for meta-analysis by Belleville et al. (2010). This may reflect a file-drawer effect in which sleep data were omitted from reports without treatment-related sleep improvement. Furthermore, most of the studies in the meta-analysis by Belleville et al. (2010) implemented cognitive behavioral therapy in individual sessions rather than therapy groups. In contrast, most of the treatment studies reviewed here used a group treatment format. One of the IR studies included in our meta-analysis tested for moderation of treatment efficacy by treatment format and failed to find differences in nightmare frequency, sleep quality, or PTSD severity between individuals treated in groups versus individual sessions (Nappi, Drummond, Thorp, & McQuaid, 2010). However, none

of the other studies explicitly compared the efficacy of group versus individual treatment. In sum, the relative efficacy of nightmare-directed IR compared to cognitive-behavioral therapies for PTSD is difficult to determine in the absence of direct comparisons with equivalent samples and comparable treatment formats. Studies that compare IR to cognitive-behavioral therapies for PTSD would help guide treatment recommendations for individuals for whom posttraumatic nightmares are of primary concern.

Notably, IR appears less efficacious than PTSD-directed cognitive-behavioral treatments when it comes to reducing PTSD symptoms. A meta-analysis of pre- to post-treatment change in PTSD symptoms following trauma-focused behavioral therapies reported effect sizes that ranged from 1.27 (*90% CI* = 0.80–1.74, self report) to 1.89 (*90% CI* = 1.66–2.12, observer report; Van Etten & Taylor, 1998). Furthermore, a more recent meta-analysis of trauma-focused behavioral treatment versus control group differences reported effect sizes that ranged from 0.83 (*95% CI* = 0.53 to 1.12, versus supportive control) to 1.11 (*95% CI* = 0.76–1.47, versus wait-list control; Bradley, Greene, Russ, Dutra, & Westen, 2005). These effect sizes are generally larger than the within- and between-group effect sizes for PTSD symptoms reported here ($ES_{WG} = 0.72$, $ES_{BG} = 0.67$), though they have overlapping confidence intervals. However, only one of the studies included in the present meta-analysis compared IR to an active control condition, and most studies ($n = 8$) lacked a wait-list control condition. These data suggest that individually-delivered cognitive-behavioral treatments which target the broad range of PTSD symptoms should be considered before IR if the primary aim is to reduce PTSD symptoms. Future research should include direct comparisons of IR and cognitive-behavioral therapies for PTSD in equivalent samples.

The persistence of clinically significant sleep symptoms following PTSD-directed treatment and reductions in global PTSD symptoms is common (e.g., Belleville et al., 2011; Galovski et al., 2009; Zayfert & DeViva, 2004). IR is one of the most well-supported interventions for posttraumatic nightmares, and it may benefit patients who report persistent trauma-related nightmares following PTSD-directed therapy. IR and other sleep-focused interventions may also engage patients who will not pursue PTSD-directed treatment due to stigma or posttraumatic avoidance (Krakow et al., 2001a). As many as 50% of individuals with PTSD do not seek trauma-focused treatment, and those who do often discontinue treatment without receiving therapeutic benefit (Hoge, 2011). The average rate of attrition from IR therapies (27%) is slightly larger than the rates reported for cognitive-behavioral interventions for PTSD (14–21%; Bradley et al., 2005; Van Etten & Taylor, 1998). However, IR may be a reasonable first-line intervention for individuals with posttraumatic nightmares who decline more general treatments for PTSD.

Proposed mechanisms of IR include habituation, emotional catharsis/abreaction, mastery, cognitive reappraisal, competitive retrieval, and improved sleep regulation (Harvey et al., 2003; Long & Quevillon, 2009; Phelps et al., 2008). Notably, exploratory tests of moderation indicate that IR with direct exposure to nightmare content is as effective as IR without nightmare exposure. The lack of difference between IR protocols that included exposure and those that did not suggests that habituation to trauma-related anxiety may not be necessary for symptom improvement. Tests of moderation also indicated that integrated CBTI + IR protocols produced more improvement in sleep quality than protocols without CBTI. However, the inclusion of CBTI did not have incremental benefit for nightmares or PTSD symptoms. CBTI protocols place a greater emphasis on sleep regulation than the sleep education component of IR. This suggests that sleep regulation may not be as relevant to IR-related improvements in nightmare frequency and PTSD symptoms as it is to sleep quality. However, tests of moderation were limited by the small number of studies available for inclusion in the meta-analysis and should be interpreted cautiously. In addition, studies varied considerably in the type of exposure to nightmare content (e.g., writing a nightmare narrative, writing a nightmare narrative and reading it aloud to the therapist or treatment group, writing a nightmare narrative and reading it daily) and the degree of emphasis on CBTI. This further complicates interpretation of the moderation analyses presented here. More work is needed to delineate the active components of IR and their relative benefits. Moreover, there is a fair degree of overlap between the proposed mechanisms of cognitive behavioral therapies for PTSD and IR for nightmares. Treatment dismantling studies, particularly those with transdiagnostic interventions (e.g., exposure, cognitive reappraisal, sleep and circadian regulation), may offer exciting insights that will aid the development and revision of treatments for nightmares and PTSD in the future.

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