Reducing Exposure to Ultraviolet Radiation From the Sun and Indoor Tanning: A Meta-Analysis

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Objective: Skin cancer is the most frequently diagnosed cancer and rates are increasing because of global warming. This article reports a meta-analysis of randomized controlled trials of behavioral interventions to reduce exposure to ultraviolet radiation (UVR). The review aimed to (a) quantify the magnitude of intervention effects on indoor tanning, sun exposure, and sunscreen use, and (b) determine which intervention strategies maximize behavior change. ***Method:*** Out of 17,437 records identified via literature searches, 190 independent tests (N = 89,365) met the inclusion criteria. Sample, intervention, and methodological characteristics, and change techniques were coded, and random effects meta-analyses and metaregressions were conducted. ***Results:*** The sample-weighted average effect size across all studies was $d_+ = .193$ (95% confidence interval, CI [.161, .226]), and there were significant effects on indoor tanning, sun exposure, and sunscreen use ($d_+ = .080$, .149, and .196, respectively). However, there was evidence of publication bias, and trim and fill analyses indicated that the corrected effects for sun exposure and sunscreen use were of very small magnitude ($d_+ \sim .06$) and were not significantly different from zero for indoor tanning ($d_+ = -.011$, 95% CI [−.096, .074]). Metaregression analyses identified several intervention strategies that predicted effect sizes. For instance, interventions delivered individually that promoted alternatives to tanning were associated with larger effect sizes for indoor tanning. ***Conclusion:*** Interventions to date have had only a modest impact on behavioral exposure to UVR. The present findings offer new insights into how the effectiveness of future interventions can be improved.

Keywords: skin cancer, sun protection, indoor tanning, meta-analysis, randomized trial

Supplemental materials: http://dx.doi.org/10.1037/hea0000863.supp

Skin cancer is the most common cancer in the United States, with more than 5 million new cases annually (American Cancer Society, 2020). It is estimated that one in five people in the United States will develop skin cancer during their lifetime (Stern, 2010). Nearly 20 Americans die from melanoma every day and by 2030, the number of newly diagnosed cases is expected to more than

This article was published Online First April 13, 2020.

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This research was supported by a Lineberger Comprehensive Cancer Center Tier II Developmental Award to Paschal Sheeran, Seth M. Noar, & Adam O. Goldstein. The funders had no role in the design, conduct, or reporting of this research. We thank Jennifer Walker and Rachael Posey (Medical Librarians) for invaluable assistance with the computerized literature searches.

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double, and the annual cost of treating newly diagnosed melanomas is expected to triple (Guy et al., 2015). Exposure to ultraviolet radiation (UVR) from the sun and indoor tanning is a preventable cause of skin cancer, meaning that behavior change (i.e., reducing indoor and outdoor tanning) has a crucial role in shrinking incidence rates (American Academy of Dermatology, 2018). Although a large literature has accumulated that tests the impact of interventions to reduce UVR exposure, there is, as yet, no comprehensive quantitative synthesis of this research. This article reports a meta-analysis that aimed to address two questions: (1) How effective are interventions to protect against UVR exposure? and (2) Which strategies lead to greater effectiveness?

As reducing UVR exposure involves multiple, varied behaviors, we attempted to systematize the dependent variables examined in the present review and their relations to outcomes (see Figure 1). The two key behaviors involved in UVR protection relate to reducing indoor and outdoor tanning. Reducing indoor tanning involves decreasing the use of artificial UV light from a tanning beds or booths. Reducing outdoor tanning embraces two behavioral categories, namely, reducing sun exposure, and increasing sunscreen use. Reducing sun exposure involves two further behavioral categories, namely, avoiding the sun and wearing protective attire. Avoiding the sun and wearing protective attire have a dependent relationship as there is no need to wear protective attire if the person avoids the sun, whereas protective attire should be worn if the person is exposed to the sun. Avoiding the sun involves behaviors such as (not) spending time in the sun, (not) engaging in intentional tanning, and seeking shade. Wearing protective attire involves wearing a hat and wearing clothing that reduces exposure to the sun (e.g., long sleeves). Increasing topical sunscreen use is known to prevent UVR-induced DNA damage (Olson et al., 2007). Thus, the key behavioral variables examined in the present review are (a) indoor tanning, (b) sun exposure, and (c) sunscreen use. The outcomes of engaging in indoor tanning, sun exposure, or failing to use sunscreen are sunburn and skin damage that can ultimately result in skin cancer (Ziegler et al., 1994).

There is considerable scope for reducing rates of indoor tanning and sun exposure and increasing sunscreen use. A meta-analysis of indoor tanning rates in the United States, Europe, and Australia indicated that the summary prevalence of ever-exposure was 35.7% for adults, 55.0% for university students, and 19.3% for adolescents; the corresponding prevalence for last year exposure was 14.0, 43.1, and 18.3%, respectively (Wehner et al., 2014). A nationally representative survey of 31,162 U.S. adults from the 2015 National Health Interview Survey–Cancer Control Supplement revealed suboptimal rates of sun exposure and sunscreen use (Holman et al., 2018). Approximately 58% of adults failed to avoid the sun during peak hours and stay in the shade, 61.2% did not wear protective attire, and 63.4% did not use sunscreen with SPF $\geq$15; 34.2% of adults experienced sunburn. Moreover, these values may underestimate the scale of UVR exposure as Dobbinson et al. (2014) observed that self-reports of UVR-protective behaviors may be liable to social desirability bias.

A small number of previous reviews have examined the efficacy of UVR-protective interventions. However, these reviews were circumscribed by a focus on particular samples (e.g., outdoor workers; Horsham et al., 2014), settings (e.g., recreational settings; Rodrigues, Sniehotta, & Araújo-Soares, 2012), approaches (e.g., appearance-based interventions; Williams, Grogan, Clark-Carter, & Buckley, 2012), or offer primarily qualitative summaries of the literature (e.g., Saraiya et al., 2004). There is a need for a comprehensive review that quantifies the impact UVR-protective interventions across different intervention approaches, samples, and settings, and for a wide range of relevant behaviors (i.e., indoor tanning, sun exposure, and sunscreen use).

Merely assessing the overall effectiveness of interventions does not clarify which intervention strategies are effective in promoting UVR protection or offer guidance about which strategies should be

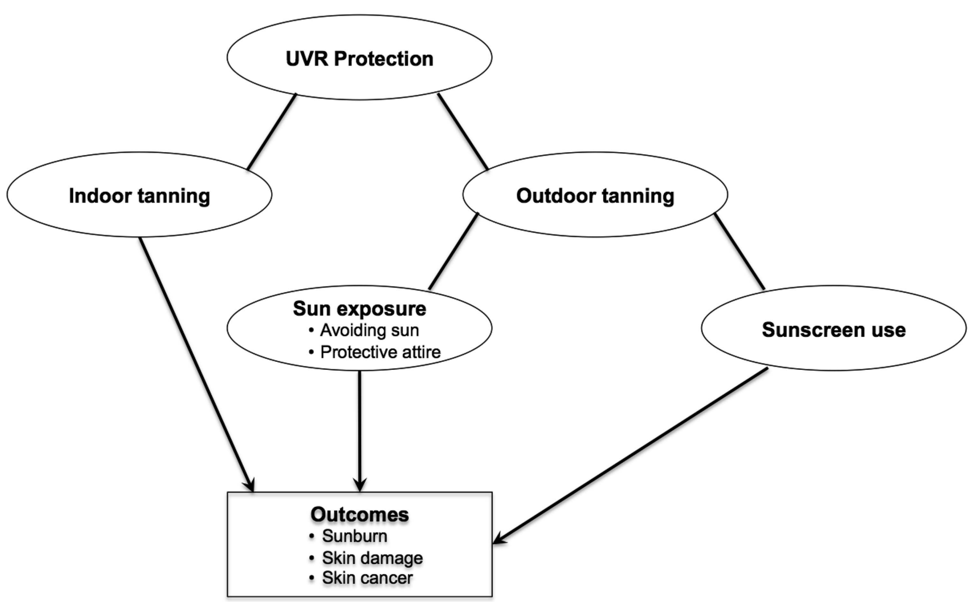

Figure 1. The structure of ultraviolet radiation (UVR) protective behaviors and their relation to outcomes.

deployed in future interventions (Abraham & Michie, 2008; Sheeran, Klein, & Rothman, 2017). To address this issue, categories of psychological change techniques and intervention features were coded for each RCT and metaregression analyses were used to identify strategies that predicted larger effect sizes. Psychological change techniques are mechanism-based intervention content that is designed to generate a specified psychological change (e.g., increase knowledge, promote motivation, or enhance self-efficacy). Abraham and Michie (2008) demonstrated that it is possible to reliably identify and categorize change techniques from intervention descriptions. Michie, Abraham, Whittington, McAteer, and Gupta (2009) showed that metaregression can specify techniques that are associated with greater intervention effectiveness. Intervention features refer to characteristics of the intervention that could potentially be changed to improve intervention effectiveness. Key intervention features examined here were the setting (e.g., home vs. clinic/hospital), format (individual vs. group), mode of delivery (e.g., video, interactive activities), intensity (i.e., duration, contact time, and number of sessions), and source (e.g., researcher vs. teacher). Characteristics of the sample (e.g., age, gender) and methodological features (e.g., active control condition, risk of bias) were also coded and moderation by these variables was tested.

The aims of the present meta-analysis were twofold: (1) To quantify the effectiveness of interventions to reduce indoor tanning and sun exposure, and increase sunscreen use, and (2) To determine which intervention strategies (i.e., change techniques and intervention features) are associated with more effective promotion of these behaviors.

Method

The meta-analysis was registered at Prospero (CRD420160 46079) and followed PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009).

Search Strategy

Studies were obtained via (a) a computerized search of relevant databases (CINAHL, PubMed, EMBASE, MEDLINE, PsycINFO, Web of Science, Cochrane Library, and ProQuest) that was initiated on January 1, 2016 and last updated on December 18, 2018; (b) a manual search of the reference lists of previous reviews and papers that met the inclusion criteria for the review; and (c) requests for unpublished studies via emails to key researchers and the listservs of professional societies (Society of Behavioral Medicine, European Health Psychology Society, Social Personality and Health Network, European Association of Social Psychology, and the Society for Personality and Social Psychology).

The computerized search strategy was optimized by a medical librarian and included terms for (a) randomized controlled trial (e.g., *trial*, *intervention*), and (b) UVR exposure or protection (e.g., *tanning*, *sun exposure*) or skin cancer or damage (e.g., *melanoma*, *sunburn*; see Table S1 in the online supplemental materials for the precise search terms used in each database). There were four inclusion criteria for the review. First, the study used a randomized controlled design (participants were allocated at random to a treatment vs. a control condition). Second, a behavioral intervention to promote sun protection and/or prevent skin cancer was tested. Third, a posttest or follow-up measure of UVR protection was obtained for treatment and control conditions in the wake of the intervention (e.g., frequency of sunscreen use, time spent in the sun). Fourth, the report was written in English.

Figure 2 shows the flow of information through the phases of the review (Moher et al., 2009). The computerized database search identified 17,430 articles and dissertations, and seven additional articles were identified through the alternative search methods. De-duplication removed 3,458 articles, leaving 13,972. Initial screening of titles and abstracts resulted in the exclusion of a further 13,487 records because they did not concern UVR protection or did not report findings from a randomized controlled trial. Assessment of the eligibility of 485 full-text records led to the exclusion of 359 articles. Reasons for exclusion were (a) does not concern UVR-protective behavior change or outcomes ($n = 147$); (b) is not a randomized controlled trial ($n = 82$); (c) reports duplicate information (e.g., protocol papers, baseline-only results reported, or preceding paper reporting different outcomes, timepoints, or samples; $n = 47$); (d) does not contain sufficient information to retrieve effect size information, even after contacting authors ($n = 43$); (e) is an ongoing trial ($n = 22$); (f) is a conference abstract ($n = 12$); (g) is not written in English ($n = 5$); and (h) has a duplicate sample but administered a separate intervention ($n = 1$). Thus, 126 papers met our inclusion criteria. As some papers reported multiple studies or trials had multiple intervention groups, a total of 190 effect sizes could be computed from these reports. The online supplemental materials present the characteristics of each study included in the review (Table S2) and the references for the 126 papers.

Analysis Strategy

Cohen's *d* formed the effect size metric. Effect sizes represent the difference in UVR-protective behaviors at follow-up for the treatment compared with the control condition; larger positive values indicate more effective interventions (i.e., greater UVR protection). When multiple indicators of protective behaviors were reported in a single study, we used each individual effect size to assess the impact of interventions on these different outcomes and also computed the average effect size within the study to represent the overall study effect. When studies included more than one treatment condition, the sample size for the control group was divided by the number of treatment groups, so as not to "double count" participants (Higgins & Green, 2011). To offer a strict test of the effectiveness of interventions (Sheeran, Harris, & Epton, 2014), effect sizes were computed using data from (a) the longest follow-up after the intervention, and (b) intention-to-treat analyses if both intention-to-treat and per protocol analyses were reported.

STATA Version 14.2 (StataCorp, 2015) was used to conduct random effects meta-analyses and metaregressions. We first computed the sample-weighted average effect size and computed heterogeneity statistics (Q, I^2). Next, publication bias was assessed using the funnel plot and Egger's regression, and Duval and Tweedie's (2000) trim and fill procedure was used to correct for bias. Small sample bias was assessed using the procedure recommended by Coyne, Thombs, and Hagedoorn (2010). We coded whether or not studies had adequate power (i.e., 55% power to detect a medium-sized effect even when it is present) and regressed effect sizes on this predictor. Random effects metaregres-

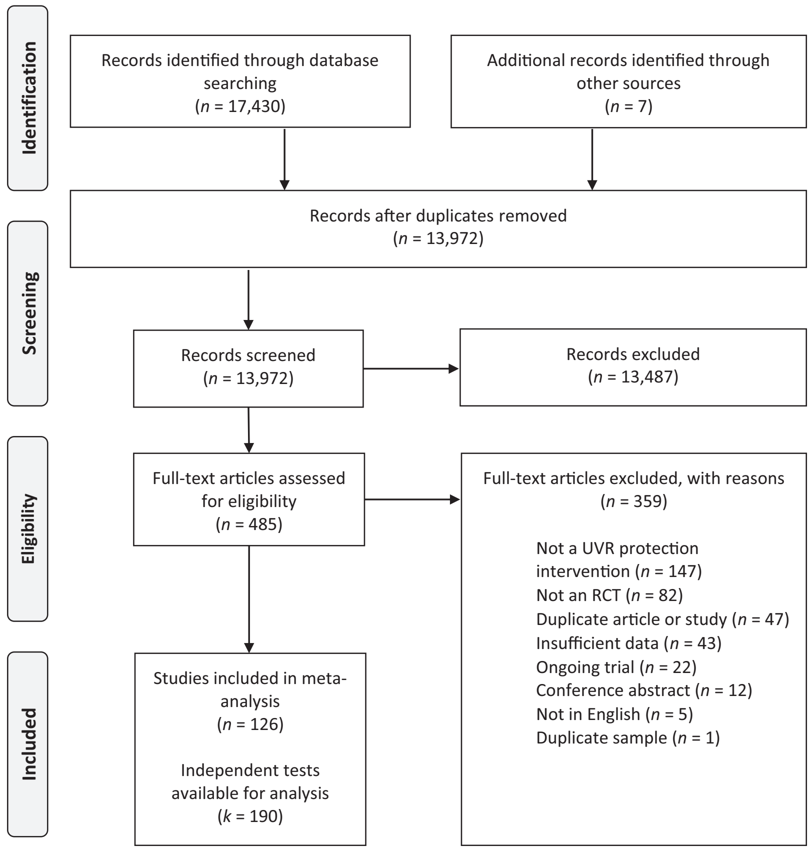

Figure 2. Flow of information through the phases of the review.

sions were also used to test the associations between effect sizes and (a) sample characteristics, (b) methodological features, (c) features of the intervention, and (d), change techniques whenever at least four tests were available for analysis (see Michie et al., 2009).

Coded Variables

Categories of change techniques. We developed a bespoke taxonomy of categories of change techniques designed to change precursors of UVR-protective behavior. Top-down (previous taxonomic research) and bottom-up (in-depth inductive analysis of the empirical studies included in the review) approaches were combined (see Abraham, 2016; Skinner, Edge, Altman, & Sherwood, 2003, for discussion; see Sheeran et al., 2019, for empirical example) to generate a taxonomy comprising 39 distinct techniques (see Table S3 in the online supplemental materials for definitions of each technique category). Nineteen techniques defined in Abraham and Michie's (2008) taxonomy were found to be relevant. An additional 20 techniques were identified from careful assessment of the intervention descriptions provided in papers and included Provide alternatives to tanning (e.g., sunless tanning products) and Challenge the tan ideal (i.e., encourage the person to question the cultural perception that one needs to be tan to look attractive, healthy, etc.). The presence versus absence of each technique was coded 1 and 0, respectively, for each treatment condition.

Sample, intervention, and methodological characteristics. Sample, intervention, and methodological features that could potentially moderate effect sizes were coded from each study. Sample characteristics included mean age, gender composition of sample, and ethnicity; intervention characteristics included the source and setting of the intervention, total contact time, as well as mode of delivery; methodological features included whether the control condition was active and aspects of study quality, assessed using the Cochrane Collaboration's Tool for Assessing Risk of Bias (Higgins & Green, 2011).

Reliability of coding. Three of the authors independently coded effect sizes, change techniques, and sample, intervention, and methodological characteristics (k = 34, 20% of tests). Coding proved reliable (M_{ICC} = 0.99, M_{PABAK} = 0.94, M_{KAPPA} = 0.92; all ICC, PABAK, and κ values were greater than 0.70). Discrepancies were resolved through discussion.

Results

Overview of Trials

On average, trials involved 241 participants in the treatment condition and 229 control participants (SD = 612.3 and 608.2, respectively). Participants were predominately female (67.68%) and White (70.29%) and had a mean age of 28.23 years (SD = 16.21). Interventions were most often administered in participants' homes (k = 69), in schools or universities (k = 65), and at tourist or recreation sites (k = 31). Intervention content was delivered using individual (k = 131) or group formats (k = 64), predominantly by a researcher involved in the study (k = 138). The delivery mode was most often in-person (k = 98), followed by receiving a packet, workbook or leaflet (k = 71), interactive activities (k = 42), and viewing a video or slideshow (k = 39).

Interventions were either brief and lasted for one hour or less (k = 44), or intensive and continued for more than one month and up to 6 months (k = 40). The mean number of intervention sessions was 2.77 (SD = 11.64) and the average total contact time was 89.67 min (SD = 110.73). The number of change techniques used in interventions ranged from 1 to 20 (M = 5.20, SD = 2.84). The timing of behavioral follow-ups ranged from the same day as the intervention to 1.25 years following the intervention (M = 23.83 weeks, SD = 35.89). Sixty-four studies used an active control condition, which mainly involved educational materials. Attrition rates were modest for both treatment (M = 19.55, SD = 17.84) and control groups (M = 18.88, SD = 17.34), and the majority of trials (k = 152) were adequately powered according to Coyne et al.'s (2010) criterion.

Effects of Interventions on UVR Protection

Table 1 presents the sample-weighted average effect sizes for interventions across all studies, for indoor tanning, outdoor tanning, and outcomes, and for component behaviors. (Forest plots are presented in Figures S1 to S3 in the online supplemental materials). The overall effect size was d_+ = .193 (95% confidence interval, CI [.161, .226]) based on 190 tests involving 89,365 participants. This is a "small" effect according to Cohen's (1992) guidelines. We checked whether using data from the longest follow-up in the wake of the intervention may have influenced effect sizes, by redoing the analyses using data from the follow-up closest to the end of the intervention. There was a negligible difference compared with the original effect size (d_+ = .198, 95% CI [.159, .236]).

Interventions had a very small effect on reducing indoor tanning (d_+ = .080), and a small effect on outdoor tanning behaviors (d_+ = .211, k = 175). Effect sizes for reducing sun exposure (d_+ = .149) and increasing sunscreen use (d_+ = .196) as components of outdoor tanning were of similar magnitude. Interventions appeared to be more effective in reducing intentional tanning/sunbathing (d_+ = .242) and avoiding peak sunshine (d_+ = .159) and less effective in promoting seeking shade (d_+ = .101) and wearing protective attire (d_+ = .108). The effect on time spent in sunshine was not significant (95% CI [−.006, .090]). Thirteen studies (N = 4,138) used uptake of a sunscreen coupon/sample as a measure of sunscreen behavior; no significant intervention effect was observed for this measure (d_+ = .104, 95% CI [−.079, .287]; data not shown in Table 1). The effect of interventions on outcomes (sunburn and skin damage) was very small (d_+ = .063).

Funnel plots for indoor tanning, sun exposure, and sunscreen use indicated publication bias (Figures S4–S7 in the online supplemental materials), and Egger's regressions confirmed that this was the case for all three behaviors (B = 1.19, .72, and 1.20, SE = .51, .25, and .32, respectively, all $ps < .05$). Trim and fill analyses imputed 8, 26, and 26 values, respectively, for indoor tanning, sun exposure, and sunscreen use. The corrected effect size for reducing indoor tanning was not significantly different from zero (d_+ = −.011, 95% CI [−.096, .074]). The corrected effect sizes for reducing sun exposure and increasing sunscreen use were much smaller than the uncorrected values (d_+ = .062 and .065, respectively) though both confidence intervals excluded zero (95% CI [.016, .107] and [.010, .119], respectively).

Overall, 14.7% of tests (k = 28) were unpublished. Publication status did not predict effect sizes across all studies (B = .064, p = .30), or in studies of indoor tanning (B = .013, p = .95) or sun exposure (B = −.023, p = .81). Publication status predicted effect

Table 1
Effect Sizes for UVR Protection Outcomes

Outcome	N	k	d	95% CI	Q	I^2
All studies	89,365	190	.193	[.161, .226]	40.31*	40.5
Indoor tanning	6,082	25	.080	[.004, .157]	141.96***	81.7
Outdoor tanning	72,601	175	.211	[.174, .249]	714.61***	75.7
Sun exposure						
Avoiding the sun	50,558	114	.149	[.108, .189]	363.95***	69.0
Shade seeking behavior	14,052	38	.101	[.040, .162]	91.05***	59.4
Avoiding peak sun or limiting exposure	14,761	32	.159	[.073, .244]	143.98***	78.5
Intentional outdoor tanning or sunbathing	6,561	43	.242	[.141, .344]	125.23***	66.5
Time spent in sunshine	16,428	35	.042	[−.006, .090]	42.04	19.1
Wearing protective attire	40,444	66	.108	[.068, .147]	123.37***	47.3
Wearing protective clothing	27,805	42	.089	[.051, .128]	70.81**	42.1
Wearing a hat	33,746	55	.125	[.079, .170]	157.66***	65.7
Sunscreen use	47,432	100	.196	[.146, .247]	510.37***	80.6
Outcomes	48,476	47	.059	[.032, .087]	63.58***	27.6
Sunburn and skin damage	46,020	43	.063	[.034, .092]	60.71***	30.8
Frequency of sunburn	45,868	43	.059	[.031, .088]	58.72***	28.5
Change in skin color	2,376	5	.030	[−.051, .111]	3.14	0.0
Reported skin damage	507	3	.296	[.116, .476]	2.06*	3.0

Note. UVR = ultraviolet radiation; N = number of participants; k = number of independent tests; d = sample-weighted average effect size; 95% CI = 95% confidence interval; Q and I^2 = homogeneity statistics.
* $p < .05$. ** $p < .01$. *** $p < .001$.

sizes for interventions to promote sunscreen use (B = .221, p = .022). The effect size from published studies (d_+ = .163) was *smaller* than the effect size in unpublished studies (d_+ = .393). Whether or not trials were adequately powered according to Coyne et al.'s (2010) criteria was unrelated to effect sizes (B = −.27, .12, and −.18, SE = .19, .11, and .12, for indoor tanning, sun exposure, and sunscreen use, respectively, all ps > .15).

Moderation of Effect Sizes by Features of the Sample and Methodology

Although there was moderate heterogeneity across all studies (I^2 = 40.5%), there was considerable heterogeneity in effect sizes for reducing indoor tanning and increasing sunscreen use (I^2 = 81.7 and 80.6%, respectively), and substantial heterogeneity for reducing sun exposure (I^2 = 69.0%), according to Higgins and Green's (2011) criteria. This heterogeneity encourages the search for moderators.

Out of the many sample and methodological characteristics that were tested, relatively few features predicted effect sizes (see Table 2). Recruiting college students as participants was associated with larger effect sizes for both indoor tanning and sun exposure behaviors (B = .243 and .166, respectively, ps < .05), whereas participation by adults predicted smaller effect sizes for sunscreen use (B = .230, p < .05). For indoor tanning, the mean age of the

Table 2
Meta-Regression of UVR Protection Outcomes on Sample and Methodological Features

	Indoor tanning						Outdoor tanning		
				Sun exposure			Sunscreen use		
Moderator variable	Used	B	R^2	Used	B	R^2	Used	B	R^2
Sample features									
Gender	25 (100)	.001	−5.22	103 (90.4)	.002	7.31	101 (93.5)	.001	−0.98
Age	19 (76.0)	−.013*	100.0	76 (66.7)	.002	−1.20	69 (63.9)	−.001	−2.46
Ethnicity	12 (48.0)	−.001	0.00	72 (63.2)	−.005***	58.64	71 (65.7)	−.001	−0.60
Country of study									
United States	20 (80.0)	.230**	91.42	81 (71.7)	−.002	−3.10	80 (75.5)	.060	−0.81
Australia	0 (0.0)	—	—	10 (8.8)	.001	−2.98	4 (3.8)	−.104	1.40
Risk factors									
Previous diagnosis of skin cancer	3 (12.0)	.017	−5.56	28 (24.6)	.000	−2.77	23 (21.3)	−.001	−1.47
Family history of skin cancer	6 (24.0)	−.002	−5.40	38 (33.3)	.000	−2.65	27 (25.0)	−.002	1.77
History of sunburn	1 (4.0)	−.003	−1.49	30 (26.3)	−.001	0.66	29 (26.9)	−.001	−0.36
History of sunbed use	11 (44.0)	.001	0.38	10 (8.8)	.000	−2.42	5 (4.6)	−.001	−1.43
Eye color	0 (0.0)	—	—	13 (11.4)	−.098	1.54	11 (10.2)	−.139	1.37
Skin type	15 (60.0)	.068	16.66	62 (54.4)	.067	1.51	58 (53.7)	−.073	0.13
Hair color	0 (0.0)	—	—	18 (15.8)	−.083	0.86	15 (13.9)	−.167	2.97
Participants									
Adults (age 18 years and over)	6 (24.0)	−.102	−8.83	53 (46.5)	−.008	−2.54	39 (36.1)	−.167*	6.68
Adolescents (ages 13–17)	3 (12.0)	−.172*	64.18	26 (22.8)	−.087	−2.24	13 (12.0)	.121	−0.84
Children (age 12 and under)	0 (0.0)	—	—	11 (9.6)	−.035	−.06	22 (20.4)	.007	−1.70
Community members (all ages)	0 (0.0)	—	—	10 (8.8)	−.112	1.60	9 (8.3)	−.021	−1.51
Sample recruited from clinic	3 (12.0)	−.223	2.99	19 (16.7)	.071	2.91	14 (13.0)	−.022	−1.47
College students	16 (64.0)	.243***	100.0	22 (19.3)	.166*	16.64	17 (15.7)	−.030	−1.25
Recreation site visitors	0 (0.0)	—	—	11 (9.6)	−.118	5.20	12 (11.1)	−.102	−0.93
Parents	1 (4.0)	—	—	5 (4.4)	−.026	−3.57	12 (11.1)	−.086	−0.58
Daycare or recreation staff	0 (0.0)	—	—	4 (3.5)	−.071	−2.01	8 (7.4)	.145	1.68
Outdoor workers	0 (0.0)	—	—	0 (0.0)	—	—	6 (5.6)	.147	0.24
Methodological features									
Pretest was undertaken	22 (88.0)	−.090	−7.76	108 (94.7)	.112	1.72	100 (92.6)	.179	0.93
Mention of treatment fidelity	7 (28.0)	−.040	−7.61	21 (18.4)	.008	−3.37	19 (17.6)	−.043	−0.86
Active control condition	10 (40.0)	−.023	−10.07	42 (36.8)	−.076	4.03	41 (38.0)	.003	−1.61
Time interval (intervention to longest follow-up)	25 (100)	−.002	6.27	102 (89.5)	.000	−0.76	90 (83.3)	−.001	−0.97
Attrition: Treatment condition	15 (60.0)	−.005	62.19	88 (77.2)	−.003	3.79	78 (72.2)	−.005*	8.20
Attrition: Control condition	15 (60.0)	−.005	56.67	88 (77.2)	−.003	4.01	78 (72.2)	−.002	−2.59
Behavior measured by self-report	25 (100)	—	—	108 (94.7)	−.027	−3.94	99 (91.7)	−.045	−1.52
Risk of bias									
Random sequence generation	22 (88.0)	−.171	31.49	73 (64.0)	.026	−0.81	76 (70.4)	−.094	−.75
Allocation concealment	19 (76.0)	−.127	29.84	83 (72.8)	−.010	−3.69	90 (83.3)	.002	−1.66
Blinding of participants and personnel	25 (100)	—	—	98 (86.0)	−.003	−3.11	95 (88.0)	−.039	−1.49
Blinding of outcome assessment	25 (100)	—	—	95 (83.3)	−.031	−1.10	93 (86.1)	−.065	−1.04
Incomplete outcome data	4 (16.0)	.096	−3.11	34 (29.8)	−.032	−3.51	30 (27.8)	−.003	−1.59
Selective reporting	9 (36.0)	.021	−5.68	41 (36.0)	.042	3.33	35 (32.4)	.093	1.24
Other bias	15 (60.0)	.038	0.12	73 (64.0)	.059	1.71	65 (60.2)	.158*	7.48

Note. Used (%) = number of tests in which feature was used (percentage of tests), except for Risk of Bias where values indicate high or unclear rates of bias. B = unstandardized coefficient from meta-regression analysis; R^2 = coefficient of determination. An emdash (—) indicates insufficient tests were available for analysis or all studies had this feature (value is a constant).
* p < .05. ** p < .01. *** p < .001.

sample was negatively related to effect sizes ($B = -.167$, $p < .05$) and recruiting a U.S. sample was associated with larger effects ($B = .230$, $p < .05$). Non-White samples exhibited larger effect sizes in sun exposure interventions ($B = -.005$, $p < .001$). For sunscreen use interventions, greater risk of other bias on the Cochrane tool predicted larger effects ($B = .158$, $p < .05$) whereas attrition from the treatment condition was associated with a smaller effect sizes ($B = -.005$, $p < .05$).

Which Intervention Strategies Predict Effect Sizes?

To identify intervention strategies that predict effect sizes, and so inform future intervention design, effect sizes were regressed on modifiable features of interventions including change techniques (see Table 3). The most frequently used types of change technique across indoor tanning, sun exposure, and sunscreen use behaviors involved: Provide information on consequences ($k > 75\%$), Provide instruction ($k \geq 32\%$), Prescribe performance of the behavior ($k \geq 28\%$), Expert recommendation ($k \geq 16\%$), and Provide information about others' approval ($k \geq 8\%$). It is notable that none of these techniques predicted effect sizes, except Expert recommendation in interventions for reducing sun exposure ($B = .124$, $p < .05$).

Only one change technique was associated with the effectiveness of indoor tanning interventions—Promote alternatives to tanning ($B = .181$, $p < .05$). Six techniques (including Expert recommendation) predicted effect sizes for reducing sun exposure. Ordered by the proportion of variance explained in effect sizes, these techniques involved: Provide information that emphasizes health consequences ($B = .387$, $p < .001$), Challenge the tan ideal ($B = .722$, $p < .001$), Plan social support or social change ($B = .455$, $p < .001$), Identify pros and cons of sun exposure ($B = .489$, $p < .001$), and Increase threat salience ($B = .191$, $p < .01$).

Four change techniques predicted the effectiveness of sunscreen use interventions: Provide free sunscreen or supplies had the largest coefficient of determination ($B = .209$, $p < .01$), followed by Model or demonstrate the behavior ($B = .315$, $p < .01$), Provide opportunities for social comparison ($B = .228$, $p < .01$), and Use follow-up prompts ($B = .206$, $p < .01$).

Potentially modifiable features of the intervention concern (a) the use of theory to inform the intervention, (b) tailoring the intervention using participants' baseline data, (c) the setting, (d) format, (e) mode of delivery, (f) intensity, and (g) the source of the intervention. There were no significant associations for use of theory or tailoring. Two particular settings mattered for effect sizes. Interventions to reduce sun exposure were less effective in tourist or recreational settings ($B = -.129$, $p < .05$) and interventions to increase sunscreen use were more effective in schools or universities ($B = .149$, $p < .05$). Intervention format and mode of delivery had different associations depending on the particular UVR-protective behavior. Use of an individual format enhanced effect sizes in indoor tanning interventions ($B = .183$, $p < .03$) but reduced effect sizes in sun exposure interventions ($B = -.134$, $p < .05$; beta coefficients for group format mirrored these associations). Only one aspect of interventions' intensity predicted effect sizes: Longer interventions were associated with smaller effect sizes in sun exposure interventions ($B = -.020$, $p < .05$). The source of the intervention was related to the effectiveness of indoor tanning and sun exposure interventions. For indoor tanning, interventions delivered by researchers were more effective ($B = .220$, $p < .01$), whereas interventions delivered by teachers were less effective ($B = -.1901$, $p < .05$). Interventions delivered by a trained educator led to larger effect sizes in interventions to reduce sun exposure ($B = .218$, $p < .05$).[1]

Discussion

From a database of more than 17,000 records, we identified 190 tests of interventions to reduce UVR exposure that recruited almost 90,000 participants. Indoor tanning, sun exposure, and sunscreen use formed the dependent variables and random effects meta-analysis was used to quantify the efficacy of respective interventions. Across all studies, the sample-weighted average effect size was $d_+ = .193$. The effect of interventions on sunscreen use and sun exposure were similar to the overall effect ($d_+ = .196$ and .149, respectively) but was smaller for interventions to reduce indoor tanning ($d_+ = .080$). Even though the gray literature was searched and 14.7% ($k = 28$) of tests included in the review were unpublished, there was evidence of publication bias. Trim and fill analyses to counter publication bias led to the imputation of a substantial proportion of additional values (23% to 39%) and generated corrected values of $d_+ \sim .06$ for reducing sun exposure and increasing sunscreen use, and $d_+ = -.011$ for indoor tanning. The $d_+ = -.011$ for reducing indoor tanning was not significantly different from zero.

According to Cohen's (1992) qualitative criteria, $d_+ \sim .06$ is a very small effect and it remains "very small" using Funder and Ozer's (2019) recent and more lenient criteria. This effect size also compares unfavorably to the median effect size, $d_+ = .44$, observed in Lipsey and Wilson's (1993) meta-analysis of the efficacy of psychological, educational, and behavioral treatments (but see Funder & Ozer, 2019, for discussion of expected effect sizes in behavioral research). Applying Rosenthal and Rubin's (1982) binomial effect size display (BESD), $d_+ \sim .06$ approximates a change in the rates of sun avoidance and sunscreen use from 49% in the control condition to 52% in the treatment condition. Thus, although interventions to reduce sun exposure and increase sunscreen use are significantly better than no intervention, it seems fair to characterize the magnitude of the observed effects as "modest" at best.

Why were UVR-protective interventions only modestly effective? First, certain strategies that did not predict effect sizes were repeatedly used in the interventions reviewed here. Forty percent to 60% of interventions provided informational packets or leaflets but this mode of delivery did not benefit effectiveness. Similarly, the most frequently deployed change techniques (Provide information on consequences, Provide instruction, Prescribe performance of the behavior, and Provide information about others' approval) were not associated with effects on behavior. UVR-

[1] For completeness, we also analyzed which intervention strategies predicted ultraviolet radiation (UVR) outcomes (sunburn and skin damage). Meta-regression analyses revealed no significant additional strategies beyond those identified for indoor tanning, sun exposure, and sunscreen use. As the present review is concerned with UVR protective *behaviors*, rather than the outcomes of performing those behaviors (that are also a product of nonbehavioral factors such as skin type), UVR outcomes are not considered further.

Table 3
Meta-Regression of Intervention Features and Change Techniques Used in Treatment Conditions

	Indoor tanning			Outdoor tanning					
				Sun exposure			Sunscreen use		
Moderator variable	Used (%)	*B*	R^2	Used (%)	*B*	R^2	Used (%)	*B*	R^2
Intervention features									
Theory used to develop intervention	10 (40.0)	.078	13.91	53 (46.5)	−.017	−2.22	59 (54.6)	.020	−1.19
Intervention tailored on baseline information	4 (16.0)	−.156	−7.20	33 (28.9)	−.027	−4.13	28 (25.9)	−.123	2.47
Setting									
Home	7 (28.0)	.024	−8.32	45 (39.5)	.021	−2.28	42 (38.9)	−.122	4.65
Tourist/recreational site	0 (0.0)	—	—	19 (16.7)	−.129*	16.57	26 (24.1)	−.042	−1.68
Hospital/clinic	3 (12.0)	−.223	2.99	14 (12.3)	−.061	−0.18	12 (11.1)	−.035	−1.74
School/university	13 (52.0)	−.033	1.31	37 (32.5)	.043	−1.35	32 (29.6)	.149*	4.82
Laboratory	2 (8.0)	—	—	7 (6.1)	.008	−1.57	4 (3.7)	.031	−1.34
Format									
Individual	21 (84.0)	.183*	69.07	81 (71.1)	−.134*	13.24	70 (64.8)	−.081	0.94
Group	4 (16.0)	−.183*	69.07	34 (29.8)	.106*	5.75	43 (39.8)	.103	2.53
Mode of delivery									
In-person	13 (52.0)	−.155*	58.33	54 (47.4)	.114*	7.82	58 (53.7)	.145*	6.90
Online or computer-based	7 (28.0)	−.128	46.29	16 (14.0)	−.043	−1.86	16 (14.8)	−.103	0.43
Video/slideshow presentation	6 (24.0)	−.163*	61.37	21 (18.4)	−.012	−2.38	23 (21.3)	.260**	14.81
Interactive activities	4 (16.0)	−.127	38.91	21 (18.4)	−.031	−3.10	29 (26.9)	−.043	−1.66
Informational packet/leaflet given to participants	8 (32.0)	.065	9.38	40 (35.1)	−.062	2.25	39 (36.1)	−.041	−1.49
Informational packet/leaflet mailed to participants	2 (8.0)	—	—	22 (19.3)	−.075	−0.80	18 (16.7)	−.100	0.93
Telephone	0 (0.0)	—	—	10 (8.8)	−.092	−0.76	7 (6.5)	−.193	1.17
Text/email reminders	0 (0.0)	—	—	6 (5.3)	−.034	−2.91	7 (6.5)	.146	−0.47
Mass media message	0 (0.0)	—	—	4 (3.5)	.035	−1.56	4 (3.7)	.041	−1.20
Environmental change (e.g., signage, structure)	3 (12.0)	−.068	−5.04	16 (14.0)	−.071	2.65	16 (14.8)	−.001	−1.73
Intensity									
Contact time	11 (44.0)	—	—	36 (31.6)	.000	−3.80	37 (34.3)	−.001	−0.87
Number of sessions	19 (76.0)	−.016	11.41	78 (68.4)	−.008	1.78	66 (61.1)	−.019	1.59
Duration	25 (100)	−.009	−5.71	108 (94.7)	−.020*	14.69	103 (95.4)	.013	−0.85
Source									
Researcher	19 (76.0)	.220**	90.87	80 (72.0)	−.035	−1.68	80 (74.1)	−.006	−1.68
Doctor/expert	3 (12.0)	−.223	2.99	16 (14.0)	.025	−3.35	13 (12.0)	.017	−1.62
Trained educator	0 (0.0)	—	—	6 (5.3)	.218*	10.48	6 (5.6)	.197	0.50
Teacher	2 (8.0)	—	—	10 (8.8)	−.093	1.43	13 (12.0)	.058	−1.04
Behavior change techniques									
Provide information on consequences	19 (76.0)	.071	−10.37	88 (77.2)	.099	6.25	88 (81.5)	.111	0.77
Appearance effects emphasized	7 (28.0)	.094	6.59	21 (18.4)	−.008	−1.82	14 (13.0)	.185	4.82
Health consequences emphasized	1 (4.0)	−.221	−1.49	15 (13.1)	.387***	44.17	7 (6.5)	.151	−0.80
Provide information about others' approval	9 (36.0)	.000	−10.93	11 (9.6)	.137	−4.32	9 (8.3)	.107	−0.98
Expert recommendations	4 (16.0)	−.200	1.38	26 (22.8)	.124*	2.42	23 (21.3)	.050	−0.93
Prompt intention formation	2 (8.0)	—	—	15 (13.2)	−.028	−3.42	16 (14.8)	.069	−1.14
Prompt barrier identification	1 (4.0)	—	—	19 (16.7)	.084	−1.78	18 (16.7)	.048	−1.19
Provide general encouragement	0 (0.0)	—	—	8 (7.0)	.076	−4.55	10 (9.3)	.179	1.15
Prescribe performance of behavior	7 (28.0)	.070	11.90	60 (52.6)	.063	−1.80	60 (55.6)	.121	3.48
Provide instruction	8 (32.0)	.078	−4.01	68 (59.6)	−.064	−1.05	63 (58.3)	.021	−1.58
Model or demonstrate the behavior	0 (0.0)	—	—	10 (8.8)	.046	−3.46	14 (13.0)	.315**	10.85
Prompt specific goal setting	0 (0.0)	—	—	6 (5.3)	−.034	−1.64	7 (6.5)	.110	−0.85
Prompt review of behavioral goals	0 (0.0)	—	—	8 (7.0)	.004	−3.31	4 (3.7)	−.021	−1.76
Prompt self-monitoring of behavior	1 (4.0)	—	—	14 (12.3)	−.061	−2.65	12 (11.1)	−.029	−1.13
Provide feedback on performance	0 (0.0)	—	—	8 (7.0)	−.025	−3.69	10 (9.3)	.099	−0.83
Provide contingent rewards	0 (0.0)	—	—	2 (1.8)	—	—	6 (5.6)	.038	−1.29
Teach to use prompts or cues	0 (0.0)	—	—	5 (4.4)	−.098	0.92	5 (4.6)	−.114	−1.12
Prompt practice	0 (0.0)	—	—	7 (6.1)	−.084	0.43	8 (7.4)	.195	3.17
Use follow-up prompts	2 (8.0)	—	—	18 (15.8)	.058	−2.05	19 (17.6)	.206**	5.67
Provide opportunities for social comparison	6 (24.0)	.034	−4.40	18 (15.8)	.043	−3.49	22 (20.4)	.228**	10.64
Plan social support or social change	1 (4.0)	—	—	5 (4.4)	.455***	17.33	2 (1.9)	—	—
Prompt identification as a role model	3 (12.0)	−.196*	69.08	5 (4.4)	.047	−1.99	8 (7.4)	.157	2.48
Prompt self-talk	1 (4.0)	—	—	3 (2.6)	−.077	−0.87	2 (1.9)	—	—
Free sunscreen/supplies provided	0 (0.0)	—	—	36 (31.6)	−.029	−1.37	45 (41.7)	.209**	12.39
UV index information provided	0 (0.0)	—	—	8 (7.0)	−.098	2.97	6 (5.6)	−.108	−0.93
UVR intensity indicator given	0 (0.0)	—	—	6 (5.3)	−.114	0.64	3 (2.8)	−.263	1.02
Framing participant perception of study aim	2 (8.0)	—	—	2 (1.8)	—	—	3 (2.8)	−.001	−1.39
Protective reminders given	0 (0.0)	—	—	9 (7.9)	−.090	−0.32	7 (6.5)	.037	−1.49
UV photograph taken of participant	4 (16.0)	.165	5.47	20 (17.5)	−.015	−2.62	16 (14.8)	.126	1.99

(*table continues*)

Table 3 (*continued*)

Moderator variable	Indoor tanning Used (%)	Indoor tanning B	Indoor tanning R^2	Sun exposure Used (%)	Sun exposure B	Sun exposure R^2	Sunscreen use Used (%)	Sunscreen use B	Sunscreen use R^2
Challenge the tan ideal	4 (16.0)	−.127	38.91	4 (3.5)	.722***	38.37	1 (0.9)	—	—
Promote alternatives to tanning	8 (32.0)	.181*	69.52	4 (3.5)	.127	1.97	3 (2.8)	.196	−0.71
Provide sunless tanning products	0 (0.0)	—	—	3 (2.6)	—	—	3 (2.8)	.196	−0.71
Signposting	6 (24.0)	.098	21.05	11 (9.6)	.004	−3.56	7 (6.5)	−.168	1.33
Enhance self-efficacy	1 (4.0)	—	—	24 (21.1)	−.015	−2.40	24 (22.2)	.095	0.17
Challenge myths about tanning	1 (4.0)	—	—	3 (2.6)	.569***	−11.13	3 (2.8)	.343	4.22
Assess motivational readiness and use to tailor	0 (0.0)	—	—	10 (8.8)	−.065	−4.26	10 (9.3)	−.046	−1.39
Identify pros and cons of behavior	0 (0.0)	—	—	6 (5.3)	.489***	4.75	3 (2.8)	.299	−0.29
Prompt mental visualization	0 (0.0)	—	—	4 (3.5)	−.048	−1.74	3 (2.8)	−.051	−1.69
Increase threat salience	2 (8.0)	—	—	20 (17.5)	.191**	−2.86	17 (15.7)	.031	−1.47

Note. Used (%) = number of tests in which feature was used (percentage of tests); B = unstandardized regression coefficient from meta-regression analysis; R^2 = coefficient of determination. An emdash (—) indicates insufficient tests were available for analysis or all studies had this feature (value is a constant).
* $p < .05$. ** $p < .01$. *** $p < .001$.

protective trials cannot be effective if ineffective intervention strategies are mainly deployed.

Second, different strategies proved effective for the different UVR-protective behaviors examined here. Interventions delivered individually were effective in indoor tanning interventions whereas group formats were counterproductive. Conversely, using a group format was effective for sun exposure interventions whereas an individual format was counterproductive. In-person interventions were associated with smaller effect sizes in indoor tanning trials, but were associated with improved effectiveness in interventions for sun exposure and sunscreen use. Primary research is needed to uncover precisely why intervention format and delivery mode have differential effects on indoor tanning versus sun exposure versus sunscreen use intervention. However, a key message of these findings is that intervention features may need to be tailored to the focal UVR-protective behavior; otherwise, interventions could risk being ineffective.

Third, the methodological quality of the trials reviewed here offers a mixed picture. Whereas most interventions were adequately powered, attrition was modest, and a substantial proportion of trials (≥37%) used active control conditions, risk of bias was relatively high. Greater attention to, and reporting of, allocation concealment and blinding procedures, in particular, would be valuable. In addition, UVR-protective behaviors were measured almost exclusively via self-reports and there were few attempts to control for social desirability or memory biases, or experimenter demand. These methodological factors could serve to obscure the magnitude of intervention effects. For instance, it was notable that greater attrition was associated with reduced effectiveness of sunscreen use interventions.

The present findings not only summarize the impact of UVR-protective interventions to date, but also offer insights into how the behavioral impact of future trials could be enhanced. Metaregression analyses identified multiple change techniques and intervention features that predicted improved effectiveness. The source of the intervention proved influential. In particular, indoor tanning interventions delivered by researchers were especially effective and explained a substantial proportion of the variance in the effect sizes. Indoor tanning interventions delivered by teachers, on the other hand, were associated with reduced effectiveness. Delivery by trained educators led to larger effect sizes in sun exposure interventions. These findings indicate modifiable intervention features including the format (individual vs. group), delivery mode (e.g., in-person sessions), and the source (e.g., researchers) can be configured so as to maximize impacts on indoor tanning, sun exposure, and sunscreen use.

The intensity of interventions (duration, number of sessions, and total contact time) was largely unrelated to effect sizes. In fact, the only significant association was observed for the duration of sun exposure interventions and was negatively related to effect sizes; more intensive interventions were *less* effective. This finding may be indicative of reactance to warnings about UVR exposure (see Hall et al., 2016, for discussion). More generally, the absence of significant associations for treatment duration, number of sessions, and contact time offers grounds for testing brief or low-intensity interventions in future trials.

The content of interventions, that is, the types of change technique deployed, also predicted effect sizes. No single change technique proved effective across the UVR-protective behaviors examined here. Instead, different techniques predicted effect sizes for indoor tanning versus sun exposure versus sunscreen use interventions. One psychological change technique—Promote alternatives to tanning—proved effective in reducing indoor tanning and explained ~70% of the variance in effect sizes. In an illustrative trial, Hillhouse, Turrisi, Stapleton, and Robinson (2008) used focus groups, surveys, and interviews to develop a booklet that contained three "appearance-enhancing alternatives" to indoor tanning, namely exercise, clothing, and sunless tanning. The effectiveness of the Promote alternatives to tanning technique is consistent with self-regulation research wherein affording substitution of a desired but unhealthy behavior with an attractive alternative option (e.g., a piece of fruit instead of candy) proved more effective than merely prohibiting the unhealthy behavior (see Adriaanse, Gollwitzer, et al., 2011; Adriaanse, van Oosten, et al., 2011).

Six change techniques predicted effect sizes in sun exposure interventions. The significant techniques pertained to learning the health costs of sun exposure (Provide information that emphasizes health consequences, Expert recommendation, and Increase threat salience), disputing the putative benefits of exposing oneself to the sun (Challenge the tan ideal, Identify pros and cons of sun exposure), and garnering help from other people to facilitate behavior change (Plan social support or social change). Expert recommendation also improved effect sizes.

The most effective technique for promoting sunscreen use was Provide free sunscreen or supplies. This finding would seem to suggest that the price of sunscreen is an important factor is determining sunscreen use. However, other research indicates that financial cost is a relatively minor consideration in sunscreen decisions (Xu, Kwa, Agarwal, Rademaker, & Kundu, 2016). Therefore, it seems probable that sunscreen provision is effective not only via a price mechanism ("It's free!") but also because its provision cues sunscreen use ("It's free, I've got it, I'll use it!"). Further research would be desirable to disentangle the role of price versus cueing mechanisms, not least because Use follow-up prompts also proved an effective technique in sunscreen use interventions.

Two other techniques were also effective in promoting sunscreen use, Provide opportunities for social comparison and Model or demonstrate the behavior. In an intervention with outdoor workers (Operating Engineers), Duffy, Hall, Waltje, and Louzon (2017) instigated social comparisons by presenting both pictures of other Operating Engineers and the results of a sun protection survey that they had completed. Significant effects on sunscreen use and sunburn were observed, consistent with the contention that social comparison information can be vital for decisions about preventive behaviors (Tennen, McKee, & Affleck, 2000). Model or demonstrate the behavior could be effective because this technique increases the speed, efficiency, or effectiveness of participants' application of sunscreen or because it enhances self-efficacy about sunscreen use. Evidence indicates that people may lack confidence in their ability to use sunscreen and do not use sunscreen effectively especially for particular anatomical sites (e.g., Loesch & Kaplan, 1994).

The findings for intervention features and change techniques speak to the importance of designing UVR-protective interventions that are tailored to the behavior(s) at hand. Treating UVR-protection as a unitary behavior rather than distinct behavioral categories—indoor tanning, sun exposure, and sunscreen use—risks obscuring intervention strategies that are effective for particular behaviors. In future trials, interventions delivered by researchers using an individual format that promote alternatives to tanning are supported for indoor tanning, whereas for sun exposure, there is support for shorter interventions delivered by trained educators, using in-person sessions with a group format, that target threat, health consequences, the tanning ideal, pros and cons, and planning support and social change. In-person sessions using videos that offer free supplies, provide opportunities for social comparison, model the behavior, and implement follow-up prompts are warranted to promote sunscreen use.

These conclusions must be tempered by consideration of the limitations of the database upon which the present meta-analysis rests. Even though we (a) started with more than 17,000 records, (b) searched the gray literature, and (c) identified 190 tests that met the inclusion criteria for the review, it should be acknowledged there were relatively few tests of indoor tanning interventions, in particular ($k = 25$). There was evidence of publication bias for all three UVR-protective behavioral categories that had to be corrected via trim and fill analyses to accurately estimate effect sizes. It was also the case that intervention effect sizes could not be retrieved from some 43 reports, even after contacting the authors. These considerations invite researchers, in the future, to undertake further UVR-protective interventions, particularly in relation to indoor tanning, to publish findings irrespective of trials' efficacy, and to report sufficient information to permit computation of effect sizes.

The present review indicates that much remains to be done to effectively reduce rates of indoor tanning and sun exposure and increase rates of sunscreen use. Although interventions to date proved only modestly effective, the literature has developed to the point where it is possible to specify intervention strategies that are likely to be more versus less effective. Future trials should be geared both at corroborating the effectiveness of the particular strategies identified here and at exploiting innovative ideas that could augment the behavioral impact of those strategies. Climate change threatens to dramatically increase rates of UVR exposure (van der Leun, Piacentini, & de Gruijl, 2008), which should galvanize efforts by behavioral scientists to develop more, and more effective, interventions to help people protect themselves against UVR.

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Received July 19, 2019
Revision received January 14, 2020
Accepted January 16, 2020