

# Interventions to Improve CPAP Adherence and Outcomes: Role of Theory and Behavioral Change Techniques

Carl Stepnowsky<sup>1,2\*</sup>, Tania Zamora<sup>1</sup>, Christine Edwards<sup>1</sup>, Lin Liu<sup>1,3</sup>, and Zia Agha<sup>1,2</sup>

<sup>1</sup>Health Services Research & Development Unit, Veterans Affairs San Diego Healthcare System, San Diego, CA, USA

<sup>2</sup>Department of Medicine, University of California, San Diego, USA

<sup>3</sup>Department of Family and Preventive Medicine, University of California, San Diego, USA

## Abstract

**Study Background:** Low patient adherence to nasal Continuous Positive Airway Pressure (CPAP) limits treatment effectiveness. A wide variety of CPAP adherence intervention studies have been performed to date, with many showing some improvement in CPAP adherence. Better understanding of the theoretical foundations, specific behavioral change techniques, and modes of intervention delivery can help provide guidance for future interventional efforts and reflects efforts underway in the general treatment adherence literature.

**Methods:** The CPAP adherence literature was reviewed to identify those studies that included a specific intervention designed to increase CPAP use. Twenty-nine studies were included in this review. Published coding schemes were used.

**Results:** The average effect size of the CPAP adherence interventions in adults who are new users of CPAP was 0.52 (SD=0.42, range: 0-1.52). This moderate effect size did not appear to be related to the number of behavioral change techniques, use of theory, or to mode of delivery.

**Conclusion:** Future research efforts should build on previous interventional studies, with the ultimate goal of identifying those techniques that can help improve CPAP adherence and patient outcomes.

**Keywords:** Behavioral change; Continuous positive airway pressure; Sleep apnea; Treatment adherence

## Introduction

Obstructive Sleep Apnea (OSA) is a disorder characterized by repeated breathing cessations during sleep, which can result in potentially serious consequences affecting cardiovascular, physiological, neurocognitive, emotional, and psychosocial functioning [1]. Nasal Continuous Positive Airway Pressure (CPAP) [2] is the treatment of choice for this condition [3], with meta-analytic studies reporting that CPAP improves both objectively and subjectively measured daytime sleepiness [4] and health-related quality of life [5]. CPAP has also been shown to normalize sleep architecture [6] and reduce blood pressure [7]. Many, if not most, patients have difficulty adhering to CPAP therapy despite its documented efficacy. It is estimated that over 50% of those started on CPAP will not be using it one year later [3]. Of those patients continuing to use it one year later, most are not using CPAP for the entire night, as prescribed. Published adherence rates from studies in the United States range from 3.3 to 5.3 hours per night [8-11]. One study showed that only 6% of patients used the machine for > 7 hours per night on at least 70% of the nights [8]. It seems reasonable to claim that CPAP adherence can be significantly improved.

Treatment adherence is a critically important area of research for helping to maximize the potential health and financial benefits of this highly efficacious therapy. The health outcomes of OSA patients depend largely on their adherence to appropriate treatment recommendations. In chronic disease literature, patient nonadherence is a pervasive problem that can lead to the continued onset and progression of chronic illnesses and to more difficult clinical management. The same can be said of CPAP treatment nonadherence. Those OSA patients who stop using CPAP and do not start another treatment remain at risk for the consequences of untreated OSA. Studies that examine the relationship between amount of CPAP use and response to treatment have generally

found that the less CPAP use is associated with fewer benefits [12-14], and conversely, more CPAP use results in an increase in benefits. One of the most important financial costs of CPAP nonadherence is the indirect cost of lost productivity and decreased quality of life for patients who are under- or untreated and continue to live with the effects of a chronic sleep disorder. In addition, while we are not aware of any studies that have specifically examined the monetary cost to the healthcare system of CPAP nonadherence, it seems reasonable to assert that a percentage of the diagnostic and treatment initialization costs, as well as any direct costs to the patient, may be considered costs of nonadherence.

There have been a number of previous reviews that summarize the findings of CPAP adherence intervention studies [15-19]. However, the specific Behavioral Change Techniques (BCT) employed in these interventional studies have not been standardized, nor have they been well studied for efficacy. There is a movement in the behavioral change literature to better define these techniques so that they might be standardized [20,21], thereby allowing for the replication of the intervention and for identification of effective interventions. This can be accomplished by examining the following factors: the theoretical basis of the CPAP adherence interventions, the behavior change techniques utilized in those interventions, and the modes of intervention delivery [20,21].

**\*Corresponding author:** Carl Stepnowsky, VA San Diego Healthcare System, 3350 La Jolla Village Drive (111N-1), San Diego, CA 92161, USA, Tel: 858-642-1240; Fax: 858-642-1234; E-mail: [cstepnowsky@ucsd.edu](mailto:cstepnowsky@ucsd.edu)

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The goals of this paper, therefore, are to (1) to provide background information in these three areas (theoretical basis, BCT, and mode of intervention delivery) and (2) to present the results of a literature review of published CPAP adherence interventions in each of these three areas.

### Theoretical basis

Theory-based behavioral change interventions are thought to be more effective than those that do not use, or are not based on, theory. It should be noted that while “model” and “theory” are often used interchangeably in the literature, a brief comment about their distinction might be useful. Theories help to explain or understand events by illustrating or describing the relationships between variables. Models, on the other hand, tend to pull from one or more theories, and even other models, to help explain a particular problem or issue [22]. This will help to explain why the Health Belief Model, for example, looks very different now than when it was first conceptualized, and also why for example, various authors interpret and use Social Cognitive Theory differently in their models.

Using theory to guide research is important for a number of reasons: (1) theories help to describe (and explain) how behaviors change and symptoms improve through the use of behavioral change programs; (2) theories guide program development and facilitate testing of the intervention; and (3) they help to firmly link an intervention to a theoretical foundation. Finally, grounding adherence interventions in theory are important to help the literature build a foundation and grow over time. Because of the importance of theoretical foundations, one recent study examined the extent to which theory has been used (i.e., operationalized, informed, applied, and tested) in the empirical health behavior research literature [23]. The study included 193 studies across different health behaviors and found that 35.7% mentioned theory. Of these studies, most (68.1%) used theory to “inform” the research project. Theory was used to a significantly lesser extent for the following purposes: applying theory (18%), building theory (9.4%), and testing theory (3.6%).

However, while most researchers would agree that use of theory leads to more effective Interventions, it should be noted that there is some debate about the importance of theory [24,25]. For example, Jeffery has argued that the behavioral change literature of the last 25 years has been dominated by cognitive decision making and cognitive variables, yet (a) it has come up short in terms of consistently predicting behavioral outcomes very well, (b) there is little evidence that cognitive schema help to cause behavioral change, and (c) cognitive processes are hard to directly change. However, more recent evidence based on meta-analysis suggests that medium-to-large change in intention (i.e., cognition) leads to a small-to-medium change in health behaviors [26]. This ongoing debate is mentioned here because it is important that our field be well aware of current theories’ potential limitations, with an eye toward newer developments that may have a greater impact on behavioral change.

There are many ways one might categorize the interventions employed in an attempt to improve CPAP adherence. Because one goal of this review is to understand the theoretical foundation and associated techniques or strategies of the existing CPAP adherence interventions, we classified interventions as primarily concerned with providing educational, clinical, or behavioral change support. Educational support includes providing information for informational or knowledge purposes, but does not include education related to skills or psycho-educational purposes (i.e., behavioral change). Similarly, clinical support will refer to medical support and decision making

offered by medical providers, and typically includes mask changes, pressure changes, or other kinds of medical support. It often includes increased access to medical professionals. Behavioral change will refer to those interventions that specifically attempt to change the way a patient thinks or acts using some defined behavioral change theory or model, with the express purpose of increasing the amount of CPAP use.

**Behavioral change theory and models:** There are a wide variety of behavioral change theories and models available to use, each with advantages and disadvantages (for a good review, see [22]). Models that have already been described within the CPAP literature include Social-Cognitive Theory, Transtheoretical Model, Health Belief Model, Triandis Theory of Behavioral Change, and the Health Action Process Model (see Appendix). A recent review of the most commonly used health behavior change models used in the general medical literature found the following order of use: Transtheoretical Model (27.5%), Social-Cognitive Theory (27.5%), and Health Belief Model (20%) [23].

One problem in the general treatment adherence literature, as related to the use of theory and models, is the lack of empirical studies. In a recent large meta-analysis, DiMatteo found that nearly 87% of the general adherence literature consisted of reviews, description of conceptual frameworks and models, and suggestions for improving patient adherence [27]. In other words, empirical studies make up only 13% of the general adherence literature. DiMatteo’s review is important because it reviewed and analyzed over 16,000 English language citations and in all likelihood represents the largest review of its kind [27].

**Modes of delivery:** Interventions are delivered to the patients in three ways: individual or group format; use of supplemental educational tools; and use of remote technologies. Because of various ways an intervention may be delivered, a taxonomy for organizing modes of delivery is required. Webb et al. [28] have proposed a taxonomy focused on the physical manner in which participants receive the intervention (i.e., individual or group) and the nature of the person delivering the intervention (i.e., medical professional or trained facilitator). Another coding scheme, or organizing taxonomy, has focused on the delivery of interventions using health information technologies. It includes the use of supplemental modes of delivery (e.g., use of email; telephone; text messaging; cd-rom; videoconferencing/ teleconferencing; and video education) and the use of automated functions (e.g., automated tailored feedback; automated follow-up messages; as-needed remote access to an advisor to request advice; scheduled remote contact with an advisor; and peer-to-peer access) [28].

### Specific Behavioral Change Techniques

Specific BCTs represent the “active” components of the interventions and refer to the strategies employed within the interventions that promote behavioral change. There have been attempts in the past to classify BCTs. On a broad basis, the developers of the Transtheoretical Model generated a list of the “processes of change” that enabled categorization of the ways in which shifts in behavior occur. These change processes are the covert and overt activities and experiences that individuals engage in when they attempt to modify their behaviors. The ten processes of change are consciousness raising, counter conditioning, dramatic relief, environmental reevaluation, helping relationships, reinforcement management, self-liberation, self-reevaluation, social liberation, and stimulus control. However, each process is a broad category encompassing multiple techniques, methods, and interventions that are traditionally associated with disparate theoretical orientations.

There have been various attempts to identify specific BCTs within

particular domains, for example: physical activity [29,30], weight management [31], and HIV-related condom use [32]. Additionally, there has been a call for more comprehensive categorization of specific BCTs across various illness domains [26]. One of the most comprehensive efforts to date has been that by Abraham and Michie [20], who empirically developed a theory-linked taxonomy of BCTs. The result was a list of BCTs with standardized, operational definitions that provides a useful starting point for identifying the BCTs used in CPAP adherence interventions. This taxonomy will be used to guide our review; its methods are described in the next section.

## Summary

While most behavior change research describes a specific intervention approach that may or may not be based on theory, there appears to have been little examination of the specific behavior change elements or techniques that comprise those interventions. Clearly, the majority of CPAP adherence interventional research is based on intervention with multiple components. A better understanding of what components are included in an intervention, and ultimately, the critical components that lead to behavioral change, is what may be needed to develop interventions that are more effective. There is good reason for taking these steps; when an intervention is described as being comprised of, for example, “classes,” “workshops,” or “counseling sessions,” such general descriptions can mask procedurally distinct change components and may fail to adequately describe techniques such that they are not reproducible. In addition to promoting identification of specific intervention techniques, improved (or even standardized) descriptions of intervention content would facilitate the fidelity of intervention operationalization in replication studies and applications. To the extent that the effective change techniques that help to increase CPAP adherence can be identified, the opportunity to advance our field through the dissemination of efficacious interventions and techniques is increased. The second goal of this paper is to present the results of a literature review of published CPAP adherence interventions in each of these three areas (theoretical basis, BCT, and mode of intervention delivery) per the recommendations of Michie and colleagues [20,21].

## Methods

### Literature review

The CPAP adherence literature was reviewed to identify those studies that included a specific intervention designed to increase CPAP use. Studies were included in this review if they were considered to be an evaluation of an intervention to improve CPAP adherence (even if a case series or single group design), in order to be comprehensive. PubMed was searched using the terms “continuous positive airway pressure,” “compliance,” and their variants. Each abstract was reviewed and articles that met the criteria of testing or evaluating an intervention whose goal was to increase CPAP adherence or use were retrieved. This search was supplemented by examining each of the article’s reference lists and any relevant review articles.

### Study selection

Relevant CPAP adherence interventions are defined as those interventions that are designed with an educational, clinical support, or behavioral change approach with the expressed purpose of helping the OSA patient initially start CPAP therapy and/or maintain use over time. Studies that were focused on one aspect of CPAP adherence (e.g., feelings of claustrophobia or difficulty breathing with CPAP) were included, given the intended broad scope of this review. Pediatric studies were also included. We did not include studies that (1) only examined a

technological intervention (e.g., the effect of humidification, the effect of pressure modification, or evaluation of a new mask type) but had no behavioral component; (2) were focused on providing descriptions of CPAP adherence rates (but that did not include description of an intervention or an evaluation of that intervention); (3) focused solely on examining predictors of CPAP adherence, but without an explicit intervention. In all, 29 studies met inclusion and exclusion criteria (see Table 1).

### Use of theory

The use of theory was coded using item 1 of the theory coding scheme developed by Michie and Prestwich [21]: whether or not “methods/theories that specify relations among variables in order to explain or predict behavior are mentioned.”

### Behavioral change techniques

All the specific BCTs that were coded included CPAP intervention studies, including those that did not follow a specific behavioral model or theory. A 26-item list of behavioral change techniques was utilized per Abraham and Michie [20]. Their recommendation for implementing the coding scheme is to not code for behavioral change techniques if they overlap with the comparison intervention, the rationale being that any effect of the behavioral change technique would not be unique.

### Mode of delivery

This review first classifies whether an intervention was delivered on an individual or group basis, as the mode of delivery may have an impact on outcomes. Secondly, studies were classified according to whether they were primarily delivered “in person” or “remotely.” In person refers to face-to-face contact (whether in the clinic or in the home). Remote refers to the use of some form of electronic means of communication at a distance, examples of which include the following: email, telephone, text messaging, or videoconferencing/teleconferencing. In addition to classifying mode of delivery into delivery format (individual or group) and delivery method (in person or remote), supplemental forms of education were coded as well, for example, web-based interactive modules or use of video education.

### Data analysis

Descriptive and count data were used to describe the number of studies that cited a theoretical basis, the number of BCTs used per study, and the number of modes of delivery used throughout this literature. The *d*-index, used as a measure of effect size for the CPAP intervention studies, was defined as the difference between the means of the two groups being compared divided by the mean standard deviation (for CPAP adherence, in hours per night). An effect size was calculated for studies examining one group pre-intervention and post intervention. Mean effect sizes for the studies that employed a Randomized Controlled Trial design (RCT) were reported separately. An alpha level of 0.05 was used. Cohen recommended one classification of categorizing effect sizes:  $d=0.2$  (small),  $d=0.5$  (medium) and  $d=0.8$  (large) [33].

## Results

### Use of theory

Theories and models were used relatively infrequently in the reviewed CPAP adherence intervention studies (Table 2). Out of the 29 studies, 11 unique (37%) studies mentioned a theory or a model (from Table 1: studies 6, 7, 12, 16, 18, 20, 21, 23, 24, 27, and 29). Richards et

	Study	Design	Effect Size (d)	Intervention and control group descriptions	Approach <sup>a</sup>	Theoretical Model <sup>b</sup>	Format <sup>c</sup> (method)
1	Fletcher and Lockett [57]	Cross-over	0.03	Basic: Video education, CPAP titration. Telephone Support: CPAP trouble-shooting via telephone.	Clinical Support	Not specified	Individual (remote)
2	Chervin et al. [58]	RCT	Lit: 1.11 Tele: 0.47	Basic: CPAP instruction & set-up. Literature support: Educational pamphlet and CPAP use guidelines written by PI's. Telephone support: Weekly follow-up phone calls.	Clinical Support	Not specified	Individual (remote)
3	Likar et al. [59]	Self-selected cohort	0.40	Basic: Nurse instruction of CPAP and OSA, 6-month follow-up, invited to contact with concerns. Group support: Basic, plus optional 2-h support meetings.	Clinical Support	Not specified	Group
4	Hoy et al. [60]	RCT	0.63	Basic support: OSA education by nurse & video; CPAP acclimatization; 24-hour help line; 1-mo f/u. Intensive support: Basic + home education with partner involvement; CPAP titration at home; multiple check-up home visits by nurses.	Clinical Support & Additional Educational Support	Not specified	Individual (in person)
5	Hui et al. [61]	RCT	0.00	Basic support: CPAP education via nurse & OSA brochure; telephone support. Intensive support: Basic + video education; multiple physician & nurse f/u visits and phone calls.	Clinical Support	Not specified	Individual (in person)
6	Aloia et al. [34]	RCT	1.14	Usual care: Overnight titration, physician follow-up. Cognitive-Behavioral Intervention: Usual + 2 one-to-one sessions by a clinical psychologist.	Behavioral Change	Cognitive-Behavioral Theory	Individual (in person)
7	Koontz et al. [62]	Retro-spective	N/A <sup>e</sup>	Consultation and Recommendation (CR) Session vs. CR + Behavioral Therapy (BT) vs. CR with BT referral, but BT not utilized	Behavioral Change	Behavioral Therapy	Individual (in person)
8	DeMolles et al. [63]	RCT	0.55	Usual care: Usual medical care alone. TLC-CPAP: Telephone-linked communications for CPAP was an interactive, touch-pad response system.	Clinical Support	Not specified	Individual (remote)
9	Palmer et al. [64]	Pre- vs. post- design	CAR: 0.16 NHV: 0.37	Consultant Annual Review (CAR): by consultant clinic appointment. Nurse Home Visit (NHV): by specialist nurse	Clinical Support	Not specified	Individual (in person)
10	Smith et al. [65]	One group pre/post	N/A <sup>e</sup>	Standard sleep apnea education program: Booklet provision and nurse-led group education.	Educational Support	Not specified	Group
11	Wiese et al. [66]	RCT	N/A <sup>e</sup>	Usual Care: MD provided information with Respiratory Therapist support. Educational Video: 15 min, author scripted video.	Educational Support	Not specified	Individual (in person)
12	Golay et al. [67]	One-group pre/post	0.33	Therapeutic Educational Program: CPAP hands on workshop; educational courses and spousal roundtables.	Educational, Clinical, & Behavioral Support	Health Belief Model	Group
13	Lewis et al. [68]	RCT	0.24	Standard follow-up: Phone number provided for needed support. Extra early support: Consisted of a video (20-min), telephonic support 2-5 days post-start, MD visit 1-2 weeks.	Clinical support	Not specified	Individual (in person)
14	Smith et al. [69]	RCT	1.0	Control group: telehealth intervention on importance of vitamins. Telehealth group: telehealth intervention using video conferencing between nurse and patient focusing on CPAP use.	Clinical Support	Not specified	Individual (remote)
15	Taylor et al. [70]	RCT	0.03	Traditional Care vs. Telemedicine Support: Health Buddy computer that allowed for informational support and problem trouble-shooting.	Clinical Support	Not specified	Individual (remote)
16	Aloia et al. [11]	RCT	SE: 0.36 MET: 0.23	Standard Care: Provision of print materials and MD visits at diagnosis and 8-10 weeks post. Simple Education (SE): completely didactic intervention and focused on OSA and CPAP. Motivational Enhancement Therapy (MET): based on principles of motivational interviewing.	Behavioral Change	Motivational Enhancement	Individual (in person)
17	Ballard et al. [71]	One group	0.05	Two-phase intervention: Phase I focused on standard interventions including mask optimization, humidification, topical nasal therapy, and OSA education; Phase II was for persistently noncompliant patients and included randomization to CPAP or BiPAP.	Clinical Support	Not specified	Individual (in person)
18	Means et al. [72]	One group	1.52	Graded exposure therapy. This study was based on a previously published protocol and represents the report of a clinical case series	Behavioral Change	Graded Exposure Therapy	Individual (in person)
19	Meurice et al. [73]	RCT	0.0	Standard education vs. Reinforced education: included standard education plus written support. This study added the component of who was delivering education (prescriber and homecare network)	Educational Support	Not specified	Individual (in person)
20	Richards et al. [74]	RCT	1.09	Usual Care vs. Cognitive Behavioral group approach: Primarily group education (didactics via slide presentation, video and booklet) with CBT components (correction of distorted beliefs, promotion of positive treatment outlook).	Educational with Behavioral Change component	Cognitive-Behavioral Theory; Social-Cognitive Theory	Group

21	Slifer et al. [75]	Case series	6.0 <sup>e</sup>	Behavioral Therapy: comprised of counterconditioning, shaping, and education.	Behavioral Change	Behavioral Therapy	Individual (in person)
22	Stepnowsky et al. [76]	RCT	0.65	Control group: Usual care of 1-week phone call and 1-month clinic visit. Telemonitoring group: Based on the premise of therapist having daily access to CPAP adherence and efficacy data, and acting on that data proactively.	Clinical Support	Not specified	Individual (remote)
23	Stepnowsky et al. [77]	Single group	N/A <sup>e</sup>	Self-Management: comprised of OSA & CPAP education, self-monitoring, decision-making, and problem-solving	Educational & Behavioral Change	Cognitive-Behavioral Therapy	Group
24	Smith et al. [78]	RCT	0.84	Control group: placebo focused on daily vitamins. Music and habit-forming intervention: Didactics on OSA and CPAP benefits; problem-solving guide; nightly use reminder placards; and 20 min music audiotape for sleep onset with CPAP.	Educational and Behavioral Change	Triandis Theory of Behavior	Individual (in person)
25	Damjanovic et al. [79]	RCT	0.49	Standard support vs. Intensive support consisted of optimizing mask fit, using moisturizers as needed, and identification of early low compliance.	Clinical Support	Not specified	Individual (in person)
26	Fuchs et al. [81]	Two-group design	1.08	Patient Information Program (PIP): 2 hour standardized educational lecture + summary booklet. Control group: PIP nonattendance. Nonrandomized, uncontrolled study.	Educational Support	Not specified	Group
27	Roecklin et al. [81]	RCT	0.17	Standard Information: 3 AASM pamphlets Personalized Feedback: inclusive of OSA severity and OSA risks.	Educational Support	Motivational Approach	Individual (in person)
28	Sparrow et al. [83]	RCT	N/A <sup>e</sup>	Attention placebo control: Usual medical care alone. TLC-CPAP: Telephone-linked communications for CPAP was an interactive, touch-pad response system.	Clinical Support	Not specified	Individual (remote)
29	Trupp et al. [83]	RCT	0.53 <sup>e</sup>	Educational Message Framing: positive vs. negative framing	Educational Support	Prospect Theory	Individual (in person)

Note. RCT = randomized controlled trial. <sup>a</sup> Approach allowed for the classification of the experimental intervention as primarily being Educational, Clinical Support or Behavioral Change. <sup>b</sup> For those studies labeled with a theoretical model as “not specified,” one could presume that more education and/or more support was the guiding principle behind these studies. <sup>c</sup> Format was classified as the intervention being delivered individually or in group format. Individual format was further divided into “in person” or “remote,” with “remote” referring to the use of some sort of electronic communication (e.g., telephone; telephone-linked communications; telemedicine device; telemonitoring). <sup>d</sup> Pediatric study. <sup>e</sup> Notes on Effect Size. (1) Koontz et al. (2003) was a retrospective chart review and did not use a well-defined control group against which to make comparisons; however, if one considered the intervention group from within-subject perspective, effect sizes would be large (with BT increasing adherence from 0.77 hrs/nt to 5.51 hrs/nt, and CR+BT increasing adherence from 1.72 hrs/nt to 7.47 hrs/nt) (note: SD was not reported for this data); (2) Smith et al. (2004) did not report adherence data; (3) Wiese et al. (2004) did not report sufficient data for ES calculation (video education did result in greater attendance at one-month follow-up visit (72.9% vs. 48.9%; p=0.02); (4) Meurice et al. 2007 found no differences among type of education and deliverer of the education (prescriber and homecare team); (5) Slifer et al. 2007 was a case series of 4 children; it should be noted that Figure 2 of the paper presents adherence data for each child and shows large improvements in PAP use over 26 to 60 nights; (6) Stepnowsky et al. (2007) presents pilot data on a single group of new OSA patients, with mean adherence = 5.5 ± 2.5 hrs/nt; (7) Sparrow et al. (2010) does not report mean or standard deviation so the effect size was unable to be calculated (authors did not respond to inquiries); (8) Trupp et al. (2011) did not report the mean and SD for the adherence data, so effect size was calculated based on the p-value.

**Table 1:** Review of Psychoeducational Interventions Designed to Increase CPAP Adherence

al. (study 20) mentioned both Cognitive-Behavioral Theory and Social-Cognitive Theory and was therefore counted twice. Aloia and colleagues [34] (study 6) mentioned that their study is based on Cognitive-Behavioral Theory; however, given a later study by the same group, it would appear the 2001 study may have been a pilot of the Motivational Enhancement Training intervention [11]. Two pediatric studies cited using Behavioral Therapy (studies 7 and 21). In terms of the amount of text describing the interventional methods, the two pediatric studies were the most comprehensive.

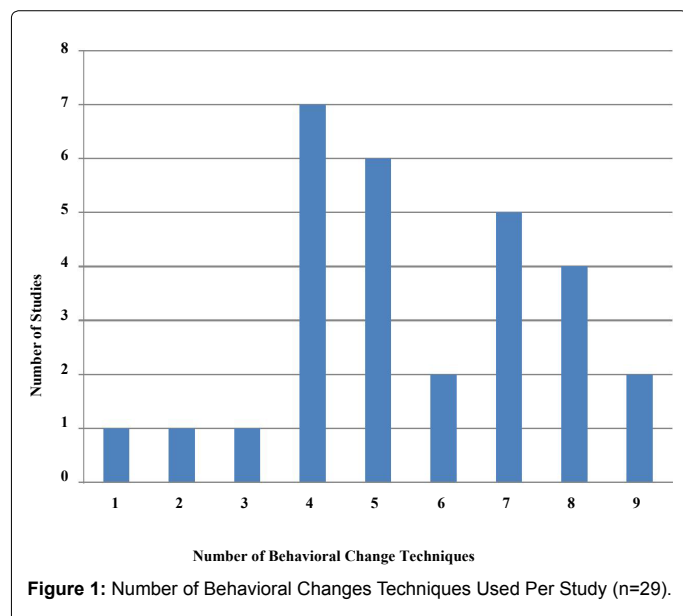
### Behavioral change techniques

Out of the possible 26 different behavioral change techniques, the two most common techniques were “provide general information” and “provide instruction.” This is not unexpected, given that OSA patients require significant amounts of information and education regarding OSA and CPAP, as well as detailed initial and ongoing instruction on CPAP use. The third most commonly used technique was “provide information on consequences,” fourth was “provide general encouragement,” and fifth was “prompt barrier identification.” Table 3 provides a rank ordering of the frequency with which specific behavioral change techniques were employed.

The next most common behavioral change techniques were “provide feedback on performance” (6th); “prompt practice” (7thT, where “T” refers to “tie”); and “model or demonstrate the behavior” (7thT). It

was surprising that the provision of feedback was not used more often because of the common availability of CPAP data downloads and the important information they provide regarding CPAP adherence and efficacy. It is unlikely that the year of study plays a role, as only four of the 29 intervention studies were published before 2000. It was also surprising that demonstration and prompt practice (i.e., using CPAP in presence of provider in initial visit) were not more commonly used techniques because of the benefit of being sure the patient can tolerate the air pressure prior to home use. Three or fewer studies utilized techniques 7, 10-12, 14, 15, 18-20, and 25. And no studies utilized techniques 3, 4, 16, 21-24, or 26.

In terms of BCT use by study, the mean number of BCTs used across the 29 studies was 4.3 ± 2.0 (mean ± SD) per intervention, the minimum number of BCTs used per intervention was one, and the maximum was nine. Figure 1 shows the distribution of studies by number of BCTs. The most common number of BCTs per study was 4. Clearly, BCTs used per study ranged from one BCT per study, representing simple, one-component interventions, up through multicomponent studies. When the same data were examined only for those studies that employed a two-group (typically randomized controlled trial) design, the mean number of BCTs was nearly the same as for the entire group: 4.3 ± 2.0 (mean ± SD) (range: 1-9) per intervention. The d-index measure of effect size is



reported in Table 1 for each study. The mean d-index across all studies in the review was  $0.72 \pm 1.13$  (range: 0 – 6). When the outlier effect size for the one case-series pediatric study was excluded, the mean d-index was  $0.52 \pm 0.42$  (range: 0– 1.52). This d-index then represents the mean d-index of CPAP adherence interventions for adults with OSA who were new users of CPAP. When only the studies that employed a two group (typically randomized, controlled trial, or RCT) were included, the mean d-index was  $0.56 \pm 0.39$  (range: 0 – 1.14). In terms of Cohen's effect size, a medium effect size is considered to be 0.50, which helps provide some context for the CPAP adherence intervention effect sizes found in this review [33].

Across all studies, the correlation between the d-index and the number of BCTs was positive such that the higher the number of BCTs, the higher the effect size, though it did not reach statistical significance ( $r=0.365$ ;  $p=0.061$ ;  $n=27$ ). In only those RCT studies, the correlation between the d-index and number of BCTs was not statistically significant ( $r = 0.304$ ;  $p=0.205$ ;  $n=19$ ).

The studies were then classified according to primary CPAP adherence intervention type (clinical support, educational support, or behavioral change). Across all studies in the review, the d-index was statistically different across intervention type ( $F(2,24)=4.445$ ;  $p=.023$ ). These results held when the one case series pediatric study (with a d-index of 6.0) was excluded ( $F(2,23)=4.349$ ;  $p=0.025$ ) such that behavioral interventional studies had the highest effect size ( $0.96 \pm 0.48$ ), followed by educational interventions ( $0.43 \pm 0.42$ ) and clinical support interventions ( $0.41 \pm 0.33$ ). However, these results changed when only RCT studies were examined, with the d-index not significantly different across type of CPAP adherence intervention ( $F(2,16)=1.281$ ;  $p=.305$ ; behavioral change interventions:  $0.83 \pm 0.42$ ; clinical interventions:  $0.52 \pm 0.37$ ; and educational interventions:  $0.43 \pm 0.42$ ).

The number of BCTs by CPAP adherence intervention type was also examined. For all studies, the difference approached statistical significance ( $F(2,29)=3.009$ ;  $p=.065$ ), with the most BCTs found in behavioral interventional studies ( $5.4 \pm 1.7$  BCTs), followed by clinical support ( $4.4 \pm 2.1$  BCTs) and educational support:  $3.0 \pm 1.3$  BCTs). When examining only RCTs, there was not a statistically different number of BCTs by intervention type ( $F(2,18)=2.479$ ;  $p=.112$ ), with

nearly the same distribution of BCTs by intervention type: behavioral interventional studies ( $5.5 \pm 0.60$  BCTs), followed by clinical support ( $4.3 \pm 2.0$  BCTs) and educational support:  $3.2 \pm 1.3$  BCTs).

The relationship between format type (group vs. individual) and the d-index and number of BCTs was examined next. Across all studies, format type was not related to the d-index ( $t=-0.455$ ;  $p=0.653$ ) but was associated with the number of BCTs ( $t=-2.046$ ;  $p=0.050$ ). These results held when examining only RCT studies, with format type not related to the d-index ( $t=-0.800$ ;  $p=0.435$ ), but was related to the number of BCTs ( $t=-2.154$ ;  $p=0.044$ ) such that group format had  $5.75 \pm 1.0$  BCTs while the individual format had  $3.8 \pm 1.7$  BCTs.

Lastly the relationship between use of theory and the d-index and number of BCTs was examined. Across all studies, use of theory was not related to the d-index ( $t=-1.546$ ;  $p=0.135$ ) or to the number of BCTs ( $t=-1.752$ ;  $p=0.090$ ). These results held when examining only RCT studies, with use of theory not related to the d-index ( $t=-0.533$ ;  $p=0.601$ ) or to the number of BCTs ( $t=-.432$ ;  $p=0.671$ ).

### Mode of delivery

Table 1 shows the intervention delivery format (group or individual) and delivery method (in person or remote). Six out of the 29 CPAP interventions utilized a group-based format (smallest group = 3 patients; largest group = 12 patients). In most cases, spouses were encouraged to participate in the group-based format. Of the 6 group interventions, one used a supplemental video to provide education, and none appeared to use supplemental forms of electronic communication. Twenty-three out of the 29 interventions utilized individual-based interactions. Of the 23 interventions, 7 utilized remote interactions as the primary contact method. It is important to note that none of the studies were conducted entirely via remote, as all started with in-person interactions at the outset. In addition, all 7 interventions provided mechanisms to schedule in-person meetings should they be needed. Of the 7 studies that used remote interactions, three studies used telephone (with one study using telemonitoring to obtain CPAP adherence and efficacy data, and then calling patients via telephone); two used telephone-linked communications (i.e., interactive voice response, or IVR); one used a telemedicine device called Health Buddy; and one used videoconferencing. The only form of supplemental education used, video education, was used in 9 out of the 29 interventions. Few studies (2 out of 9) described the video education intervention in detail. For those studies that reported video length, it ranged from 14 to 20 minutes. One study indicated that ResMed was the video manufacturer, and in another case, it appeared that the video was scripted and taped by the study authors.

### Discussion

Low patient adherence to nasal Continuous Positive Airway Pressure (CPAP) treatment limits treatment effectiveness. A number of CPAP adherence interventional approaches have been studied to date, including clinical support, educational support, and behavioral change interventions. The average effect size of the studies on new adult OSA patients who were newly prescribed CPAP was 0.52 (SD=0.42, range: 0-1.52), suggesting that CPAP adherence interventions have a moderate effect on increasing the amount of nightly use with CPAP. The number of Behavioral Change Techniques (BCTs) used in each intervention did not appear to be associated with the effect size. However, those studies designated as being primarily focused on behavioral change did have higher effect sizes than either clinical or educational support intervention studies when all studies were included; when only RCTs

Theory	Number of Studies	Study Numbers <sup>a</sup>
Cognitive Behavioral Therapy/Theory	3	6, 20, 23
Behavioral Therapy	2	7, 21
Motivational Interviewing Theory	2	16, 27
Social Cognitive Theory	1	20
Health Belief Model	1	12
Triandis Theory of Behavior	1	24
Graded Exposure Therapy	1	18
Prospect Theory	1	29
Total	12	

Note. <sup>a</sup> Study numbers are from Table 1.

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**Table 2:** Theoretical Basis of CPAP Adherence Intervention Studies

Rank #	Behavioral Change Technique <sup>a</sup>	Count <sup>b</sup>
1	Provide general information (1)	24
2	Provide instruction (8)	18
3	Provide information on consequences (2)	15
4	Provide general encouragement (6)	11
5	Prompt barrier identification (5)	10
6	Provide feedback on performance (13)	9
7T <sup>c</sup>	Model or demonstrate the behavior (9)	7
7T	Prompt practice (17)	7
8T	Set graded tasks (7)	3
8T	Prompt self-monitoring of behavior (12)	3
9T	Prompt specific goal setting (10)	2
9T	Prompt review of behavioral goals (11)	2
9T	Provide contingent rewards (14)	2
9T	Use follow-up prompts (18)	2
9T	Provide opportunities for social comparison (19)	2
9T	Motivational interviewing (25)	2
10T	Teach to use prompts/cues (15)	1
10T	Plan social support/social change (20)	1
--	Provide information about others' approval (3)	0
--	Prompt intention formation (4)	0
--	Agree on behavioral contract (16)	0
--	Prompt identification as a role model (21)	0
--	Prompt self-talk (22)	0
--	Relapse prevention (23)	0
--	Stress Management (24)	0
--	Time Management (26)	0

Note. <sup>a</sup> Name of specific Behavioral Change Technique along with its identification number in parentheses from the original Abraham & Michie (2008) BCT coding scheme. The text in the Results section identifies some of the BCTs in this table by their number. <sup>b</sup> Count refers to the number of CPAP adherence studies that used that specific BCT. <sup>c</sup> "T" indicates that two or more techniques were tied in terms of the count.

**Table 3:** Behavioral Change Techniques Used In CPAP Adherence Studies: Count and Rank Order

were examined, this relationship did not hold. Finally, whether an intervention was delivered in group or individual format, or whether it stated it was based on a theoretical foundation, did not appear related to the effect size. Group formats were associated with a greater number of BCTs than individual format.

Better understanding of the theoretical foundation and BCTs used in this literature may help provide direction for future efforts. The findings of this review suggest that a relatively small percentage of CPAP adherence studies (~25%) are based on, or use, theory. However, relative to the general medical literature on the use of theory

in adherence interventions (~35%), this percentage is only ~10% less. It would appear that most studies, both in the CPAP adherence literature (~75%) and in the general medical literature (~65%), either do not use, or do not report using, a theoretical basis.

Given the needs of new OSA patients prescribed CPAP therapy, it was not surprising that the most commonly used BCTs are concerned with providing general information, instruction, and information on consequences. Given that OSA is a chronic illness that occurs while one is asleep, providing basic information and education regarding OSA and its consequences is clearly a necessary step. And given that CPAP is a complex treatment regimen, it is reasonable that most interventions include providing CPAP-related instruction, both initially and on an ongoing basis.

Clinical experience and the research literature suggest that barriers are common reasons why OSA patients limit, or do not use, CPAP. The fifth most commonly used BCT concerns barrier identification, and it was used in only 10 out of the 29 reviewed studies. Barrier identification allows for improved troubleshooting and problem-solving.

Providing feedback on performance was identified in only 9 out of the 29 reviewed studies, which was surprising given the CPAP adherence and efficacy data recorded by the CPAP units, and the ease with which this information can be obtained by providers and shared with OSA patients. Our own research has found this to be a central part of what we do in terms of providing patients with objective feedback on how well CPAP may be working for them, and it engenders patient-centered, collaborative care.

While it is clear that not every BCT can be incorporated into a CPAP adherence intervention, 30% of the possible BCTs that comprised this specific coding scheme were not utilized in any CPAP adherence intervention. One reasonable possibility for this is that the published literature provides limited descriptions of the interventions themselves. This review was based only on what was described in the articles and did not seek to obtain intervention manuals or ask for further information from study authors (as some of the studies are more than 10 years old). It may very well have been that more BCTs would have been identified had these steps been taken. Indeed, the interventional methods sections of the reviewed CPAP adherence papers ranged in length from one to thirteen paragraphs. Clearly, more description allowed for the possibility of reporting greater numbers of BCTs. Another possibility is that our field is not utilizing one or more BCTs that might be effective for CPAP adherence. Future research would do well to consider those BCTs that are untested for CPAP adherence. Readers should be cautioned that the current review included a wide range of studies, including across age ranges (pediatric and adult), across study design types (i.e., those designed for all new users and those designed for more specific subsets of users), and utilizing multiple formats.

This raises the issue of future directions for our field. Clearly, as was established in other health domains, improved reporting of the specific BCTs is needed. While there is clear guidance on reporting clinical trials, both generally as per the CONSORT statement [35,36] and specifically on reporting behavioral trials [37], the recommended level of description or clarity requested for the "content or elements" for a behavioral change intervention remains problematic. The CONSORT statement states that evaluators should report the "precise details of interventions" [36], but the problem remains that there is no standardized or commonly agreed upon vocabulary with which to describe the techniques used in behavioral change trials. This results in a whole host of consequences, including not being able to identify the

“active” component of an intervention or not being able to reproduce the intervention. Using the relatively new taxonomy of BCTs, as developed by Abraham and Michie [20], provides a good first step toward being able to use common and standardized descriptions within our field. Given that CPAP adherence is a unique complex behavioral treatment regimen, it may very well be that each BCT will need some modification (or qualifications) to be most applicable and useful to our field.

Future reporting of CPAP adherence intervention trials would do well to follow the guidelines for behavioral scientists in reporting behavioral trials for interventions [37]: (1) the content or elements of the intervention (e.g., oral communication, written material, videos, others), (2) the characteristics of those delivering the intervention (e.g., level of education or amount of training required), (3) the characteristics of the recipients, (4) the setting (e.g., worksite, community, medical center), (5) the mode of delivery (e.g., face-to-face, individual, group), (6) the intensity (e.g., contact time), (7) the duration (e.g., number of sessions over a given period), and (8) adherence to delivery protocols. It should be noted that there was a recent effort to disseminate behavioral treatments for sleep disorders, including several CPAP adherence interventions, in a recently published book [38].

Lastly, it should be noted that globally there are ever increasing cost pressures in healthcare, whether the costs are borne by individuals, governments, or third-party payers. In the United States, the Centers for Medicare and Medicaid Services have issued a CMS Local Coverage Determination adherence criterion for continued reimbursement of CPAP after 90 days of use. This example of reimbursement linked to use level suggests there is an urgent need to identify those interventions, and specifically BCTs, that foster the greatest level of use in OSA patients relatively early in the treatment initialization process, whether within the 3-month period defined by CMS in the US, or the various standards in other countries. Furthermore, it may be that policy-related efforts are also needed to help influence health service delivery factors, as follows: (1) examining how OSA care is currently organized and how it might be improved to better facilitate good chronic illness care and (2) examining how reimbursement is currently structured. For example, there may be a good rationale for cost-shifting away from expensive diagnostic testing for routine OSA screening and moving those savings to CPAP treatment initialization and follow-up efforts, which is significantly underfunded currently in the US. This critical point is made because the reality of implementing efficacious CPAP interventions is largely dependent on adequate reimbursement. Finally, it may be that utilizing a stepped care approach that best matches various kinds of BCTs to those who need them, and when they need them, is a viable future direction [39].

## Appendix

**Social cognitive theory:** Social Cognitive Theory (SCT) posits multiple influences on behavior, with an emphasis on personal (e.g., cognitive) and environmental (e.g., social) factors [40]. Variables derived from this model include self-efficacy, outcome expectations, social support, and knowledge. Self-efficacy refers to the beliefs in one's abilities to engage in a particular behavior [41]. Outcome expectations refer to beliefs that engaging in a particular behavior will result in certain outcomes [41]. Because these judgments occur in and are influenced by social situations, social support is a key variable of the model. Social support refers to the availability and usefulness of the tangible support of family, friends, and medical staff. Though knowledge alone rarely translates into health-related behavior change, SCT [42] holds that accurate information provides the basis for such change. SCT has provided the basis for both specific and general chronic disease self-

management programs. Self-management refers to the day-to-day tasks an individual must undertake to control or reduce the impact of disease on health status.

**Cognitive behavioral therapy:** Cognitive-Behavioral Therapies (CBT) do not necessarily represent a specific theoretical foundation, but a general therapeutic approach that aims to solve problems concerning problematic cognitions, behaviors, and emotions through a goal-oriented, systematic procedure. By definition, CBTs draw from an assortment of therapeutic approaches, including cognitive, behavioral, and educational. Within each of these approaches, various theoretical foundations may or may not be made explicit. Indeed, defining the scope of what constitutes CBT is a difficulty that has persisted throughout its history [43]. While it is convenient to label an interventional approach as being “CBT,” for our field to advance, specification of the following is necessary: underlying theoretical model, the proposed relationships between measured constructs or predictors and the outcome, and BCTs. CBT has been shown to be effective for a variety of problems, including treatment adherence.

**Transtheoretical model:** The Transtheoretical Model (TM) is a multidimensional approach to behavior change that integrates behavior change processes and principles from across leading theories [44]. The core construct, around which the other dimensions are organized, is the stages of change, which represents ordered categories along a continuum of motivational readiness to change a specific behavior. Five categories comprise the stage of change construct and include pre-contemplation, contemplation, preparation, action, and maintenance. Pre-contemplation is the stage at which there is little or no intention to change behavior in the near future. Many individuals in this stage are unaware of their options. In the contemplation stage, individuals seriously consider changing their behavior, but have not yet made a commitment to take action. The preparation stage combines both intention and behavioral aspects. The individual in the preparation stage has clear intentions to change behavior and has made some behavioral attempts. In the action stage, individuals modify their behavior, experiences, or environment in order to make the change. The individual in the action stage has made overt behavioral changes that have required considerable time and energy, and has typically done so for a defined period of time, often 1 month or more. Maintenance is the stage in which the individual has engaged in behavior change for a defined period of time, typically 6 months or more.

The model asserts that patients engage in a decisional “balance sheet” of comparative potential gains and losses, termed the decisional balance. The decisional balance is a summary index of the pros and cons of engaging in the behavior. This balance varies depending in which stage the individual may be classified, and is said to get at the “why” of behavior change. For example, it has been shown that the number of cons significantly outweigh the number of pros for an individual in the pre-contemplation stage of change, while the number of pros outweigh the number of cons for an individual in the maintenance stage of change [45].

**Health belief model:** The Health Belief Model (HBM) was initially developed to help predict the engagement in a single health behavior [46], for example, obtaining a vaccination or wearing a bicycle helmet [47]. However, given the need for behavior change models to help understand more complex behavior, the HBM borrowed other concepts developed in other areas and included them in its model. HBM also allows for the inclusion of demographic, psychological, and social influences on adherence [48]. HBM has been applied to the prediction of compliance outside of the sleep research literature [48-



50], and within the sleep research literature, has been applied to CPAP adherence prediction [19,51]. Future research will determine how well it can be applied to the development and testing of CPAP adherence interventions.

**Health action process approach:** The Health Action Process Approach (HAPA) suggests that the adoption, initiation, and maintenance of health behaviors are conceived as a process that consists of at least a motivation phase and a volition phase [52]. The latter is further subdivided into a planning phase, action phase, and maintenance phase. It is claimed that perceived self-efficacy plays a crucial role at all stages, along with other cognitions [41]. For example, risk perceptions serve predominantly to set the stage for a contemplation process early in the motivation phase but do not extend beyond. Similarly, outcome expectancies are chiefly important in the motivation phase when individuals balance the pros and cons of certain consequences of behaviors, but they lose their predictive power after a personal decision has been made. However, if one does not believe in one's capability to perform a desired action, one will fail to adopt, initiate, and maintain it. Therefore, the HAPA model is closely related to both Social Cognitive Theory and the Health Belief Model. While SCT is comprised of outcome expectations and perceived self-efficacy, perception of risk is not one of its core concepts. From Bandura's perspective, perception of risk would probably be best conceptualized as a physical outcome expectation. It may be that perception of risk can play a role in mediating some kinds of health behavior change, and it may, after it is appropriately modeled and empirically tested, prove to be a useful construct for its potential role in understanding CPAP adherence. The HAPA Model is included because one set of assessment tools for CPAP adherence research appears to be in large part based on this model: self-efficacy measure for sleep apnea [53].

**Triandis theory of behavioral change:** Social psychologist Harry Triandis attempted to develop an integrated model of "interpersonal" behavior [54] over thirty years ago. He recognized the important role played by both social and emotional factors in forming intentions, as well as the importance of past behavior on future behavior. On the basis of these observations, he proposed a theory in which intentions are immediate antecedents of behavior, which is consistent with many other models. However, he proposed two main distinctions from other models: (1) that habits also mediate behavior (in an attempt to incorporate the role of past behavior) and (2) that both of these influences (intentions and habits) are moderated by facilitating conditions (i.e., objective environmental factors that enable persons to engage in the behavior). CPAP adherence researchers have used this theory to provide a foundation for the importance of habit formation and environmental modification to facilitate health-related behaviors. Researchers using Triandis Theory have found empirical support that following routines that guide treatment use and sensitizing patients to benefits and nontreatment risks result in improved adherence [55,56].

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