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New directions in the management of chronic pain: Self-regulation theory as a model for integrative clinical psychology practice

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ABSTRACT

The next generation of empirically derived clinical health psychology involves use of self-regulation theory for understanding and treating chronic pain. Temporomandibular disorders serve as a model to illustrate how increasing self-regulatory strength facilitates small, behavioral changes that positively influence the underlying physiological factors known to be important in the etiology and maintenance of chronic pain conditions. For individuals with chronic temporomandibular disorders, physical self-regulation is an integrative clinical health psychology intervention that decreases both physical and psychological symptoms via improvements in self-regulatory strength and autonomic nervous system regulation. Suggestions for the application of self-regulation to other chronic pain disorders and future research directions are provided.

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Physical pain will afflict almost all individuals at some point in their lifetimes (Centers for Disease Control and Prevention, 2006; Demyttenaere et al., 2007), and the experience of pain may have serious implications for workplace productivity and disability status (Gauntlett-Gilbert & Eccleston, 2007; van Leeuwn, Blyth, March, Nicholas, & Cousins, 2006). Furthermore, chronic pain can negatively alter an individual's psychological health (Demyttenaere et al., 2007; Skevington, 1998). As psychosocial factors often maintain or exacerbate pain symptoms (Gatchel, Peng, Peters, Fuchs, & Turk, 2007; Turk, 1996), and psychopathology is frequently found to be comorbid with chronic pain (Demyttenaere et al., 2007; Haythornthwaite, Seiber, & Kerns, 2005; Sharp & Harvey, 2001), clinical psychologists have rightly taken a major role in evaluating and treating individuals with either chronic pain (i.e., pain symptoms that persist longer than three months) or recurrent pain (i.e., pain symptoms that come and go over time) conditions (for reviews, see Innes, 2005; Novy, Nelson, Francis, & Turk, 1995).

Currently in the field of clinical psychology, there is a growing appreciation of the need for integrative theory and practice. Such integration requires acknowledging the complexities of a given problem and fully addressing each factor thought to contribute to its etiology and maintenance. In chronic pain, the current exemplar of an integrative model is the biopyschosocial approach to chronic pain managment (Engel, 1977). In this approach, equal emphasis is given to treating the physical and psychological factors evident in chronic pain, and thus far, this approach has resulted in substantial improvements in both psychological theory and applied care (Gatchel et al., 2007). Current efforts toward integration are limited, however, because they operate primarily at the physical and psychological symptom levels, as opposed to modifying the underlying physiological processes (e.g., autonomic nervous system dysregulation) thought to be important in the etiology and maintenance of chronic pain.

In recent years, though, there have been advances in identifying common physiological mechanisms that underlie the seemingly disparate problems associated with chronic pain. As an example, there is a large body of literature that documents the role of hypothalamic-pituitary-adrenal (HPA) axis dysfunction in both chronic pain and mood disorders (Ehlert, Gaab, & Heinrichs, 2001; Blackburn-Munro, 2004). Also, immune system dysregulation, in the form of hyperactivation, simultaneously influences both medical and psychological disorders (Dessein, Joffe, & Stanwix, 2004; Goehler, Lyte, & Gaykema, 2007; Hamed, 2009). While it remains true that intervening at the symptom level can result in improved functioning, perhaps it would be more efficient to target directly the underlying factors that precipitated symptom appearance. With advances in scientific knowledge, it is now possible to develop integrative treatment models that address the underlying mechanisms that simultaneously affect multiple problems or domains.

The specific aim of this paper is to offer one example of the kind of integration described above. The authors describe a tailored, behavior change intervention that targets the autonomic nervous system (ANS) dysregulation thought to underlie both the physical and psychological problems evident in chronic pain. The small, behavioral changes involved in such interventions increase self-regulatory strength, which then promotes ANS regulation and increases functioning. Such integrative approaches are significant for both future theory and applied psychology. With respect to theory, the current model can be readily adapted to develop a more integrated, and hence more accurate, understanding of other conditions and behaviors. With respect to applied psychology, it is believed that continued application of psychological theory and techniques can directly alter physical health status, thereby improving the quality of life of people in general, not just those suffering from psychological disorders. In short, authors are advocating for integration of the physical and psychological domains.

1. Current review

The authors believe the next generation of empirically derived clinical health psychology may be found in the application of self-regulation to chronic pain management. To focus the discussion, chronic temporomandibular (TM) disorders have been selected to exemplify the application of self-regulation theory (Carver & Scheier, 1982, 1998) to chronic pain more broadly considered. As deficits in self-regulation are believed to exacerbate both physical and psychological domains of an individual's trigeminally-mediated pain experience, attempts to increase self-regulatory strength are thought to be especially useful in the treatment of TM disorders. To achieve the above objective, the article has been divided into four parts: First, a brief review of literature examining the incidence, signs, symptoms, and etiology of TM disorders is provided to orient the reader to this spectrum of chronic pain. Second, biopsychosocial approaches to the treatment of TM disorders are discussed and evaluated. In accomplishing this, the authors systematically review the relevant review papers published to date. Third, the underpinnings of self-regulatory theory are presented, and it is advanced as a suitable framework for understanding and treating TM disorders. Finally, clinical applications of this conceptualization and ideas for future research are discussed.

2. Temporomandibular disorders

2.1. Incidence

Epidemiological research suggests that TM disorders will affect 40% to 85% of the United States population at some point in their lives (Dworkin et al., 1990; Okeson, 2007; Scrivani, Keith, & Kaban, 2008), and that 5% to 12% of the population will develop chronic symptoms (Duckro, Tait, Margolis, & DeSheilds, 1990; Svensson & Graven-Neilson, 2001). TM disorders are commonly diagnosed among female (Drangsholt & LeResche, 1999; Huang, LeResche, Critchlow, Martin, & Drangsholt, 2002; Scrivani et al., 2008) and middle-aged populations (Moss, Garrette, & Chiodo, 1982), though the reasons for this pattern of diagnoses are presently not fully understood (Okeson, 2007; Scrivani et al., 2008).

2.2. Signs and symptoms

TM disorders are a heterogeneous collection of disorders that involve the TM joint, masticatory system, and associated head and neck musculoskeletal structures (Okeson, 2007; Scrivani et al., 2008). Most cases of TM disorders involve muscle disorders (e.g., myalgia, myofascial pain), disk derangements (e.g., disk displacement), degenerative changes of the TM joint (e.g., osteoarthritis), or some combination of the above. Review papers and guides for the diagnosis and management of TM disorders have reached some consensus on the signs and symptoms of TM disorders: (a) pain and tenderness of the masticatory muscles and/or TM joint areas, (b) pain associated with TM joint sounds, such as clicking, crepitus, and popping, and (c) limitations of jaw movements that may involve either restricted mouth opening or deviation (de Leeuw, 2008; Dworkin & LeResche, 1992; Okeson, 2007; Scrivani et al., 2008). Symptoms often found to occur with TM disorders include ear pain and stuffiness, headache, tinnitus, dizziness, migraine, vertigo, and neck pain (Okeson, 2007; Scrivani et al., 2008).

2.3. Etiology

Although several theories have been offered, there is still considerable controversy surrounding the etiology of TM disorders (Dworkin, 1994b; Moss et al., 1982; Okeson, 2007). Among other factors, trauma (e.g., blow to the jaw), osteoarthritis, rheumatoid arthritis, inflammatory changes, disk derangements, and malocclusion have all been identified as potentially having a causative role in the development of TM disorders (Celic, Jerolimov, & Panduric, 2002; Huang et al., 2002; Glaros, Williams, & Lausten, 2005; Scrivani et al., 2008). In addition, parafunctional oral habits and excessive muscle activity may cause the structural damage and painful symptoms commonly found among patients with TM disorders (Moss et al., 1982; Okeson, 2007). Beyond the peripheral or local causes cited above, ANS dysregulation, which simultaneously affects multiple domains, has been hypothesized as a central factor in the etiology and maintenance of TM disorders (Carlson, 2007; Robinson & Riley, 1999). As stated by Moss et al. (1982), advocacy of any one causative factor alone is premature as the etiology of TM disorders is most likely multifactorial.

2.4. Perpetuating factors

2.4.1. Diurnal and nocturnal parafunctional activity

Learned parafunctional habits, such as clenching and grinding one's teeth or biting one's nails, can contribute to the maintenance of TM disorders (Glaros, Tabacchi, & Glass, 1998; Moss et al., 1982; Schwartz, Gramling, & Grayson, 2001). Nocturnal parafunctional activity (i.e., bruxing one's teeth) is also considered a contributing factor (Okeson, 2007). As an individual may engage in parafunctional behavior without full awareness of his or her doing so (Marbach, Lennon, & Dohrenwend, 1988), it is often difficult to intervene successfully with the hopes of reducing painful symptoms.

2.4.2. Sleep disturbances

Sleep laboratory studies (Dao, Lund, & Lavigne, 1994), as well as self-report studies (de Leeuw, Studts, & Carlson, 2005; Yatani, Studts, Cordova, Carlson, & Okeson, 2002), have found that persons with chronic TM disorders have poor sleep quality, and in some cases report symptoms of chronic fatigue syndrome (Aaron, Burke & Buchwald, 2000; Aaron et al., 2001). Carlson (2007) noted that a "pain–fatigue–sleep disturbance" triad is characteristic of many chronic TM disorders patients, and may provide an indication of the body's inability to rest and repair itself.

2.4.3. Psychological distress

Perhaps most pertinent to clinical psychologists, there is strong correspondence between chronic TM disorders and psychological distress (Carlson, 2007; Carlson et al., 1993; de Leeuw, Bertoli, Schmidt, & Carlson, 2005; Dohrenwend, Raphael, Marbach, & Gallagher, 1999; Dworkin, 1994a,b). Studies using structured clinical interviews for the assessment of psychopathology have shown a higher prevalence of *Diagnostic and Statistical Manual* (DSM; American Psychiatric Association, 2000) Axis I and Axis II disorders among chronic TM disorders patients compared to acute TM disorders patients and the general population (for examples, see Kight, Gatchel, & Wesley, 1999; Phillips, Gatchel, Wesley, & Ellis, 2001; Sherman, Carlson, Wilson, Okeson, & McCubbin, 2005). Further, individuals with chronic TM disorders show high elevations on self-report measures of psychopathology (Bertoli, de Leeuw, Schmidt, Okeson, & Carlson, 2007; de Leeuw, Bertoli, et al., 2005; Glaros et al., 2005; Nilsson, Drangsholt, & List, 2009). Some psychological variables have even been shown to predict onset of TM disorders (Drangsholt & LeResche, 1999; Huang et al., 2002; Slade et al., 2007), the transition from acute to chronic symptoms (Phillips et al., 2001), and treatment response (Rudy, Turk, Kubinski, & Zaki, 1995). As psychological distress places undue strain on an individual's capacity to cope effectively, the presence of significant distress can maintain or exacerbate TM disorders.

3. Biopsychosocial approach to TM disorders

3.1. Background and conceptualization

The biopsychosocial approach is comprehensive in its management of painful conditions. Engel (1977) introduced the term "biopsychosocial" as a broad construct to convey the importance of considering the interacting roles that biological/physical, psychological, and social factors play in illness and disease. In order to appreciate fully the importance of factors included in the biopsychosocial approach, it is important draw distinctions between four dimensions of pain experience: nociception, pain perception, suffering, and pain behavior (Loeser, 1982).

First, nociception, which refers to stimulation of the nerves that convey information about tissue damage to the brain, accounts for the "bio" part of "biopsychosocial." In the treatment of TM disorders, a biomedical reductionist approach limits its focus to addressing nociceptive inputs, using traditional dental and medical treatments, such as splints and analgesic medications. However, a 1:1 correlation between tissue damage and patients' pain experience is rarely observed. To illustrate, reports of pain in the absence of tissue damage is common among psychiatric patients (Chaturvedi, 1987), and pain can persist after the healing of tissue in conditions such as causalgia and phantom limb syndrome (Melzack, 1973). Thus, a second dimension to consider is pain perception, which is a complex subjective experience that involves sensory input being filtered through an individual's genetic composition, prior learning, psychological status, and sociocultural influences. The distinction between nociception and pain perception can be likened to the distinction between disease (objective biological event involving the disruption of specific body structures) and illness (subjective experience of disease).

The third dimension characterizing an individual's pain experience is suffering, which refers to the emotional (e.g., anxiety, anger) and cognitive (e.g., thoughts of helplessness) responses to pain perception. It is important to assess an individual's emotional reactions to and cognitions about pain because they can influence recovery. For example, increased disability is associated with beliefs that pain is a sign of damage, that activity should be avoided when one has pain, and that pain is permanent (Balderson, Lin, & Von Korff, 2004). Similarly, pain patients who are depressed may have little motivation to comply with treatment recommendations (Von Korff & Simon, 1996), and those with anxiety may be afraid to engage in day to day activities out of fear that doing so will exacerbate their pain (Vlaeyen, Kole-Snijders, Rotteveel, Ruesink, & Heuts, 1995). In sum, people's affective and cognitive responses to pain have the potential to negatively influence the course of their pain condition.

The last dimension is pain behavior, which refers to overt communications of pain, such as avoiding activities for fear of re-injury (Vlaeyen, de Jong, Geilen, Heuts, & van Breukelen, 2002). An individual's beliefs about pain, emotional experience, and pain behavior are interrelated. For instance, behavioral experience can show patients they are capable of participating in their regular, daily activities, and reduce thoughts of helplessness and negative emotions (Vlaeyen et al., 2002). Additionally, some cognitive coping strategies (e.g., problems solving, goal setting) can increase an individual's self-efficacy regarding the control of emotional and behavioral responses (Samwel, Evers, Crul, & Kraaimaat, 2006; Turner & Romano, 2001). In sum, the biopsychosocial approach is a significant advancement from the biomedical approach to chronic pain management because it considers the four dimensions of pain experience (nociception, pain perception, suffering, and pain behavior) to be equally important for understanding and treating chronic pain.

3.2. Evaluation and diagnosis

To engage in successful, streamlined treatment that focuses on the most problematic aspects of an individual's pain experience, a necessary first step involves diagnosing TM disorders in terms of the dimensions of the biopsychosocial model. In acknowledgement of this, the Research Diagnostic Criteria for TM Disorders (RDC/TM disorders; Dworkin & LeResche, 1992) assesses physical, cognitive, affective, and behavioral factors, all of which are thought important in understanding an individual's pain experience. The RDC/TM disorders uses a dual axis system for classifying patients (Dworkin & LeResche, 1992). Axis I categorizes TM disorders into three groups: (1) muscle disorders, (2) TM joint disk displacements, and (3) arthralgia, arthritis, and arthroses of the TM joint, and Axis II assesses behavioral, psychological, and social factors relevant to individuals seeking treatment.

3.3. Treatment protocol

TM disorders treatment approaches informed by the biopsychosocial model aim to address all dimensions of an individual's pain experience. For this to be accomplished, one must consider not only the physical aspects of pain, but also its cognitive, emotional, and behavioral aspects. So while nociception can be addressed through medical and dental approaches, the remaining aspects of pain must be addressed by other means, of which biofeedback training, cognitive-behavioral therapy (CBT), and relaxation training are the most common (Myers, White, & Heft, 2002; Sherman & Turk, 2001).

3.3.1. Biofeedback

Electromyographic (EMG) biofeedback is a procedure that combines muscle relaxation with continuous recording and presentation of information about muscle activity. Levels of muscular arousal are recorded and converted into signals, usually auditory or visual, which permit patients to observe their current levels of muscle tension. Crider and Glaros (1999) conducted a meta-analysis to determine the efficacy of biofeedback interventions for TM disorders. A preliminary box score analysis was conducted to determine the number of occasions where biofeedback interventions had a statistically significant advantage over no treatment or placebo control groups. Of the six controlled trials comparing biofeedback to a no treatment control group, 4 reported significant advantages for biofeedback conditions in regard to self-reported pain reduction, but only 2 reported significant advantages for biofeedback in regard to clinical exam findings. To determine the average degree of improvement to be expected from biofeedback interventions for TM disorders, Crider and Glaros (1999) calculated pre- to post- treatment effect sizes for the biofeedback, no treatment, and placebo conditions. The effect size for patients' pain reports was not significantly different between the biofeedback interventions ($d = 1.04$) and the no treatment and placebo groups ($d = .47$), but the effect size for clinical exam findings was significantly larger for the biofeedback interventions ($d = 1.33$) than the no treatment and placebo groups ($d = .26$). Thus, evidence about the effectiveness of biofeedback based on this meta-analysis is mixed.

A limitation of biofeedback interventions is that the mechanism underlying change is not well understood. Many of the studies reviewed by Crider and Glaros employed biofeedback as a way to reduce EMG activity in the masticatory muscles, the assumption behind this practice being that hyperactivity in these muscles causes or maintains TM disorders. However, there is inconclusive evidence to support this theoretical justification as older research showed high levels of EMG activity for TM disorder patients (Dahlstrom, Carlsson, Gale & Jansson, 1985; Kapel, Glaros, & McGlynn, 1989), and more recent research has not (Carlson et al., 1993; Glaros, 1996). Overall, the empirical support for the use of biofeedback interventions is hindered due mixed efficacy and limited theoretical grounding.

3.3.2. Cognitive-behavioral therapy (CBT)

CBT for chronic pain usually involves interventions that target both maladaptive cognitive processes and behavioral contributions to pain. Three general approaches to chronic pain treatment that fall under the umbrella of CBT. First, CBT for chronic pain typically includes education about the nature of the pain condition. Second, CBT involves behavioral exercises aimed at increasing physical and functional activities; an example of this is behavioral activation, in which patients are encouraged to pursue activities they usually avoid due to pain (e.g., work, social events). Finally, patients are presented with cognitive exercises to help alter their responses to pain; examples include cognitive restructuring and problem solving (Turk & Okifuji, 1999). Large, quantitative review papers support the efficacy of CBT for treating chronic pain conditions (Morley, Eccleston, & Williams, 1999; Turner & Romano, 2001); however, these papers addressed a wide range of conditions with little exploration of the efficacy of CBT for TM disorders specifically. Orlando, Manfredini, Salvetti and Bosco (2007), however, recently published a qualitative literature review of biopsychosocial interventions for TM disorders, and included in this review were five RCTs addressing the efficacy of CBT interventions. Studies were included in the review if they compared CBT interventions to a control group and included only TM disorder patients. One of the studies was a controlled trial, in which a CBT intervention was compared to no treatment, and four were comparative trials, in which CBT was contrasted with an alternative therapy (3 comparison groups were treatment as usual and 1 was a self-care education class). Across these five studies, several outcome measures were examined, including pain severity, life interference due to pain, psychological symptoms, and range of motion. Compared to the control/comparison conditions, three of the 5 studies found that CBT was better able to reduce psychological symptoms, and two of the 5 reported that CBT was better able to reduce pain severity and life interference. Results from these studies, therefore, suggest the efficacy of CBT for TM disorders is modest, but may be limited to subjective (e.g., pain severity) as opposed to objective (e.g., range of movement) outcomes.

3.3.3. Relaxation training

Relaxation training can be defined as a heterogeneous group of interventions that aim to induce muscle relaxation, reduce sympathetic nervous system tone, and suppress neuroendocrine responses associated with unfavorable environmental conditions. Methods used to achieve these aims include progressive muscle relaxation, autogenic relaxation, yoga, and meditation. Relaxation training can be contrasted with CBT in that it does not include efforts to change maladaptive thought patterns or behaviors that extend beyond the scope of relaxation (e.g., work or social behaviors). However, relaxation techniques are thought to be a suitable tool to address emotional responding in patients with TM disorders.

Orlando et al. (2007) reviewed two studies examining the efficacy of relaxation techniques for the treatment of TM disorders. Studies were included in the review if compared relaxation interventions to a control group and included only TM disorder patients. Both of the reviewed studies (Okeson, Kemper, Moody, & Hadley, 1983; Wahlund, List, & Larsson, 2003) were comparative trials, in which relaxation training was contrasted with occlusal appliances, and both reported significant advantages for occlusal appliances over relaxation training. Specifically, Okeson et al. (1983) found that only patients who received occlusal appliances experienced a significant decrease in muscle tenderness, and Wahlund et al. (2003) found that patients treated with occlusal appliances experienced pain to a lesser degree (frequency and severity) than patients treated with relaxation training, who experienced no significant improvements. Unfortunately, neither study provided a detailed description of the relaxation training, which is a limitation given that this treatment category can be quite heterogeneous. It should also be noted that one of the challenges associated with evaluating the effectiveness of any skills training intervention is insuring that patients have actually learned the skills to a specific criterion level before evaluation occurs, and this was not done in either study. Overall, though, the empirical support for the use of relaxation techniques for TM disorders is not strong as two methodologically sound studies found that relaxation training did not alleviate TM disorder symptoms.

3.3.4. Combined interventions

Although a review paper has not yet been published, three RCTs have been conducted examining the efficacy of combined CBT and biofeedback interventions for TM disorders (Gardea, Gatchel, & Mishra, 2001; Gatchel, Stowell, Wildenstein, & Riggs, 2006; Mishra, Gatchel, & Gardea, 2000). All three of these studies compared a combined CBT-biofeedback intervention group with a biofeedback only group, CBT only group, and no treatment control group. Several outcome measures were examined, including self-reported pain severity, life interference, number of visits to healthcare providers, and psychological symptoms. In each study, the authors concluded that receiving combined CBT-biofeedback led to significant improvements when compared to the no treatment control group. However, an examination of the effect sizes comparing the difference scores (score at 1-year follow-up minus initial scores) for the combined intervention and no treatment control suggest the effects of the interventions were only medium.

3.4. Conclusions

Adopting a biopsychosocial approach to understanding chronic pain represents a groundbreaking advancement from biomedical reductionist approaches because the former acknowledges the importance of psychological factors in maintenance of chronic pain. Surprisingly, treatments based on the biopsychosocial approach, such as biofeedback, relaxation, CBT, and combined interventions, appear to have little success in reducing or eliminating both the physical and psychological problems experienced by TM disorder patients. Authors of the reviews and studies examined above often describe their results as entirely supportive of the biopsychosocial approach, but examination of effect sizes using Cohen's (1988) specifications suggest that the effectiveness of biopsychosocial-based treatments may be modest at best.

Although the biopsychosocial approach to understanding chronic pain represents an informative, thorough way of describing the problems that should be addressed in treating TM disorders, it falls short of providing the most integrative treatment possible. As seen in the treatment outcomes studies reviewed above, the biopsychosocial approach has been applied to the treatment of TM disorders by granting separate attention to each dimension of an individual's pain experience. Generally speaking, traditional medical and dental approaches are used to treat physical symptoms, CBT is used to target cognitive and emotional factors, and biofeedback and relaxation are used to address behavioral factors associated with long-standing pain. In this way, biopsychosocial treatment approaches give little consideration to how changes in physical domains impact psychological domains and vice versa, which would represent true understanding of the complexities in chronic pain. Furthermore, since TM disorders are often comorbid with psychological distress, and such distress may significantly influence the course of the disorder, psychological interventions should not operate in parallel to the biomedical management of TM disorders, but should be integrated fully within a system of care that targets the underlying physiological processes that contribute simultaneously to the physical and psychological problems common in TM disorders. Such an approach would represent true integration, and is considered the next logical step in the development of psychological theory and applied psychology in the area of chronic pain.

4. Self-regulation theory and treatment of TM disorders

4.1. Background and conceptualization

ANS dysregulation may represent a common mechanism underlying the major components of TM disorders, contributing simultaneously to the physical, cognitive and emotional problems associated with this disease (Robinson & Riley, 1999). The ANS is comprised of two divisions with differing responsibilities: (1) the sympathetic nervous system organizes and mobilizes energy during periods of threat, and (2) the parasympathetic nervous system carries signals that act to conserve energy during periods of quiescence (for a review, see Robertson, 2004). While sympathetic activation is a normal and adaptive response to stress, chronic sympathetic activation, characterized by heightened physical and psychological responses, can develop in the presence of relentless stressors (Boscarino, 1996; Lepore, Miles, & Levy, 1997; McEwen, 1998). Nociception has been demonstrated as one of the most significant activators of the sympathetic nervous system (Guyton & Hall, 2006), and emotional stress can also lead to sympathetic activation (Lepore et al., 1997; McEwen & Stellar, 1993; Robinson & Riley, 1999). As both nociception and psychological distress are central to chronic pain conditions, it is not unreasonable to expect that patients with chronic TM disorder likely suffer from sustained activation of the ANS.

To examine whether ANS dysregulation is a defining feature of TM disorders, Schmidt and Carlson (2009) examined the physiological and psychological differences between chronic TM disorder patients and pain-free controls. Patients were selected for participation if they met RDC/TM disorders criteria for an Axis I TM disorders diagnosis of masticatory muscle pain, and they were matched with controls on age, height, and weight. The authors measured participants' physiological activation and emotional reactivity while resting (baseline), discussing a personally relevant stressor (stressor), and resting in a post-stressor recovery period (recovery). Schmidt and Carlson found that TM disorder patients showed significantly more physiological activation and emotional reactivity during the baseline and recovery periods than the control participants. This suggests that TM disorder patients are not unique in the way they react to a particular stressor, but are unique in their experience of ANS dysregulation which presents as prolonged sympathetic activation. Compared to controls, TM disorder patients also reported more anxiety following the baseline period and more anger following the recovery period, which suggests emotional reactivity may contribute to the physiological dysfunction among TM disorder patients.

There is additional evidence of physiological dysregulation among persons with chronic TM disorders. Compared to matched normal controls, TM disorder patients with muscle pain have been shown to have excessive cardiovascular activity (Curran, Carlson, & Okeson, 1996), less heart rate variability (Schmidt & Carlson, 2009), lower diastolic blood pressure (Carlson et al., 1998), higher systolic blood pressure (Carlson et al., 1993), altered breathing rates (Curran et al., 1996), and lower end tidal carbon dioxide levels in the blood (Carlson et al., 1998). Thus evidence suggests there are distinct and clinically meaningful physiological differences between persons with and without TM disorders, namely, overactivation of the sympathetic nervous system. Regardless of whether ANS dysregulation is activated by physical or psychological triggers, such activation may have significant effects on nociceptive transmission and subsequent pain experiences. So, although it is unclear whether physiological dysregulation is a consequence and/or causative factor in an individual's chronic pain experience, better self-regulation of physiological activation can be regarded as an important treatment goal for persons with TM disorders and other chronic pains.

Self-regulation theory (Carver & Scheier, 1982, 1998) is a useful framework to address the physiological dysregulation that contributes to the physical and psychological problems reported by TM disorder patients. The goal is to provide TM disorder patients with interventions that facilitate behavioral changes that have been demonstrated to positively impact the physiological dysregulation described above. Self-regulation (sometimes referred to as self-control) refers to the capacity to override impulses or modify responses, including thoughts, emotions, desires, and performance tendencies (Baumeister, 2005). The primary assumption in applying self-regulation theory to the management of TM disorders is that individuals have the capacity to change their behavioral repertoire in a manner that regulates better the physiological domains contributing to their pain condition. Thus, it is important to appreciate that the self-regulation literature has ample evidence that humans can regulate their thoughts, feelings, impulses, and task performances (for a review, see Muraven & Baumeister, 2000). In fact, self-regulation is considered an adaptive quality linked to a range of positive outcomes, including healthier relationships (DeWall, Baumeister, Stillman, & Galliot, 2007), attainment of goals (Duckworth & Seligman, 2005), adherence to moral standards, laws, and social norms (Finkel & Campbell, 2001), better mental health (Galliot, Schmeichel, & Baumeister, 2006), coping skills (Shoda, Mischel, & Peake, 1990), and reduced susceptibility to substance abuse and eating disorders (Tangney, Baumeister, & Boone, 2004). Extending the benefits of self-regulation to the management of painful conditions, therefore, is a reasonable evolution of the theory's application.

The ability to self-regulate has been reported to rely on a limited energy source that is depleted as individuals engage in self-regulatory activities (e.g., resisting temptation), and "ego depletion" is a term used to describe the process by which engaging in acts of self-regulation impairs one's ability to self-regulate on subsequent tasks (e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven & Baumeister, 2000; Segerstrom & Solberg Nes, 2007). Until recently, conceptualizing self-regulatory strength as a limited energy resource served only as a theoretical explanation for the empirical findings in the self-regulation literature. However, Galliot, Plant, Butz, and Baumeister (2007) have provided evidence that the actual energy source implicated in self-regulation may be blood glucose. Related to this point, three important findings have been demonstrated in the literature: (1) acts of self-regulation generally reduce blood glucose levels, (2) low glucose levels predict poorer performance on subsequent self-regulation tasks, and (3) consuming a drink containing glucose eliminates impairments in performance on a second self-regulatory task (Fortenberry et al., 2009; Galliot et al., 2007). Overall, these findings suggest one's ability to self-regulate effectively is dependent upon a limited energy resource, namely blood glucose.

Another important finding in the literature is that self-regulatory strength can be extended through exercise and practice (e.g., Muraven, Baumeister, & Tice, 1999). Several studies have shown that self-regulatory practice on one task can lead to improvement in self-regulation on a seemingly unrelated task. For example, Muraven et al. (1999) showed that individuals who monitored their posture for two weeks performed better on a grip strength task than control subjects who did not monitor posture. In another study, Oaten and Cheng (2007) found that persons randomly assigned to maintain a two month exercise program, which presumably requires self-regulation for adherence, performed better than a control group on subsequent self-regulation laboratory tasks. The finding that self-regulatory strength can be increased has important implications for the general public, and TM disorder patients, in particular.

Recently, Solberg Nes (2009) explored whether chronic TM disorder and fibromyalgia pain patients were more vulnerable to self-regulatory fatigue as compared to matched normal controls. In this study, participants were given an experimental self-regulation task followed by a persistence task. Consistent with other findings in the self-regulation literature, results demonstrated that participants in the high self-regulatory condition persisted less than participants in the low self-regulatory condition. Overall, it was found that the chronic pain patients persisted less than controls. It is equally important to highlight that chronic pain patients in the low self-regulatory condition displayed similar persistence as patients and controls in the high self-regulatory condition, indicating that TM disorder and fibromyalgia patients suffer from chronic self-regulatory fatigue. These results indicate that persons with chronic pain conditions do indeed struggle with self-regulatory deficits.

Increasing self-regulatory strength is believed to facilitate one's capacity for the behavior changes necessary to impact the ANS dysregulation implicated in the physical and psychological problems associated with TM disorders. Since coping with physical pain and emotional distress can lead to depletion of self-regulatory resources, improvements in these areas may lead to increases in self-regulatory strength. Thus, the relationships among self-regulatory strength, ANS regulation, physical and psychological functioning are thought to be highly correlated. See Fig. 1 for a summary of these relationships.

4.2. Clinical applications

In light of literature suggesting that ANS dysregulation is associated with chronic TM disorders, Carlson and Bertrand (1995) developed an intervention that directly targets the physiological factors that differentiate TM disorder patients from healthy controls. This intervention, known as physical self-regulation (PSR), involves several elements, all of which were designed to increase a TM disorder patient's ability to self-regulate her or his physical and psychological state. Components of PSR include the following, each of which will be discussed in turn: (1) education and reassurance, (2) strategies to monitor and reduce muscle parafunction, (3) proprioceptive awareness training, (4) postural relaxation training, (5) diaphragmatic breathing entrainment to criteria, (6) methods of improving sleep onset, and (7) instruction regarding physical activity, diet, and fluid intake (Carlson & Bertrand, 1995; Carlson, Bertrand, Ehrlich, Maxwell, & Burton, 2001). When working with TM disorder patients, PSR training involves three 50-minute sessions (2 training and 1 follow-up session) and daily home practice. In the first session, all components of PSR, except for diaphragmatic breathing entrainment, are discussed. In the second session, skills covered in the first session are reviewed, home practice is discussed, and instruction in diaphragmatic breathing occurs. In the third and final session, all

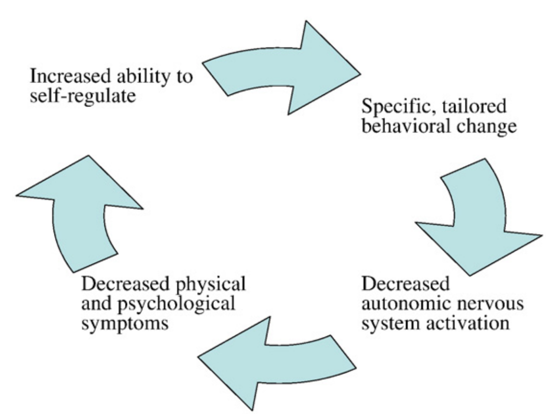

Fig. 1. Relations among self-regulatory strength, behavioral change, autonomic nervous system functioning, physical and psychological symptoms.

components of PSR are reviewed and any remaining questions are answered.

Before PSR skills are introduced to TM disorder patients, information about the role of pain and possible etiologic mechanisms accounting for the patient's presenting pain complaints are presented. Once this information exchange between patient and provider is accomplished and patients understand fully that PSR is designed for management of trigeminally-mediated painful conditions and, therefore, does not have curative intent, PSR skills training proceeds. It is important to note that patients are told that each component of PSR should be done without increasing the patient's sense of discomfort or pain.

The first PSR skill taught to patients involves monitoring and reducing muscle parafunction in the head and neck region. Since unnecessarily using the muscles of mastication (e.g., clenching one's teeth) can cause muscle fatigue, pain, and tissue damage in the head and neck region (Huang et al., 2002; Okeson, 2007), TM disorder patients are taught rest positions for the jaw, lips, and tongue. In addition, patients' habitual head and neck position are examined and those who carry their heads slightly forward or tilted to one side are taught how to recognize and correct this maladaptive behavior. Building upon these skills, proprioceptive awareness training is undertaken to improve better symmetric head and neck posture, gently stretch the muscles of the neck and shoulders, and help patients learn neutral shoulder positions. The importance of head position on muscle efficiency has been demonstrated experimentally (Mayoux-Benhamou & Revel, 1993), thus correcting patients' maladaptive habits is thought to be an important PSR skill.

As TM disorder patients commonly report psychological distress (Burris, Cyders, de Leeuw, Smith, & Carlson, 2009; de Leeuw, Bertoli, et al., 2005; Yatani et al., 2002), relaxation is introduced as the next PSR skill. The method of relaxation used in PSR training is consistent with Poppen's (1998) behavioral relaxation and consists of first making patients aware of body positions that promote relaxation, and then having patients put themselves in positions of rest. The goal of this aspect of PSR training is to teach patients to take brief relaxation breaks throughout their day, in addition to setting aside time for sustained periods of relaxation at least once or twice daily.

As described earlier, poor sleep is considered both a perpetuating factor and consequence of the pain associated with TM disorders (de Leeuw, Studts, et al., 2005; Yatani et al., 2002). Therefore, PSR training incorporates guidelines for improving sleep onset, duration, and quality as an attempt to interrupt the pain–fatigue–sleep disturbance cycle thought central to chronic TM disorders and other pain conditions (Carlson, 2007). A National Institutes of Health (1995) consensus panel suggested that in the treatment of some sleep problems (e.g., insomnia), relaxation techniques might have positive effects by decreasing sympathetic nervous system activity and increasing parasympathetic system activity. Since there is reason to believe patients with TM disorder suffer from ANS dysregulation, relaxation training was incorporated into recommendations regarding sleep onset. Specifically, patients are instructed to begin sleep in a posturally neutral position, and if needed, to use imagery techniques to induce the relaxation response needed before sleep.

PSR training also involves instruction regarding physical activity, diet, and fluid intake. Briefly stated, physical inactivity may have negative effects on overall health status (Fontaine & Haaz, 2007; Motl, McAuley, Snook, & Gliottoni, 2009), painful symptoms (Motl et al., 2009; O'Connor, 2006), and mood (Motl et al., 2009; Puetz, O'Connor, & Dishman, 2006). For these reasons, TM disorder patients are encouraged to increase their physical activity in a manner that does not increase pain symptoms. For most patients this involves beginning a graded walking program starting with five minutes once a day and increasing the amount of time spent walking at a 3 to 4-mile per hour pace until the individual can sustain 45 to 60 min of continuous walking. Of course, as with any physical activity change in individuals over the age of 35 years, physician approval is sought before the patient engages in this dimension of the PSR protocol.

Understanding that a balanced diet and adequate fluid intake are also important aspects of a healthy lifestyle, PSR incorporates appropriate recommendations about behavioral change in these areas. Many TM disorder patients must be reminded to develop or maintain healthy nutritional habits, especially since this aspect of a healthy lifestyle may have been neglected in the presence of chronic pain. Additionally, the finding that some TM disorder patients have lower resting diastolic blood pressure than matched normal controls (Carlson et al., 1998) could be due to blood pooling in venules as a consequence of sustained sympathetic activity (Guyton & Hall, 2006). One potential implication of venous pooling is diminished tissue perfusion (Clark, Polle-Wilson, & Coats, 1996; Reddi & Carpenter, 2005), and increasing fluid intake is a possible solution to this problem (Carlson et al., 2001); therefore, patients are encouraged to increase fluid intake with a general marker of adequate hydration being that urine is light in color and clear.

Finally, diaphragmatic breathing entrainment involves teaching patients to meet two criteria for their breathing: (1) 4 to 6 breaths per minute when deliberately engaging in diaphragmatic breathing (Noms, Fabriom, & Oikawa, 2007; Song & Lehrer, 2003), and (2) sole reliance on diaphragmatic function during inspiration so that the accessory muscles of inspiration (e.g., scalene, sternocleidomastoid, and cervical paraspinals) can rest. The inclusion of slow, diaphragmatic breathing in the PSR protocol assists in increased carbon dioxide levels, which can inhibit trigeminal pain pathways (Casale et al., 2006). Since end tidal carbon dioxide levels have been found to be lower for TM disorder patients than normal individuals (Carlson et al. 1998), promoting an increase in the concentration of carbon dioxide dissolved in the blood can beneficial for TM disorder, and other chronic pain, patients (Casale et al., 2006). Another potential benefit of criterion-training patients in diaphragmatic breathing is the associated increase in HRV (Song & Lehrer, 2003) and feelings of relaxation. Overall, diaphragmatic breathing training can have direct affects on the physiological functioning of TM disorder patients, while also providing patients with a greater sense of self-efficacy in their ability to regulate their pain condition.

4.3. Evaluation of PSR

To evaluate efficacy of PSR for treating chronic TM disorder, Carlson et al. (2001) conducted a RCT. In their study, 44 individuals meeting RDC/TM disorder criteria for an Axis I muscle disorder were randomly assigned to PSR training or standard dental treatment. For those assigned to the PSR condition, training was presented during two 50-minute sessions spaced 3-weeks apart. For all other patients, treatment included fabrication, delivery, and adjustment of an occlusal appliance. Post-treatment evaluations, which took place 6 and 26 weeks after the initiation of treatment, were conducted by a third dentist who was blinded to participants' experimental condition. While both groups showed improvements from baseline to the 6 week follow-up, the PSR group demonstrated greater improvement than the comparison group at the 26 week follow-up on measures of both pain and clinical functioning. To illustrate, PSR participants reported less pain severity and greater range of movement with and without pain than persons receiving dental treatment. Group differences at the 26 week follow-up were not found on all measures of psychological functioning, though overall affective distress decreased significantly over time for PSR participants. The average effect size comparing PSR to dental treatment at the 26 week follow-up was large and clinically meaningful ($d = .96$). Given that each component of PSR was designed to modify directly the physiological dysregulation found to be characteristic of TM disorder patients, and increased self-regulatory ability can mediate significant change, results of Carlson et al. constitute evidence that interventions consistent with self-regulation theory can alter both physical and psychological health status.

When evaluating available data pertaining to application of self-regulation to the management of TM disorders, it is important to give equal consideration to the strengths and limitations of the study just reviewed. Several strengths, including the quality of the study design and careful reporting of the sample, treatment protocols, and statistical analyses performed should be appreciated. Also, by comparing PSR to an appropriate control and having dentists administer both interventions, Carlson et al. made deliberate attempts to control for the possibility of placebo effects (Bootzin, 1985; Ross & Olson, 1981). Further, the use of standardized outcome measures and a longer-term follow-up were notable. The major limitation of the current study, of course, is the sample size and focus on patients with masticatory muscle pain only. As replication of the study findings has not been accomplished by Carlson et al. and the protocol has not yet been examined by an independent research group, generalizability of study findings is also an important consideration.

4.4. Conclusions

The Carlson et al. (2001) paper illustrates two important dimensions to consider in the application of self-regulation theory (Carver & Scheier, 1982; 1998) to understanding and treatment chronic pain. First, premises of the theory were embedded in the PSR approach to management of TM disorders. Aware that the capacity to self-regulate requires an energy source that may be depleted without renewal (e.g., Segerstrom & Solberg Nes, 2007), TM disorder patients were instructed in healthy diet and fluid intake to ensure the glucose levels necessary for effortful behavioral change. Similarly, since there is evidence self-regulatory strength can be extended through practice (e.g., Oaten & Cheng, 2007), treatment requires daily practice of PSR skills. Further, the generalization of self-regulatory strength is encouraged by introducing PSR in a manner such that mastery of one skill makes mastery of the next skill introduced simpler. The second dimension to consider is that PSR targets the underlying physiological dysregulation that has been documented among chronic pain patients, including chronic activation of the sympathetic nervous system, low end tidal carbon dioxide, and little HRV. In this way, the behavioral change interventions included in PSR training are designed to reverse, or at the least halt, self-regulatory deficits. Overall, the approach taken by Carlson et al. demonstrates the manner in which principles of self-regulation can be applied to the management of chronic pain.

5. Summary and conclusions

The purpose of the present paper was to present self-regulation theory (Carver & Scheier, 1982, 1998) as a framework for understanding and treating chronic pain disorders, and TM disorders were used as an illustration of how training in self-regulation could be viewed as an integrative treatment approach. First, a review of literature examining the etiology, signs, and symptoms of TM disorders was provided to illustrate the issues that must be targeted for successful treatment. Perhaps most important is an appreciation that in addition to the physical pathology associated with TM disorders (e.g., muscle pain, limited mandibular movements), psychopathology is very prominent. In light of this, we next presented an overview of the biopsychosocial approach to the management of TM disorders, and then discussed what we viewed as limitations. The biopsychosocial model represents a comprehensive approach to treatment by including separate interventions to treat the biological, psychological, and behavioral problems associated with TM disorders. While the biopsychosocial approach has clear theoretical advantages over traditional dental approaches that address only physical pathology, the effectiveness of the interventions associated with this approach are limited because it does not consider how changes in one domain directly influence changes in another. After some discussion, we proposed one intervention that would simultaneously target physical and psychological aspects of TM disorders: physical self-regulation (PSR; Carlson et al., 2001). Since dysregulation in self-regulatory systems is believed to exacerbate all components of an individual's trigeminally-mediated pain experience, streamlined and integrated treatment must be designed to increase self-regulatory strength. As PSR aims to re-direct self-regulatory effort toward regulation of the ANS, behavioral and emotional responses, it is useful in managing chronic TM disorders and observed benefits may be extended easily to other chronic pain conditions.

6. Directions for future research

Research is needed to determine whether PSR can be applied successfully to the management of other chronic pains. Fibromyalgia is a disorder of aberrant central pain processing (Goldenberg, Burckhardt, & Crofford, 2004), and because it is often associated with psychopathology, sleep dysfunction, and fatigue (Epstein et al., 1999; Theime, Turk, & Flor, 2004; Wolfe et al., 1990), it shares many commonalities with chronic TM disorders. For this reason, the next logical step in the application of self-regulation theory (Carver & Scheier, 1982, 1998) to the management of chronic pain disorders is to test whether the major dimensions of Carlson et al.'s (2001) treatment program are effective at changing the physical and psychological problems associated with fibromyalgia. If it is found that PSR's benefits are limited to TM disorders, then more generalizable interventions should be developed, and their efficacy evaluated in RCTs.

In addition, efforts should be made to disaggregate the components of PSR that are most important in altering the physiological states of chronic pain patients. In other words, it is time to determine the mechanism of action most relevant for positive change. A preliminary study found HRV biofeedback mediates clinically significant changes in depression and pain outcomes among fibromyalgia patients (Hassett et al., 2007). Thus, it could be the case that increasing HRV through diaphragmatic breathing entrainment is the most important aspect of PSR training. If so, perhaps PSR training could be streamlined considerably and only the most potent components used with chronic pain patients.

Since engaging in self-regulation is often a difficult task even under the best of circumstances, providers responsible for the delivery of treatment to persons with chronic pain would benefit from knowledge regarding reliable methods for enhancing self-regulatory strength. As we discussed earlier, there is a growing database describing the relationships between blood glucose level, glucose utilization, and self-regulatory capacity (Fortenberry et al., 2009; Gailliot et al., 2007), and this knowledge may have significant implications for an individual's capacity to engage successfully in the self-regulatory processes required for achieving better health. Therefore, future research should examine the potential effects of chronic pain patients' blood glucose level, glucose utilization, and insulin sensitivity on physical outcomes during PSR. Additionally, it has been demonstrated that self-regulatory capacity can be extended through practice. Thus, future research should evaluate what effect, if any, developing one's self-regulatory “muscle” in one area (e.g., avoidance of tobacco use) has on one's capacity to acquire PSR skills.

In conclusion, building on current formulations of chronic pain, the authors proposed that the experience of sustained nociception and associated psychological distress leads to or maintains ANS dysregulation. With focused efforts to increase self-regulatory strength and alter the physiological dysregulation common among chronic TM disorder patients, PSR may be seen as an integrative treatment approach that warrants further consideration in the management of chronic pain. Treatment approaches, like PSR, that serve to regulate better the ANS through enhanced self-regulatory capacity provide a streamlined way of addressing the equally important physical and psychological components of the chronic pain experience.

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