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Biofeedback in the Treatment of Headache and Other Childhood Pain

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Since the first biofeedback (BFB) studies on pediatric pain were published in the early 1980s, most of the studies have focused on the treatment of pediatric migraine. More recently, BFB has also been evaluated in the treatment of tension headache in children. Not surprisingly, most of what we know about the efficacy and mechanisms of BFB in the treatment of children's pain problems concerns the treatment of childhood headache (HA). In this review, we provide a detailed summary of studies that have evaluated BFB in the treatment of childhood HAs with an emphasis on treatment outcome and maintenance of treatment success. Moreover, findings and hypotheses with regard to the mechanisms that may mediate the treatment effects of BFB are addressed. Finally, we discuss specific issues relating to the treatment of pain in children with BFB and outline future directions of research.

KEY WORDS: childhood pain; pediatric headache; biofeedback; efficacy; treatment mechanisms.

INTRODUCTION

Children experience pain from a number of different sources. Pediatric pain problems that have been the target of medical and/or psychological interventions are procedure-related pains (e.g., venipuncture, bone marrow aspiration), disease- or trauma-related chronic pain (e.g., rheumatoid arthritis, cancer, sickle cell anemia, burns), and recurrent pain of benign origin (e.g., primary headaches [HAs], abdominal pain).

Aside from acute pain, recurrent pain without an underlying disease is the most common type of pain condition during childhood and adolescence. The prevalence of HA, and especially migraine has been most extensively studied (for a general review, see Goodman & McGrath, 1991). Migraine has been estimated to affect between 3 and 10% of children and adolescents depending on age and sex (e.g., Linet, Stewart, Celentano, Ziegler, & Sprecher, 1989; Sillanpää, 1983a, 1983b). The total prevalence of HA tends to be somewhat higher (Passchier & Orlebeke, 1985) and seems to have increased over the past 25 years.

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For example, Sillanpäa and Anttila (1996) found that HA had a prevalence of 51.5% among 7-year-olds in 1992 as compared to 14.4% in 1974. Weekly HAs may affect up to 30% of children and adolescents aged 10–17 years (Mikkelsson, Salminen, & Kautiainen, 1997; Passchier & Orlebeke, 1985; Rhee, 2000). The specific prevalence of tension HA is unknown, because most epidemiological studies did not apply adequate diagnostic criteria. Recurrent abdominal pain (RAP) has been estimated to occur in approximately 10–15% of school-aged children (Apley, 1975; Faull & Nicol, 1986; Hyams, Burke, Davis, Rzepski, & Andrulonis, 1996; Oster, 1972). Recent epidemiological surveys suggest that weekly nonspecific musculoskeletal pains may affect up to one third of school children between the ages of 9 and 12 years and persist in about half of these children at least for 1 year (Mikkelsson, Salminen, & Kautiainen, 1997; Mikkelsson, Salminen, Sourander, & Kautiainen, 1997).

Despite the obviously common occurrence of recurrent pain in children and adolescents, conclusions with regard to its severity and with regard to recurrent pain as a health problem are difficult to draw. In fact, the majority of children tend to cope quite well and never seek medical/psychological treatment. Because of the rather soft criteria used to assess HA (except migraine) and other pain problems in most studies, the prevalence data are likely to overestimate the actual need for treatment in children. Although they are scarce, prognostic data suggest that about a third of children reporting recurrent pains will simply outgrow this problem (Bille, 1989; Mikkelsson, Salminen, Sourander, et al., 1997). Yet, in a subgroup of children, recurrent pain tends to persist. In a 5-year follow-up, children with RAP were more likely to suffer from abdominal pain and other somatic symptoms and reported higher levels of functional disability than did control children (Walker, Garber, Van Slyke, & Greene, 1995; Walker, Guite, Duke, Barnard, & Greene, 1998). An impressive 30-year follow-up of Swedish pediatric migraineurs revealed that one third of the children continued to suffer from migraine throughout the 30-year period (Bille, 1989). Furthermore, in a recent longitudinal study it was found that children who complained about HAs at least once a month at age 7, 9, or 11 were more likely to have developed combined HA at age 26 (Waldie, 2001). Thus, recurrent pain during childhood may increase the risk of a lifetime of chronic pain, at least in a subgroup of children. From this perspective, the treatment of recurrent pain in children and adolescents is not only important as a primary intervention (at least for some of the children), but may also constitute an important measure of secondary prevention.

BIOFEEDBACK FOR CHILDHOOD PAIN AND THE EMPIRICAL LITERATURE

Since the mid-1970s when the undertreatment of pain in children was beginning to be acknowledged, increasing efforts have been made to develop psychological pain management programs for children. Cognitive–behavioral treatments exist for almost all of the different types of childhood pain, whereas biofeedback (BFB) treatments have primarily been developed and evaluated for recurrent pain conditions. Skin temperature or thermal biofeedback (TBF; i.e. volitional handwarming) and EMG-BFB from the m. frontalis are the types of BFB that have been evaluated most often in the treatment of childhood (and adult) pain.

Searching PsychInfo or Medline using variations of key words such as pain, BFB child/pediatric/adolescent yields about 50 publications since 1980. A closer look reveals that a substantial number are reviews and overviews describing the usefulness of BFB in

the treatment of HA (e.g., Holden, Deichmann, & Levy, 1999), disease-related symptoms (e.g., McQuaid & Nassau, 1999), chronic pain (e.g., Murphy & Carr, 2000), or childhood disorders in general (e.g., Barowsky, 1990; Culbert, Kajander, & Reaney, 1996). In fact, there are about as many reviews and overviews as there are empirical studies that provide actual treatment data based on controlled single-case or group studies.

In our review, we attempt to provide a summary of the available empirical evidence for the effectiveness of BFB for different childhood pain problems, address treatment mechanisms, and discuss child-related issues of BFB treatments. Because of the preponderance of BFB treatment studies for childhood HA, our review will largely have to rely on what is known about the use of BFB in the treatment of child HA.

CHILDHOOD PAIN AND THE EFFECTIVENESS OF BFB TREATMENTS

Pediatric Migraine

The vast majority of BFB treatment studies that have been published since the mid-1980s has been devoted to pediatric migraine. As can readily be seen in the summary of these studies in Table I, TBF alone, or in combination with other interventions, has been studied most extensively.

With few exceptions (e.g., Allen & Shriver, 1998, condition "TBF alone"), TBF has been proven to be highly successful in alleviating HA activity in children. In fact, in most studies more than two thirds of the children could be classified as treatment successes based on the widely accepted criterion of a 50% symptom reduction (Blanchard & Schwarz, 1988). If one considers the effect sizes (*ES*s) based on the pre- to postimprovement[4] ("within-group" *ES*; for details, see Hermann, Kim, & Blanchard, 1995), the average *ES* of 2.2 suggests excellent efficacy. Moreover, the average *ES* based on all studies published since the 1980s (with the exception of Labbé, 1995) is comparable to the *ES* of 2.57 we had reported in our 1995 review based on a total of five studies. This suggests a considerable robustness of TBF efficacy across studies. Unfortunately, TBF has not directly been compared to a credible placebo condition or other potentially efficacious treatments such as cognitive behavior therapy (CBT) in children. If the evaluation criteria of the Task Force on Promotion and Dissemination of Psychological Procedures (1995) are applied, TBF for pediatric migraine is to be categorized as probably efficacious, but does not qualify as a well-established intervention (as it does for adults) that requires the demonstrated superiority over placebo or other alternative treatments.

Although the studies summarized in Table I leave little doubt that TBF is efficacious, treatment outcome is somewhat heterogeneous across studies. Aside from methodological differences, the format of treatment delivery differs between studies. From early on, two TBF formats have been evaluated. The clinic-based treatment typically consists of 10–12 TBF

[4]Unlike the traditional approach comparing a treatment group and a control group ("between-group" *ES*), an *ES* can also be derived from pre- to posttreatment changes within a treatment or control group ("within-group" *ES*; e.g., Kraemer & Andrew, 1982). Because of computational differences, Cohen's rule of thumb for small ($0.2 < ES < 0.5$), medium ($0.5 < ES < 0.8$), and large between-group *ES* (>0.8) cannot be used for interpreting within-group *ES*s (Cohen, 1987). According to a study comparing different between-group and within-group approaches to derive an *ES*, a within-group *ES* greater than 1 reflects a medium-to-large effect (Hartmann & Herzog, 1995).

Table I. Overview of Treatment Studies Using Biofeedback for Pediatric Migraine

	Study design	Treatment	Patients	Treatment outcome[a]	Long-term follow-up[b]
Thermal biofeedback					
Andrasik et al. (1984)	Randomized wait list control: TBF vs. PMR vs. wait list	*TBF*: 10 sessions over 8 weeks; *PMR*: 10 sessions over 8 weeks	*TBF*: $N = 14$, *PMR*: $N = 16$, *wait list*: $N = 18$; age range: 8–17 years	*TBF*: $N = 12$ succ. (85.7%); $ES = 3.22$; *PMR*: $N = 10$ succ. (71.4%); $ES = 1.72$; *wait list*: $N = 4$ succ. (22.2%), $ES = 0.71$; outcome variable: HA index	6-month FU suggests maintenance of treatment outcome
Labbé and Williamson (1984)	Randomized wait list control: TBF vs. wait list	10 sessions of TFB (15-min adaptation + BL, 5-min self-control, 15-min BFB, 5-min self-control) *Note.* $N = 10$ of the wait list controls received TBF subsequent to the waiting period	*TBF*: $N = 14$ (7 M/7 F; mean age = 10.6 years, age range: 7–14 years); *wait list*: $N = 14$ (7 M/7 F; mean age: 10.8 years, age range: 7–16 years)	*TBF*: $N = 13$ succ. (92.8%), $ES = 4.74$; *wait list*: $N = 1$ succ. (0.7%), $ES = 0.37$; outcome variable: HA index	6-month FU (data available for $N = 13$ of all $N = 24$ treated patients): $N = 8$ succ. (61.5%), $ES = 1.65$
Burke and Andrasik (1989)	Multiple baseline: TBF only	*Clinic-based TBF*: 10 sessions (20-min actual TBF) over 8 weeks and regular home practice; *child- or parent-administered home-based TBF*: 3 sessions with therapist, 7 manual-guided home sessions (administered by child or parent), regular home practice	*Clinic-based TBF*: $N = 3$ (3 M; mean age = 11 years); *child-administered TBF*: $N = 3$ (2 M/1 F; mean age = 12.6 years); *parent-administered TBF*: $N = 3$ (1 M/2 F; mean age = 10.6 years); age range: 9–14 years	Total $N = 7$ succ. (77.8%); overall $ES = +2.30$ *Note*. Outcome is based on all patients because there were no apparent differences between treatment formats; outcome variable: HA index	6-month FU ($N = 7$): $N = 5$ succ. (71%); 8-month FU ($N = 8$): $N =$ 7 succ. (87.5%)
Guarnieri and Blanchard (1990)	Multiple baseline: TBF only	*Clinic-based TBF*: 10 sessions (12-min actual TBF) over 8 weeks, daily home practice (12–15-min); *home-based TBF*: 4 sessions TBF in clinic over 8 weeks, manuals for home training, daily home practice	$N = 17$ (6 M/11 F; mean age: 10.9 years, age range: 8–16 years); $N = 1$ dropout, thus $N = 8$ completers per TBF format	*Clinic-based TBF*: $N =$ 5 succ. (62.5%); *home-based TBF*: $N = 3$ succ. (37.5%); overall $ES = 1.33$ (*Note*. There were no significant differences between treatment formats) outcome variable: HA index	4 month FU ($N = 5$ children): 4 succ. (80%)

Allen and McKeen (1991)	Multiple baseline: TBF only	*Home-based TBF*: 3 clinic sessions (10-min BL, 10-min BFB, 5-min self-control trial) and daily home practice, in Session 2: parental instruction not to reinforce pain behavior	$N = 21$ (age range 7–12 years)	Outcome data refer to $N = 15$ patients who were compliant with home practice and parental guidelines: $N = 13$ succ. (86.7%), $ES = 3.38$; outcome variable: HA index	8-month and 3.5-year FU data (Kuhn & Allen, 1993): HA reduction was maintained 8 months after treatment, but had returned to baseline 3.5 years after the initial treatment
Labbé (1995)	Randomized group design: TBF vs. AT vs. wait list	*TBF*: 10 sessions (15-min BL, 15-min BFB, 5-min self-control) across 7 weeks; *AT*: 10 sessions	Total $N = 30$ (17 M/13 F; mean age = 12 years, age range: 8–18 years) with $N = 10$ per group	*TBF*: $N = 10$ succ. (100%) *AT*: $N = 9$ succ. (90%), *wait list*: 6 succ. (60%); outcome variable: HA frequency	6-month FU ($N = 30$): *TBF*: $N = 9$ succ. (90%); *AT*: $N = 10$ succ. (100%); *wait list*: $N = 1$ success (10%)
Hermann, Blanchard, and Flor (1997)	Clinical trial: TBF	*Home-based TBF*: 4 sessions (4-min BL, 4-min self-control, 6 × 3-min BFB) across 8 weeks, manual for home sessions and regular home practice	$N = 32$ (19 M/13 F, mean age = 11.6 years, age range: 8–16 years)	$N = 22$ succ. (68.8%), $ES = 0.89$; outcome variable: HA index	—
Allen and Shriver (1998)	Randomized group design: TBF with vs. TBF without parent training	*TBF*: 6 sessions (10-min habituation, 2 × 10-min BFB) and daily home practice; *parent training*: education (1 session) about role of learning factors and pain management guidelines; weekly review of implementation of parent guidelines	*TBF alone*: $N = 13$ (4 M/9 F; mean age = 12.3 years); *TBF with parent training*: $N = 14$ (7 M/7 F; mean age = 12 years); age range: 7–18 years	*TBF alone*: 3 succ. (23%), $ES = 0.32$; *TBF with parent training*: 11 succ. (78.6%), $ES = 1.07$; outcome variable: HA frequency	1-year FU: *TBF alone*: 6 succ. (46.1%), $ES = 1.27$; *TBF with parent training*: 10 succ. (71.4%), $ES = 1.77$
Biofeedback and cognitive–behavioral pain/stress management					
Osterhaus et al. (1993)	Nonrandomized wait list control: TBF + CBT vs. wait list (*Note*: Treatment group was first filled)	*TBF + CBT*: 4 individual TBF sessions (10 min adaptation, self-control, TBF), 4 group CBT sessions (education, RET principles, PMR, AT), daily home practice (2×)	*TBF + CBT*: $N = 32$ (8 M/24 F, mean age = 15.2 years); *wait list*: $N = 9$ (2 M/7 F, mean age = 14.3 years), age range: 12–19 years)	*TBF + CBT*: $N = 14$ succ. (45%), $ES = 0.46$; *wait list*: $N = 1$ succ. (11%), $ES = 0.03$; outcome variable: HA index	7-month FU (for *TBF + CBT*): HA reduction continued to improve from end of treatment to FU with a mean reduction of 54%

(*Continued*)

Table I. (*Continued*)

	Study design	Treatment	Patients	Treatment outcome[a]	Long-term follow-up[b]
Sartory, Müller, Metsch, and Pothmann (1998)	Randomized group design: VCT + CBT vs. PMR + CBT vs. Metoprolol	*VCT/PMR + CBT*: 10 sessions PMR or VCT (VCT: 3 min self-contr., 12 min VCT, 3 min self-contr.) and CBT ("stress management"; McGrath et al., 1992) over 6 weeks; *prophylactic med.*: Metoprolol	*VCT+*: $N = 15$ (8 M/7 F; mean age = 11.8 years); *PMR+*: $N = 15$ (9 M/6 F; mean age = 11.4 years); *Metoprolol*: $N = 13$ (9 M/4 F; mean age = 10.5 years); age range: 8–16 years	*VCT + CBT*: $N = 8$ succ. (53.3%), $ES = 0.88$; *PMR + CBT*: $N = 12$ succ., (80%); $ES = 1.00$; *Metoprolol*: $N = 5$ succ. (38.5%), $ES = 0.87$; outcome variable: HA frequency	8-month FU: *VCT + CBT*: $ES = 0.60$ ($N = 10$); *PMR + CBT*: $ES = 0.46$ ($N = 11$); *Metoprolol*: $ES = 0.24$ ($N = 6$)
EEG-biofeedback					
Siniatchkin et al. (2000)	Wait list control (randomization?): CNV-BFB vs. wait list	*CNV-BFB*: 10 sessions (20 trials baseline CNV in standard paradigm; 30 trials CNV increase (+15 transfer trials), 30 trials CNV decrease (+15 transfer trials)	*CNV-BFB*: $N = 10$ (8 M/2 F; mean age = 10.5 years); *wait list*: $N = 10$ (8 M/2 F; mean age = 11.6 years)	*CNV-BFB*: $N = 5$ succ. (50%), $ES = 0.97$; *wait list*: $N = 0$ succ. (0%), $ES = 0.17$; outcome variable: HA index	—
Thermal biofeedback and EMG-biofeedback					
Werder and Sargent (1984)	Open clinical trial: EMG-BFB + TBF	On the average 7 sessions using EMG-BFB and TBF	$N = 19$ (12 M/7 F; mean age = 13.6 years, age range: 7–17 years)	$N = 18$ succ. (94.7%), $ES = 5.71$; outcome variable: N of HA hours per week	1-year FU: $N = 15$ succ. (78.9%), $ES = 2.74$; 2–3-year FU: $N = 12$ succ. (63.1%); $ES = 1.85$
Fentress, Masek, Mehegan, and Benson (1986)	Randomized wait list control: Relax + TBF + EMG-BFB vs. relaxation vs. wait list	*Relax + BFB*: 9 sessions meditative relaxation, during 5 sessions EMG-BFB + TBF; *relaxation*: 9 sessions meditative relaxation; 1st session (both conditions): guidelines for parents how not to reinforce pain behavior	Total $N = 18$ (7 M/11 F, mean age = 10.1 years, age range: 8–12 years); $N = 6$ per group	*Relax + BFB*: $N = 5$ succ. (83.3%), $ES = 2.30$; *relax*: $N = 5$ succ. (83.3%), $ES = 2.30$; *wait list*: $N = 2$ succ. (41.7%), $ES = 1.03$	1-year FU ($N = 5$ per treatment group): no significant change in HA activity from end of treatment to FU suggesting the maintenance of the treatment effects

Mehegan, Masek, Harrison, Russo, and Leviton (1987)	Multiple baseline: EMG-BFB + PMR + operant parent education	9 sessions across 11 weeks: frontal EMG-BFB (4 min BL, 4 min BFB, 4 min BL, 4 min BFB), PMR; first session: guidelines for parents how not to reinforce pain behaviors	$N = 18$ (9 M/9 F; mean age: 10.2 years, age range: 7–12 years)	$N = 16$ succ.; $ES = 3.80$; outcome variable: HA index	6-month FU ($N = 17$): $N = 14$ succ. (82%), $ES = 2.88$; 12-month FU ($N = 17$): $N = 11$ succ. (76%), $ES = 2.41$
Womack, Smith, and Chen (1988)	Open clinical trial: EMG-BFB and/or TBF	8 sessions of EMG-BFB and/or TBF, daily relaxation (PMR or meditative or mental imagery)	Total $N = 56$ ($N = 29$ migraine, $N = 27$ mixed HA, age range: 4–20 years)	$N = 44$ succ. (78.6%), $ES = 2.67$; outcome variable: HA frequency	—

Note. The effect sizes (*ES*s) for long-term follow-up data were only computed if the same outcome variable (e.g., HA frequency) was used as for the pre–post comparison, and if the provided outcome data were of the same nature (e.g., mean/standard deviation, *p* value, etc.) as the pre–post outcome data. AT = autogenic training; CBT = cognitive behavior therapy; CNV = contingent negative variation; *ES* = effect size; PMR = progressive muscle relaxation; RET = rational–emotive therapy; TBF = thermal biofeedback; VCT = vasoconstriction training; FU = follow-up; HA = headache.

[a] If possible, two indices of treatment outcome were obtained: Number of treatment successes (succ.) defined as a reduction of HA activity of at least 50% and within-group effect size (*ES*) based on the pre- to postchange in headache activity. If the standard deviation for the within-group change was not provided, it was estimated based on the pooled standard deviations for the time points included in the comparison.

[b] If sufficiently detailed information was provided, number of treatment successes and effect size are indicated. If follow-up data were not available for all treatment completers, the number of patients included in the follow-up is given in parentheses.

sessions that are administered by a trained clinician (e.g., Labbé & Williamson, 1984). In the home-based format the children typically receive about three therapist-guided BFB sessions, the remaining treatment program includes self-administered, manual-guided home sessions and home practice (e.g., Allen & McKeen, 1991; Burke & Andrasik, 1989). Although the direct comparison between clinic- and home-based TBF formats (Guarnieri & Blanchard, 1990) has failed to show a reliable difference in efficacy, probably because of a lack of statistical power, home-based TBF tends to yield less improvement than does therapist-administered TBF. This situation probably accounts substantially for the heterogeneity of TBF efficacy across studies. For example, in the Hermann et al. (1997) study, which involved the largest sample of pediatric migraineurs treated in a home-based TBF format, approximately 69% of the children were clinically improved as compared to success rates of up to 100% that have been obtained for clinician-administered TBF (e.g., Andrasik et al., 1984; Labbé, 1995; Labbé & Williamson, 1984). At this point, little is known about why home-based TBF as compared to clinic-based TBF tends to be less successful. It is certainly not the case that older children are necessarily better suited for receiving home-based TBF (Hermann et al., 1997). One may speculate that clinic sessions guarantee a certain amount of regular TBF practice time, whereas actual practice time is hard to control in a home-based treatment format. Moreover, children may more easily acquire a sense of self-control when regularly reinforced by a therapist. Also, regular contacts with a therapist could facilitate the transfer of the acquired handwarming skill into daily life by providing contingent feedback to the child about his/her progress. On an individual basis, it is difficult to predict whether home-based TBF or clinician-administered TBF is more successful.

TBF has also been used in combination with EMG-BFB and progressive muscle relaxation (PMR) or cognitive therapy in the treatment of migraine (see Table I). When compared to studies using TBF alone, the combination of TBF and EMG-BFB appears to be at least as efficacious. The only study involving a combination of TBF and CBT (Osterhaus et al., 1993) yielded a lower success rate than did TBF alone that may be partially due to the slightly older patients in this study. Whether EMG-BFB or cognitive therapy adds to the treatment effect above and beyond TBF is unclear, because there are no direct comparisons between TBF and alternative treatments (see also Hermann et al., 1995). A parsimonious interpretation of the outcome data certainly suggests that there is no advantage of adding EMG-BFB or cognitive therapy to TBF. In his review of the adult HA treatment literature, Blanchard (1992) came to a very similar conclusion.

Recently, alternative types of BFB in the treatment of pediatric migraine have been tested. In one study (Sartory et al., 1998), children were taught vasoconstriction of the temporal artery (VCT) by providing feedback of the blood volume pulse amplitude recorded by a photoplethysmographic sensor. Overall, the combination of VCT and stress management was not superior to the combination of PMR and stress management or the prophylactic medication. Although conclusions as to the specific treatment effect of VCT are precluded because of the use of treatment combinations, VCT does not seem to provide an advantage. Again, such a conclusion would be consistent with the adult treatment literature. As Blanchard (1992) pointed out, the specific efficacy of VCT in migraine remains to be demonstrated given the paucity of controlled studies with sufficient sample sizes.

A new BFB approach was evaluated by Siniatchkin et al. (2000). On the basis of findings that migraine is associated with cortical hyperexcitability (e.g., Kropp & Gerber, 1993; Welch, 1998), they trained children suffering from migraine to control the contingent

negative variation (CNV). The CNV is a slow cortical potential that is observed after a warning stimulus when a participant is awaiting an imperative stimulus to perform a response such as pressing a key as fast as possible (for a review, see Birbaumer, Elbert, Canavan, & Rockstroh, 1990). Because slow cortical potentials are presumed to reflect cortical excitability, learning how to self-regulate the CNV may enable the individual to prevent migraine attacks. CNV-BFB has been shown as a promising approach to treat drug-refractory epilepsy by voluntarily reducing the cortical excitation threshold (Kotchoubey, Blankenhorn, Froscher, Strehl, & Birbaumer, 1997). In the study by Siniatchkin et al. (2000), CNV-BFB yielded a moderate success rate of 50%, but was superior to a wait list control. Because of the limited sample size and the lack of other studies, conclusions as to the efficacy of CNV-BFB are not possible at this point. Because BFB of slow cortical potentials requires sophisticated BFB equipment, TBF should remain the treatment of choice until the superiority of CNV-BFB over TBF is demonstrated.

Maintenance

A number of the TBF (alone or combined with EMG-BFB or CBT) treatment studies provide follow-up data for periods of 6 months up to 1 year. Even if there may be a self-selection bias due to the attrition of some of the treatment completers, the data suggest a satisfactory maintenance of the treatment gains, at least for this intermediate time range (see Table I). Yet, given the very limited data on the natural course of pediatric migraine, nonspecific factors such as "simply growing out of the pain problem" cannot be completely ruled out (cf. Hernandez-Latorre & Roig, 2000).

Tension Headache

Contrary to pediatric migraine, few studies have evaluated psychological interventions (BFB or other treatment modalities) for tension HA in children. This may reflect a lesser request for treatment because of a relative infrequency of tension HA or because of other factors influencing treatment participation. Although tension HA is certainly not uncommon in children, the actual prevalence has yet to be determined (see above; Labbé, 1988). Tension HA seems to be more prevalent among adolescents aged 14–15 and above. Not surprisingly, most of the available psychological intervention studies for adolescent tension HA sufferers are therefore school-based relaxation trainings designed for adolescents 14 and above (e.g., Larsson, Melin, & Döberl, 1990). It is also possible that parents and children are less concerned about tension HAs and, therefore, do not actively seek treatment. In addition, the natural course of tension HA may be more variable and include longer intervals of HA remission, again making requests for treatment less likely.

Mirroring the adult treatment literature, EMG-BFB from the m. frontralis has been the BFB modality of choice in the treatment of tension HA in children. Aside from case reports (Andrasik, Blanchard, Edlund, & Attanasio, 1983; Labbé & Ward, 1990), few larger scale or even controlled studies are available that have evaluated the effectiveness of EMG-BFB. If treatment outcome is compared across the three available studies (see Table II), EMG-BFB alone seems to yield remarkably consistent success rates of about 80–90% and an *ES* of about 1.5. Although the *ES* and success rates reported by Kröner-Herwig et al. (1998)

Table II. Overview of Biofeedback Treatment for Tension and Mixed Headache in Children and Adolescents

	Study design	Treatment	Patients	Treatment outcome[a]	Long-term follow-up[b]
EMG-biofeedback					
Grazzi, Leone, Frediani, and Bussone (1990)	Multiple baseline EMG-BFB	24 sessions EMG-BFB (M. frontalis) over 12 weeks (10-min BL, 10-min BFB, 10-min BL), home practice of self-regulation skills	$N = 10$ (5 M/5 F, mean age = 12.8 years, age range: 12–15 years)	$N = 9$ succ. (90%), $ES = 1.52$; outcome variable: HA index	1-year FU: $N = 10$ succ. (100%), $ES = 1.69$
Kröner-Herwig, Plump, and Pothmann (1992)	Nonrandomized group design: EMG-BFB vs. PMR	*EMG-BFB* (*M. frontalis*): 12–30-min sessions over 6 weeks (3-min BL, self-control; 10-min BFB, self-control), home practice of self-regulation skill; *PMR*: 6 weekly 1-h sessions and home practice	*EMG-BFB*: $N = 8$ (3 M/5 F, mean age = 10.6 years, age range: 8–14 years); *PMR*: $N = 8$ (4 M/4 F, mean age = 11.6 years, age range: 9–14 years) *Note*. $N = 2$ mixed HA patients in each group	*EMG-BFB*: $ES = 1.54$; *PMR*: $ES = 1.48$; outcome variable: HA frequency	6-month FU: *EMG-BFB*: $ES = 1.33$ ($N = 8$); *PMR*: $ES = 1.47$ ($N = 7$)
Kröner-Herwig, Mohn, and Pothmann (1998)	Randomized wait list control: EMG-BFB with/without parental involvement vs. PMR with/without parental involvement vs. wait list	*EMG-BFB* (*M. frontalis*): 12–30-min sessions (6–9 min BFB, 2–3 × 2-min self-control trials); *PMR*: 6 sessions, audio cassette for home practice; *parental involvement*: 3 sessions (education, parental guidelines how not to reinforce pain behavior, review of implementation)	Total $N = 50$ (20 M/30 F, mean age = 10.96 years, age range: 8–14 years) with a diagnosis of tension or mixed HA; $N = 10$ per group	*EMG-BFB alone*: $N = 8$ succ. (80%), $ES = 1.41$; *EMG-BFB with parent involvement*: $N = 6$ succ. (60%), $ES = 0.58$; *PMR alone*: $N = 4$ succ. (40%), $ES = 0.18$; *PMR with parent involvement*: $N = 7$ succ. (70%), $ES = 0.52$; *wait list*: $N = 4$ succ. (40%), $ES = 0.25$; outcome variable: HA frequency	6-month FU: *EMG-BFB alone*: $N = 9$ succ. (90%), $ES = 2.07$; *EMG-BFB with parent involvement*: $N = 7$ succ. (70%), $ES = 1.08$; *PMR alone*: $N = 5$ succ. (50%), ES = 0.63; *PMR with parent involvement*: $N = 5$ succ. (50%), ES = 0.55

Biofeedback-assisted relaxation					
Bussone, Grazzi, D'Amico, Leone, and Andrasik (1998)	Randomized placebo-control: EMG-BFB + PMR vs. placebo	*EMG-BFB (M. frontalis) + PMR*: initially 4–20-min sessions PMR, then 6–21-min sessions BFB (7-min baseline, 7-min BFB, 7-min self-control); *Placebo*: 10 sessions, EMG was recorded while participants sat calmly and tried to relax on their own, no feedback was provided; in both conditions: 2 sessions per week	*EMG-BFB + PMR*: $N = 20$ (10 M/10 F), mean age = 11.1 years, *Placebo*: $N = 10$ (5 M/5F), mean age = 13 years; all patients: IHS-diagnosis of episodic tension HA; age range: 11–15 years; during baseline: sign. higher HA activity in the placebo group	*EMG*-BFB + PMR: mean HA reduction: 54.2%, *ES* = 0.9; *Placebo*: mean HA reduction: 56.5%, *ES* = 1.0; outcome variable: HA index	*3-month FU-EMG-BFB + PMR*: mean HA red.: 58.2%, *ES* = 0.83; *3-month FU-Placebo*: mean HA red.: 63.7%, *ES* = 1.16; *6-month FU-EMG-BFB + PMR*: mean HA red.: 75.9%, *ES* = 1.36; *6-month FU-Placebo*: mean HA red.: 63.3%, *ES* = 1.14; *1-year FU-EMG-BFB + PMR*: mean HA red.: 86.0%, *ES* = 1.59; *1-year FU-Placebo*: mean HA red.: 60.0%, *ES* = 0.95
Grazzi et al. (2001)	Open clinical trial: EMG-BFB + PMR	*EMG-BFB (M. frontalis) + PMR*: initially 4–20-min sessions PMR, then 6–21-min sessions BFB (7-min baseline, 7-min BFB, 7-min self-control)	$N = 38$ completers (16 M/22 F), age range: 7–17 years; all patients: episodic tension HA; $N = 6$ dropouts (2 M/4 F); $N = 10$ (3 M/7 F): 3 years FU data not available	Mean HA index[c,d]: pre: $M = 155.95$ ($SD = 26.7$), post: $M = 52.7$ ($SD = 10.48$); there was a significant reduction in HA activity from pre- to posttreatment; outcome variable: HA index	*1-year FU* (*mean HA index*): $M = 41.91$ ($SD = 15.7$) *3-years FU (mean HA index)* $M = 8.56$ ($SD = 6.86$); there was a significant further HA reduction from the 1-year up to the 3-years FU

Note. The effect size (*ES*) for long-term follow-up data was only computed if the same outcome variable (e.g., HA frequency) was used as for the pre–post comparison, and if the provided outcome data were of the same nature (e.g., mean/standard deviation, *p* value, etc.) as the pre–post outcome data. EMG-BFB = EMG-biofeedback; *ES* = effect size; HA = headache; PMR = progressive muscle relaxation.

[a] If possible, 2 indices of treatment outcome were obtained: Number of treatment successes (succ.) defined as a reduction of HA activity of at least 50% and within-group effect size (*ES*) based on the pre- to post-change in headache activity. If the standard deviation for the within-group change was not provided, it was estimated based on the pooled standard deviations for the time points included in the comparison.

[b] If sufficiently detailed information was provided, number of treatment successes and *ES* are indicated. If follow-up data were not available for all treatment completers, the number of patients included in the follow-up is given in parentheses.

[c] The number of treatment successes was not provided.

[d] The group means and standard deviation had to be estimated based on the data that were provided for the males and females. No *ES* could be computed.

suggest differential effectiveness of EMG-BFB with or without parental involvement in comparison to PMR and the wait list controls, these differences failed to reach statistical significance, most likely due to the limited power (cell size of 10). In light of the large variation in treatment outcome for PMR in the studies by Kröner-Herwig et al., the superiority of EMG-BFB over alternative treatments such as PMR awaits further investigation. Unlike EMG-BFB alone, the combination of EMG-BFB and PMR has recently been evaluated against a placebo condition (Bussone et al., 1998). Both BFB-assisted PMR and the relaxation placebo were found to be equally effective up to 6 months after the end of treatment, whereas BFB-assisted relaxation was found to be superior at longer follow-up intervals because of a continued improvement in the treatment group. It is certainly noteworthy that the children in the placebo condition maintained the substantial reduction in HA activity from the end of treatment throughout the follow-up period.

If the criteria proposed by the Task Force on Promotion and Dissemination of Psychological Procedures (1995) are applied rather leniently, EMG-BFB alone can be considered as a promising intervention for pediatric tension HA. However, a caveat is warranted. Both studies by the Kröner-Herwig group included children suffering from tension HAs as well as children suffering from mixed (both tension and migraine HA symptoms) HA, but did not test for differences in treatment outcome depending on HA diagnosis. BFB-assisted PMR also seems to be a promising treatment approach. Yet, the specific contribution of EMG-BFB versus relaxation to treatment outcome needs to determined, especially because the *ES* obtained for this treatment combination seems to be somewhat lower than that for EMG-BFB alone.

Maintenance

All three studies on EMG-BFB for pediatric tension HA have provided 6-month or 1-year follow-up data. Overall, the reduction in HA activity was maintained (e.g., Kröner-Herwig et al., 1992) or improved even further throughout the follow-up period (Grazzi et al., 1990; Kröner-Herwig et al., 1998). Similar results were obtained for BFB-assisted relaxation (Bussone et al., 1998; Grazzi et al., 2001). Grazzi et al. (2001) even reported continued improvement from the 1-year up to the 3-year follow-up. Although these findings suggest a very favorable maintenance of treatment gains, the same limitations apply as for the migraine treatment studies. In fact, one may even speculate that spontaneous remissions of tension HA (e.g., due to stress relief associated with a change of school) are more likely to occur than in migraine. In this regard, it is certainly noteworthy that the placebo condition in the Bussone et al. (1998) study yielded an average reduction in HA activity by more than 50% ($ES = 1$) that was maintained throughout the 1-year follow-up period.

Other Childhood Pain Problems

Despite the fact that children also suffer from recurrent or chronic pain other than HAs, the merit of BFB in treating other pain problems has rarely (e.g., rheumatoid arthritis, sickle cell disease), if at all (e.g., recurrent abdominal pain, cancer-related pain), been investigated. One reason for the paucity of treatment trials may be that the physiological response that should be changed in the desired direction seems less clear in the case of disease-related pains (e.g., rheumatoid arthritis, cancer) or, specifically, in the case of recurrent abdominal

pain. Hence, BFB (TBF or EMG-BFB from the frontalis muscles) has been used mostly as a relaxation method and, as such, may not necessarily be superior over other relaxation procedures such as PMR. Lavigne, Ross, Berry, Hayford, and Pachman (1992) reported moderate levels of pain relief in eight children suffering from juvenile arthritis who had been treated with a treatment package consisting of PMR, EMG-BFB, and TBF (two sessions each) and a parental pain management training. In eight children and adolescents (10–20 years) suffering from sickle cell disease, BFB-assisted relaxation (six sessions EMG-BFB and TBF) was found to significantly reduce perceived pain and frequency of self-treated pain episodes, but did not change the number of pain crises treated in the hospital (Cozzi, Tryon, & Sedlacek, 1987). If psychological factors such as perceived self-efficacy are crucial for mediating the success of BFB (see below), a stronger emphasis on the aspect of self-control rather than on relaxation could improve BFB efficacy and may make BFB an interesting treatment option also for childhood pain other than HA.

TREATMENT MECHANISMS OF BIOFEEDBACK

Placebo Response

Obviously, one of the first questions to ask is whether the treatment effects are due to nonspecific effects such as expectation of improvement, the instillation of "hope" or to a placebo effect. If it is true that children have more confidence in special abilities including psychophysiological self-regulation skills (e.g., Attanasio et al., 1985), children may be even more prone to a placebo effect than are adults. Unfortunately, with the exception of BFB-assisted relaxation (Bussone et al., 1998), none of the BFB procedures for any of the childhood pain problems has been compared directly to a credible placebo condition. Thus far, there is only indirect evidence that BFB is superior to placebo, at least for pediatric migraine. In our 1995 meta-analytic review (Hermann et al., 1995), we obtained an average *ES* of 0.56 for psychological placebo conditions based on a sample of four studies. The average *ES* for TBF alone or combined with EMG-BFB (both $ES > 2.5$) was significantly higher suggesting an effectiveness greater than placebo. If it is assumed that placebo treatments yield effects of similar magnitude irrespective of HA type, EMG-BFB for tension HA may be more effective than placebo. As shown by Bussone et al. (1998), BFB-assisted relaxation is superior to placebo in the treatment of pediatric tension HA, at least in the long run. Nonetheless, the sizable placebo effect ($ES = 1$) that was observed in the same study even at the 1-year follow-up clearly emphasizes the need to further elucidate the role of placebo effects in mediating treatment success of BFB. Strictly based on the empirical literature available at this point in time, placebo effects cannot be ruled out in mediating BFB treatment effects for childhood HA and for childhood pain in general.

Mediating Mechanisms

The success of BFB has been attributed to physiological and/or psychological factors. Physiological accounts are based on the assumption that a dysregulation of specific physiological processes (e.g., elevated muscle tension) underlies the pain problem. Hence, learned control of the relevant physiological process should lead to a corresponding pain relief. Yet, studies with adult HA sufferers have found little or no association between BFB

performance and amount of HA relief (for a review, see Blanchard, 1992). In children, few studies have specifically tested this relationship. For CNV-BFB, no correlation between the acquired CNV self-control and the reduction of HA activity was found (Siniatchkin et al., 2000). Similarly, an analysis of the data on percent HA improvement and percent change in EMG activity provided for each participant in the Grazzi et al. (1990) study does not reveal a significant correlation ($r = .11$) between BFB performance and treatment outcome in tension HA participants. Moreover, in the Bussone et al. (1998) study, BFB-assisted PMR did not yield significant changes in EMG resting levels despite the change in HA activity. By contrast, Allen and McKeen (1991) reported a correlation of .85 between HA relief and the extent to which the children's handwarming skills improved. The internal validity of the obtained measure to represent acquisition of handwarming skills is, however, questionable because no significant overall improvement of handwarming ability was demonstrated. Osterhaus et al. (1993) found a significant correlation of .42 only between the rise in finger temperature during the last session and pre- to postchange in HA frequency (but not for other HA outcome measures).

Taken together, these findings do not provide strong evidence for a purely physiological model of BFB success. Thus far, a strict evaluation of this model (both in adults and in children) has been impeded by the difficulty in specifying the type and magnitude of dysregulation (e.g., elevated baseline levels, enhanced stress reactivity) that presumably contributes to the pain problem (Flor & Turk, 1989) and, by consequence, to clearly define criteria on how to operationalize "acquired physiological control."

Psychological factors such as perceived self-efficacy or perceived control have also been put forth as the basis of the efficacy of BFB. In a recent study, six children suffering from migraine were treated with TBF (Allen & Shriver, 1997). Initially, they received performance feedback indicating moderate success. When HA activity had reached a stable level, high success feedback was provided that suggested a marked increase in handwarming skills relative to peers even when there was no actual improvement. In four of the patients, high success feedback was associated with a marked reduction in HA activity that occurred regardless of the actual BFB performance. These preliminary findings support the importance of cognitive processes such as perceived self-control and possibly self-efficacy as a mediating mechanism and are consistent with findings in adult HA sufferers (Blanchard et al., 1994; Holroyd et al., 1984) . Clearly, at this point in time, the available data do not allow us to determine the relative importance of physiological or psychological factors in mediating BFB treatment outcome. If the success of BFB is mediated largely by psychological mechanisms, BFB may prove to be useful in the treatment of a variety of childhood pain problems (e.g., RAP), even if the specific contribution of muscle tension or other possibly dysregulated physiological processes is not fully understood.

Predictors of Treatment Outcome

Few efforts have been made to identify variables that may predict treatment outcome. Procedure-related aspects such as home practice have been shown to predict treatment success (Allen & McKeen, 1991) or were unrelated to it (Hermann et al., 1997). Similarly, the specific importance of psychosocial, pain-related, and background variables is unclear. Osterhaus et al. (1993) determined that girls with a shorter history of migraine experienced the greatest reduction in HA frequency in response to their treatment package including TBF

and stress management techniques. Hermann et al. (1997) found that the younger the child, the higher the initial level of psychosomatic symptoms and the greater the externalizing behavior tendencies (e.g., acting out, difficulty with impulse control), the greater was the HA relief due to a home-based TBF treatment. No significant relationship between treatment success and the child's sex and HA chronicity was observed. Because of differences in the provided treatment (i.e., CBT + TBF vs. home-based TBF) and with regard to the treated sample of patients (i.e., mean age, age range, sex proportion), the results cannot be directly compared. In light of the sex-specific and probably hormonally mediated change in migraine prevalence between the ages of 12 and 18 (e.g., Linet & Stewart, 1984) and the age-related increase in reported stress (Compas, Davis, & Forsythe, 1985), it seems plausible to assume that outcome predictors may differ in type (e.g., age, sex, emotional adjustment, family environment, treatment format) and relative importance between preadolescent and adolescent migraineurs. Whether this hypothesis holds true not only for migraine but also for other types of recurrent childhood pain remains to be demonstrated.

Role of Operant Factors

On the basis of the importance of social reinforcement for the maintenance of pain (e.g., Fordyce, 1976; Rachlin, 1985), attempts have been made to enhance the efficacy of BFB in the treatment of childhood HAs by adding a behavioral pain management training for parents. Although this combination may appear somewhat unusual, given that an individual's self-regulatory abilities constitute the core rationale underlying BFB, it has been argued early on that BFB is only useful under the condition (among others) that positive or negative reinforcement is not involved in symptom maintenance (Miller & Dworkin, 1977). The parental training typically comprises pain management guidelines that aim to minimize positively (e.g., paying attention) or negatively reinforcing (e.g., excuse from daily chores) parental responses to the child's pain behaviors. Moreover, the parents are taught to encourage their children to practice and use their self-regulation skills and to maintain normal daily activities during pain episodes. Thus far, results have been mixed. Allen and Shriver (1998) found that TBF combined with a parent pain management training yielded greater HA relief in pediatric migraineurs than did TBF alone, thus suggesting a beneficial effect of the added parental training. Furthermore, the parents in both groups significantly decreased their maladaptive responses to the child's pain. This decrease was especially pronounced if the parents had received pain management training. Nonetheless, the observed difference in treatment outcome between the two TBF conditions could also be accounted for by the unusually small treatment effect of the TBF alone condition if compared to other TBF studies including previous studies by the same authors.

Kröner-Herwig et al. (1998) reported that the addition of parent training did not significantly influence the outcome of a EMG-BFB or PMR treatment. If the *ES*s are considered, however, the parent training seems to have an opposite effect depending on the type of treatment: Children treated with EMG-BFB benefited less from treatment if their parents were involved, whereas children treated with PMR improved more. Whether parents engaged in maladaptive responses prior to treatment, and whether the parental training was successful in modifying the parental responses, was not assessed in this study. Hence, it is not clear whether the two groups were comparable with regard to the level of maladaptive

parent responses before treatment, and whether the parent training had similar effects in both groups.

Undoubtedly, efforts to bolster the effectiveness of BFB interventions by adding operant therapy components are worthwhile. However, to determine the specific contribution and advantage of an added operant parent training, the extent of maladaptive parental responses to children's pain at pretreatment and treatment-induced changes in those parental responses needs to be investigated in sufficient detail.

CHILD-RELATED ISSUES OF BFB TREATMENT

Motivation and Learning Success

For a variety of reasons, children have been considered as prime candidates for BFB. On the basis of clinical observations, Attanasio et al. (1985) have argued that children are more enthusiastic and less skeptical, have more psychophysiological ability, learn more quickly, and experience fewer failures with treatment (see also Culbert et al., 1996). Because motivation for and acceptance of BFB (and their impact on treatment outcome) have not been directly assessed in children, it is not clear whether such descriptions primarily reflect clinicians' (and researchers') impressions and beliefs. The purportedly greater enthusiasm and faster learning rate of children has been forwarded to explain the widely held belief that children are better at acquiring BFB skills. Suter and Loughry-Machado (1981) have reported that (healthy) children as compared to adults were better at controlling their skin temperature with the latter group failing to acquire any skin temperature control. In a subsequent study, however, these findings could not be replicated (Suter, Fredericson, & Portuesi, 1983). Furthermore, a recent archival analysis of TBF and EMG-BFB data obtained from a selected sample of treatment studies for HA in adults and children failed to find evidence for children's superiority over adults in acquiring self-regulation skills (Sarafino & Goehring, 2000). Even if the limited database is taken into account, there is considerable reason to believe that children and adults do not differ significantly in their ability to learn how to self-control psychophysiological responses.

Treatment Success

Unlike the acquisition of BFB control, the archival analysis by Sarafino and Goehring (2000) corroborated that, in fact, children suffering from HAs benefit significantly more from BFB than do adults. On the basis of the analysis of a total of 6 versus 15 TBF studies including children or adults, respectively, children achieved a mean HA reduction of 62.3% as compared to 33.9% in adults. EMG-BFB led to an average HA relief of 80.8% in children (4 studies) versus 48% in adults (25 studies). The reasons for this substantial difference in treatment outcome between children and adults are less clear. As Sarafino and Goehring (2000) showed, methodological aspects such as differences in the accuracy of the children's versus adults' HA diaries or the added relaxation training in many of the child treatment studies cannot fully explain this difference in treatment success. Aside from age-related differences in motivation and outcome expectation, the chronicity and severity of the pain problem together with the accompanying increased psychological distress and prolonged use of medication may explain the greater refractoriness of HAs to BFB in adults. Children suffering from recurrent pain are not particularly prone to clinically relevant levels

of anxiety or depression (e.g., Hermann et al., 1997; Walker, Garber, & Greene, 1993), whereas depression and anxiety problems are highly common among adult pain patients and probably reflect the psychological consequences of prolonged living with pain (e.g., Banks & Kerns, 1996; Holroyd et al., 2000; Marcus, 2000).

Early Treatment as a Secondary Prevention

As mentioned above, BFB (and other psychological treatments) for childhood pain may not only be indicated as a primary intervention but may also hold promise to reduce the risk of pain chronicity and pain-related emotional sequelae. Yet, despite its appeal, there is little empirical evidence to support this hypothesis. Kuhn and Allen (1993) collected longer term (3.5 years) follow-up data for 18 of the 21 children suffering from migraine in their original study (Allen & McKeen, 1991). Although treatment success had been maintained at the 8-month follow-up, HA activity had returned to baseline levels more than 3 years after treatment. This return to baseline was observed both in noncompliant children who had initially experienced little reduction of HA activity and in children who had been compliant and had been clinically improved. Moreover, at the 3.5-year follow-up, there was no difference in HA activity between children who had undergone treatment and a group of five children who had dropped out from the original study before receiving treatment. A more favorable long-term outcome was reported by Grazzi et al. (2001). A total of 92% of their sample of children suffering from episodic tension HAs who had received BFB-assisted relaxation training were clinically improved 3 years after the end of treatment. However, no control group was included, thus making it impossible to determine whether this improvement was primarily due to treatment or reflects the natural course of episodic tension HA in children. These data clearly caution against too much optimism regarding long-term treatment benefits in children receiving BFB for recurrent pain. Whether booster sessions may be helpful to stabilize treatment success has not been investigated.

SUMMARY AND CONCLUSION

Consistent with the available empirical literature, our review on the use of BFB in the treatment of childhood pain has focused mainly on childhood HA. TBF is probably efficacious in the treatment of pediatric migraine, and EMG-BFB is a promising treatment approach for tension HA in children, whereas the usefulness of BFB in the treatment of other childhood pain problems such as RAP or rheumatoid arthritis has not been demonstrated. In recent years, BFB protocols have increasingly been combined with other interventions such as parental pain management, thus obscuring BFB-specific treatment effects. As it has been hypothesized by clinicians early on, children suffering from HAs benefit significantly more from BFB than do adults. However, the higher treatment success is not accounted for by a better BFB performance in children. Overall, little research has been done to determine the relative importance of physiological (i.e., BFB performance) and psychological (e.g., self-efficacy, outcome expectation) factors in mediating the treatment effect of BFB in children.

In our opinion, there are three promising avenues for future research on the use of BFB in the treatment of childhood HAs and other pain problems. First, placebo-controlled studies are necessary to demonstrate the superiority of BFB over placebo. This is especially warranted because children may be more prone to placebo effects possibly because of their

greater enthusiasm and belief in treatment success. Second, more efforts should be made to identify mediating mechanisms (i.e., physiological vs. psychological) and outcome predictors. For example, if outcome predictors are shown to be age-dependent, treatment efficacy could be further enhanced by tailoring age-specific BFB protocols. Third, research should focus more on systematically demonstrating that BFB efficacy can (or cannot) be enhanced by additional treatment components such as parental pain management training rather than evaluating treatment packages that do not allow one to disentangle which intervention works or is redundant.

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REFERENCES

Allen, K. D., & McKeen, L. R. (1991). Home-based multicomponent treatment of pediatric migraine. *Headache, 31,* 467–472.

Allen, K. D., & Shriver, M. D. (1997). Enhanced performance feedback to strengthen biofeedback treatment outcome with childhood migraine. *Headache, 37,* 169–173.

Allen, K. D., & Shriver, M. D. (1998). Role of parent-mediated pain behavior management strategies in biofeedback treatment of childhood migraines. *Behavior Therapy, 29,* 477–490.

Andrasik, F., Attanasio, V., Blanchard, E. B., Burke, E., Kabela, E., McCarran, M., et al. (1984). Behavioral treatment of pediatric migraine headache. In F. Andrasik (Chair), *Recent developments in the assessment and treatment of headache*. Symposium held at the annual meeting of the Association for the Advancement of Behavior Therapy, Philadelphia.

Andrasik, F., Blanchard, E. B., Edlund, S. R., & Attanasio, V. (1983). EMG biofeedback treatment of a child with muscle contraction headache. *American Journal of Clinical Biofeedback, 6,* 96–102.

Apley, J. (1975). *The child with abdominal pains.* London: Blackwell.

Attanasio, V., Andrasik, F., Burke, E., Blake, D., Kabela, E., & McCarran, M. (1985). Clinical issues in utilizing biofeedback with children. *Clinical Biofeedback and Health, 8,* 134–141.

Banks, S. M., & Kerns, R. D. (1996). Explaining high rates of depression in chronic pain: A diathesis-stress framework. *Psychological Bulletin, 119,* 95–110.

Barowsky, E. (1990). The use of biofeedback in the treatment of disorders of childhood. *Annals of New York Academy of Sciences, 602,* 221–233.

Bille, B. (1989). Migraine in childhood: A 30 years follow-up. In G. Lanzi, U. Balottin, & A. Cernibori (Eds.), *Headache in children and adolescents* (pp. 12–26). New York: Elsevier.

Birbaumer, N., Elbert, T., Canavan, A. G., & Rockstroh, B. (1990). Slow potentials of the cerebral cortex and behavior. *Physiological Reviews, 70,* 1–41.

Blanchard, E. B. (1992). Psychological treatment of benign headache disorders. *Journal of Consulting and Clinical Psychology, 60,* 537–551.

Blanchard, E. B., Kim, M., Hermann, C., Steffek, B. D., Nicholson, N. I., & Taylor, A. E. (1994). The role of perception of success in the thermal biofeedback treatment of vascular headache. *Headache Quarterly, 5,* 231–236.

Blanchard, E. B., & Schwarz, S. P. (1988). Clinically significant changes in behavioral medicine. *Behavioral Assessment, 10,* 171–188.

Burke, E. J., & Andrasik, F. (1989). Home- vs. clinic-based biofeedback treatment for pediatric migraine: Results of treatment through one-year follow-up. *Headache, 29,* 434–440.

Bussone, G., Grazzi, L., D'Amico, D., Leone, M., & Andrasik, F. (1998). Biofeedback-assisted relaxation training for young adolescents with tension-type headache: A controlled study. *Cephalalgia, 18,* 463–467.

Cohen, J. (1987). *Statistical power analysis for the behavioral sciences* (2nd Rev. ed.). Hillsdale, NJ: Erlbaum.

Compas, B. E., Davis, G. E., & Forsythe, C. J. (1985). Characteristics of life events during adolescence. *American Journal of Community Psychology, 13,* 677–691.

Cozzi, L., Tryon, W. W., & Sedlacek, K. (1987). The effectiveness of biofeedback-assisted relaxation in modifying sickle cell crisis. *Biofeedback and Self-Regulation, 12,* 51–61.

Culbert, T. P., Kajander, R. L., & Reaney, J. B. (1996). Biofeedback with children and adolescents: Clinical observations and patient perspectives. *Developmental and Behavioral Pediatrics, 17,* 342–350.

Faull, C., & Nicol, A. R. (1986). Abdominal pain in six-year-olds: An epidemiological study in a new town. *Journal of Child Psychology and Psychiatry, 27,* 251–260.
Fentress, D. W., Masek, B. J., Mehegan, J. E., & Benson, H. (1986). Biofeedback and relaxation–response training in the treatment of pediatric migraine. *Developmental Medicine and Child Neurology, 28,* 139–146.
Flor, H., & Turk, D. C. (1989). Psychophysiology of chronic pain: Do chronic pain patients exhibit symptom-specific psychophysiological responses? *Psychological Bulletin, 105,* 215–259.
Fordyce, W. E. (1976). *Behavioral methods in chronic pain.* St. Louis, MO: Mosby.
Goodman, J. E., & McGrath, P. J. (1991). The epidemiology of pain in children and adolescents: A review. *Pain, 46,* 247–264.
Grazzi, L., Andrasik, F., D'Amico, D., Leone, M., Moschiano, F., & Bussone, G. (2001). Electromygraphic biofeedback-assisted relaxation training in juvenile episodic tension-type headache: Clinical outcome at three year follow-up. *Cephalalgia, 21,* 798–803.
Grazzi, L., Leone, M., Frediani, F., & Bussone, G. (1990). A therapeutic alternative for tension headache in children: Treatment and 1-year follow-up results. *Biofeedback and Self-Regulation, 15,* 1–7.
Guarnieri, P., & Blanchard, E. B. (1990). Evaluation of home-based thermal biofeedback treatment of pediatric migraine headache. *Biofeedback and Self-Regulation, 15,* 179–184.
Hartmann, A., & Herzog, T. (1995). Varianten der Effektstärkenberechnung in Meta-Analysen: Kommt es zu variablen Ergebnissen? [Variants in effect size calculation: How much do the results differ?] *Zeitschrift für Klinische Psychologie, 24,* 337–443.
Hermann, C., Blanchard, E. B., & Flor, H. (1997). Biofeedback treatment for pediatric migraine: Prediction of treatment outcome. *Journal of Consulting and Clinical Psychology, 85,* 611–616.
Hermann, C., Kim, M., & Blanchard, E. B. (1995). Behavioral and prophylactic pharmacological intervention studies of pediatric migraine: An exploratory meta-analysis. *Pain, 60,* 239–256.
Hernandez-Latorre, M. A., & Roig, M. (2000). Natural history of migraine in childhood. *Cephalalgia, 20,* 573–579.
Holden, E. W., Deichmann, M. M., & Levy, J. D. (1999). Empirically supported treatments in pediatric psychology: Recurrent pediatric headache. *Journal of Pediatric Psychology, 24,* 91–109.
Holroyd, K. A., Penzien, D. B., Hursey, K. G., Tobin, D. L., Rogers, L., Holm, J. E., et al. (1984). Change mechanisms in EMG biofeedback training: Cognitive changes underlying improvements in tension headache. *Journal of Consulting and Clinical Psychology, 52,* 1039–1053.
Holroyd, K. A., Stensland, M., Lipchik, G. L., Hill, K. R., O'Donnell, F. S., & Cordingley, G. (2000). Psychosocial correlates and impact of chronic tension-type headaches. *Headache, 40,* 3–16.
Hyams, J. S., Burke, G., Davis, P. M., Rzepski, B., & Andrulonis, P. A. (1996). Abdominal pain and irritable bowel syndrome in adolescents: A community-based study. *Journal of Pediatrics, 129,* 220–226.
Kotchoubey, B., Blankenhorn, V., Froscher, W., Strehl, U., & Birbaumer, N. (1997). Stability of cortical self-regulation in epilepsy patients. *NeuroReport, 8,* 1867–1870.
Kraemer, H., & Andrew, G. (1982). A non-parametric technique for meta-analysis effect size calculation. *Psychological Bulletin, 91,* 404–412.
Kröner-Herwig, B., Mohn, U., & Pothmann, R. (1998). Comparison of biofeedback and relaxation in the treatment of pediatric headache and the influence of parent involvement on outcome. *Applied Psychophysiology and Biofeedback, 23,* 143–157.
Kröner-Herwig, B., Plump, U., & Pothmann, R. (1992). Progressive relaxation und EMG-Biofeedback in der Therapie von chronischem Kopfschmerz bei Kindern. *Der Schmerz, 6,* 121–127.
Kropp, P., & Gerber, W. D. (1993). Contingent negative variation—findings and perspectives in migraine. *Cephalalgia, 13,* 33–36.
Kuhn, B. R., & Allen, K. D. (1993). *Long-term follow-up of a home-based multicomponent treatment for pediatric migraine.* Poster presented at the 27th annual meeting of the Association for Advancement of Behavior Therapy, Atlanta, GA.
Labbé, E. E. (1988). Childhood muscle contraction headache: Current issues in assessment and treatment. *Headache, 28,* 430–434.
Labbé, E. E. (1995). Treatment of childhood migraine with autogenic training and skin temperature biofeedback: A component analysis. *Headache, 35,* 10–13.
Labbé, E. E., & Ward, C. H. (1990). Electromyographic biofeedback with mental imagery and home practice in the treatment of children with muscle-contraction headache. *Developmental and Behavioral Pediatrics, 11,* 65–68.
Labbé, E. E., & Williamson, D. A. (1984). Treatment of childhood migraine using autogenic feedback training. *Journal of Consulting and Clinical Psychology, 52,* 968–976.
Larsson, B., Melin, L., & Döberl, A. (1990). Recurrent tension headache in adolescents treated with self-help relaxation training and a muscle relaxant drug. *Headache, 30,* 665–671.
Lavigne, J. V., Ross, C. K., Berry, S. L., Hayford, J. R., & Pachman, L. M. (1992). Evaluation of a psychological treatment package for treating pain in juvenile rheumatoid arthritis. *Arthritis Care and Research, 5,* 101–110.
Linet, M. S., & Stewart, W. F. (1984). Migraine headache: Epidemiologic perspectives. *Epidemiological Review, 6,* 107–139.

Linet, M. S., Stewart, W. F., Celentano, D. D., Ziegler, D., & Sprecher, M. (1989). An epidemiologic study of headache among adolescents and young adults. *JAMA, 261,* 2211–2216.
Marcus, D. A. (2000). Identification of patients with headache at risk of psychological distress. *Headache, 40,* 373–376.
McGrath, P. J., Humphreys, P., Keene, D., Goodman, J. T., Lascelles, M. A., Cunningham, S. J., et al. (1992). The efficacy and efficiency of a self-administered treatment for adolescent migraine. *Pain, 49,* 321–324.
McQuaid, E. L., & Nassau, J. H. (1999). Empirically supported treatments of disease-related symptoms in pediatric psychology: Asthma, diabetes, and cancer. *Journal of Pediatric Psychology, 24,* 305–328.
Mehegan, J. E., Masek, B. J., Harrison, R. H., Russo, D. C., & Leviton, A. (1987). A multicomponent behavioral treatment for pediatric migraine. *Clinical Journal of Pain, 2,* 191–196.
Mikkelsson, M., Salminen, J. J., & Kautiainen, H. (1997). Non-specific musculoskeletal pain in preadolescents. Prevalence and 1-year persistence. *Pain, 73,* 29–35.
Mikkelsson, M., Salminen, J. J., Sourander, A., & Kautiainen, H. (1997). Contributing factors to the persistence of musculoskeletal pain in preadolescents: A prospective 1-year follow-up study. *Pain, 77,* 67–72.
Miller, N. E., & Dworkin, B. R. (1977). Effects of learning on visceral functions: Biofeedback. *New England Journal of Medicine, 296,* 1274–1278.
Murphy, E., & Carr, A. (2000). Pediatric pain problems. In A. Carr (Ed.), *What works with children and adolescents? A critical review of psychological interventions with children, adolescents and their families* (pp. 258–279). Florence, KY: Taylor & Francis/Routledge.
Oster, J. (1972). Recurrent abdominal pain, headache and limb pains in children and adolescents. *Pediatrics, 50,* 429–436.
Osterhaus, S. O. L., Passchier, J., van der Helm-Hylkema, H., de Jong, K. T., Orlebeke, J. F., de Grauw, A. J. C., et al. (1993). Effects of behavioral psychophysiological treatment on schoolchildren with migraine in a nonclinical setting: Predictors and process variables. *Journal of Pediatric Psychology, 18,* 697–715.
Passchier, J., & Orlebeke, J. F. (1985). Headaches and stress in schoolchildren: An epidemiological study. *Cephalalgia, 5,* 167–176.
Rachlin, H. (1985). Pain and behavior. *Behavioral and Brain Sciences, 8,* 43–83.
Rhee, H. (2000). Prevalence and predictors of headaches in US adolescents. *Headache, 40,* 528–538.
Sarafino, E. P., & Goehring, P. (2000). Age comparisons in acquiring biofeedback control and success in reducing headache pain. *Annals of Behavioral Medicine, 22,* 10–16.
Sartory, G., Müller, B., Metsch, J., & Pothmann, R. (1998). A comparison of psychological and pharmacological treatment of pediatric migraine. *Behaviour Research and Therapy, 36,* 1155–1170.
Sillanpää, M. (1983a). Prevalence of headache in prepuberty. *Headache, 23,* 10–14.
Sillanpää, M. (1983b). Changes in the prevalence of migraine and other headaches during the first seven school years. *Headache, 23,* 15–19.
Sillanpää, M., & Anttila, P. (1996). Increasing prevalence of headache in 7-year-old schoolchildren. *Headache, 36,* 466–470.
Siniatchkin, M., Hierundar, A., Kropp, P., Kuhnert, R., Gerber, W.-D., & Stephani, U. (2000). Self-regulation of slow cortical potentials in children with migraine: An exploratory study. *Applied Psychophysiology and Biofeedback, 25,* 13–32.
Suter, S., Fredericson, M., & Portuesi, L. (1983). Mediation of skin temperature biofeedback effects in children. *Biofeedback and Self-Regulation, 8,* 567–584.
Suter, S., & Loughry-Machado, G. (1981). Skin temperature biofeedback in children and adults. *Journal of Experimental Child Psychology, 32,* 77–87.
Task Force on Promotion and Dissemination of Psychological Procedures. (1995). Training in and dissemination of empricially-validated psychological treatments: Report and recommendation. *Clinical Psychologist, 48,* 3–23.
Waldie, K. (2001). Childhood headache, stress in adolescence, and primary headache in young adulthood: A longitudinal cohort study. *Headache, 41,* 1–10.
Walker, L. S., Garber, J., & Greene, J. W. (1993). Psychosocial correlates of recurrent childhood pain: A comparison of pediatric patients with recurrent abdominal pain, organic illness, and psychiatric disorders. *Journal of Abnormal Psychology, 102,* 248–258.
Walker, L. S., Garber, J., Van Slyke, D. A., & Greene, J. W. (1995). Long-term health outcomes in patients with recurrent abdominal pain. *Journal of Pediatric Psychology, 20,* 233–245.
Walker, L. S., Guite, J. W., Duke, M., Barnard, J. A., & Greene, J. W. (1998). Recurrent abdominal pain: A potential precursor of irritable bowel syndrome in adolescents and young adults. *Journal of Pediatrics, 132,* 1010–1015.
Welch, K. M. (1998). Current opinions in headache pathogenesis: Introduction and synthesis. *Current Opinion in Neurology, 11,* 193–197.
Werder, D. S., & Sargent, J. D. (1984). A study of childhood headache using biofeedback as a treatment alternative. *Headache, 24,* 122–126.
Womack, W. M., Smith, M. S., & Chen, A. C. N. (1988). Behavioral management of childhood headache: A pilot study and case history report. *Pain, 32,* 279–283.