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Attentional Bias Modification for Pain: a Systematic Review and Meta-analytic Investigation

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Despite the increasing need to investigate the efficacy of attentional bias modification for pain (ABM-P) in pain-related situations and organize the accumulating research, only a few systematic reviews or meta-analyses have been conducted so far. This study aimed to confirm the clinical efficacy of ABM-P and to integrate the existing literature. This study followed the PRISMA guidelines. We searched the literature through PubMed, ScienceDirect, the Cochrane library, Springer, and ProQuest and also conducted a manual search. A total of 549 works were identified. Eleven articles (12 studies) were included in the systematic review, and meta-analysis was conducted with six articles (seven studies). These results demonstrate that ABM-P is effective in alleviating pain intensity. The effect of the ABM-P was inconsistent regarding emotion and attentional bias. This inconsistent finding implies that ABM-P has a partial effect on emotion and attentional bias.

Keywords: attentional bias modification (ABM), attentional bias, pain, pain experience, meta-analysis, systematic review

Introduction

As a chief function of pain is detecting warning signals of bodily threats, it seems natural and adaptive to allocate more attention to pain-related information (Van Damme et al., 2002). Nevertheless, maladaptive, excessive selective attention, termed attentional bias (AB) appears in some situations (Sharpe, 2014). Previous meta-analyses underpinned the presence of AB in both healthy individuals and in acute and chronic pain patients (Crombez et al., 2013; Todd et al., 2018; Broadbent et al., 2021). Because of its detrimental effect on pain experience, AB has been stressed as a point of clinical intervention. AB contributes to higher pain perception and impairment of daily functioning regardless of pain intensity (McCracken, 1997). In addition, patients who report a more marked AB experience a greater impact of pain intensity on disability and cognitive functions in everyday life (Van Ryckeghem et al., 2013).

Several theories provide explanations the development and maintenance of AB. The vigilance–avoidance model suggests that threatening stimuli automatically draw attention, and subsequently, attentional avoidance ensues in the pursuit of relieving negative emotions caused by threats (Mogg et al., 2004). The fear–avoidance model also emphasizes the role of AB (Vlaeyen & Linton, 2000). In this model, a catastrophic interpretation of the pain makes an individual attempt to avoid it. When an individual acts to avoid pain, pain-related stimuli attract more attention.

Since psychological aspects comprise a large part of the pain experience, the importance of psychological interventions has been high lighted in the context of pain management (Hylands-White et al., 2017). Cognitive behavioral therapy is a well-established psychological intervention for pain, though, there is an increasing demand for more cost- and time-efficient cognitive interventions

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(Eccleston, 2001). In line with this need for new approaches, attention bias modification (ABM) has been suggested as a promising alternative based on its successful use for various disorders (Beard, 2011; Browning et al., 2012; Schoorl et al., 2013; Cox et al., 2014). ABM is a computerized training program designed to reduce excessive attention to threat-related information (MacLeod & Mathews, 2012) by decreasing the automatic attention given to threat stimuli and strengthening attention control with relatively little cognitive effort (Paulewicz et al., 2012; Mogg & Bradley, 2016).

McGowan et al. (2009) tried the first form of ABM for pain (ABM-P) with pain related words and confirmed its promising effect on pain perception. Since then, ABM-P targeting hypervigilance has been shown to affect pain intensity, pain-related disorders, emotion, and AB (Carleton et al., 2011; Carleton et al., 2020). However, some questions have been raised about the efficacy of ABM-P. A growing body of literature reports the null effect of ABM-P (Van Ryckeghem et al., 2018; Carleton et al., 2020). Furthermore, its therapeutic mechanism remains uncertain owing to the ill-defined pattern of AB in the chronic pain population (Bar-Haim et al., 2007). Previous meta-analyses also reported a blended effect size of ABM (Beard et al., 2012; Mogoaşe et al., 2014; Price et al., 2017). These inconsistent findings suggest the need for an in-depth exploration of the efficacy of ABM-P.

Although researchers have previously conducted systematic reviews and meta-analyses of ABM-P, there is still insufficient evidence of its effectiveness. For instance, Bowler's (2015) dissertation offers a systematic review and meta-analysis with only four articles as subsidiary results. Todd et al. (2015) reviewed six articles but only reported the effect size for each study, without synthesizing them. They also included other intervention types (e.g., Wells' attention training task and mindfulness). Since attention is a crucial component of the cognitive behavioral approach to pain management (Morley et al., 2004), it is necessary to establish clear evidence for the clinical application of ABM-P through a comprehensive investigation. Despite the small number of studies on ABM-P compared to other disorders, we must assess its clinical efficacy and suggest a way forward. Therefore, we conducted a preliminary systematic review and meta-analysis. In this study, we aimed to synthesize the current findings and limitations of ABM-P and explore the direction of future ABM-P research.

Materials and Methods

Literature Search

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysissystems (PRISMA). Potentially relevant studies for systematic review and meta-analysis were searched for through PubMed, ScienceDirect, the Cochrane Library, Springer, and ProQuest electronic databases published up until January 2022. Registered trials were not included. The search terms are as follows: "attentional bias modification," "attentional bias training," "cognitive bias modification" combined with "pain" by "AND." We also performed a manual search, inspecting the references of systematic reviews of ABM to find missing relevant literature.

Inclusion and Exclusion Criteria

Studiesthat met the inclusion criteria were included in the systematic review. (1) The participants were adults over 18 years old; (2) the study used an ABM intervention; (3) the study was designed to compare the ABM condition with another active treatment or control condition; (4) the study was written in English; (5) the study measured pain outcomes; and (6) the study's full-text article was a vailable. Besides the criteria above, the studies presenting data allowing the computation of effect size were included in the meta-analysis. Three researchers independently screened the relevant literature.

Quality Assessment

The Risk of Bias2 (RoB2) tool was used to assess the quality of the literature (Sterne et al., 2019). Three researchers independently conducted thequality assessment. Five domains of bias were explored as follows: "Bias arising from the randomization process," "Bias due to deviations from intended interventions," "Bias due to missing outcome data," "Bias in the measurement of the outcome," "Bias in selection of the reported result," and "Overall bias." The studies were evaluated in the range of "High risk of bias," "Some concerns," and "Low risk of bias."

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Data Analysis

Data for thesystematic review were extracted on the researcher, publication year, participants, comparison group, features of ABM training, follow-up, outcome variables, and measurement scales. Meta-analysis was performed by R3.5.2. To compare each outcome, the standardized mean difference was calculated. Because Cohen's *d* can be overestimated in small samples, we used Hedges'g with a 95% confidential interval (CI) as the effect size measure. The random-effect model was applied because ofthe heterogeneity of study populations. The degree of heterogeneity was assessed by using the Higgins' I^2.

Results

Literature Selection

From the initial search, 549 articles were found, and seven more were added following a manual review of references. After removing duplicates, irrelevant articles were excluded from the initial screening of titles. A total of 32 articles were identified as potentially eligible for screening. As the following step, research abstracts were screened, leaving 12 studies, and three studies were excluded because the full-text articles were unavailable. Finally, when we examined full-text articles, eight studies did not meet the inclusion criteria for the following reasons: one study did not use a comparison group, four studies did not carry out ABM-P, two studies were an editorial/commentary articles, and one study was duplicated because it was a dissertation that was also published in a journal. If the data for the meta-analysis were not presented, the authors were asked for the data by e-mail. Finally, a total of 11 articles (12 studies) were included in the systematic review. The meta-analysis was conducted on six articles (seven studies), excluding five studies that did not present appropriate results for meta-analysis. Figure 1 summarizes the literature selection process.

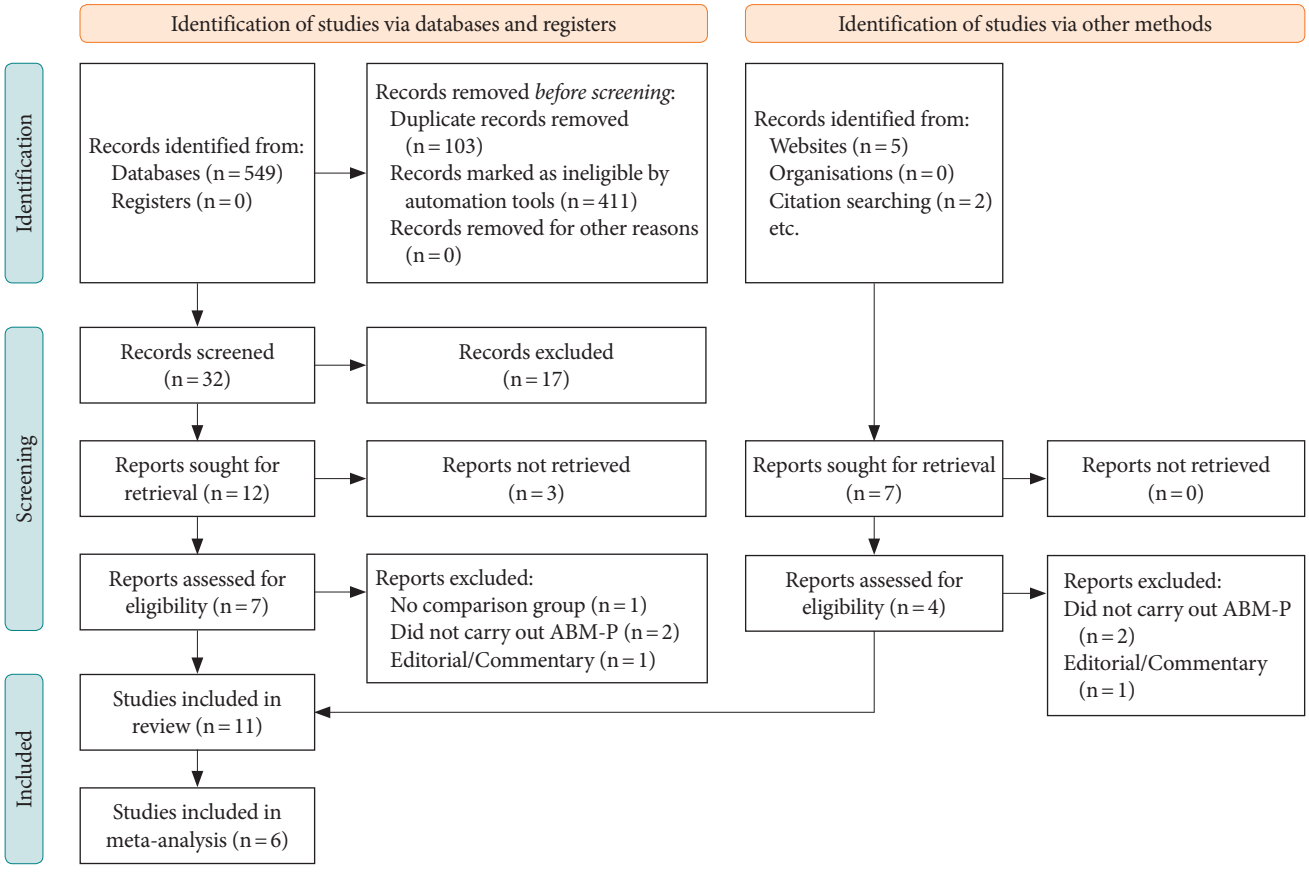

Figure 1. *PRISMA flow diagram of systematic review and meta-analysis.*

Table 1. *Characteristics of Studies Included in Systematic Review and Meat-analysis*

Authors (Publication year)	Participants (N)	Age *M* (*SD*)	Comparison group	Randomization/ mlinded/ counter-balanced	ABM-P	Follow-up	Measure	AB assessment	Outcomes	Meta
McGowan et al. (2009)	Healthy adults (104)	21.35 (5.88)	Threat (toward pain/toward neutral) vs. Non-threat (toward pain/ toward neutral)	Randomized/ Single blind/ Not-presented	Dot-probe task Stimuli: word Present time: 500 ms Trials: 320 Session: 1	X	▪ CPT ▪ DASS-42 ▪ FPQ-III	Pre/post Dot-probe task (80 trials)	▪ CPT - pain threshold - pain intensity at 30s - pain tolerance ▪ Fear of pain ▪ Depression ▪ Anxiety ▪ Stress ▪ AB	X
Carleton et al. (2011)	Fibromyalgia (17)	51.2 (6.00)	ABM-P vs. control (placebo)	Randomized/ double blind/ counter-balanced	Dot-probe task Stimuli: word Present time: 500 ms Trials: 160 Session: 8 (2 sessions/week: 4 weeks)	X	▪ ASI-3 ▪ FPQ-SF ▪ ISI-R ▪ PASS-20 ▪ STAI ▪ VAS	Not measured	▪ Pain intensity ▪ Anxiety sensitivity ▪ Illness/injury sensitivity ▪ Pain anxiety ▪ Fear of pain	O
Sharpe et al. (2012) study 1	Acute pain (54)	ABM: 41.4 (14.1) Placebo: 40.64 (15.80)	ABM-P vs. control (placebo)	Randomized/ double blind/ counter-balanced	Dot-probe task Stimuli: word Present time: 500 ms Trials: 320 Session: 1	3 months	▪ DASS-42 ▪ ÖMPQ ▪ PSEQ ▪ RDQ ▪ TSK ▪ VAS	Pre/post Dot-probe task (80 trials)	▪ Musculoskeletal pain ▪ Pain intensity ▪ Disability ▪ Kinesiophobia ▪ Depression ▪ Anxiety ▪ Stress ▪ Pain self-efficacy ▪ AB	O
Sharpe et al. (2012) study 2	Chronic pain (34)	45.60 (14.54)	ABM-P vs. control (placebo)	Randomized/ double blind/ counter-balanced	Dot-probe task Stimuli: word Present time: 500 ms Trials: 80 Session: 4 With 8 weeks CBT	6 months	▪ ASI ▪ DASS-42 ▪ FPQ-SF ▪ PSEQ ▪ RDQ ▪ TSK ▪ VAS	Pre/post Dot-probe task (80 trials) After CBT Dot-probe task (160 trials)	▪ Pain intensity ▪ Disability ▪ Kiensiophobia ▪ Depression ▪ Anxiety ▪ Stress ▪ Pain self-efficacy ▪ Fear of pain ▪ Anxiety sensitivity ▪ AB	O
Sharpe et al. (2015)	Healthy adults (111)	19.63 (3.30)	Word stimuli Training vs. face stimuli Training	Randomized/ single blind/ counter-balanced	Dot-probe task Stimuli: word, image Present time: 500 ms Trials: 320 Session: 1	X	▪ CPT ▪ DASS-42 ▪ FPQ-III ▪ NRS	Pre/post Dot-probe task (80 trials)	▪ CPT - pain threshold - pain tolerance - Pain intensity	X

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Table 1. *Continued*

Authors (Publication year)	Participants (N)	Age *M* (*SD*)	Comparison group	Randomization/ mlinded/ counter-balanced	ABM-P	Follow-up	Measure	AB assessment	Outcomes	Meta
Babai et al. (2016)	Chronic pain (36)	41.36 (18.30)	ABM-P vs. CBT vs. control (placebo)	Randomized/ not blinded/ not presented	Dot-probe task Stimuli: image Present time: 500 ms Trials: 200 Session: 8	X	▪ BPI-SF	Pre/post Dot-probe task (Not presented)	▪ Pain intensity	X
Todd et al. (2016)	Healthy adults (106)	20	Toward training vs. away training	Randomized/ double blind/ counter-balanced	Dot-probe task Stimuli: word Present time: 500 ms Trials: 320 Session: 1	X	▪ CPT ▪ DASS-42 ▪ FPQ-SF ▪ Incidentallearning task (IB) ▪ PCS ▪ VAS	Pre/post Dot-probe task (80 trials) Eye-tracking	▪ CPT - Pain intensity - Pain hesitance - Pain tolerance - Pain threshold ▪ AB ▪ IB	O
Bowler et al. (2017)	Healthy adults (81)	19.98 (2.15)	ABM-500 (ms) vs. ABM-1250 (ms) vs. control (placebo)	Randomized/ single blind/ counter-balanced	Dot-probe task Stimuli: word Present time: 500 ms/1250 ms Trials: 192 Session: 1	X	▪ ACS ▪ ASI-3 ▪ CPT ▪ FPQ-SF ▪ HADS ▪ NRS ▪ PVAQ	Pre/post Dot-probe task (96 trials)	▪ CPT - Pain intensity - Pain tolerance - Pain threshold ▪ AB	O
Van Ryckeghem et al. (2018)	Healthy adults (58)	18.64 (1.53)	ABM-P vs. control (placebo)	Randomized/ double blind/ not-presented	Dot-probe task Stimuli: word Present time: 500 ms Trials: 420 Session: 1	X	▪ ACS ▪ CPT ▪ DASS-42 ▪ NRS ▪ PCS ▪ RIP-task (pain interference) ▪ STAI-T	Last block of ABM training was used as post training index (105 trials)	▪ CPT - Pain intensity - pain unpleasantness ▪ AB ▪ RIPtask outcomes	O
Carleton et al. (2020)	Fibromyalgia (117)	47.92 (10.75)	ABM-P vs. control (placebo)	Randomized/ double blind/ counter-balanced	Dot-probe task Stimuli: word Present time: 500 ms Trials: 240 Session: 8	1 month	▪ ASI-3 ▪ DASS-21 ▪ FIQR ▪ ISI-R ▪ MPQ-SF ▪ PASS-20	Pre/post Dot-probe task (240 trials)	▪ Pain intensity ▪ Anxiety. sensitivity ▪ Depression ▪ Anxiety ▪ Stress ▪ Illness/injury sensitivity ▪ Pain anxiety ▪ Fibromyalgia impact	O
Shiasy (2020)	Chronic low back pain (60)	Not presented	ABM-P vs. ABM-P+tDCS vs. Sham tDCS vs. control	Randomized/ single blind/ counter-balanced	Dot-probe task Stimuli: image Present time: 500 ms Trials: 400 Session: 5 (5 consec-utive days)	1 month	▪ BPI ▪ DASS-21 ▪ RDQ	Pre/post Dot-probe task (Not presented)	▪ Pain intensity ▪ AB ▪ Depression ▪ Anxiety ▪ Stress	X

(*Continued to the next page*)

Table 1. *Continued*

Authors (Publication year)	Participants (N)	Age *M* (*SD*)	Comparison group	Randomization/ mlinded/ counter-balanced	ABM-P	Follow-up	Measure	AB assessment	Outcomes	Meta
Hasegawa et al. (2021)	Old/chronic pain (36)	ABM leading: 77.9 (7.0)	ABM trailing: 79.9 (5.9)	ABM leading vs. ABM trailing	Randomized/ no blinging/ not presented Stimuli: image Present time: 500 ms Trials: 128 Session: 24 (2 sessions/week: 12 weeks) With 12 weeks normal intervention	Dot-probe task X	▪ NRS ▪ PCS ▪ FABQ ▪ HADS ▪ SSS-8 ▪ EQ-5D-3L ▪ CS-30 task ▪ TUG	Not measured	▪ Pain intensity ▪ Pain catastrophizing ▪ Depression ▪ Anxiety ▪ avoidance thinking ▪ burden of physical symptom ▪ health-related quality of life ▪ physical function	O

AB = Attentional bias; ACS = Attentional Control Scale; ASI-3 = Anxiety Sensitivity Inventory-3; BPI = Brief Pain Inventory; BPI-SF = Brief Pain Inventory-Short form; CS-30 = 30-second chair-stand test; CPT = Cold pressor task; DASS-21 = Depression, Anxiety, Stress Scale-21; DASS-42 = Depression, Anxiety, Stress Scale-42; EQ-5D-3L = EuroQol 5 Dimension-3Levels-Questionnaire; FABQ = Fear-avoidance beliefs Questionnaire; FPQ-III = Fear of Pain Questionnaire; FPQ-SF = Fear of Pain Questionnaire-Short form; FIQR = Revised-Fibromyalgia Impact Questionnaire; HADS = Hospital Anxiety and Depression Scale; ISI-R = Illness/Injury Sensitivity Index-Revised; IB = Interpretation bias; MPQ-SF = Mcgill Pain Questionnaire-Short form; NRS = Numeric Rating Scale; ÖMPQ = Revised Örebro Musculoskeletal Pain Questionnaire; PASS-20 = Pain Anxiety Symptoms Scale-20; PCS = Pain Catastrophizing Scale; PSEQ = Pain Self-Efficacy Questionnaire; PVAQ = Pain Vigilance and Awareness Questionnaire; RDQ = Roland Morris Disability Questionnaire; STAI = State-Trait Anxiety Inventory; SATI-T = State-Trait Anxiety Inventory-Trait version; SSS-8 = Somatic Symptom Scale-8; TSK = Tampa Scale for Kinesiophobia; TUG = Time up & Go test; VAS = Visual analog scale.

Characteristics of the literature included.

Table 1 presents the characteristics of the studies. Among the 12 studies (11 articles) included in the systematic review, seven were pain patient studies. There were two studies on fibromyalgia, four on chronic pain such as low-back pain, and one on acute pain. The other five studies were on experimentally induced acute pain engendered in healthy adults using the cold pressor task (CPT). The total sample size of the studies included in the systematic review was 382 ($M = 66.58$, $SD = 36.29$). Of the 12 studies, five studies compared the ABM-P group and control groupand two compared ABM-P with another active treatment (e.g., cognitive behavioral therapy) or combined treatment. The other five studies were comparing different ABM paradigms. In all the studies, the dot-probe task was used for attention training. Word stimuli were used for training in eight studies, and image stimuli were used in three studies, and both stimuli in one study. In the six studies, a single session AMB-P was applied. For the multi-session studies, one study used four, five, and 24 sessions each and three studies used eight sessions. The stimulus presentation time was 500 ms in allstudies. Only one study used two different presentation times (500 ms and 1,250 ms). The number of trials varied in therange of 160 to 420 trials, with 320 trials being the most common (in four studies). For AB measure, all studies used the dot-probe task. Only one study attempted to determine accurate attention patterns, additionally using an eye tracker. Pain outcomes weremeasured in all studies. Most of the studies used emotion as an outcome variable (eight studies). Depression was assessed in six studies, and anxiety/pain anxiety, in seven studies. Seven studies assessed AB as an outcome variable.

Quality Assessment

Figures 2 and 3 present the results for RoB2. Most studies were at low for "Bias arising from the randomization process" (11 studies). The risk of "Bias due to deviations from intended interventions" was 8 at low, and two studies had some concerns. All studies were at low in both "Bias due to missing outcome data" and "Bias in selection of the reported result." In "Bias in the measurement of the outcome," 10 studies were at low, one study had some concerns and was high accordingly. For "Overall bias," seven studies were categorized as low risk of bias, four as some concerns, and one as high risk of bias.

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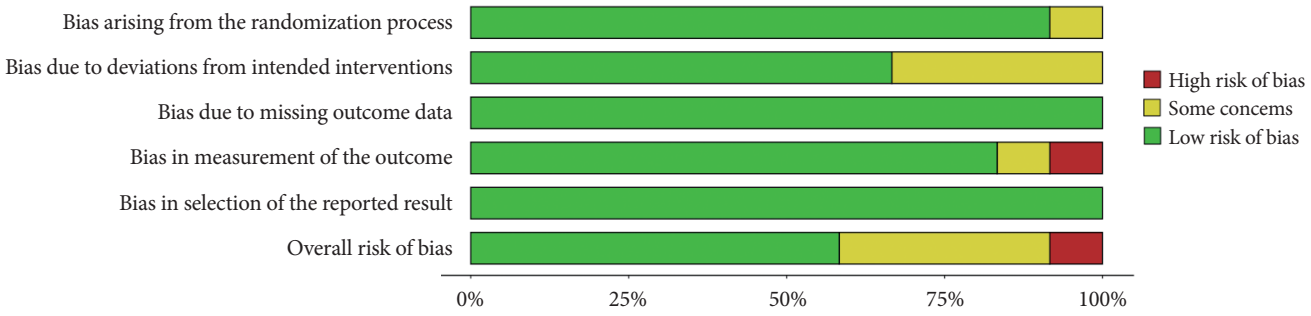

Figure 2. *Summary plot of ROB2 assessment.*

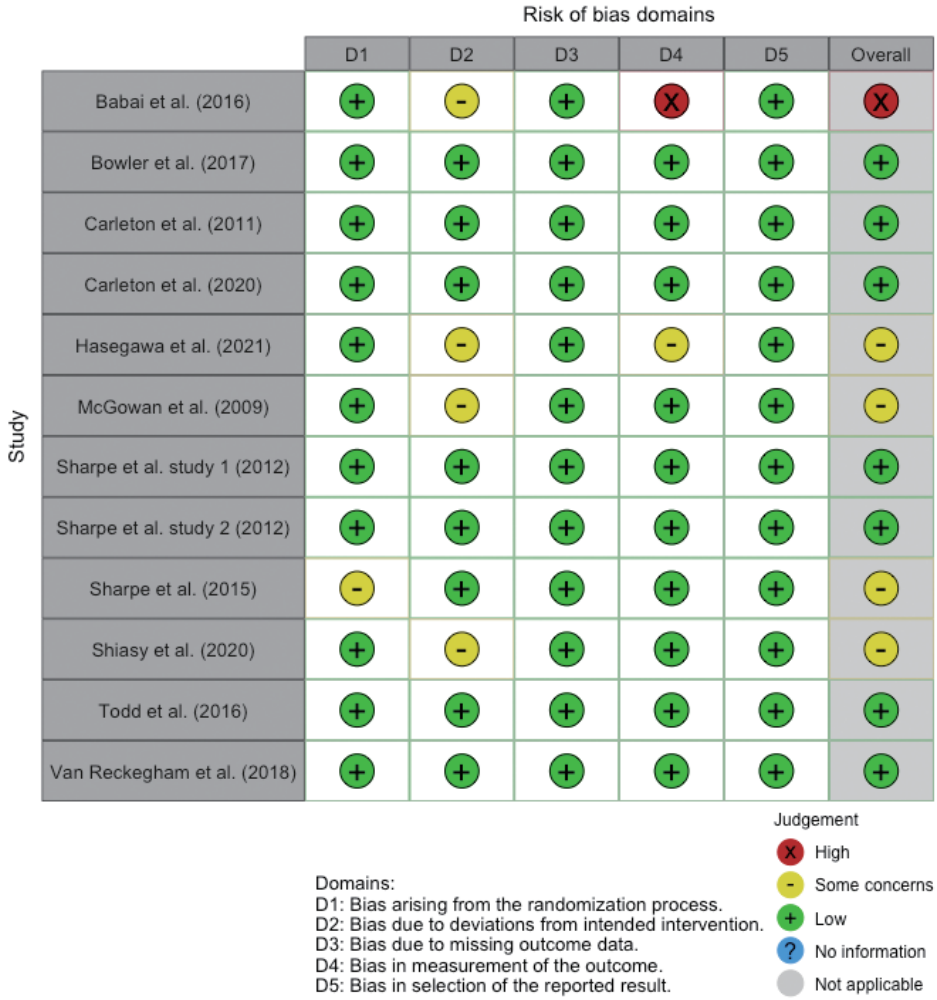

Figure 3. *Traffic light plot of ROB2 assessment.*

Systematic Review

Effect of ABM–P on Pain Outcomes

Of the 12 studies, nine showed a significant effect of ABM-P on pain outcomes. With healthy adults, there were consistent results that ABM-P can improve pain outcomes. Healthy adults reported lower pain intensity at the 30s point and a higher pain threshold (Bowler et al., 2017; McGowan et al., 2009; Sharpe et al., 2015) in CPT after disengagement training from pain words. In contrast, a study that comparing different training conditions confirmed the opposite results. Participants who were trained to engage affec-

tive-pain words reported a higher pain threshold than the disengagement training group (Todd et al., 2016). Most of the findings were depicted a null effect on pain tolerance (McGowan et al., 2009; Sharpe et al., 2015; Todd et al., 2016) except one (Bowler et al., 2017). This means that ABM-P has a positive effect on pain intensity and pain threshold, but its impact on pain tolerance was found to be limited.

On the other hand, there were mixed results in pain patient studies. Several studies found that ABM-P decreases pain intensity in the short term (Carleton et al., 2011; Sharpe et al., 2012; Carleton et al., 2020). However, the long-term effects of ABM-P on pain intensity showed contradictory results. Among the four longitudinal studies, only one study reported a significant effect of ABM-P. After a single session of ABM-P, patients with acute pain reported lower average/current pain intensity and fewer pain days than the control group in the 3 months follow-up (Sharpe et al., 2012). The effect of ABM-P was not maintained in 1 month follow-up with chronic pain patients although a longer treatment session was deployed (eight sessions). Moreover, some findings showed a significant reduction in pain intensity even in the placebo control group (Carleton et al., 2011; Carleton et al., 2020).

Additionally, some studies attempted to examine whether a combined treatment or another treatment entirely can change pain outcomes more effectively. When comparing ABM-P with CBT, there was a significant effect on pain intensity for both treatments (Babai et al., 2016), but CBT was found to be more helpful in alleviating pain intensity in patients with chronic pain than ABM-P. The CBT+ABM-P treatment combination was not found to be superior to the CBT+control training. Another study examined the effect of ABM-P+tDCS (transcranial direct current stimulation) treatment (Shiasy et al., 2020). ABM-P can reduce pain, regardless of its use in tDCS. Nevertheless, the effect of treatment persisted longer in combined treatment than with ABM-P alone. The results were showing null effects, even if multi-session ABM-P was applied with additional treatmentin patients with chronic pain (Hasegawa et al., 2021; Sharpe et al., 2012). In summary, ABM-P affects pain, and this analgesic effect would be more helpful when used in combination with other psychological/medical interventions.

Effect of ABM–P on Attentional Bias

Of the seven studies, four identified the effect of ABM-P on reducing attentional bias. As a treatment for improving the ability to disengage from pain-related stimuli in patients with chronic pain, ABM-P was helpful compared with placebo or tDCS treatment (Shiasy et al., 2020). Training in ABM-P also showed a significant effect on changing attentional bias in a healthy adult study. When participants are trained to engage or disengage from pain-related stimuli, the pattern of attention was changed according to the training directions (McGowan et al., 2009; Sharpe et al., 2015). Todd et al. (2016) found a significant decrease in the eye movement index, although it was not always effective in addressing AB. In contrast, five findings demonstrated disappointing results of ABM-P both in healthy adults and patients with pain (Sharpe et al., 2012; Bowler et al., 2017; Van Ryckeghem et al., 2018; Carleton et al., 2020; Hasegawa et al., 2021).

Relationship Between AB Change and Pain Outcomes

Only four out of 12 studies investigated whether the effect of ABM-P on pain outcomes was due to the change in AB. In healthy adults, pieces of evidence show that a change of AB leads to an improvement in pain outcomes. The changes in AB and pain threshold were positively correlated (Todd et al., 2016), and also in pain tolerance (Bowler et al. 2017). Moreover, when participants took a longer time to pay attention to affective-pain stimuli, they reported higher distress at pain tolerance (Todd et al., 2016), and pain intensity (Sharpe et al., 2015). These findings suggest that attempts to distract from affective-pain stimuli can, paradoxically, cause more painful experiences. Nevertheless, AB change and pain outcomes were not significantly correlated in patients with chronic pain (Carleton et al., 2020). This result implies that AB may only be associated with pain outcomes in healthy adults.

Effect of ABM–P on Emotion

Of the eight studies that used emotion as an outcome variable, five confirmed that ABM-P affects emotions. The effect of ABM-P on discomfort was not significant (Van Ryckeghem et al., 2018). In addition, when applying engagement training to affective-pain words, an aversive effect on higher distress in terms of pain tolerance was observed (Todd et al., 2016). In patients with acute pain,

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ABM-P did not affect emotional outcomes. However, anxiety sensitivity decreased when ABM-P was used with CBT. The findings imply that ABM-P would not be effective on its ownin changing the emotional experience of acute pain.

In chronic pain patients, there are several indications that ABM-P affects emotions. Anxiety sensitivity and pain-related fear diminished after training (Carleton et al., 2011; Sharpe et al., 2012). Carleton et al. (2020) found there was no difference between ABM-P and the control group in emotional outcomes immediately after the training. Nevertheless, the effect of ABM-P on depression, anxiety, and stress manifested in follow-up. Another study investigating the effect of ABM-P in chronic low-back pain showed that participants who received ABM-P reported lower anxiety and stress than the control group, and this positive effect of ABM-P was maintained for 1 month (Shiasy et al., 2020). These results suggest that the effect of ABM-P may not be expressed in the short term; however, it may take more time to manifest its effect on changing emotional experiences in patients with chronic pain.

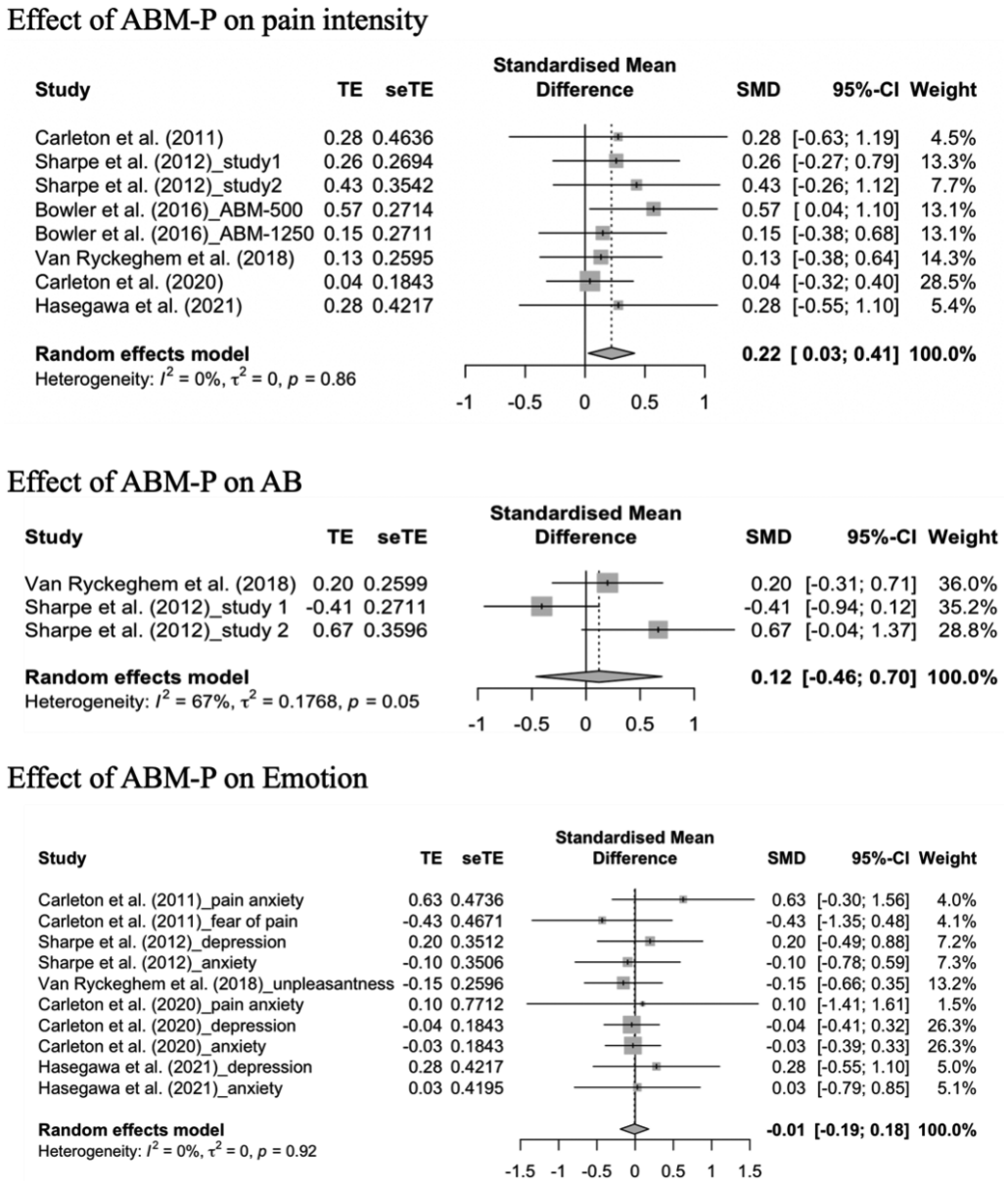

Figure 4. *Effect of ABM-P on pain outcomes.*

Meta-analysis

Effect of ABM-P on Pain Intensity

To investigate the overall effect of ABM-P on pain intensity, we conducted a between-group meta-analysis on six studies that presented there sults of pain intensity (k = 8). There was asmall and significant effect size of ABM-P on pain intensity ($Z = 2.24$, $p = 0.025$, Hedges'g = 0.22, 95% CI = [0.03–0.41]). This result shows that ABM-P training has a greater effect than with the control training group. The heterogeneity was not significant ($I^2 = 0\%$, $Q = 3.22$, $df = 7$, $p = 0.864$). Figure 4 presents the results of the meta-analysis of pain intensity.

Effect of ABM-P on AB

Only three studies presented data available for the meta-analysis (k = 3). The analysis found that the effect size was not significant ($Z = 0.40$, $p = 0.687$, Hedges'g = 0.12, 95% CI = [-0.46–0.70]). The heterogeneity was significant ($I^2 = 0\%$, $Q = 0.61$, $df = 2$, $p = 0.047$). Figure 4 presents the result of a meta-analysis on AB.

Effect of ABM-P on Emotions

A meta-analysis of the five studies that reported the results of emotions was conducted. The variables included in the meta-analysis were pain anxiety, pain-related fear, depression, anxiety, and unpleasantness (k = 10). There was no significant effect size ($Z = -0.09$, $p = 0.929$, Hedges'g = -0.01, 95% CI = [-0.19–0.18]). The heterogeneity was not significant ($I^2 = 0\%$, $Q = 3.89$, $df = 9$, $p = 0.918$). Figure 4 presents the result of themeta-analysis on emotions.

Discussion

The present study aimed to investigate the efficacy and limitations of ABM-P through a systematic review and meta-analysis. Our results demonstrate that ABM-P has a significant small effect size on pain intensity. In addition, the systematic review shows discrepant results depending on the sample. In healthy adults, ABM-P has positive effects whereas mixed results are found in patients with chronic pain. The different results between samples may stem from characteristics of the sample contributing to the magnitude of AB. Several results of meta-analysis proposed that chronic pain patients show higher AB than healthy adults (Schoth et al., 2012; Crombez et al., 2013; Todd et al., 2018). Low AB in acute pain conditions can be easily modified, therefore, there is a possibility of decreased AB resulting in an alleviation of pain intensity.

The embodied defense model (Eccleston, 2018) explains the mixed results of AB found in patients with chronic pain. This model suggests that different protection stages work depending on the condition of pain. When pain interrupts one's awareness, level 2 protection operates and captures attention as a part of defensive behavior. Nevertheless, when it becomes unavoidable, dissociation occurs by protecting oneself with level 3 protection. Acute pain is associated with level 2 protection (Broadbent et al., 2021), andchronic pain is the most representative example of an "unavoidable" condition that is related to level 3 protection. Attention management such as ABM-P may not work well in dissociative protection.

In our study, we observed the possibility of AB change through attentional training in a systematic review, but the effect size was not significant. This result verified the plasticity of AB, whereas consistency and directions are still uncertain. As Todd et al. (2015) mentioned, ABM-P studies have been conducted discursively with too various variables. This may be a factor contributing to the lack of consensus and standardization of ABM-P. In addition, no more than three studies were included in the meta-analysis to confirm the effect of ABM-P on attentional bias. Hence, more caution is required in generalizing the results of this study.

Regarding emotional outcomes, the long-term efficacy of ABM-P in patients with chronic pain was found in the systematic review. Some findings indicate that ABM has a null or paradoxically aversive effect on the emotional outcomes (Baert et al., 2010; Bunnell et al., 2013; Kruijt et al., 2013). We also found a null effect of ABM-P in the meta-analysis. This may be because we cannot include long-term results due to the lack of longitudinal study. Only four studies followed up long-term outcomes of ABM-P, and no longitudinal study met the criteria of the meta-analysis. Jackson et al. (2019) study showed the long-term impact of AB in late attention on pain intensity and disability; hence, ABM-P studies should be considering the prolonged influence of AB. Exploring the long-term effect of ABM-P could allow a clear understanding of the emotional perspective of ABM-P.

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Despite the partial impact of ABM-P, the results of the present study also highlight some limitations of ABM-P that need to be discussed. First, it was unclear whether AB is the driver of the analgesic effect. Most studies have merely applied correlation analysis to investigate the association between the changes in AB and pain experiences. This allows only a fragmented understanding of the treatment mechanism of ABM-P. Moreover, there is the possibility that mechanisms other than AB change (e.g., attention control) are involved in the positive effect of ABM (Chen et al., 2015). Second, the methodological problems of the dot-probe task may influence the results of ABM-P. The test-retest reliability and internal consistency of the dot-probe task were both low (Dear et al., 2011), and it does not seem sufficient to accurately measure the efficacy ofABM-P. Besides, the ways of attention training may hinder the efficacy of ABM-P. The traditional ABM-P focuses on modifying hypervigilance in early attention. Although avoiding threat stimuli can be a strategy for emotional regulation, in the long-term, it causes repetitive brief exposure that interrupts the processing of threat stimuli and maintains unstable emotional states (Mohlman & Zinbarg, 2000; McNally, 2007).

Based on the limitations discussed above, a new theoretical, methodological approach is required to enhance the efficacy of ABM-P. Van Ryckeghem et al. (2019) proposed that cognitive biases such as AB should be understood in the context of functionalcontextualism. The adaptive value of cognitive bias could be change depending on the contextual factors. Under the control of protective behaviors, AB serves as an adaptive mechanism to protect oneself. By contrast, when pain-related outcomes cannot be regulated by counteracting threats, AB only plays an impeding role in daily life. In line with this view, Mogg et al. (2017) suggested that cognitive inflexibility such as AB is a contributor to AB. Kuckertz et al. (2014) also showed that the plasticity of AB, which reflects cognitive flexibility, serves as mediating role in ABM targeting PTSD. Increasing cognitive flexibility, the ability that enables one to change one's cognitive bias to meet the demands of context, is a bright alternative direction for clinical intervention (Tabor et al., 2020).

Additionally, combined intervention could be a hopeful approach for enhancing the efficacy of ABM-P. Along with cognitive flexibility, targeting motivation might be a promising approach for modulating AB adaptively. Sun et al. (2016) demonstrated that AB can be modified by motivational intervention. AB could be modulated easily when individuals have an important goal (Schrooten et al., 2012; Van Ryckeghem & Crombez, 2018). In the process of pursuing important goals, an increase of adaptive incidentally follows, and a motivational approach can supplement the shortcomings of traditional ABM-P. Furthermore, other cognitive biases (e.g., interpretation bias) that were known for interplaying with AB have to be integrated into the cognitive bias modification paradigm.

To overcome the methodological issues, eye tracking could be an effective methodological approach for ABM-P. By using an eye tracker, AB could be measured continuously and directly (Yang et al., 2013; Liossi et al., 2014). Notably, when dysphoric college students received eye tracker-based ABM, they showed a change in AB (Möbius et al., 2018). Another study demonstrated that eyetracker-based gaze contingence feedback has a positive effect on modifying maintaining attention in major depressive disorder (Shamai-Leshem et al., 2021). Not only training methods but also stimuli can be points of improvement. Instead of using a pair of monotonous stimuli, using stimuli describing specific real-life context would be helpful to generalize training efficacy (AlMoghrabi et al., 2019).

Although this study integrates current findings of ABM-P, there are some limitations. First, even with updated data, the number of studies included in the meta-analysis was insufficient to elucidate the effect of ABM-P. Because ofthe small number of studies, we cannot consider various pain outcomes other than by using VAS. Further studies must include other pain outcomes such as pain threshold or pain tolerance. Second, we could not conduct Egger's regression test to examine the risk of publication bias because of the lack of studies. Third, only studies written in English were included. Literature published in English tends to show higher effects than other languages (Egger & Smith, 1998). It is difficult to conclude whether the risk of bias was completely ruled out. Future research, which covers plenty of findings of ABM-P would promote a profound understanding of ABM-P.

Despite these limitations, this study has implications for ABM-P studies. We have updated the research data on ABM-P since the last review covered only a few studies and was published before 2014 (Todd et al., 2015). Specifically, we covered the negative re-

sults of recent studies, which enable an accurate examination of the efficacy of ABM-P. Moreover, our work sheds light on the current state of ABM-P studies. Although many studies have investigated the effects of AB on pain, studies of ABM-P remain scarce. This unbalanced state suggests that in practice ABM-P has been overly dependent on a theoretical basis rather than empirical evidence. Finally, the results of this study provide preliminary evidence for the effects of ABM-P on pain experience and AB. These findings indicate that the development of new interventions that can contribute to effective pain management would be required.

Author contributions statement

SKC, Professor at Chungnam National University: supervised the research process, HKY, graduate student at Chungnam National University: data collection, manuscript writing.

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