Cognitive biases in pain: An integrated functional-contextual framework

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1. Cognitive biases in the context of pain.

Contemporary models explaining the exacerbation and maintenance of pain, disability and distress, assign a pivotal role to cognitive biases. These models assume that cognitive biases are maladaptive, trait-like processes, and propose that individuals who selectively attend to pain-related information (attention bias), interpret ambiguous pain and/or health relevant information as threatening (interpretation bias), and/or recall pain-related information selectively or as more negative/threatening than initially experienced (memory bias), report higher levels of pain and disability and are at increased risk for developing chronic pain.[10,11,15,16,51,56,77,87,93,94] This intuitively appealing idea has resulted in an exponential increase in research addressing the presence, antecedents, and consequences of cognitive biases in people experiencing acute and chronic pain.[10,13,17,41,51,52,67,68,78] However, results are inconsistent and puzzling, with mixed support for theoretical-driven assumptions.[12,41,67,87,88,93] The aim of this review is to (a) synthesize and discuss current knowledge on the role of cognitive biases in pain, (b) provide conceptual and methodological explanations for equivocal findings, and (c) develop an integrated functional-contextual framework for understanding the role of cognitive biases in pain. Based on this framework, we propose a new research agenda and discuss implications for clinical practice.

2. The presence and impact of cognitive biases in pain: The state of the science.

Research on cognitive biases in (chronic) pain has been guided by the research agenda on cognitive biases in psychopathology, where similar theoretical processes are proposed (e.g.,[2,24,47]). As such, paradigms were adapted from psychopathology research (e.g., dot-probe[1,21,37,73], homograph or homophone task[60,67], word memory task[36,66,72]) to investigate cognitive biases for pain-related information. These paradigms typically use symbolic descriptors of health/illness or pain experiences or situations (e.g., words and/or pictures, descriptions of ambiguous situations). Recently, a number of comprehensive reviews synthesized available evidence following this research tradition.[13,52,67,68,78]

For attention bias, these reviews revealed small effects, indicating that people experiencing acute or chronic pain show a bias towards pain-related information, particularly sensory pain words.[13,78] No bias was found in people without or merely anticipating pain.[68,78] Most remarkably, no consistent relationship

was found between attention bias for pain and its theoretically-proposed antecedents (e.g., fear of pain) or consequences (e.g., pain severity).[13] Equally inconsistent relationships have been found in prospective research[42,43,44,74] and in youth with pain.[6,41] For interpretation bias, a recent meta-analysis indicated that individuals with chronic pain tend to interpret ambiguous information as more pain-related than healthy individuals.[67] This meta-analysis also revealed a lack of research addressing the link between interpretation bias and its theoretically-proposed antecedents and consequences.[41] The few studies investigating the link between pain severity or pain-related anxiety and biased interpretations for bodily threat in individuals living with chronic pain failed to find consistent associations.[57,60,but see39] Similarly, in healthy individuals, no systematic link was observed between pain-related anxiety and interpretation bias.[38,81,82] Finally, a number of studies investigated memory bias for pain- and illness-related information in people experiencing pain. This research suggests that adults and youth with chronic pain recall more sensory pain words compared to neutral words (e.g.,[18,55,64,but see96]), whereas findings on recall of illness-related words are mixed.[18,59,58] Interestingly, some studies showed that increased recall of illness-related or negative health words relates to increased negative mood, although further research is warranted.[14,58] A consistent link between memory biases for pain-related information and its theoretically-proposed antecedents and consequences is however lacking.[14,62,72]

In sum, there is limited evidence to support the role of cognitive biases for pain-related information in explaining the exacerbation and maintenance of pain and pain-related disability. Although there is evidence for the presence of cognitive biases in people experiencing pain, effect sizes are small to moderate and there is substantial heterogeneity between studies. This heterogeneity may be partly due to task parameters, such as stimuli (e.g., sensory vs. affective pain words[13,78]) or instructions (self-referent vs other-referent instructions[58]). However, much heterogeneity remains unexplained and available evidence does not show a robust link between cognitive biases for pain-related information and the theorized antecedents and consequences. Notably, research addressing the interaction between cognitive biases is lacking (see[66,69,76] for exceptions). In addition, there is a need for prospective research investigating the link between cognitive biases and the development of chronic pain. Therefore, we argue that it is premature to draw definitive conclusions from the current evidence base. Furthermore,

we urge for a shift in the conceptualization and operationalization of cognitive biases to explain existing inconsistencies.

3. Towards an integrated functional-contextual framework

We propose that cognitive biases should be understood from an integrated functional-contextual framework. Key in this framework is that cognitive biases are conceptualized as functional phenomena driven by changing contexts and motivational factors. This conceptual framework has three key assumptions: Cognitive biases are (1) functional, (2) dynamic, and (3) interrelated and/or interacting.

(1) Cognitive biases are functional phenomena

The first assumption contradicts the popular view that cognitive biases are intrinsically maladaptive phenomena. Within proposed framework, cognitive biases are suggested to be functional processes and not *necessarily* maladaptive. We propose that the adaptive value of cognitive biases for pain depends upon *context*. This assumption is in line with an evolutionary account on cognitive biases (see also[25]). In particular, we propose that cognitive biases may have an adaptive value in instances where identification of pain and adoption of protective responses to potentially threatening situations can prevent negative outcomes.[17,84,93] However, when protective responses are unavailable or ineffective, the same cognitive biases may interfere with the pursuit of daily tasks or life goals. Whether cognitive biases to pain-related information are adaptive then depends on their ability to prompt a response that can avert negative pain-related outcomes balanced against the urgency and value of competing goals. When a negative pain-related outcome cannot be prevented or modulated, interpreting situations in a threatening manner and being highly attentive to pain-related information is likely to interfere with daily goals, without benefit. If this assumption is true, adaptive cognitive processing would require the ability to shift flexibly in the way that situation-specific features are interpreted in line with presented demands, which are dependent upon the actual threat level and possibility to influence this threat balanced with the pursuit of ongoing and/or future non-pain-related goals, and attention is deployed consistent with that interpretation. Memory processes may then allow for optimal deployment of cognitive processes in

future situations with similar situation-specific features. Based upon this assumption, we propose that it is inflexibility or rigidity in the way people attend, interpret, and remember pain information, irrespective of situation-specific features, such as active goals or changing contexts, that results in negative pain outcomes. Such inflexibility may be partly due to rule-governed behavior[26,40] and/or reduced executive functioning abilities[45]. Indeed, flexible adaptation in the way of attending to, interpreting, and remembering pain-related information to contextual demands requires executive functioning, including attentional and cognitive control.[3,31,45,48]

(2) Cognitive biases are dynamic phenomena.

The second assumption proposes that cognitive biases are dynamic, fluctuating, and unfolding phenomena driven by motivational and contextual factors, rather than stable trait-like processes as often implicitly presumed.[8,67,68,94] This is supported by increasing evidence that cognitive biases are influenced by active goal pursuit and contextual factors. For example, research has shown that attention bias for pain information increases when the goal to avoid pain is pursued[54], but diminishes in the presence of salient competing goals[70,71] (e.g., rewarded task performance). Furthermore, attentional biases have been found to vary as a result of the threat of an anticipated pain-related task.[73] For interpretation bias, Moseley and Arntz (2007) showed that contextual cues (i.e., blue vs. red colored cues) influenced how ambiguous nociceptive stimuli are experienced,[49] Finally, numerous studies showed that the affective context (e.g., anxiety) of caregivers and the individual experiencing pain exerts influence on the magnitude of memory bias.[22,23,32,50,51] Each of these examples shows that cognitive biases are dynamic and supports the assumption that they are influenced by context and motivation. Differences in motivation may be due to a number of factors, including the relative importance of pain-relevant or competing goals, goal pursuit opportunities and experienced emotions.[7,84,88] Motivation may not only be influenced by proximal state variables, but may also be influenced by more distal trait-like individual difference variables, such as health anxiety, anxiety sensitivity, or pain catastrophizing. Systematic research is needed to address the impact of pain-relevant versus pain-irrelevant goal pursuit and context

variables (e.g., presence of safety cues, presence of significant others, caregiver affect etc.) on the direction and magnitude of cognitive biases. Furthermore, we contend that one cannot simply translate findings on cognitive biases from one context (e.g., a lab context) to another (e.g., a daily life context), without considering motivational and contextual factors. As such, the proposed framework underscores the need for future research to consider goal pursuit and context variables.

(3) Cognitive biases are interrelated

In line with the recent call to investigate the relationship between different cognitive biases in the field of pain[69,77,92], we argue for an integrative model in which cognitive biases are interrelated and interacting. Similar to the combined cognitive bias hypothesis, we propose that the relationships between cognitive biases are bidirectional.[29,but see27,77] In the simplest way, early attention is captured by ambiguous bodily sensations, which are then interpreted as either threatening or non-threatening. This interpretation affects later attentional processes and may consequently impact how the situation is remembered.[19,77] Finally, the pain memory is activated in the future when similar bodily sensations are experienced, which will invariably influence attention and interpretation.[53] Within this view, we argue that the interrelationship between cognitive biases is likely due to shared underlying mechanisms -i.e., motivation and contextual variables- that fuel their potential co-occurrence. Yet, it may well be that cognitive biases are not merely interrelated, but have cumulative effects and hence, particular combinations of cognitive biases have an amplified effect upon pain outcomes compared to their impact alone.[29] Since research investigating combined cognitive biases in the field of pain is still in its infancy, these hypotheses remain speculative. Hypothesis-driven and systematic research simultaneously addressing cognitive biases is needed to elucidate how they interrelate and interact with each other to affect pain intensity, pain-related disability and the development and maintenance of chronic pain.

4. The future research agenda for cognitive bias research

Adopting an integrated functional-contextual framework to explain the presence, direction, and dynamics of cognitive biases brings exciting new research avenues, as well as important methodological

challenges. Many of these challenges relate to the typical assessment of cognitive biases in the context of pain. The majority of studies involve a *single assessment* of a *single cognitive bias* for *symbolic representations* of pain or health using *a computer task in the laboratory*. Yet, if biases are interrelated, dynamic, and context-specific, as we assert, these typical laboratory assessments do not comprehensively or validly capture the nature of cognitive biases for pain as theoretically-proposed and as they would occur in real-world contexts. To propel cognitive bias research in the field of pain, we make the following recommendations. First, researchers need to ensure that the stimulus material used in cognitive bias research is relevant to the sample and the context. This may be even more challenging due to the large heterogeneity in pain samples and common comorbidity with psychopathological disorders, such as anxiety and depression.[46,95] The investigation of cognitive biases using actual pain[53], pain-relevant body locations[85], signals of impending pain[9,90] or ambiguous somatosensory stimuli[49] may increase the relevance of pain information. Furthermore, avoiding the use of symbolic pain information (particularly words) reduces the possibility that familiarity with the information (i.e., pain patients more often use pain-related words than healthy persons) can explain cognitive bias findings due to better recall of and altered attention to familiar information.[20,63] In similar vein, the link between various cognitive biases should be investigated in relation to similar relevant stimuli, as the presence and magnitude of biases may be determined by the particular type and relevance of pain-related stimuli.[92] Second, cognitive biases are typically investigated without taking context into account and in isolation from active goals, which are common in individuals' daily lives (see[70,71] for an exception). Researchers should aim to test theory-driven hypotheses in dynamic functional contexts by implementing real life actions and/or goals during pain.[9,84] This may be achieved by bringing realistic (daily life) goals and contexts into a controlled laboratory setting (e.g., by using virtual or augmented reality).[80,86] Manipulating the features of active goals and the context (e.g., safe vs. dangerous; controllable vs. uncontrollable; stressful vs. relaxed) during the assessment of cognitive biases for pain will provide a better understanding of the dynamic nature of cognitive biases in daily life. Alternatively, researchers may assess cognitive biases in the daily lives of people experiencing acute/chronic pain[65] by developing novel paradigms to assess information-processing in daily life. Ecological momentary assessment methods may then be used to assess pain outcomes, context and motivational variables.[35] Third, we propose that inflexibility in

attending, interpreting, and recalling pain-related information may be central for negative pain outcomes, rather than the temporary presence or direction of cognitive biases. Current study designs often do not enable investigating flexibility in the way that people attend, interpret, and recall pain information (see[89,97] for an exception). Using repeated measurements of cognitive biases for pain-related information in varying contexts would (a) increase the representativeness of the existence and magnitude of cognitive biases for pain in daily contexts and (b) allow to determine whether a person is flexible in the way he or she attends, interprets, and recalls pain-related information. Fourth, researchers should move beyond examining the impact of isolated cognitive biases on pain outcomes. Indeed, although examining single biases is valuable for understanding the exact phenomenon it provides only one piece of the larger puzzle to explain higher levels of pain and disability and increased risk for developing chronic pain. Without adopting an integrative view, including the relationship between cognitive biases, active goals and context, equivocal findings will likely remain unexplained.

5. Clinical Implications.

Our integrated functional-contextual framework also has consequences for the treatment of acute and chronic pain. First, we suggest that targeting cognitive biases without considering context or goal pursuit is likely to prove ineffective. For example, attention bias modification interventions focus upon training attention away from pain-related information independent of context or goal pursuit. Although such training may affect cognitive biases within the trained context[4,5,33,74], it often proves futile in different contexts.[27,91,but see74] The current model suggests that treatment should (a) target contextual and motivational, including affective, factors that drive cognitive biases; and/or (b) increase flexibility in the way that people attend, interpret, and recall pain-related information. Clinical psychologists have a plethora of techniques to target and change motivation (e.g., motivational interviewing[83]). Clinicians may also be more effective in impacting cognitive biases for pain by targeting the meaning or the threat value of pain or increasing peoples' awareness of their personal goals by using cognitive behavioral therapy or acceptance and commitment therapy.[34,61,77,87] Finally, one may also aim to directly train people to flexibly attend, interpret, and remember pain-related information in a changing environment.[30]

In addition, the current framework provides a clear imperative to investigate the interplay between cognitive biases, which can help to identify under which circumstances it is helpful to target a single bias or multiple interacting cognitive bias(es) or their underlying mechanisms of action.[92]

6. Conflict of interest statement

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7. References

[1] Asmundson GJG, Kuperos JL, Norton GR. Do patients with chronic pain selectively attend to pain-related information?: Preliminary evidence for the mediating role of fear. PAIN 1997;72:27-32.

[2] Bar-Haim, Y. Research Review: Attention bias modification (ABM): A novel treatment for anxiety disorders. J Child Psychol Psychiatry 2007;51:859-870.

[3] Basanovic J, Notebaert L, Grafton B, Hirsch CR, Clarke PJF. Attentional control predicts change in bias in response to attentional bias modification. Behav Res Ther. 2017;99:47-56.

[4] Blaisdale Jones E, Sharpe L. The effect of cognitive bias modification for interpretation on avoidance of pain during an acute experimental pain task. PAIN 2014;155:1569–1576

[5] Bowler JO, Bartholomew KJ, Kellar I, Mackintosh B, Hoppitt L, Bayliss AP. Attentional bias modification for acute experimental pain: A randomized controlled trial of retraining early versus later attention on pain severity, threshold and tolerance. Eur J Pain 2017;21:112-124.

[6] Brookes M, Sharpe L, Kozlowska K. Attentional and Interpretational Biases Toward Pain-Related Stimuli in Children and Adolescents: A Systematic Review of the Evidence. J Pain 2018;S1526-5900(18)30160-3.

[7] Carver CS, Lawrence JW, Scheier MF. A control-process perspective on the origins of affect. In Martin LL, Tesser A, editors. Striving and feeling: Interactions among goals, affect, and self-regulation. Hillsdale, NJ, US: Lawrence Erlbaum Associates, 1996.

[8] Chapman CR. Pain: the perception of noxious events. In: Sternbach RA, editor. The psychology of pain. New York: Raven Press; 1978.

[9] Clauwaert A, Torta DM, Danneels L, Van Damme S. Attentional modulation of somatosensory processing during the anticipation of movements accompanying pain: an event-related potential study. J Pain 2018;19:219–27.

[10] Crombez G, Van Damme S, Eccleston C. Hypervigilance to pain: an experimental and clinical analysis. Pain 2005;116:4-7.

[11] Crombez G, Eccleston C, Van Damme S, Vlaeyen JWS, Karoly P. Fear-avoidance model of chronic pain: the next generation. Clin J Pain 2012;28:475–83.

[12] Crombez G, Heathcote L, Fox E. The puzzle of attentional biases to pain: Beyond attention. PAIN 2015;156:1581–1582.

[13] Crombez G, Van Ryckeghem DML, Eccleston C, Van Damme S. Attentional bias to pain-related information: A meta-analysis. PAIN 2013;154:497-510.

[14] Denton FJ, Sharpe L, Schrieber L. Cognitive bias in systemic lupus erythematosus. Eur J Pain 2005;9:5-14.

[15] Eccleston C, Crombez G. Pain demands attention: a cognitive-affective model on the interruptive function of pain. Psychol Bull 1999;125:356–66.

[16] Eccleston C, Crombez G. Worry and chronic pain: a misdirected problem solving model. Pain. 2007;132:233-236.

[17] Eccleston C, Crombez G. Advancing psychological therapies for chronic pain. F1000Research. 2017;6:461.

[18] Edwards L, Pearce S, Collett BJ, Pugh R. Selective memory for sensory and affective information in chronic pain and depression. Br J Clin Psychol 1992;31:239-248.

[19] Everaert J, Duyck W, Koster EH. Attention, interpretation, and memory biases in subclinical depression: a proof-of-principle test of the combined cognitive biases hypothesis. Emotion 2014;14:331-340.

[20] Eysenck, M. W. (1992). Anxiety: The cognitive perspective. Hillsdale, NJ: Erlbaum

[21] Fashler SR, Katz J. Keeping an eye on pain: investigating visual attention biases in individuals with chronic pain using eye-tracking methodology. J Pain Res 2016;9:551-561.

[22] Gedney JJ, Logan H. Memory for stress-associated acute pain. J Pain 2004;5:83-91.

[23] Gorin AA, Stone AA. Recall biases and cognitive errors in retrospective self-reports: A call for momentary assessments. In: Baum A, Revenson TA, Singer JE, editors. Handbook of Health Psychology. Mahwah, NJ: Lawrence Erlbaum Associates; 2001. pp. 405–413.

[24] Hallion LS, Ruscio AM. A meta-analysis of the effect of cognitive bias modification on anxiety and depression. Psychol Bull 2011;137:940-58.

[25] Haselton MG, Nettle D, Murray DR (2015). The Evolution of Cognitive Bias. In Buss DM. editor The Handbook of Evolutionary Psychology. Wiley, 2015

[26] Hayes SC. Acceptance and Commitment Therapy, Relational Frame Theory, and the third wave of behavioral and cognitive therapies. Behav Ther 2004;35: 639-665.

[27] Heathcote LC, Eccleston C. Pain and cancer survival: a cognitive-affective model of symptom appraisal and the uncertain threat of disease recurrence. PAIN 2017;158:1187-1191.

[28] Heathcote LC, Jacobs K, Van Ryckeghem DML, Fisher E, Eccleston C, Fox E, Lau JYF. Attention bias modification training for adolescents with chronic pain: a randomized placebo-controlled trial. PAIN 2018;159:239-251.

[29] Hirsch CR, Clark DM, Mathews A. Imagery and interpretations in social phobia: Support for the combined cognitive biases hypothesis. Behav Ther 2006;37:223-236.

[30] Hoorelbeke K, Koster E, Demeyer I, Loeys T, Vanderhasselt M-A. Effects of cognitive control training on the dynamics of (mal)adaptive emotion regulation in daily life. Emotion 2016;16:945–56.

[31] Hou R, Moss-Morris R, Risdale A, Lynch J, Jeevaratnam P, Bradley BP, Mogg K. Attention processes in chronic fatigue syndrome: attentional bias for health-related threat and the role of attentional control. Behav Res Ther 2014;52:9-16.

[32] Hufford MR, Shiffman S, Paty J, Stone AA. Ecological Momentary Assessment: Real-world, real-time measurement of patient experience. In Fahrenberg J., Myrtek M. editors. Progress in ambulatory assessment. Kirkland, WA: Hogrefe & Huber, 2001.

[33] Jones EB, Sharpe L. The effect of cognitive bias modification for interpretation on avoidance of pain during an acute experimental pain task. PAIN 2014;155:1569-1576.

[34] Kangasniemi AM, Lappalainen R, Kankaanpää A, Tolvanen A, Tammelin T. Towards a physically more active lifestyle based on one's own values: the results of a randomized controlled trial among physically inactive adults. BMC Public Health. 2015;15:260.

[35] Kaplan RM, Stone AA. Bringing the Laboratory and Clinic to the Community: Mobile Technologies for Health Promotion and Disease Prevention. Ann Rev Psychol 2013;64:471-498.

[36] Karimi Z, Pilenko A, Held SM, Hasenbring MI. Recall Bias in Patients with Chronic Low Back Pain: Individual Pain Response Patterns Are More Important Than Pain Itself! Int J Behav Med 2016;23:12-20.

[37] Keogh E, Ellery D, Hunt C, Hannent I. Selective attentional bias for pain-related stimuli amongst pain fearful individuals. PAIN 2001;91:91-100.

[38] Keogh E, Hamid R, Hamid S, Ellery D. Investigating the effect of anxiety sensitivity, gender and negative interpretative bias on the perception of chest pain. PAIN 2004;111:209-217.

[39] Khatibi A, Sharpe L, Jafari H, Gholami S, Dehghani M. Interpretation biases in chronic pain patients: an incidental learning task. Eur J Pain 2015;19:1139-47.

[40] Kissi A, Hughes SJ, De Schryver M, De Houwer J, Crombez G. Examining the Moderating Impact of Plys and Tracks on the Insensitivity Effect: A Preliminary Investigation. Psychol Record 2018.

[41] Lau JYF, Heathcore LC, Beale S, Gray S, Jacobs K, Wilkinson N, Crombez G. Cognitive Biases in Children and Adolescents With Chronic Pain: A Review of Findings and a Call for Developmental Research. J Pain 2018;19:589-598.

[42] Lautenbacher S, Huber C, Kunz M, Parthum A, Weber PG, Griessinger N, Sittl R. Hypervigilance as predictor of postoperative acute pain: its predictive potency compared with experimental pain sensitivity, cortisol reactivity, and affective state. Clin J Pain 2009;25:92-100.

[43] Lautenbacher S, Huber C, Schöfer D, Kunz M, Parthum A, Weber PG, Roman C, Griessinger N, Sittl R. Attentional and emotional mechanisms related to pain as predictors of chronic postoperative pain: a comparison with other psychological and physiological predictors. PAIN 2010;151:722-731.

[44] Lautenbacher S, Huber C, Baum C, Rossaint R, Hochrein S, Heesen M. Attentional avoidance of negative experiences as predictor of postoperative pain ratings and consumption of analgesics: comparison with other psychological predictors. Pain Med 2011;12:645-53.

[45] Legrain V, Van Damme S, Eccleston C, Davis KD, Seminowicz DA, Crombez G. A neurocognitive model of attention to pain: behavioural and neuroimaging evidence. PAIN 2009;144:230–2.

[46] McWilliams LAm Cox BJ Enns MW. Mood and anxiety disorders associated with chronic pain: an examination in a nationally representative sample. PAIN 2003;106: 127-133.

[47] Mitte K. Memory bias for threatening information in anxiety and anxiety disorders: A meta-analytic review. Psychol Bull 2008;134:886-911.

[48] Mogg K, Bradley BP. Anxiety and attention to threat: Cognitive mechanisms and treatment with attention bias modification. Behav Res Ther 2016;87:76-108.

[49] Moseley GL, Arntz A. The context of a noxious stimulus affects the pain it evokes. PAIN 2007;133:64-71.

[50] Noel M, Chambers CT, McGrath PJ, Klein RM, Stewart SH. The role of state anxiety in children's memories for pain. J Pediatr Psychol 2012;37:567-79.

[51] Noel M, Palermo TM, Chambers CT, Taddio A, Hermann C. Remembering the pain of childhood: Applying a developmental perspective to the study of pain memories. PAIN 2015;156:31-34.

[52] Noel M, Pavlova M, McCallum L, Vinall J. Remembering the hurt of childhood: A psychological review and call for future research. Can Psychol 2017;58:58-68.

[53] Noel M, Rabbitts JA, Fales J, Chorney J, Palermo TM. The influence of pain memories on children's and adolescents' post-surgical pain experience: A longitudinal dyadic analysis. Health Psychol 2017;36:987-995.

[54] Notebaert L, Crombez G, Vogt J, De Houwer J, Van Damme S, Theeuwes J. Attempts to control pain prioritize attention towards signals of pain: an experimental study. PAIN 2011;152:1068-1073.

[55] Pearce SA, Isherwood S, Hrouda D, Richardson PH, Erskine A, Skinner J. Memory and pain: tests of mood congruity and state dependent learning in experimentally induced and clinical pain. PAIN 1990;43:187-193.

[56] Pincus T, Morley S. Cognitive-processing bias in chronic pain: A review and integration. Psychol Bull 2001;127:599-617.

[57] Pincus T, Pearce S, McClelland A, Farley S, Vogel S. Interpretation bias in responses to ambiguous cues in pain patients. J Psychosom Res 1994;38:347-53.

[58] Pincus T, Pearce S, McClelland A, Isenberg D. Endorsement and memory bias of self-referential pain stimuli in depressed pain patients. Br J Clin Psychol 1995;34:267-277.

[59] Pincus T, Pearce S, McClelland A, Turner-Stokes L. Self-referential selective memory in pain patients. Br J Clin Psychol 1993;32:365-374.

[60] Pincus T, Pearce S, Perrott A. Pain patients' bias in the interpretation of ambiguous homophones. Br J Med Psychol 1996;69:259-66.

[61] Powers MB, Zum Vorde Sive Vording MB, Emmelkamp PM. Acceptance and commitment therapy: a meta-analytic review. Psychother Psychosom 2009;78:73-80.

[62] Read J, Pincus T. Cognitive bias in back pain patients attending osteopathy: testing the enmeshment model in reference to future thinking. Eur J Pain 2004;8:525-31.

[63] Richards, A., & French, C. C. (1992). An anxiety-related bias in semantic activation when processing threat/neutral homographs. Q J Exp Psychol, 45A, 503–525.

[64] Rusu AC, Pincus T, Morley S. Depressed pain patients differ from other depressed groups: examination of cognitive content in a sentence completion task. PAIN 2012;153:1898-1904

[65] Schneider S, Stone AA, Schwartz JE, Broderick JE. Peak and end effects in patients' daily recall of pain and fatigue: a within-subjects analysis. J Pain 2011;12:228-235.

[66] Schoth DE, Beaney R, Broadbent P, Zhang J, Liossi C. Attentional, interpretation and memory biases for sensory-pain words in individuals with chronic headache. Brit J Pain 2018.

[67] Schoth DE, Liossi C. Biased interpretation of ambiguous information in patients with chronic pain: A systematic review and meta-analysis of current studies. Health Psychol 2016;35:944-56.

[68] Schoth DE, Nunes VD, Liossi C. Attentional bias towards pain-related information in chronic pain; a meta-analysis of visual-probe investigations. Clin Psychol Rev 2012;32:13-25.

[69] Schoth DE, Parry L, Liossi C. Combined cognitive biases for pain and disability information in individuals with chronic headache: A preliminary investigation. J Health Psychol 2016;1:1359105316664136.

[70] Schrooten MGS, Van Damme S, Crombez G, Kindermans H, Vlaeyen JWS. Winning or not losing? The impact of non-pain goal focus on attentional bias to learned pain signals. Scand J Pain 2018.

[71] Schrooten MG, Van Damme S, Crombez G, Peters ML, Vogt J, Vlaeyen JW. Nonpain goal pursuit inhibits attentional bias to pain. PAIN 2012;153:1180-1186.

[72] Serbic D, Pincus T. Diagnostic uncertainty and recall bias in chronic low back pain. Pain 2014;155:1540-1546.

[73] Sharpe L, Brookes M, Jones E, Gittins C, Wufong E, Nicholas MK. Threat and fear of pain induces attentional bias to pain words: An eye-tracking study. Eur J Pain. 2017;21:385-396

[74] Sharpe L, Ianiello M, Dear BF, Nicholson Perry K, Refshauge K, Nicholas MK. Is there a potential role for attention bias modification in pain patients? Results of 2 randomised, controlled trials. PAIN 2012;153:722-731.

[75] Sharpe L, Johnson A, Dear BF. Attention bias modification and its impact on experimental pain outcomes: Comparison of training with words versus faces in pain. Eur J Pain 2015;19:1248-1257.

[76] Todd J, Sharpe L, Colagiuri B. Attentional bias modification and pain: The role of sensory and affective stimuli. Behav Res Ther. 2016, 83:53-61. doi: 10.1016/j.brat.2016.06.002.

[77] Todd J, Sharpe L, Johnson A, Perry KN, Colagiuri B, Dear B. Towards a new model of attentional biases in the development, maintenance and management of pain. PAIN 2015;156:1589-1600.

[78] Todd J, Van Ryckeghem DML, Sharpe L, Crombez G. Attentional bias to pain-related information: A meta-analysis of dot-probe studies. Health Psychol Rev 2018.

[79] Turner JA, Holtzman S, Mancl L. Mediators, moderators, and predictors of therapeutic change in cognitive-behavioral therapy for chronic pain. PAIN 2007;127:276-86.

[80] Urech A, Krieger T, Chesham A, Mast FW, Berger T. Virtual Reality-Based Attention Bias Modification Training for Social Anxiety: A Feasibility and Proof of Concept Study. Front Psychiatry. 2015;28:154.

[81] Vancleef LM, Hanssen MM, Peters ML. Are individual levels of pain anxiety related to negative interpretation bias? An examination using an ambiguous word priming task. Eur J Pain 2016;20:833-44.

[82] Vancleef LM, Peters ML, De Jong PJ. Interpreting ambiguous health and bodily threat: are individual differences in pain-related vulnerability constructs associated with an on-line negative interpretation bias? J Behav Ther Exp Psychiatry 2009;40:59-69.

[83] Van Damme S, Kindermans H. A self-regulation perspective on avoidance and persistence behavior in chronic pain: new theories, new challenges? Clin J Pain 2015;31:115-122.

[84] Van Damme S, Legrain V, Vogt J, Crombez G. Keeping pain in mind: a motivational account of attention to pain. Neurosci Biobehav Rev 2010;34:204–13.

[85] Van Damme S, Vanden Bulcke C, Van Den Berghe L, Poppe L, Crombez G. Do patients with chronic unilateral orofacial pain due to a temporomandibular disorder show increased attending to somatosensory input at the painful side of the jaw? PEERJ. 2018;6.

[86] Van Ryckeghem DML. The interference of pain with task performance: Increasing ecological validity in research. Scan J Pain 2017:91–92.

[87] Van Ryckeghem DML, Crombez G. Attentional bias and chronic pain: Where to go from here? PAIN 2014;155:6-7.

[88] Van Ryckeghem DML, Crombez G. Pain and attention: towards a motivational account. In: Karoly P, Crombez G, editors. Motivational perspectives on chronic pain: theory, research, and practice. New York: Oxford University Press, 2018.

[89] Van Ryckeghem D, Crombez G, Eccleston C, Liefooghe B, Van Damme S. The interruptive effect of pain in a multitask environment: an experimental investigation. J Pain 2012;13:131–138.

[90] Van Ryckeghem DM, Crombez G, Goubert L, De Houwer J, Onraedt T, Van Damme S. The predictive value of attentional bias towards pain-related information in chronic pain patients: a diary study. PAIN 2013;154:468-75.

[91] Van Ryckeghem DML, Van Damme S, Vervoort T. Does attention bias modification training impact on task performance in the context of pain: An experimental study in healthy participants. PLoS One 2018;13:e0200629.

[92] Van Ryckeghem DML, Vervoort T. Towards an integrative view of cognitive biases in pain. Eur J Pain 2016;20:1201-1202.

[93] Vlaeyen JWS, Morley S, Crombez G. The experimental analysis of the interruptive, interfering, and identity-distorting effects of chronic pain. Behav Res Ther 2016;86:23-34.

[94] Vlaeyen JWS, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. PAIN 2000;85:317–32.

[95] Vinall J, Pavlova M, Asmundson GJC, Rasic N, Noel M. Mental health comorbidities in pediatric chronic pain: A narrative review of epidemiology, models, neurobiological mechanisms and treatment. Children 2016;3(4):1-31.

[96] Wells HJ, Pincus T, McWilliams E. Information processing biases among chronic pain patients and ankylosing spondylitis patients: the impact of diagnosis. Eur J Pain 2003;7:105-111.

[97] Zvielli A, Bernstein A, Koster E. Temporal Dynamics of Attention Bias. Clin Psychol Sci 2015;3:772–788.