ORIGINAL ARTICLE

Pain and Distraction According to Sensory Modalities: Current Findings and Future Directions

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■ **Abstract**

Background: This review discusses the findings in the literature on pain and distraction tasks according to their sensory modality. Distraction tasks have been shown to reduce (experimentally induced) acute pain and chronic pain. This can be influenced by nature and by the sensory modalities used in the distraction tasks. Yet the effect on reducing pain according to the sensory modality of the distraction task has received little attention.

Methods: A bibliographic search was performed in different databases. The studies will be systematized according to the sensory modality in which the distraction task was applied.

Results: The analyzed studies with auditory distractors showed a reduction of acute pain in adults. However, these are not effective at healthy children and in adults with chronic pain. Visual distractors showed promising results in acute pain in adults and children. Similarly, tactile and mixed distractors decreased acute pain in adults.

Conclusion: Distraction tasks by diverse sensory modalities have a positive effect on decreasing the perception of acute pain in adults. Future studies are necessary given the paucity of research on this topic, particularly with tactile distractors (there is only one study). Finally, the most rigorous methodology and the use of ecological contexts are encouraged in future research. ■

Key Words: pain, attention, distraction task, sensory modality

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Submitted: April 24, 2019; Revision accepted: May 12, 2019
DOI. 10.1111/papr.12799

INTRODUCTION

A biopsychosocial perspective on pain is widely accepted as a heuristic framework to understand and manage pain.[1] Consequently, pain must be understood as a subjective experience that goes beyond a mere

sensory process, since it also involves affective-motivational and cognitive processes.[2] To understand this, it is necessary to differentiate between nociception and pain. Nociception refers to the neuronal processes of encoding and processing noxious stimuli of potential or actual tissue damage.[3] On the other hand, pain is understood as a perceptual process or subjective experience resulting from a nociceptive process. Although nociception usually leads to pain, one can exist without the other (eg, congenital analgia). In addition to nociception, the central nervous system considers multiple sensory, emotional, social, and cognitive factors to respond with or without pain, and with less or more pain intensity.[4–7] Consequently, nociception can be understood as the processing of an afferent stimulus and pain as an efference (ie, response; see Moseley[8]). In this way, the magnitude of the stimulus or health problem may not always be proportional to the intensity of the pain.[9–12]

In this context, cognitive processes have gained great relevance in recent years among the factors that affect pain.[13] Thus, for example, studies using functional imaging have revealed a significant overlap between brain regions involved in cognition and pain modulation.[14–16] Among the cognitive processes, attention stands out as one of the main factors in the pain experience. This is due in particular to pain consuming attentional resources.[17] In this vein, attentional resources can modulate the pain processing.[18,19] The attention capacity model holds that there is a limited and general offering of attentional resources, which can be allocated to 1 or more tasks at a given moment.[20] Thus, when the demands of 2 activities exceed the "pool" of attentional resources available, there is a reduction or complete failure in the performance of 1 or both tasks.[20] On the other hand, the multiple resource model[21] proposes that there are relatively independent resources for the processing of information according to the sensory modality (ie, independent reserve for various stimuli: visual, auditory, tactile, etc.): if 2 tasks demand the same sensory modality, the result is a decrease in the performance of 1 or both tasks, which would not happen in tasks that require different sensory modalities.

Several theoretical models have developed this relation between attention and pain (eg, McCaul and Malott[22] and Eccleston and Crombez[17]; see also Buhle and Wager[23]), all of them with the underlying idea that attentional resources are captured by pain or by sensory, cognitive, or affective processes. These models have been complemented by more current models, in which pain is interpreted as a motivating stimulus for action in a threatening context.[17,19,24] Thus, given its nature of raising the alarm to a threatening stimulus, pain is a process with priority for the allocation of attentional resources. Therefore, it is possible to assign attentional resources to other processes at the expense of the resources allocated to pain (ie, to distract from the pain). Due to its intuitive nature, distraction is one of the most popular and commonly employed attentional strategies.[1] The analgesia brought about by a distraction task is contingent upon the deflection of attentional resources from the pain-related sensory or emotional reactions to the processing of the distractor stimulus.[25] Of interest here, Buhle et al.[25] revealed that placebo treatment and distraction tasks operate through independent processes of pain relief, while their joint administration leads to a stronger analgesia. Thus, unlike distortion tasks, placebo strategies do not depend on the reallocation of attentional resources.

In this context, various studies have emerged that assess the reduction of the intensity of the pain and discomfort associated with the use of distraction tasks. The distraction tasks include the act of directing attention away from the pain by inducing an alternative demand so it cannot be focused on the pain.[1]

Despite wide acceptance, the effect of these techniques is not conclusive, either for acute pain or for chronic pain. The literature has reported varying results regarding the impact of distraction tasks on pain. Many studies have endorsed the palliative effect of distraction tasks on pain.[26–32] However, other studies have found no evidence between distraction tasks and pain.[33–35] Moreover, some studies have even pointed to an increase in pain perception.[36,37]

The differences in the outcomes of previous studies could be related to the distraction tasks used. Yet these tasks have received scant attention in the scientific literature. Distraction tasks can consist of different sensory stimuli or a combination of these. The use of one or another sensory stimulus could have an impact on the effect of the distraction task to capture attentional resources, as this is critical to the analgesic effect of the task. For example, sight has been reported as the dominant sense in terms of perception,[38] and it has also been shown to play a prominent role in pain perception.[39,40]

Consequently, the aim of this article is to review the main findings in the literature on distraction and pain, emphasizing the nature of the distraction tasks used. To do this, the studies will be systematized according to the

sensory modality in which the distraction task was applied. It should be considered that the mechanisms underlying acute and chronic pain are different. Chronic pain is present every day for more than 3 months, and, more importantly, it is related to plastic changes on multiple levels of the nervous system (pathways of sensory transduction, spinal cord, and brain). Thus, the duration of pain will be taken into consideration in the current systematization.

METHOD

Literature Review

The following databases were consulted independently: EMBASE (1980 to 2019), Medline (via EBSCOhost, 1982 to 2019), the Cumulative Index to Nursing and Allied Health Literature (via EBSCOhost, 1996 to 2019), and PsycINFO (1967 to 2019). A unique search strategy was designed for each of the 4 databases. The review was limited to studies on humans, published in English. The search was performed using the combined terms "attention," "distraction task," and "pain," joined by the Boolean operator "AND." Duplicate articles were eliminated. This review was conducted in March 2019.

Eligibility Criteria

The inclusion criteria in this review were: (1) empirical studies; (2) studies in which attention was manipulated (ie, distraction task); (3) studies in which the effect of attention (distraction) on pain perception was analyzed; and (4) studies conducted on individuals who suffered from pain, as well as studies in which pain was induced. The search was not limited by year of publication.

Study Selection

A bibliographic search was done in the databases mentioned, identifying 67 publications, of which 34 were discarded as duplicates. A total of 33 publications were analyzed based on the title and abstract. Of these, 9 were discarded for being conference abstracts (n = 3), not measuring the variable pain (n = 5), and not manipulating the variable attention (n =1). Consequently, 24 studies fulfilled the previously established selection criteria and were included in this review (Figure 1). It should be noted that performing a meta-analysis with these studies becomes very difficult owing to the heterogeneity of the participants of the different studies (ie, healthy, with specific pathologies) and the few investigations addressing sensory modalities (ie, there is only 1 study on tactile modality)

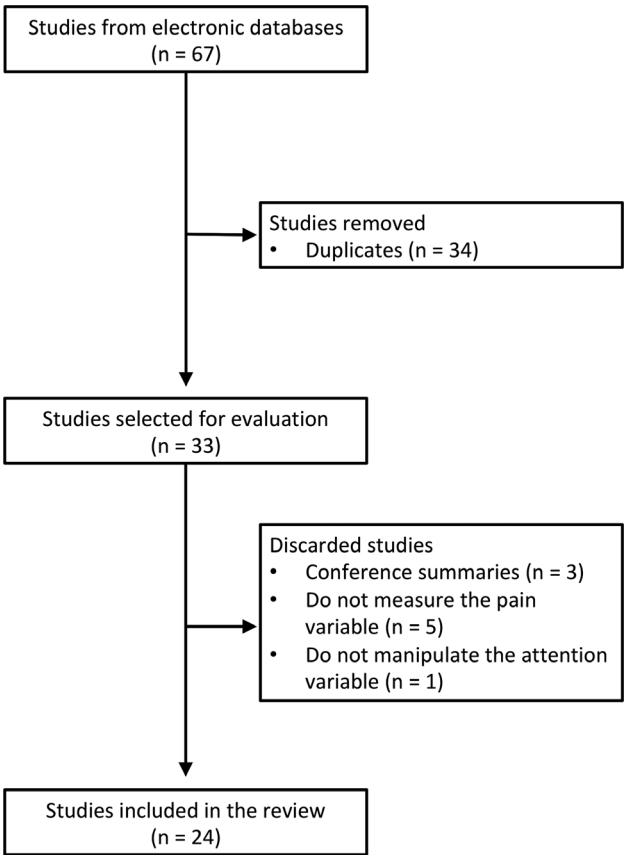

Figure 1. Search flowchart.

RESULTS

In the studies reviewed, the distraction tasks involved the diversion of attentional resources to a specific task to the detriment of the attentional resources dedicated to the sensory or emotional reactions caused by the pain. The articles included in this review included the manipulation of attention, in most cases through tasks that affected a sense, whereas a smaller percentage used cognitive tasks. The main findings in the field are systematized in Table 1. These findings are described, grouping them according to sensory modality (auditory, visual, tactile, and mixed), where the distraction task was applied, and what cognitive tasks were used as the distractors. In addition, we describe the methodology of the exposed studies, and differentiate between the findings in chronic and acute pain, as well as between the findings among children and adults. In the

Table 1. Details of Studies That Incorporate Distraction Tasks

Author and Year	Sensory Modality of the Distraction Task	Sample (% male)	Age *M* (SD or Range)	Type of Target Pain	Study Design	Distraction Task/Type of Response	Results
Van Damme et al. (2008)[32]	Auditory	101 healthy individuals (21.85%)	19.14 (1.87)	Pain induced by cold pressor task	Randomized controlled trial, multiple-arm trials	Random interval repetition task/pressing a button	Distraction reduced the pain
Verhoeven et al. (2010)[41]	Auditory	78 healthy individuals (15.4%)	18.67 (1.36)	Pain induced by cold pressor task	Randomized controlled trial, multiple-arm trials	Random interval repetition task/pressing a button	Distraction reduced the pain
Verhoeven et al. (2011)[42]	Auditory	91 healthy individuals (20.9%)	18.68 (1.3)	Pain induced by cold pressor task	Randomized controlled trial, 2-arm parallel groups	Random interval repetition task/pressing a button	Distraction reduced the pain
Dunckley et al. (2007)[43]	Auditory	12 healthy individuals (58.3%)	26 (20–32)	Pain induced by visceral electrical and somatic stimuli	Within-subject study; conditions were counterbalanced	Identify frequency of sounds/verbal report	Distraction reduced the pain
Huber et al. (2006)[33]	Auditory	20 healthy men (100%)	26.9 (3.3)	Pain induced by a series of heat pulses	Within-subject study without randomized conditions	Identify acoustic signals/pressing a button	Distraction did not affect the pain
Verhoeven et al. (2012)[35]	Auditory	87 healthy children (49.4%)	13.46 (2.62)	Pain induced by cold pressor task	Randomized controlled trial, 2-arm parallel groups	Random interval repetition task/pressing a button	Distraction did not affect the pain
Verhoeven et al. (2014)[34]	Auditory	162 children CG = 84 (52.4%) DG = 78 (46.2%)	CG 13.8 (2.68) DG 13.95 (2.55)	Pain induced by cold pressor task	Randomized controlled trial, 2-arm parallel groups	Random interval repetition task/pressing a button	Distraction did not affect the pain
Goubert et al. (2004)[37]	Auditory	60 individuals with chronic or recurring low back pain (45%)	46.3 (9.33)	Lumbar pain longer than 3 mo	Within-subject study; conditions were counterbalanced	Random interval repetition task/pressing a button	Distraction increased the pain immediately afterward
Fox et al. (2016)[47]	Auditory	43 individuals with chronic pain (14%)	46.36 (13.1)	Pain longer than 3 mo	Within-subject study; conditions were counterbalanced	Listen to visualization instructions/without response	Distraction did not affect the pain
Chayadi & McConnell (2019)[48]	Visual	106 healthy adults (33%)	22.6 (4.36)	Pain induced by heat stimuli	Randomized controlled trial, multiple-arm trials	Play a game	Distraction reduced the pain. It also increased the threshold and tolerance to pain.
Hylands-White et al. (2007)[49]	Visual	24 healthy individuals (41.7%)	21 (18–28)	Pain induced by cold pressor task	Within-subject study; conditions were counterbalanced	Necker cube illusion/ verbal report	Distraction reduced the pain
Bantick et al. (2002)[50]	Visual	8 healthy individuals (75%)	30 (9)	Pain induced using heat stimulus	Within-subject study; conditions were counterbalanced	Stroop counting task/ verbal report	The pain intensity was lower during the Stroop counting task with greater cognitive demand

Table 1. (Continued)

Author and Year	Sensory Modality of the Distraction Task	Sample (% male)	Age *M* (SD or Range)	Type of Target Pain	Study Design	Distraction Task/Type of Response	Results
Liu et al. (2011)[51]	Visual	3 individuals with untreatable epilepsy (33%)	N/D (21–51)	Laser-induced pain	Within-subject study	Reading comprehension/ verbal report	Distraction reduced the pain
Stancak et al. (2017)[52]	Visual	24 healthy individuals (50%)	26.2 (3.4)	Laser-induced pain	Within-subject study; conditions were counterbalanced	Rubin vase illusion/touch a screen	Distraction did not influence pain intensity
Law et al. (2010)[53]	Visual	79 healthy children (52%)	8.91 (2.04)	Pain induced by cold pressor task	Within-subject study; conditions were counterbalanced	Virtual reality video game/play the game	Greater pain tolerance during interactive distraction task
Stankewitz et al. (2018)[54]	Visual	13 patients with chronic pain13 healthy subjects	50.6 (8.9) 47.6 (9.5)	Pain induced by heat stimuli	Case-control; conditions were counterbalanced	Stroop task/pressing a button	Distraction decreased the pain in patients and in healthy subjects
Markman et al. (2013)[27]	Tactile	16 healthy individuals (62.5%)	N/D (22–57)	Painful stimulus using a laser	Within-subject study; stimuli were counterbalanced	Counting painless electrical stimuli/ verbal report	Distraction reduced the pain
Van Ryckeghem et al. (2012)[55]	Mixed	53 healthy individuals (20.75%)	18.1 (1.1)	Induced through electrical stimulus	Within-subject study; stimuli were counterbalanced	Attention on tactile and auditory stimuli/pressing a button	Distraction reduced the pain, mainly in individuals with great attentional bias
Van Ryckeghem et al. (2013)[56]	Mixed	32 healthy individuals (46.9%)	19.2 (1.8)	Induced through electrical stimulus	Within-subject study; stimuli were counterbalanced	Attention on tactile and auditory stimuli/ verbal report	Distraction reduced the pain
Schreiber et al. (2014)[58]	Mixed	149 individuals with chronic back pain (45%)	47.8 (10.5)	Back pain longer than 6 mo	Cross-sectional cohort study	Gripping an instrument with a certain force (proprioceptive and visual)/maintain handgrip strength	Distraction reduced the pain, mainly in individuals with high levels of catastrophizing
Johnson & Petrie (1997)[59]	Mixed	20 individuals with chronic low back pain (40%) 18 control individuals (50%)	45 (11.3) 36 (10.8)	Low back pain longer than 3 mo and pain induced by the cold pressor task	Case-control	Listen and repeat words and look at a monitor/verbal report	Distraction did not increase tolerance to the cold pressor task in individuals with lumbar pain, but did so in pain-free individuals
	Cognitive tasks		19 (18–41)				

Table 1. (Continued)

Author and Year	Sensory Modality of the Distraction Task	Sample (% male)	Age *M* (SD or Range)	Type of Target Pain	Study Design	Distraction Task/Type of Response	Results
Zeidan et al. (2010)[60]		20 healthy individuals (35%)		Induced by electrical stimuli	Within-subject study; conditions were counterbalanced	Count backwards by sevens/verbal report	Distraction reduced the pain
Dowman (2004)[26]	Cognitive tasks	28 healthy individuals (82.1%)	20.4 (3.6)	Pain induced by electrical stimuli	Within-subject study; conditions were counterbalanced	Count backwards by threes/verbal report	Distraction reduced the pain
Frankenstein et al. (2001)[61]	Cognitive tasks	12 healthy individuals (50%)	23.3 (19–39)	Pain induced by cold pressor task	Within-subject study	Generate words/verbal report	Distraction reduced the pain

CG, control group; DG, distraction group; M, mean; N/D, no data; SD, standard deviation.

conclusion section, we discuss the main findings in the literature, with an emphasis on new studies to be undertaken.

Auditory Distractors

Nine articles were found that analyzed the effect of auditory distraction tasks on pain: 5 on acute pain in adults, 2 on acute pain in children, and 2 on chronic pain in adults. It should be noted that most of them (6 studies) used random interval repetition (RIR), which consists of detecting tones and pressing a button as quickly as possible.

In several randomized controlled trials (RCTs), the pain brought about by the cold pressor test (CPT; immersion of the hand in cold water) decreased when the RIR task was performed on adults.[32,41,42] The samples in these studies numbered 101 (Refs. [32],[41]), and 91 (Ref. [42]).

Other distraction tasks with auditory stimuli have also been used with different outcomes. Dunckley et al.[43] studied acute pain in 12 adults in a within-subject study with 2 counterbalanced conditions: focusing and distraction. Participants were asked to count auditory stimuli while visceral pain and somatic pain were induced through electrical stimuli (distraction). In the focusing condition, participants were asked to count the electrical stimuli that induced visceral and somatic pain. The intensity of the pain reported by the individuals was lower during the execution of the distraction task. On the other hand, Huber et al.[33] also found no results in this regard. In their within-subject study (without counterbalance), they compared a distraction condition in 20 adults where they heard several acoustic signals and had to press a key when 2 acoustic signals were repeated and a focusing condition where they had to detect the place of the pain and the perceived sensation of pain, provoked through heat. No differences were found in either compared to a baseline control.

In the RCTs by Verhoeven et al.[35] and Verhoeven et al.[34] conducted on 87 and 162 children, respectively, the pain induced experimentally by CPT was not reduced by the RIR task. The perception of pain in children with a high level of catastrophizing (ie, cognitive processing based on negative thoughts and expectations about pain and a negative evaluation regarding the ability to take measures concerning pain[44–46]) even increased.[35]

In the case of 43 individuals with chronic pain related to various causes, in the within-subject study

(counterbalanced order for conditions) by Fox et al.,[47] the distraction task consisted of visualizing an interactive scene described by audio. The focusing task consisted of focusing on the pain sensations. None of the tasks influenced the perceived pain. In the same vein, the within-subject study (counterbalanced order for conditions) by Goubert et al.[37]in 60 individuals with chronic lumbar pain—showed that the RIR task was related to an increase in pain reported immediately after lifting a load.

Consequently, the results found for the tasks that involved hearing presented divergent results as a function of age and type of pain. In young adults, auditory distraction seems to be effective at reducing induced pain. On the other hand, in children, the auditory distraction seems not to influence the induced pain. Distraction due to auditory stimulation does not seem to be effective at reducing chronic pain in adults.

Visual Distractors

Seven studies were found in which distraction tasks were used through the sense of sight. Five studies were found in healthy adults, 1 in healthy children, and 1 in adults with chronic pain

Chayadi and McConnell[48] conducted a study on acute pain. They evaluated 106 individuals in an RCT. A distraction condition was compared to a focusing condition while applying a painful stimulus through heat. The distraction condition consisted of a computer game; while in the focused condition, participants had to attend to the painful stimulus. The distraction task reduced the intensity of the pain and increased the threshold and tolerance to pain. Hylands-White and Derbyshire,[49] in a within-subject study of acute pain, compared 2 counterbalanced conditions, distraction and control, in 24 adults. In the distraction condition, individuals had to observe an image of the Necker cube (an optical illusion of a 2-dimensional image that is interpreted as 3-dimensional) and report when the angle of the image changed, while the previously described CPT was applied. In the control condition, the participants only performed the CPT. The individuals reported less pain in the visual distraction condition. In another study, Bantick et al.[50] contrasted 2 levels of cognitive demand (high and low; counterbalanced) of a modified version of the Stroop task, the so-called Stroop counting task. This task, at both levels of difficulty, was performed by 8 adults, while pain was induced through a heat pulse stimulus. The pain intensity reported was lower in the individuals who performed the Stroop counting task with greater cognitive demand. The study by Liu et al.[51] is worth mentioning. It was conducted on a more specific and smaller sample (3 individuals diagnosed with untreatable epilepsy). A distraction condition was compared to a focusing condition. The distraction condition consisted of the individuals reading a passage and then answering 2 related questions while a pain stimulus was simultaneously induced through a laser. The focusing condition consisted of counting the painful stimuli caused by the laser. In line with most of the studies conducted on a healthy population, the visual distraction was also related to a lower level of reported pain.

Different results were found by Stancak et al.,[52] who compared 2 counterbalanced conditions in 24 adults with acute pain: distraction and focusing on the pain. In the distraction condition, the participants were asked to count the figures contained in the Rubin vase optical illusion, while pain was induced by laser pulses on one hand. In the focusing condition, the individuals had to focus on the pain sensation. The intensity of the reported pain did not differ between the 2 conditions.

Law et al.[53] conducted a study of acute pain in 79 children, in which 3 conditions were compared: control, passive distraction, and active distraction (these last 2 presented in counterbalanced order). Passive distraction consisted of using a virtual reality helmet to observe prerecorded images from a video game, whereas in the active distraction, in addition to using the virtual reality helmet, the movements of an avatar could be directed and goals could be achieved in the game. The children were evaluated in terms of their tolerance to cold-induced pain (ie, time they tolerated the immersion of their hand in cold water) at baseline (control) and during the execution of the 2 distraction tasks (passive and active). Both distraction tasks increased the tolerance to pain, but more so in the condition of active distraction.

Finally, Stankewitz et al.[54] assessed 13 adults with somatoform pain (disorder characterized by chronic pain) as compared to 13 healthy adults in a case-control study in which conditions were counterbalanced. Both groups received painful stimuli in 2 conditions: focus and distraction. In the focused condition, the participants had to attend to the painful stimuli. On the other hand, in the distraction condition, they had to perform the Stroop task. In both groups, adults with chronic pain and healthy adults, the task of distraction decreased the perception of pain.

In general, the visual task could be effective at relieving the intensity of pain in individuals with acute pain, both in children and adults. However, several studies in adults had only small samples. In addition, studies with a high methodological rigor are needed (ie, RTCs). On the other hand, the study on children presented an adequate sample size and adequate methodological design; not so the study on individuals with chronic pain, which presented a small sample. Thus, more studies are needed to strengthen the findings of these studies.

Tactile Distractors

Only 1 article was found in which acute pain was studied in 16 adults. Markman et al.[27] compared 2 distraction and focusing conditions (both counterbalanced). In the distraction condition, the participants had to count the number of painless electrical impulses applied to one of their hands, while at the same time pain was induced experimentally using laser pulses on the other hand. In the focusing condition, the number of laser pulses applied to one of their hands in the absence of other stimuli was counted (pain induction). The results showed that in the distraction condition, the individuals reported a lower intensity of perceived pain.

Although the results of this study are promising, it cannot be concluded that distraction through touch affects the perception of pain, since this was only 1 study and had a limited sample. More studies with greater methodological rigor (ie, RCTs) and with adequate sample sizes are necessary to confirm the aforementioned results.

Mixed Distractors

Four studies were found that employed 2 or more senses in distraction tasks: 2 studies in adults with acute pain and another 2 in adults with chronic pain.

Using within-subject studies, Van Ryckeghem et al.[55] and Van Ryckeghem et al.[56] assessed 53 and 32 adults, respectively, for acute pain. They were exposed to distraction tasks that consisted of auditory and tactile stimuli (vibration). In both studies, stimuli were presented in a random order. The pain was induced through an electrical stimulus. In both studies the distraction was effective at reducing pain. The effect of the distraction was greater in individuals with a strong attentional bias (ie, selective attention towards specific information in one's environment[57]) towards the predictive pain signals, as well as in individuals who experienced greater initial pain.[55]

Schreiber et al.[58] evaluated 149 adults with chronic back pain. The distraction task consisted of holding a grip dynamometer with a specific force, while consecutive pressure stimuli that caused pain were applied. In the control condition, the painful pressure stimuli were applied separately. Pain relief was found in the distraction condition, which was accentuated in individuals with a high level of catastrophizing. Johnson and Petrie[59] studied a group of 20 adults who suffered from chronic low back pain (CLBP). The most novel aspect is that the participants had to carry out a physical performance task that consisted of going up and down a step repeatedly with a distraction condition and another without distraction. The distraction task consisted of repeating words that they heard, with the exception of a pair of words that were presented on a monitor. In addition, the individuals with CLBP were compared to a group of 18 adults with acute pain according to their tolerance to pain in the CPT in both conditions. In the individuals with CLBP, the physical performance task increased the pain in the 2 conditions equally; however, in the distraction condition, the individuals improved their physical performance. On the other hand, the distraction did not increase the time that the pain was tolerated in the CPT in the individuals with CLBP. However, in the healthy individuals, the distraction was effective at increasing the time the pain was tolerated in the CPT.

In summary, mixed tasks seem to be effective at reducing pain in individuals with acute pain. On the other hand, given the contradictory results, further research is necessary in adults with chronic pain.

Cognitive Distractors

In this section, we describe studies in which the distractor stimulus consisted of the participants performing cognitive exercises not directly related to any sensory modality. Three articles were found in which the cognitive exercises were performed by adults with acute pain.

Zeidan et al.[60] compared 3 conditions in a within-subject study of 20 participants: distraction, relaxation, and control. These were presented in counterbalanced order. In the distraction condition, patients were asked to count backwards from 1,000 by sevens while a painful electrical stimulus was applied simultaneously. In the relaxation condition, they were instructed to close their eyes and relax while the painful stimuli were applied. In the control condition, no instructions were

given, and only the painful electrical stimulus was applied. The distraction task was effective at reducing the pain intensity. Similarly, the distraction task was effective at reducing pain in 28 participants in a within-subject study by Dowman,[26] in which 2 conditions, carried out in counterbalanced order, were compared: distraction and focusing. The distraction task consisted of counting backwards by threes starting with a pseudorandomly chosen 3-digit number while pain was induced by electrical impulses. In the focusing condition, individuals were instructed to direct their attention towards the electrical impulses (painful stimulus). Likewise, distraction was effective in the within-subject study by Frankenstein et al.[61] This study contrasted 2 conditions in 12 adults: distraction and focusing (without counterbalanced order). The distraction task consisted of a verbal fluency task, which consisted of generating words from a given category while pain was induced through a cold stimulus (CPT). The control condition included only the induction of pain using the CPT.

In general, cognitive tasks were effective at reducing acute pain in adults. However, studies with a larger sample size are necessary. Likewise, studies are needed to evaluate the effect of distraction by cognitive task in individuals with chronic pain and in children.

GENERAL DISCUSSION

The primary aim of this article was to review the main findings in the literature on distraction and pain, emphasizing the sensory modality of the distraction tasks used. The reviewed studies are detailed in Table 1. We will first discuss the main findings by sensory modality, addressing the possible etiologies of the data described, grouping the data into adults with acute pain, children with acute pain, and adults with chronic pain. Second, we will set out the differences found between induced and chronic pain, with a clear emphasis on the reasons for their differential pattern. Third, we will review the differences between adults and children. Finally, an additional section is included in which other limitations and future lines of enquiry are described.

Main Findings Made by Sensory Modality and Cognitive Tasks

With respect to the proposed sensory differentiation, it should be emphasized that the studies with auditory stimuli presented contradictory results. In this sensory modality, 4 studies showed a positive effect in healthy individuals with induced pain[32,41–43]: 3 RCTs[32,41,42] and 1 within-subject study.[43] Only 1 within-subject study showed no effects. In this study, Huber et al.[33] were the only researchers in this group of studies who used a heat stimulus to cause pain, which could have caused an increased threat sensation in the individuals, possibly making painful stimuli more noticeable and making it more difficult to distract participants from them. In summary, based on the criteria described by Chou,[62] there is a good level of evidence that this sensory modality relieves the pain perceived by healthy adults (ie, in acute pain).

In 2 RCTs on healthy children[34,35] in whom pain was induced experimentally, no influence of distraction through auditory stimuli was demonstrated on perceived pain. In the studies by Verhoeven et al.,[34,35] the negative result could be due to the distraction task not being a high-priority goal for the children and, therefore, it was not processed as a high priority with respect to the pain and so had no impact on the pain perception. This could be related to the sensory modality of the task or to its aim. In conclusion, there is a good level of evidence[62] of the null effect of distraction by auditory modality in healthy children.

At least 2 within-subject studies with counterbalanced conditions in which individuals with chronic pain were assessed[37,47] did not present any relief from pain with auditory distraction tasks. However, despite showing a trend, the heterogeneity of the groups evaluated (ie, different causes of chronic pain) makes the evidence insufficient to draw conclusions regarding the impact of auditory tasks on chronic pain.

The distraction tasks that use the sense of sight had a potentially greater effect than other senses in alleviating pain, since sight is the dominant sense in terms of perception,[38] playing a prominent role in pain perception.[39] Pain reduction with visual distractors in healthy children[53] and adults,[48–51] with pain induced experimentally, tends to confirm this idea.

However, 2 studies in adults presented a sample of 3 and 8 subjects, and a third study did not present positive results in pain reduction. Nevertheless, in this last study,[52] the tendency was for the distraction group to exhibit less pain than the control group; therefore, with a larger sample size it could have reached statistical significance. As a result, the level of evidence is low, and the results have a high risk of bias and provide insufficient evidence to evaluate the effect of distraction tasks in pain-free adults who use the sense of sight.

Only 1 study was found (within-subject study)[53] that assessed the effect of the sense of sight as a distractor in children. Although the study presented positive results, with an adequate sample size and an adequate methodological design, the level of evidence is low. In this same way, only 1 case-control study[54] with a small sample was found with positive results from visual tasks in individuals with chronic pain. Accordingly, more studies are needed to consolidate these results.

It should be noted that the aforementioned study in children used virtual reality as a distraction task. Wiederhold and Wiederhold[63] argued that distraction tasks like virtual reality are superior to other distraction techniques because virtual reality could obtain a high level of reality, with this translating into less attention to the pain. On the other hand, the distraction tasks were mainly supported in the attention capacity model,[20] which could affect the effect of the distraction task. The multiple resource model[21] may be more related to what these researchers[63] proposed, since virtual reality makes it possible to use distraction tasks that include multiple senses. In conclusion, virtual reality has great potential as a distraction task.

In the studies with tactile stimuli, there was only 1 within-subject study[27] on healthy individuals that demonstrated the positive effect of distraction from pain. These results are promising; however, with the small sample (16 individuals), the effectiveness of tactile stimuli in the perception of pain cannot be assessed. Therefore, studies with more adequate methodological designs and larger sample sizes should be carried out.

Something similar occurs with the mixed stimuli; their effectiveness has been proven in 2 within-subject studies in which distraction was assessed in a total of 84 healthy individuals with acute pain.[55,56] Thus, the evidence is limited but sufficient (fair level of evidence) to determine the positive effect of tasks with mixed stimuli in the perception of pain.[62] By contrast, results were found to be contradictory for chronic pain. In a cross-sectional cohort study with a large sample of adults with chronic back pain (149 participants), distraction affected the intensity of the pain.[58] However, in the study by Johnson and Petrie,[59] the participants with chronic pain did not present a reduction in pain with mixed distraction. Therefore, we can conclude that the evidence is insufficient and further research is required to establish more reliable and general conclusions.

At this point, it should be noted that in all the aforementioned research, the distractor stimulus applied was the same for all the participants. Thus, the absence of results in some studies could be explained by individual differences in terms of preference or susceptibility to the distractor stimuli, since the distractor used was not individually calibrated. Even in the studies with mixed stimuli, like the one by Van Ryckeghem et al.,[56] no measurement was taken as to how the auditory and tactile stimuli (vibration) affected the distraction in isolation. Therefore, determining whether the sum of several stimuli can increase pain distraction is a complex issue.

Finally, the cognitive distraction tasks were effective at reducing the pain in healthy adults, in whom pain was induced experimentally in the 3 within-subject studies analyzed.[26,60,61] One of these studies had a very low sample size. Nevertheless, in spite of the evidence being limited, it is sufficient (fair level)[62] to determine the positive effect of cognitive tasks on the perception of acute pain in healthy subjects. On the other hand, no studies were found on patients with chronic pain.

The positive outcomes may be related to the task network (attentional network task).[64] The task network has 2 dimensions, emotional and cognitive, which are mutually inhibited. Pain is related to the task network in its emotional dimension and to the cognitive task in its cognitive dimension. Thus, the cognitive task could inhibit the emotional dimension and thus reduce the perception of pain. This would be consistent with techniques where individuals who focus on the sensory dimension of pain report a lower intensity.[65] Another explanation could be related to the cognitive tasks requiring the implementation of executive functions in parallel (ie, counting backwards from 100 by threes). Thus, they use greater cognitive resources than other distraction tasks (ie, distinguishing between tones). In this vein, it has been confirmed that increasing the working memory load with pain-related information cannot reduce the capacity of the nociceptive afferents to capture the participant's attention, thereby managing to protect the cognitive processing of the distraction that nociception entails.[66] So perhaps an optimal way to guarantee an efficient control of attention assigned to pain is the ability to maintain the priorities of the active objectives during the achievement of the cognitive activities, keeping the pain-related information beyond the configuration of the task.

This is in line with what is proposed by the affective cognitive model,[17] which recognizes the importance of motivational factors in the task. Furthermore, this model explains that the characteristics of the

environment have an impact on the interruption of attention, and that these characteristics include factors related to the distraction tasks used for pain. This supports the idea that the sensory modality impacts the effectiveness of distraction tasks.

Differences Found Between Induced and Chronic Pain

In general, distraction has been proven to be effective at reducing pain induced experimentally or acute pain. In healthy adults, 4 RCTs and 10 within-subject studies showed distraction reduced the pain, and only 2 within-subject studies showed no effect on pain. In healthy children, the 3 studies analyzed (2 RCTs [auditory task] and 1 within-subject study [visual task]) highlighted the aforementioned idea about the predominant role of sight. Therefore, auditory tasks yielded null results, whereas visual distraction yielded positive results. This could be explained by auditory distraction not being as high a priority as the painful stimulus.[34,35] By contrast, the visual task is processed as a high priority,[38] resulting in pain reduction.

On the other hand, distraction would not be useful in patients with chronic pain, since it does not affect the perception of pain regardless of the modality used (mixed and auditory). Three studies (2 within-subject studies and 1 case-control study) showed no positive effect of distraction on pain. Only 1 cross-sectional cohort study and 1 case-control study showed that distraction reduced the pain in individuals with chronic pain. This is in line with the results of a recently published meta-analysis, which analyzed studies that included individuals with chronic pain, indicating that distraction does not differ from a control intervention in altering the experience of pain in patients with chronic pain.[1]

In this regard, it is important to emphasize that neuroanatomical studies have shown that individuals with chronic pain present morphological changes in areas of the cerebral cortex[14,67–69] associated with attention (eg, cingulate cortex[70]). There is also evidence that chronic pain could alter both attention and working memory,[71,72] with this dysfunctionality not being associated with the pain per se, since the ingestion of analgesics does not improve these cognitive processes.[72]

Another possible reason for not finding effects on patients with chronic pain could be related to the finding that this pain modality is associated with greater awareness or monitoring of the pain and/or the somatic sensations generally (ie, hypervigilance).[73–75] Thus, in chronic pain, the attentional "disconnection" from the pain through distraction would be more complicated. This hypothesis may have support in studies that have found that sensory monitoring can be superior to distraction in patients with chronic pain.[41,76,77] On the other hand, some studies suggest that patients with chronic pain are characterized by problems of executive functioning, which could be due to the previously mentioned structural deficit, or to the repeated presence of pain and/or negative emotions.[13,16] These strong negative emotions and the generally low level of executive functioning may make it more difficult for patients with chronic pain to be able to "disconnect" from the pain.[42,78–80]

In summary, the findings and hypotheses proposed could be the basis of the null effect found in the distraction studies on chronic pain. However, given the paucity of studies that assess the effect of different distraction tasks in reducing pain perception in individuals with chronic pain and the contradictory results, caution should be exercised when drawing conclusions. Future studies will have to measure how the distraction techniques used or other cognitive processes besides attention affect spontaneous pain (ie, due to a pathology or injury) vs. experimentally induced pain to accurately establish their effectiveness, as in the studies by Johnson and Petrie[59] and Schreiber et al.[58]

Differences Found Between Children and Adults

In this section, studies carried out with the RIR task (auditory sense) in participants around 20 years of age found that it was effective in adults, but did not prove to be effective at reducing the intensity of pain in children approximately 13 years of age.

On the other hand, distraction tasks that use the sense of sight show results that mark a tendency in favor of these tasks in both adults and children.[48–51,53,54] We highlight the study by Law et al.,[53] in which children with an average age of 8.9 years participated.

This seems to indicate that the age range plays an important role in attentional processes. This finding is supported by studies that have determined that the control of attention is developed through the practice and maturation of the central nervous system in childhood and adolescence in parallel with the development of the prefrontal cortex and the differentiation of brain networks.[81,82] However, given the disparate results between auditory and visual tasks, motivational factors must be considered.

Limitations of the Studies Analyzed and New Directions

Although some limitations in the studies mentioned were outlined previously, in this section we will systematize the main limitations in the studies presented and therefore the new directions to follow in future investigations.

Distraction, Attention, and the Control Group. One aspect to consider in the design of present and future studies that assess the impact of distraction on pain is the composition of a control group in which attention is clearly not manipulated, as some of the analyzed studies did not include it or used a focused attention group as a group control, instructing the individuals to turn their attentional resources to the pain. In view of the above, the studies should consider having one group that uses a pain distraction, another with clear instructions to focus their attention on the pain, or to the sensitive or affective aspects, and another control group that does not receive instructions and uses intuitive coping. This will make it possible to clarify the effect of attention on the perception of pain.

Age and Gender Factors. It is also important to emphasize the scarcity of studies that incorporate an adult and elderly population with acute pain, when this is the one mainly affected by acute and chronic pain.[83] In studies that evaluated chronic pain, only adult participants were considered. Currently, most studies present a demographic bias since they evaluate children, adolescents, and young (emerging) adults. In this regard, it is necessary to stress that there are studies that underscore that elderly participants are easier to distract,[84] which could have an impact on the use of distraction as a tool to alleviate pain. In addition, the evidence suggests that older adults show a lower sensitivity to brief cutaneous pain (eg, heat pain threshold); however, sensitivity to more sustained pain stimuli that affect deeper tissues increases with age.[5,85] Also, a greater sensitivity to stimuli repeated in a short period of time (temporal summation effect) has been demonstrated in older adults.[86] Pain modulation has consistently been shown to decrease with age.[87,88] Consequently, future studies should add different age groups.

For practically all the standard gauges of pain sensitivity, women show greater sensitivity than men, including the pain threshold (the minimum stimulus intensity required to produce pain), pain tolerance (the maximum stimulus intensity an individual is willing to tolerate), and suprathreshold stimulus levels. Since the evidence reveals differences in the perception of pain between the sexes,[89,90] future research must consider a similar number of men and women. Additionally, abundant evidence shows that chronic pain is more prevalent in women.[83] To explain this, multiple mechanisms have been proposed to explain these differences in pain by sex,[91] including the effects of sexual hormones, the differences in endogenous opioid function, cognitive/affective influences, and the contributions of social factors such as gender role stereotypes (ie, male gender norms dictate increased pain tolerance, while female gender norms accept pain as a normal part of life and are more permissive of pain expression).[89]

However, there is still debate as to whether these differences regarding age and gender are due to the underlying biological mechanisms of pain, or the contribution of psychological and social factors.[92,93] For instance, the prevalence of pain in older people is greater in those who live in residential care (28% to 73%) than in those who live in the community (20% to 46%),[93] a situation that cannot be explained solely by biological factors.

Study Design. The most common study design was within-subject, with 15 studies (62.5%). Three did not randomize the conditions and contained samples equal to or less than 20 individuals, which presents a high risk of bias. The remaining 12 studies had a suitable counterbalance. However, 7 presented small samples (around 28 participants). Three additional studies had another type of design (12.5%; 2 case-control and one cross-sectional cohort). Only 6 studies were RCTs (25%). Most of them were conducted with auditory stimuli tasks, 3 for adults and 2 for children. Therefore, it can be concluded that there is a great need for future studies of higher methodological quality and larger samples for all the senses, especially in chronic pain, for which no RCTs were found.

It should be noted that future studies are needed in applied or clinical contexts, with individuals who have acute or chronic pain, taking the complexity and variability of these scenarios into consideration. In this sense, it is important to emphasize that the clinically important minimum difference (a highly relevant and current medico-statistical concept) to reduce pain must be considered when assessing the effect of distraction techniques. In addition, it should be pointed out that the analyzed studies only employed 1 session, which could

be enough for acute pain, but not for chronic pain. How these techniques are linked to therapeutic processes for people with chronic pain must be analyzed. Moreover, the effectiveness of these techniques must be evaluated over time, including treatment and a series of sessions, and not just 1 isolated session.

Motivational Factors. In addition to what has been mentioned previously, distraction tasks must be motivating so the individual is really involved and connected with the task.[19] Hence, in some studies this interest is aroused by granting a financial reward to improve the motivation when performing the distraction task and with it to increase the effect of the distraction.[41] This is based on the relation between attention and motivation, since attentional resources prioritize the information that is relevant in a context determined by innate needs and motivations. Additionally, general motivations and concrete goals activate mental representations in the memory that guide attention to match the stimuli. The stronger the activated objective, the more attention is assigned to the information relevant to that objective. Also, multiple goals entering into conflict trigger a "protection or shielding of the objective" mechanism, in which the commitment to a focal objective inhibits access to alternative objectives and the distractor information (for a review, see Van Damme et al.[19]). Finally, the objectives often differ between people and situations, which underscores the importance of investigating various distraction tasks and how these interact between and within subjects.

Inclusion of Concomitant Psychological Variables. The inclusion of complementary psychological variables like catastrophism[35,58] and attentional bias[55] has shown that cognitive factors influence the effect of distraction on pain (ie, high attentional bias reduces the impact of the distraction,[55] and a high degree of catastrophism maximizes the analgesia brought about by the distraction;[58] however, in children, a high degree of catastrophism annuls the analgesia brought about by the distraction and even amplifies the experience of pain[35]). Likewise, experimental studies in which pain is induced in healthy individuals through different stimuli demonstrate a positive relation between pain intensity and level of catastrophism.[94–100] Considering that catastrophism, for example, is strongly linked to stress[95] (pain in itself is a stressful event), it could have an effect on distraction tasks. This factor would be fundamental to advocating these techniques in future psychological interventions in terms of individuals' cognitive styles. In addition, variables such as stress,[101–105] anxiety,[48,106,107] depression,[108–110] and sleep quality,[108,111–114] which can modify the perception of pain, should be considered.

Finally, given that cultural and sociodemographic factors influence pain perception,[115,116] research must be broadened to countries that differ in these aspects, since most studies have been conducted in European or English-speaking countries and do not reflect a universal phenomenon. Most of the studies do not report ethnic or race data.[53,60] Only 16.7% of these studies report ethnicity other than Caucasian (of these, 2 studies report 98% Caucasian participants). This is relevant, given that 1 sociocultural factor studied extensively is ethnicity.[115,117–119] For instance, African Americans demonstrated lower pain tolerance in experimental scenarios.[117] However, this cannot be explained solely by biological factors; social, cultural, and psychological factors also play an important role. For example, individuals who are in the process of adapting to a new culture (ie, acculturation) tend to have heightened pain responses.[119] In addition, research consistently suggests that the severity and impact of pain are greatest among minorities who experience chronic pain.[83,115,117] Furthermore, members of minority groups have a lower socioeconomic status, which has been associated with an increase in the prevalence of pain and more intense pain.[83,120] In light of this, it is pertinent to provide additional evidence of how the perception of pain varies in different ethnic groups, countries, and cultures. In conclusion, the description of the sociodemographic characteristics of patients is a relevant issue and one that future studies on this topic should consider.

Impact of Distraction on Other Cognitive Processes and on Performance. We know of no studies that focus on the impact of distraction on other cognitive processes (ie, different from attention) and their relation to pain. This is a fundamental limitation since distractor techniques to alleviate pain must have a minimal or null impact on other cognitive processes so they can be performed in various contexts of daily life that require other abilities. In other studies on distraction and cognitive processes, technical distractors have been found that do not affect the execution of main tasks. For example, in recent studies on motion sickness, a condition that can produce nausea and vomiting as well as other symptoms[121] owing to sensory conflicts, it has been found that distraction using Galvanic cutaneous,

auditory, and tactile stimulations[121–123] improves the symptoms of the syndrome by distracting the participants away from these symptoms. More importantly, there is no negative impact on motor control (ie, driving performance variables such as speed). These techniques could be tested in studies to alleviate pain using distraction where motor control must be preserved. Finally, we conclude that it is important to consider that there is no single method for distraction techniques, and it is most likely that one distraction technique in particular cannot be effective for every process. In summary, future research should explore the relationship between attention and other executive functioning and aspects of pain experience.

Our review sheds light on the effectiveness of distraction tasks at reducing pain. As a corollary conclusion, greater methodological rigor and ecological contexts are suggested on this topic.

ACKNOWLEDGEMENTS

This research was partially supported by a FONDECYT grant (project 1160368) from CONICYT Chile and a grant from the Universidad Autónoma de Chile (project 103-2017).

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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