

# **Distraction from pain and executive functioning: An experimental investigation of the role of inhibition, task switching and working memory.**

Verhoeven Katrien<sup>1</sup>, Van Damme Stefaan<sup>1</sup>, Eccleston Christopher<sup>2</sup>, Van Ryckeghem Dimitri M.L.<sup>1</sup>, Legrain Valéry<sup>1</sup> & Crombez Geert<sup>1</sup>

1 Department of Experimental Clinical and Health Psychology, Ghent University, Belgium

2 Centre of Pain Research, The University of Bath, United Kingdom

Corresponding author: Katrien Verhoeven, Department of Experimental Clinical and Health Psychology, Ghent University, Henri Dunantlaan 2, B- 9000 Ghent, Belgium. Tel: +32 9 264 91 06, Fax: +32 9 264 64 89, e-mail: [kat.verhoeven@ugent.be](mailto:kat.verhoeven@ugent.be)

*Number of pages: 29*

*Number of tables: 2*

*Number of figures: 2*

*Keywords: Attention, executive functioning, inhibition, switching, working memory*

*Running head: The role of executive functioning in the effectiveness of distraction.*

## **ABSTRACT**

Although many studies have investigated the effectiveness of distraction as a method of pain control, the cognitive processes by which attentional re-direction is achieved, remain unclear. In this study the role of executive functioning abilities (inhibition, task switching and working memory) in the effectiveness of distraction is investigated. We hypothesized that the effectiveness of distraction in terms of pain reduction would be larger in participants with better executive functioning abilities. Ninety-one undergraduate students first performed executive functioning tasks and subsequently participated in a cold pressor task (CPT). Participants were randomly assigned to (1) a distraction group, in which an attention-demanding tone-detection task was performed during the CPT, or (2) a control group, in which no distraction task was performed. Participants in the distraction group reported significantly less pain during the CPT, but the pain experience was not influenced by executive functioning abilities. However, distraction task performance improved with better inhibition abilities, indicating that inhibition abilities might be important in focussing on a task despite the pain.

## INTRODUCTION

The accurate performance of tasks in everyday life requires cognitive monitoring or control (e.g., planning of behaviour, regulation of cognition and emotion, switching between tasks, inhibition of responses), commonly referred to as executive functioning (Funahashi, 2001; Smith & Jonides, 1999). Three important executive functions are often distinguished: Inhibition, task switching and monitoring/updating of memory (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Because pain can operate to install a priority for attention (Eccleston & Crombez, 1999), it represents a challenge for the smooth-running of everyday behaviour. Executive functions, in particular inhibition, task switching and working memory, may then be important abilities for the successful attentional control of pain.

Distraction is a ubiquitous attentional strategy which is commonly used to control pain. It is characterized by the re-direction of attention away from an aversive experience, and the engagement of attention in other activities (McCaul & Malott, 1984). However, empirical evidence for its effectiveness is equivocal (Van Damme, Legrain, Vogt, & Crombez, 2010), with most studies finding beneficial effects (e.g., James & Hardardottir, 2002; Marchand & Arsenault, 2002), but others finding no effects (e.g., Hodes, Howland, Lightfoot, & Cleeland, 1990; McCaul, Monson, & Maki, 1992) or even counterproductive effects (e.g., Cioffi & Holloway, 1993; Goubert, Crombez, Eccleston, & Devulder, 2004). These heterogeneous findings indicate that distraction is not effective in every situation (Eccleston & Crombez, 1999). Therefore, more insight in the underlying processes of distraction effectiveness is required in order to improve its use.

In order for distraction to be effective, people should be able to engage in the distraction task and inhibit the predominant response of attending to the pain, and resist being interrupted by the pain (Friedman & Miyake, 2004; Nigg, 2000). Distraction is therefore expected to be more effective in people with good inhibition abilities. However, given its fundamentally aversive and interruptive character, it is unlikely that attention to pain can ever be fully inhibited (Eccleston & Crombez, 1999). Moreover, we expect pain to regularly interfere with the engagement in the distraction task (Eccleston, 1995a). Distraction may then be viewed as a process of the dynamic switching of attention between pain and the distraction task (Eccleston & Crombez, 1999). We

hypothesize that distraction is more effective for people with good switching abilities (Eccleston, 1995a). Finally, in order for distraction to be effective, one needs to prioritize information in working memory that is relevant for the distraction task (Dalton, Lavie, & Spence, 2009; Dalton, Santangelo, & Spence, 2009; Lavie & de Fockert, 2005). Distraction should therefore be more effective for people with good working memory abilities. In sum, executive functioning abilities, in particular inhibition, task switching and working memory, may influence the effectiveness of distraction, but this hypothesis has not yet been investigated.

In this study, undergraduate students first performed general executive functioning tasks, and subsequently performed a cold pressor task (CPT). Participants were assigned randomly to a distraction group, which performed an attention-demanding tone-detection task during the CPT, or a control group, which performed no distraction task. We hypothesized that distraction would be more effective, in terms of a pain reduction, for participants with better executive functioning abilities.

## **METHOD**

### ***Participants***

Ninety-eight undergraduate students from Ghent University (Belgium), who attended prior to any general selection on academic performance, participated in a cold pressor experiment in order to fulfill course requirements (78 females,  $M_{age}=18.65$  years,  $SD=1.28$ , all Caucasian). Exclusion criteria were Raynaud's disease, a history of epilepsy, frostbite, cardiovascular disease, and any current medical problem of the immersed hand, such as skin lesions, sores or fractures (von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer, 2005). Six participants were excluded (four cardiovascular disease, one epilepsy, and one a recent hand surgery). The remaining participants were randomly (by lottery) assigned to two groups: A distraction group, in which attention to pain during the CPT was manipulated using a distraction task ( $N=43$ ), or a control group, in which no distraction task was performed during the CPT ( $N=49$ ).

## ***Material***

### *Cold pressor task (CPT)*

Pain was induced with the cold pressor task (CPT). The cold pressor apparatus consisted of a metallic water container (type Techne B-26 with TE-10D, size 53 x 32 x 17 cm). A circulating water pump (type Techne Dip Cooler RU-200) prevented heat formation around the immersed hand (von Baeyer et al., 2005). The water temperature was kept at 12 °C, and the immersion duration was fixed at 1 minute for each participant (Verhoeven et al., 2010). This way, our self-report measure of pain was not confounded by immersion duration, and each participant experienced the same physical stimulation. The water temperature was considerably higher than other distraction studies (e.g., Cioffi & Holloway, 1993; Johnson & Petrie, 1997; Roelofs, Peters, van der Zijden, & Vlaeyen, 2004), but a recent study on distraction, and additional pilot studies have revealed that this temperature and immersion interval create a painful stimulus of moderate pain intensity, which can be endured by most people, and is ideal to measure distraction effects (Verhoeven et al., 2010). Lower temperatures often provoke high intense pain, which is undesirable for the purpose of this experiment, because distraction is argued to fail for high intense pain (Eccleston & Crombez, 1999).

Another container filled with room temperature water of 21 °C (type Julabo TW20, size 56 x 35 x 32 cm) was used to standardize hand temperature before the immersion in the cold water container (von Baeyer et al., 2005).

### *Distraction task*

The Random Interval Repetition task was used as a distraction task (RIR; Vandierendonck, De Vooght, & Van der Goten, 1998a; 1998b). The RIR-task is a well validated attention-demanding tone-detection task (Vandierendonck et al., 1998a; 1998b), that has been successfully used as a distraction task in previous research (Goubert et al., 2004; Van Damme, Crombez, Van Nieuwenborgh-De wever, & Goubert, 2008; Verhoeven et al., 2010). Participants were instructed to respond quickly (by button press) to tones (tone duration=150 ms; tone pitch=750 Hz) generated by a computer (ASUS L2000). Tones were presented through headphones (Sony MDR-V150) at random stimulus intervals (900 or 1500 ms). Responses were given by means of a

button pressing device, held in the participants' right hand. In this study, the total RIR-task duration was 1 minute (tone amount=51). Reaction time (RT), response variation (SD), and errors were used as measures of behavioural task performance. Anticipations (RTs < 100 ms), non-responses, and outliers (RTs > 3 SD above the individual mean) were removed (Goubert et al., 2004; Van Damme et al., 2008; Verhoeven et al., 2010). Errors were calculated by summing the number of anticipations and non-responses.

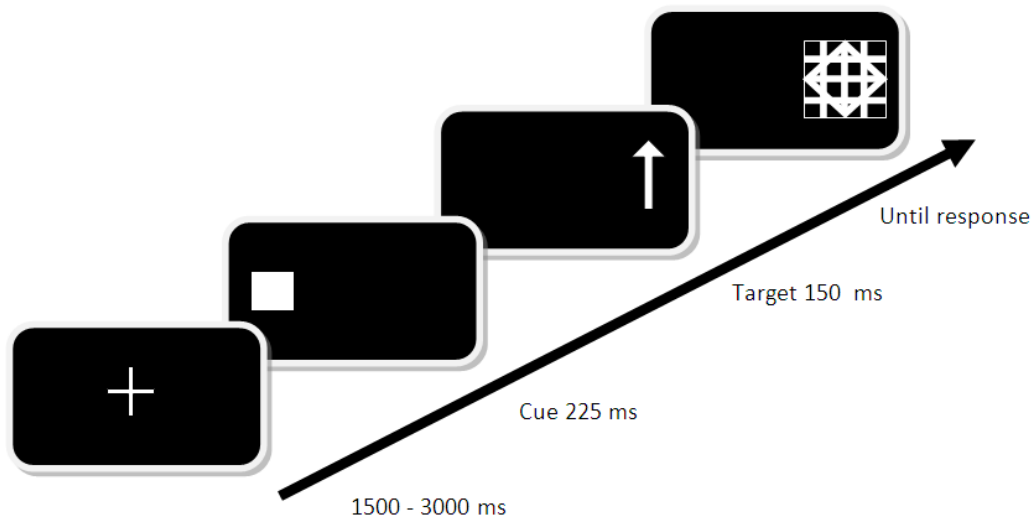
It has been argued that distraction tasks might only be effective when they are motivationally relevant (Van Damme et al., 2010). Therefore a financial reward was given to enhance the motivation to perform the distraction task (Verhoeven et al., 2010). Participants could win 10 eurocents every time they pressed the button quickly and accurately. If the response was given too late or inaccurately, they could lose 10 eurocents. During the task no feedback of task performance was given to avoid interference with the distraction process. After the experiment, participants received 3, 4 or 5 euro for their task performance. This amount was randomly assigned, and was unrelated to their actual performance.

### *Executive functioning tasks*

#### Inhibition

Inhibition was assessed with the anti-saccade task, as used by Miyake and colleagues (2000). This task is a modification of the original anti-saccade task (Everling & Fisher, 1998), as it uses manual key presses instead of eye-movements. (Figure 1). Task completion lasted approximately 10 minutes. Each trial started with a white fixation cross that was centrally displayed against a black background in the middle of a 15" computer screen (HP Compaq nc6120) with a variable duration (one of nine presentation times between 1500 ms and 3500 ms with 250 ms intervals). Then, a visual cue (white square, 1.5 x 1.5 cm) was presented on one side of the screen for 225 ms, followed by a target stimulus (white arrow inside an open square, 6.7 x 6.7 cm) on the opposite side for 150 ms before being masked by white cross-hatching. The participants' task was to indicate the direction of the arrow by pressing the corresponding keyboard key (J="left", I="up", L="right"). This task requires participants to inhibit the automatic response of looking at the cue as this hampers the discrimination of the target

orientation. Participants received on-screen written instructions. They started with a short practice phase of 18 trials, and subsequently performed 90 experimental trials. Error feedback was given on-screen. Reaction times were computed after removing anticipations (RT < 100ms) and outliers (RT > 3 SD above the individual mean). Mean reaction time served as a measure of inhibition capacity. The higher the reaction times, the lower the inhibition ability.



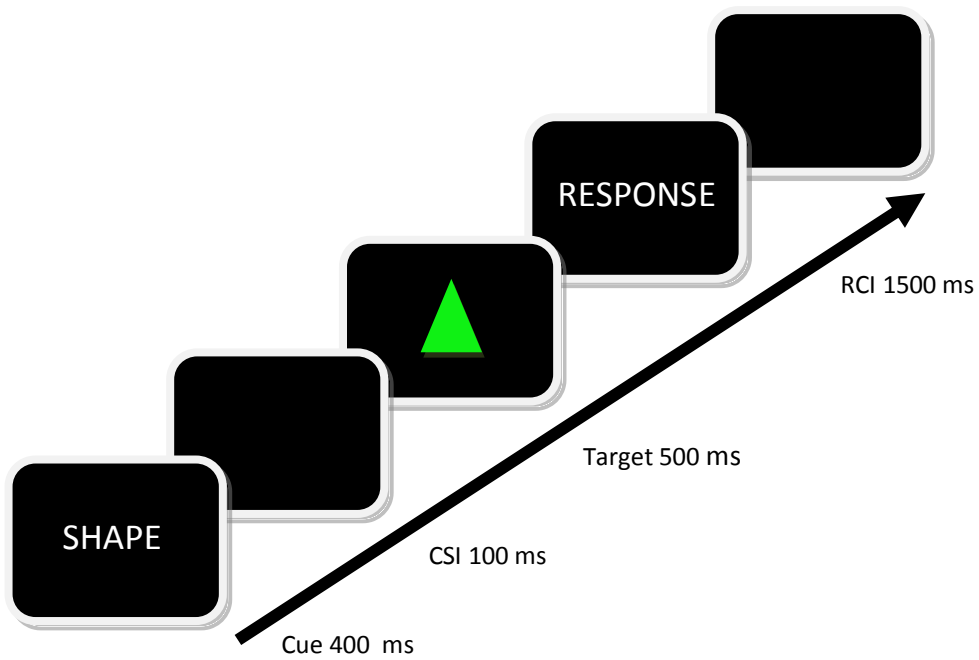
*Figure 1: Anti-saccade task*

### Task switching

Task switching abilities were assessed with a variant of the task switching paradigm (Meiran, Chorev, & Sapir, 2000) (Figure 2), which is considered to be a reliable measurement of task switching capacities (Vandierendonck, Liefoghe, & Verbruggen, 2010). In this task, which took approximately 20 minutes to perform, participants were instructed to switch as quickly as possible between two randomly presented reaction time computer tasks (50% colour discrimination task, 50% shape discrimination task). Each trial started with the presentation of the word “colour” or “shape” against a black background in the middle of a 15” computer screen for 400 ms (HP Compaq nc6120). After 100 ms, a red or green-coloured and circle or triangle-shaped target stimulus was presented for 500 ms. Participants were instructed to indicate whether the target was green or red, when presented with the cue “colour”, or whether the target was a circle

or triangle, when presented with the cue “shape”, by pressing the corresponding keyboard key (F=“green/triangle”, J=“red/circle”). Stimuli remained visible until response, or until the response time had elapsed (4000 ms). The next trial started 1500 ms after the response was given. Trials were categorized as switch trials when the current task differed from the previous task (colour-after-shape-task or shape-after-colour-task), and categorized as repetition trials when the current task was similar to the previous task (colour-after-colour-task or shape-after-shape-task). Normally, it takes more time to perform a switch trial than a repetition trial. Switch cost was calculated by subtracting reaction times on repetition trials from reaction times on switching trials ( $RT_{\text{switch}} - RT_{\text{repetition}}$ ) (Meiran et al., 2000). RTs were calculated after removing the first trial of each block, as well as error trials, and trials preceded by errors (Meiran et al., 2000), anticipations ( $RT < 200$ ) and outliers ( $RT > 3 \text{ SD}$  above the individual mean). Participants received on-screen written instructions. The experiment started with a short practice phase of 16 trials, followed by a test phase of 256 experimental trials, which were divided into four blocks. A short break was introduced after each block. In practice trials, error feedback was presented on-screen for 500 ms. Switch cost served as a measure of task switching ability, with higher levels referring to a lower switching ability.





*Figure 2 : Switching task*

### Working memory

Working memory was assessed with the “digit span” subscale of the WAIS-III (Wechsler, 2005). This test assesses processes used for temporarily storing and manipulating information. The subscale digit span is reliable and valid for different age groups (Wechsler, 2005). Participants were presented with a sequence of digits which they had to repeat initially in the same (8x2 trials), and afterwards in the reverse direction (7x2 trials). The maximum digit sequence is nine (forward) and eight (backward). Digit sequences started at two digits, and for each trial a digit was added. Participants were given two chances to repeat each sequence length. When they missed both trials, the test was aborted. The total score was calculated by summing the total amount of backward and forward recalled digits. The higher the total score, the better the working memory capacity.

## ***Self-report measures***

### *Sample characteristics*

Participants indicated their pain experience prior to the experiment by means of the Graded Chronic Pain Scale (Von Korff, Ormel, Keefe, & Dworkin, 1992). This questionnaire is valid and reliable for several pain problems (Von Korff et al., 1992). The Graded Chronic Pain Scale contains several numerical rating scales (NRS) (0-10) that measure pain intensity (three items, namely pain right now, worst pain and average pain during 6 months), and disability (three items, namely interference with daily activities, social activities and work activities). Total intensity and disability scores vary from 0 to 100. Participants were also asked to register the total number of disability days during the past 6 months (range 0-180), and were classified in grades 0 (“pain free”), 1 (“low disability-low intensity”), 2 (“low disability-high intensity”), 3 (“high disability-low intensity”) and 4 (“high disability-high intensity”).

### *Self-reported attention to pain*

Two items were used to measure self-reported attention to pain. Participants were asked to indicate how much attention they had paid to pain, and the degree to which they were able to distract themselves from pain during the CPT. Both items were scored on a numeric rating scale (NRS) from 0 (“not at all”) to 10 (“very much”). An “attention to pain” score was calculated by subtracting the ability to distract from pain from the amount of attention paid to pain (range -10 to +10). The higher the score, the more attention was paid to pain during the CPT.

### *Self-reported distraction task experience*

Distraction task experience and motivation to perform the task were assessed with six items. Participants in the distraction group were asked to indicate how difficult and interesting the task was, how much attention they paid to the task, and how important it was for them to perform the task well. They were also asked to indicate how much effort they had put in the task. Finally, at the end of the experiment, participants’ beliefs about the effectiveness of the distraction task were assessed. All items were scored on a NRS from 0 to 10 (0=“not at all”; 10=“very much”).

### *Self-reported pain during the CPT*

Pain experience during the CPT was assessed through self-report. A distinction was made between pain intensity and pain affect (Eccleston, 1995b; Leventhal, 1992). Pain intensity was assessed with two items. Participants were asked to indicate (1) the worst pain, and (2) the pain just before the end of the immersion on a NRS from 0 to 10 (0="no pain"; 10="the worst imaginable pain"). According to Kahneman and colleagues (1993), these two measures are valid indicators of the pain experience during the CPT. A total pain intensity score was computed by summing these two pain intensity items (range 0-20). Pain affect was assessed with three items. Participants were asked to indicate (1) how unpleasant the experience was, and (2) how anxious and (3) tense they were during immersion on a 0-10 NRS (0="not anxious/relaxed/pleasant" and 10="very anxious/tense/unpleasant"). A total pain affect score was computed by summing these three pain affect items (range 0-30).

### ***Procedure***

Participants received standard information about the experiment when entering the experimenter room. They were told that *"the main interest of the experiment was to examine the effect of an aversive experience on cognitive functioning"*. They were instructed to perform several cognitive tasks, and a cold pressor task (CPT). Participants were unaware that the experiment was about distraction effectiveness. After instructions, participants first conducted the general executive functioning tasks, which lasted approximately 35 minutes. Subsequently, they performed the painful cold pressor task, which in total took approximately 10 minutes. Participants received standard information about the CPT. After instructions, they immersed their left hand for 1 minute in the room temperature tank to standardize the hand temperature. Participants were instructed to *"immerse their hand and wrist, not to form a fist and not to move their fingers"* (von Baeyer et al., 2005). Before the cold water immersion, participants in the distraction condition received information about the distraction task. They were instructed to *"perform an auditory task during immersion in the cold pressor tank"* and were told that *"good performance was important"*. Participants were instructed that *"they could win 10 eurocent every time they pressed the button quickly and accurately, and could lose 10 eurocent every time they pressed the button too late or inaccurately."*

They could earn a total of 6 euro, which they would receive at the end of the experiment". Participants in the control group were instructed to "keep their thoughts on the cold water and on the pain they experienced" (Leventhal, Brown, Shacham, & Engquist, 1979). After instructions, participants immersed their left hand in the cold water container for 1 minute. Directly following immersion, the pain experience questions were assessed (Koyama, Koyama, Kroncke, & Coghill, 2004). Participants in the distraction group also completed the distraction task engagement questions. The CPT ended with submersion in the room temperature tank to recover (von Baeyer et al., 2005). The experimenter stayed in the room during the whole experiment, and was sitting behind a screen to minimize contact with participants. Participants were collectively debriefed about the study aims after study completion.

## **RESULTS**

One participant of the sample of 92 was removed because of a high number of errors on the distraction task (3 SDs above the group error mean). Statistical analyses were conducted on the remaining 91 participants (72 females, mean age=18.68 years  $\pm$  1.30), by using SPSS 15.0. Where relevant, effect sizes were calculated. The criteria of Cohen (1988) were used to determine whether results had a small (0.20), moderate (0.50) or large (0.80) effect.

### ***Descriptive statistics***

#### ***Sample characteristics***

The majority of the sample (97%) reported good health. The minority reported minor medical problems (15%), mostly allergies or occasional back pains. None of the participants experienced psychological problems. Sixty-eight percent of the participants reported having experienced pain during the past 6 months, which was of average intensity ( $M=47.42$ ,  $SD=17.50$ , range 0-100) and mildly disabling ( $M=33.33$ ,  $SD=22.94$ , range 0-100). Participants were classified in pain grades 0 (31.9%), 1 (29.7%), 2 (26.4%), 3 (11%) and 4 (1.1%). Pain grades were equally distributed between the distraction and the control group ( $\chi^2(4)=3.35$ ,  $p>.10$ ), and were unrelated to the measures of executive

functioning (all  $F < 1.8$ ,  $p > .10$ ). Furthermore, no differences in age ( $t(89) = 0.69$ ,  $p > .10$ ) and sex ( $\chi^2(1) = 0$ ,  $p > .10$ ) were found between the two experimental groups.

### *Executive functioning abilities*

Descriptive analyses showed no differences in inhibition ability between the distraction group ( $M = 338$  ms,  $SD = 84$  ms; 99% correct responses) and the control group ( $M = 346$  ms,  $SD = 68$  ms; 99% correct responses) ( $F(1,88) = 0.29$ ,  $p > .10$ ,  $d = 0.11$ ). Also, no differences were found in task switching abilities between the distraction group ( $M = 98$  ms,  $SD = 116$  ms; 95% correct responses) and the control group ( $M = 68$  ms,  $SD = 77$  ms; 95% correct responses) ( $F(1,86) = 2.06$ ,  $p > .10$ ,  $d = 0.31$ ). Finally, no differences were found in working memory abilities between the distraction group ( $M = 16.35$ ,  $SD = 3.37$ ) and the control group ( $M = 15.21$ ,  $SD = 2.56$ ) ( $F(1,89) = 3.34$ ,  $p > .05$ ,  $d = 0.38$ ). No significant correlations between inhibition, task switching and working memory abilities were observed (all  $r < .13$ , all  $p > .10$ ).

### *Engagement with the distraction task*

Descriptive analyses were conducted on distraction task performance measures and self-reported distraction task experience measures. Results showed that participants performed the distraction task quickly (RT:  $M = 221$  ms,  $SD = 57$  ms) and accurately (Errors:  $M = 1.79$ ,  $SD = 2.04$ ), with little variation in response time ( $SD: M = 57$  ms,  $SD = 22$  ms). Performance measures are comparable with other studies that have used the RIR-task as a distraction task (Van Damme et al., 2008). Furthermore, participants in the distraction group reported paying attention to the distraction task ( $M = 8.31$ ,  $SD = 1.42$ ). They evaluated the task as moderately interesting ( $M = 5.29$ ,  $SD = 2.48$ ), found it important to perform the task well ( $M = 7.02$ ,  $SD = 2.04$ ), and made an effort to do so ( $M = 6.81$ ,  $SD = 2.29$ ). The task was not rated as difficult ( $M = 2.69$ ,  $SD = 2.28$ ), and participants believed that the task could work to diminish pain during the CPT ( $M = 6.78$ ,  $SD = 2.12$ ).

We explored the relationship between distraction task performance measures, the self-reported experience of the distraction task, and the measures of executive functioning by means of Pearson correlations (see Table 1). Results indicated that task performance was significantly related to inhibition abilities. When inhibition abilities

were better, reaction times were significantly faster, and response variation was smaller. The amount of errors on the distraction task was also lower, but this correlation failed to reach significance ( $p=.09$ ). Surprisingly, when switching and working memory abilities were better, performance on the distraction task did not significantly improve. Further analyses showed, that when switching abilities were better, significantly less attention to the distraction task was reported. For working memory, this relationship just failed to reach significance ( $p=.06$ ).

### ***Overall effects of distraction on attention to pain and pain experience***

ANOVA were conducted to examine differences in attention to pain, pain intensity and pain affect between the distraction group and the control group. Results indicated that participants in the distraction group reported less attention to pain ( $M=-2.67$ ,  $SD=2.83$ ,  $min=-8$ ,  $max=3$ ) than controls ( $M=3.52$ ,  $SD=2.92$ ,  $min=-3$ ,  $max=9$ ) ( $F(1,89)=104.78$ ,  $p<.001$ ,  $d=2.15$ ), and experienced the pain as less intense ( $M=9.21$ ,  $SD=4.40$ ,  $min=2$ ,  $max=16$ ) than controls ( $M=11.17$ ,  $SD=4.16$ ,  $min=1$ ,  $max=18$ ) ( $F(1,89)=4.76$ ,  $p<.05$ ,  $d=0.46$ ). Pain affect did not significantly differ between the distraction ( $M=14.05$ ,  $SD=5.23$ ,  $min=4$ ,  $max=26$ ) and the control group ( $M=15.49$ ,  $SD=5.70$ ,  $min=1$ ,  $max=29$ ) ( $F(1,88)=1.56$ ,  $p>.10$ ,  $d=0.26$ ).

### ***Impact of executive functioning on distraction effectiveness***

To examine the role of executive functioning (inhibition, task switching and working memory) in the effectiveness of distraction, a series of moderator analyses was conducted (see Table 2). In these analyses, attention to pain, pain intensity and pain affect served as the dependent variables, and inhibition, task switching and working memory served as the moderating variables. Following the procedure of Holmbeck (1997), predictor (group) and moderating variables (inhibition, task switching and working memory) were centred, and entered in a first step. The interaction term of (predictor x moderator) was entered in a second step. The effects of the different moderator variables were examined in separate analyses. Results of these moderator analyses indicated that inhibition, task switching and working memory were not significantly related to attention to pain, pain intensity and pain affect. Contrary to our

expectations, inhibition, task switching and working memory did not moderate the relationship between the distraction manipulation and the pain experience<sup>1</sup>.

---

<sup>1</sup> Analyses were repeated by only including participants with average pain intensity scores ( $\geq 10$ ) to check whether low pain levels might explain the lacking relationship between executive functioning and distraction effectiveness (N=56). However, the same results were found using higher pain ratings, indicating that executive functioning did not influence the pain experience (all  $t < 1$ ,  $p > .10$ ), nor the effectiveness of distraction (all  $t < 1.4$ ,  $p > .10$ ).

**Table 1**

*Means (M), standard deviations (SD) and Pearson correlations of executive functions, behavioral distraction task (RIR) measures, attention to pain and to the distraction task and pain experience in the distraction group*

	<b>M (SD)</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
<b>1. Inhibition</b>	338 (84)	-	.07	-.07	.41**	.37*	.26	-.21	.11	-.08	-.08
<b>2. Task switching</b>	98 (116)		-	-.01	.08	.13	.08	.32*	.03	-.23	-.22
<b>3. Working memory</b>	16.35 (3.37)			-	-.06	.11	-.20	-.29	.18	-.04	.11
<b>4. RIR RT</b>	221 (57)				-	.64**	.13	-.26	.04	-.08	-.19
<b>5. RIR SD</b>	57 (22)					-	.37*	-.09	.21	-.10	-.11
<b>6. RIR Errors</b>	1.79 (2.04)						-	.05	.10	.17	.10
<b>7. Attention to RIR</b>	8.31 (1.42)							-	-.30	-.17	-.14
<b>8. Attention to pain</b>	-2.67 (2.83)								-	.39*	.32*
<b>9. Pain intensity</b>	9.21 (4.40)									-	.62**
<b>10. Pain affect</b>	14.05 (5.23)										-

Note: Reaction times (RT) and response variation (SD) are presented in ms, \* $p < .05$ ; \*\* $p < .01$ .



**Table 2**

*Hierarchical regression analyses with group, inhibition, task switching and working memory as predictors, and attention to pain, pain intensity and pain affect as criterion variables*

<b>Criterion variables</b>	<b>Step</b>	<b>Predictor</b>	<b><math>\beta</math></b>	<b><math>\Delta R^2</math></b>	<b>Adj. <math>R^2</math></b>
<b>Attention to pain</b>	<b>1</b>	<b>Group</b>	-.74**	.54**	.53**
		<b>Inhibition</b>	-.04		
	<b>2</b>	<b>Inhibition x group</b>	.10	.01	.53**
		<b>Group</b>	-.74**	.55**	.54**
	<b>2</b>	<b>Task switching</b>	-.05		
		<b>Task switching x group</b>	.07	.004	.54**
<b>Pain intensity</b>	<b>1</b>	<b>Group</b>	-.25*	.07 <sup>(a)</sup>	.04 <sup>(a)</sup>
		<b>Inhibition</b>	-.09		
	<b>2</b>	<b>Inhibition x group</b>	.01	.00	.03
		<b>Group</b>	-.22*	.09*	.06*
	<b>2</b>	<b>Task switching</b>	-.15		
		<b>Task switching x group</b>	-.04	.001	.05 <sup>(a)</sup>
<b>Pain affect</b>	<b>1</b>	<b>Group</b>	-.22*	.05	.03
		<b>Working memory</b>	-.03		
	<b>2</b>	<b>Working memory x group</b>	.00	.00	.02
		<b>Group</b>	-.15	.03	.01
	<b>2</b>	<b>Inhibition</b>	-.11		
		<b>Inhibition x group</b>	.04	.002	-.002
<b>Pain affect</b>	<b>1</b>	<b>Group</b>	-.13	.04	.01
		<b>Task switching</b>	-.10		
	<b>2</b>	<b>Task switching x group</b>	-.08	.01	.01
		<b>Group</b>	-.13	.02	-.01
	<b>2</b>	<b>Working memory</b>	-.01		
		<b>Working memory x group</b>	.10	.01	-.01

Note: Standardized betas of the last step are displayed, \* $p < .05$ , \*\* $p < .001$ , <sup>(a)</sup> $p = .05$ .

## DISCUSSION

This study investigated the role of executive functioning in the effectiveness of distracting attention away from pain. Participants first performed three tasks of different executive functions (inhibition, task switching and working memory). Subsequently, they performed a painful cold pressor task, during which half of the participants performed an

attention-demanding tone-detection task (distraction group), whereas the other half did not (control group). Results can be readily summarized. Distraction was effective in diminishing pain, but contrary to our expectations, participants with better executive functioning abilities did not report less pain during distraction compared to participants with less executive functioning abilities. However, we did observe that those with better executive functioning abilities performed the distraction task better compared to those with less executive functioning abilities. Results will be more extensively discussed, suggestions for future research formulated, and clinical implications outlined.

This study revealed a small effect of distraction on self-reported pain. This is in line with other studies that have shown beneficial effects of distraction (James & Hardardottir, 2002; Johnson, Breakwell, Douglas, & Humphries, 1998; McCaul & Haugtvedt, 1982; Miron, Duncan, & Bushnell, 1989; Terkelsen, Andersen, Mølgaard, Hansen, & Jensen, 2004). Our study, however, has further value. Participants were kept unaware that this experiment was about the effects of distracting attention away from pain, thereby minimizing the possibility that our distraction effects are merely the result of participants' beliefs in the effectiveness of distraction (Leventhal, 1992). This study also meets many methodological considerations in the field of distraction research (Eccleston, 1995b), including the measurement of pain, the standardisation of the pain induction method, and the measurement of distraction task performance.

Contrary to our expectations, general executive functioning abilities (inhibition, task switching and working memory) did not produce larger pain reduction during distraction, indicating that participants with better executive functioning abilities did not benefit more from distraction than participants with less executive functioning abilities. We also did not find any overall effects of executive functioning on self-reported pain intensity and affect. This is in line with a recent study in adults which examined the relationship between executive functioning and pain experience, but not its effects upon distraction effectiveness (Oosterman, Dijkerman, Kessels, & Scherder, 2010). This study did not find a relationship between the self-reported pain experience, inhibition and working memory. Participants with better inhibition abilities, however, endured cold pressor pain for a longer period of time. It remains unclear how to interpret this finding because pain tolerance was not

measured using the standard protocol (i.e., immersion until participants experienced substantial pain).

There is still some debate about the unitariness of the inhibition construct, and there is a growing consensus that inhibition consist of different aspects, namely (1) resistance to distractor interference (i.e., the ability to resist or resolve interference from information in the external environment that is irrelevant), (2) prepotent response inhibition (i.e., the ability to deliberately suppress dominant, automatic and prepotent responses), and (3) resistance to proactive interference (i.e., the ability to resist memory intrusions from information that was previously relevant but has since become irrelevant) (Friedman & Miyake, 2004; Nigg, 2000). It may be useful for future research to measure the different aspects of inhibition using a multi-method approach. This would allow the use of a latent variable analysis (cfr. structural equation modeling), which would probably create greater reliability of the inhibition measurement (Friedman & Miyake, 2004).

Additionally, we explored the role of executive functioning upon the engagement with the distraction task. Results showed that having good inhibition abilities improved the performance on a distracting task despite the presence of pain. This finding suggests that efficient engagement with tasks in the presence of pain may require inhibition. This idea is also supported by fMRI (Bantick et al., 2002) and EEG studies (Legrain, Bruyer, Guérit, & Plaghki, 2005). The dorsal anterior cingulate cortex (ACC) and the dorsolateral prefrontal cortex (DLPFC), which are also involved in the attentional control of pain (Tracey & Mantyh, 2007), are generally postulated to play a role in inhibition (Aron, Robbins, & Poldrack, 2004; Dreher & Berman, 2002; Roberts & Wallis, 2000). Results further indicated that task switching did not influence the performance on the distraction task. It may be that task switching abilities are less important than inhibition abilities in performing a distraction task during pain. However, it is also possible that switching between two neutral cognitive tasks is different from switching between the processing of pain and a distraction task. It may be that switching attention away from pain towards a distraction task, also requires the inhibition of predominant responses. A challenge for future research will then be to develop tasks that provide an independent measure of the ability to switch attention away from pain. It may well be that such specific measures would be better predictors of distraction

task performance and distraction effectiveness than the switching task here used. Inspiration may be found in recent research on the role of switching in emotion (Johnson, 2009). Finally, the significant effects of task switching, and marginally significant effects of working memory abilities on self-reported distraction task experience measures were unexpected, and at first sight counter-intuitive. When task switching and working memory abilities were better, participants reported spending less attention to the distraction task. One possible explanation might be that individuals with better task switching and working memory abilities need less effort to obtain equal distraction task performance compared to individuals with less executive functioning abilities, and can therefore simultaneously engage in both the pain and the distraction task. This interpretation is preliminary and awaits further corroboration. This idea might be further tested by using distraction tasks with a variable working memory load (Buhle & Wager, 2010; Forster & Lavie, 2007).

Our findings may have clinical implications. There is now ample evidence that chronic pain patients experience cognitive deficits that are sufficiently important to affect their daily life activities (Dick & Rashiq, 2007; Grisart, Van der Linden, & Masquelier, 2002; Hart, Martelli, & Zasler, 2000; Leavitt & Katz, 2006; Schmitz et al., 2008). Patients' attentional complaints have attracted interest from fundamental neuroscience research (Bantick et al., 2002; Bingel, Rose, Gläscher, & Büchel, 2007; Legrain et al., 2009), and this has led to a renewed interest in the attention management components of standard psychological interventions (Elomaa, Williams, & Kalso, 2009; Morley, Shapiro, & Biggs, 2004). The findings of our study suggest that attention management strategies may be more effective if they attempt to improve patients' ability to maintain attentional focus and inhibit distracting information.

This study has some limitations. First, our sample consisted of undergraduate students, who are relatively homogeneous in terms of age and intelligence (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Rosselli & Ardila, 2003). Replication in other samples with more variability in executive functioning is necessary to allow generalization of our findings. Second, the undergraduate research sample mainly consisted of women, and the number of men was too small to meaningfully examine gender differences. Future research should therefore investigate whether results differ for men. Third, executive

functioning is not the only factor that is argued to influence distraction task engagement. Other factors, for instance catastrophic thinking about pain, may also play a role in distraction task engagement (Crombez, Van Damme, & Eccleston, 2005; Goubert et al., 2004; Van Damme, Crombez, & Eccleston, 2004; Van Damme, Crombez, & Lorenz., 2007). As this study made no attempts to account for other individual differences, results are limited to general effects. Fourth, we found a relationship between distraction task performance (i.e., reaction time and response variation) and inhibition abilities. Because both tasks are reaction time tasks, it is possible that this relationship is stronger than the relationship between distraction task performance and other executive functions measures. However, we also found a marginally significant relationship between the number of errors on the distraction task and inhibition. Future research might consider using other measures of inhibition to further explore this relationship. Finally, pain was induced with the cold pressor test, a well validated pain inducing method (von Baeyer et al., 2005), that is often used in distraction research (e.g., Cioffi & Holloway, 1993; de Wied & Verbaten, 2001; Johnson & Petrie, 1997; McCaul & Haugtvedt, 1982; Van Damme et al., 2008). The CPT, however, has the disadvantage that the pain experience may fluctuate during immersion, with the pain increasing rapidly in the beginning of the immersion, and the pain leveling off after 2 to 4 minutes (Eccleston, 1995b; Handwerker & Kobal, 1993; von Baeyer et al., 2005; Walsh, Schoenfeld, Ramamurthy, & Hoffman, 1989). Therefore we used a fixed immersion paradigm of 1 minute instead of a pain tolerance paradigm to ensure that all participants would experience the same physical stimulation.

In conclusion, this study shows a relationship between executive functioning and distraction task performance, with particular support for the role of inhibition, indicating that distraction task performance improves with better inhibition abilities. How this might influence pain experience remains to be explored.

## **ACKNOWLEDGMENTS**

The authors thank Evelyne Lagrou and Lies Notebaert for programming the executive functioning tasks. Preparation of this paper was partly supported by Grant BOF/GOA2006/001 of Ghent University and FWO project G.017807.

## REFERENCES

- Anderson, V.A., Anderson, P., Northam, E., Jacobs, R., & Catroppa, C. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology, 20*, 385-406.
- Aron, A.R., Robbins, T.W., & Poldrack, R.A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences, 8*, 170-177.
- Bantick, S.J., Wise, R.G., Ploghaus, A., Clare, S., Smith, S.M., & Tracey, I. (2002). Imaging how attention modulates pain in humans using functional MRI. *Brain, 125*, 310-319.
- Bingel, U., Rose, M., Gläscher, J., & Büchel, C. (2007). fMRI reveals how pain modulates visual object processing in the ventral visual stream. *Neuron, 55*, 157-167.
- Buhle, J., & Wager, W. (2010). Performance-dependent inhibition of pain by an executive working memory task. *Pain, 149*, 19-26.
- Cioffi, D., & Holloway, J. (1993). Delayed costs of suppressed pain. *Journal of Personality and Social Psychology, 64*, 274-284.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. San Diego, CA: McGraw-Hill.
- Crombez, G., Van Damme, S., & Eccleston, C. (2005). Hypervigilance to pain: An experimental and clinical analysis. *Pain, 116*, 4-7.
- Dalton, P., Lavie, N., & Spence, C. (2009). The role of working memory in visual selective attention. *Science, 291*, 1803-1806.
- Dalton, P., Santangelo, V., & Spence, C. (2009). The role of working memory in auditory selective attention. *The Quarterly Journal of Experimental Psychology, 62*, 2126-2132.

- de Wied, M., & Verbaten, M.N. (2001). Affective pictures processing, attention and pain tolerance. *Pain, 90*, 163-172.
- Dick, B.D., & Rashedi, S. (2007). Disruption of attention and working memory traces in individuals with chronic pain. *Anesthesia and Analgesia, 104*, 1223-1229.
- Dreher, J., & Berman, K.F. (2002). Fractionating the neural substrate of cognitive control processes. *PNAS, 99*, 14595-14600.
- Eccleston, C. (1995a). Chronic pain and distraction: An experimental investigation into the role of sustained and shifting attention in the processing of chronic persistent pain. *Behaviour Research and Therapy, 33*, 391-405.
- Eccleston, C. (1995b). The attentional control of pain: Methodological and theoretical concerns. *Pain, 63*, 3-10.
- Eccleston, C., & Crombez, G. (1999). Pain demands attention: A cognitive-affective model of the interruptive function of pain. *Psychological Bulletin, 125*, 356-366.
- Elomaa, M.M., Williams, A.C.C., & Kalso, E.A. (2009). Attention management as a treatment for chronic pain. *European Journal of Pain, 13*, 1062-1067.
- Everling, S., & Fischer, B. (1998). The antisaccade: A review of basic research and clinical studies. *Neuropsychologia, 36*, 885-899.
- Forster, S., & Lavie, N. (2007). High perceptual load makes everybody equal. Eliminating individual differences in distractibility with load. *Psychological Science, 18*, 377-381.
- Friedman, N.P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology, 133*, 101-135.
- Funahashi, S. (2001). Neuronal mechanisms of executive control by the prefrontal cortex. *Neuroscience Research, 39*, 147-165.
- Goubert, L., Crombez, G., Eccleston, C., & Devulder, J. (2004). Distraction from chronic pain during a pain-inducing activity is associated with greater post-activity pain. *Pain, 110*, 220-227.
- Grisart, J., Van der Linden, M., & Masquelier, E. (2002). Controlled processes and automaticity in memory functioning in fibromyalgia patients: Relation with emotional

- distress and hypervigilance. *Journal of Clinical and Experimental Neuropsychology*, *24*, 994-1009.
- Handwerker, H.O., & Kobal, G. (1993). Psychophysiology of experimentally induced pain. *Physiological Reviews*, *73*, 639-671.
- Hart, R.P., Martelli, M.F., & Zasler, N.D. (2000). Chronic pain and neuropsychological functioning. *Neuropsychology Review*, *10*, 131-149.
- Hodes, R.L., Howland, E.W., Lightfoot, N., & Cleeland, C.S. (1990). The effects of distraction on responses to cold pressor pain. *Pain*, *41*, 109-114.
- Holmbeck, G.N. (1997). Toward terminological, conceptual and statistical clarity in the study of mediators and moderators: Examples from the child-clinical and pediatric psychology literatures. *Journal of Consulting and Clinical Psychology*, *65*, 599-610.
- James, J.E., & Hardardottir, D. (2002). Influence of attention focus and trait anxiety on tolerance of acute pain. *British Journal of Health Psychology*, *7*, 149-162.
- Johnson, D.R. (2009). Attentional control capacity for emotion: An individual-difference measure of internal controlled attention. *Cognition and Emotion*, *23*, 1516-1536.
- Johnson, M.H., Breakwell, G., Douglas, W., & Humphries, S. (1998). The effects of imagery and sensory detection distractors on different measures of pain: How does distraction work? *British Journal of Clinical Society*, *37*, 141-154.
- Johnson, M.H., & Petrie, S.M. (1997). The effects of distraction on exercise and cold pressor tolerance for chronic low back pain sufferers. *Pain*, *69*, 43-48.
- Kahneman, D., Fredrickson, B.L., Schreiber, C.A., & Redelmeier, D.A. (1993). When more pain is preferred to less: Adding a better end. *Psychological Science*, *4*, 401-405.
- Koyama, Y., Koyama, T., Kroncke, A.P., & Coghill, R.C. (2004). Effects of stimulus duration on heat induced pain: The relationship between real-time and post-stimulus pain ratings. *Pain*, *107*, 256-266.
- Lavie, N., & de Fockert, J.M. (2005). The role of working memory in attentional capture. *Psychonomic Bulletin and Review*, *12*, 669-674.
- Leavitt, F., & Katz, R. (2006). Distraction as a key determinant of impaired memory in patients with fibromyalgia. *Journal of Rheumatology*, *33*, 127-32.



- Legrain, V., Bruyer, R., Guérit, J., & Plaghki, L. (2005). Involuntary orientation of attention to unattended deviant nociceptive stimuli is modulated by concomitant visual task difficulty. Evidence from laser evoked potentials. *Clinical Neuropsychology, 116*, 2165-2174.
- Legrain, V., Van Damme, S., Eccleston, C., Davis, K.D., Seminowicz, D.A., & Crombez, G. (2009). A neurocognitive model of attention to pain: Behavioral and neuroimaging evidence. *Pain, 144*, 230-232.
- Leventhal, H. (1992). I know distraction works even though it doesn't! *Health Psychology, 11*, 208-209.
- Leventhal, H., Brown, D., Shacham, S., & Engquist, G. (1979). Effects of preparatory information about sensations, threat of pain and attention on cold pressor distress. *Journal of Personality and Social Psychology, 37*, 688-714.
- Marchand, S., & Arsenault, P. (2002). Odors modulate pain perception: A gender-specific effect. *Physiology & Behavior, 76*, 251-256.
- McCaul, K.D., & Haugtvedt, C. (1982). Attention, distraction and cold pressor pain. *Journal of Personality and Social Psychology, 43*, 154-162.
- McCaul, K.D., & Malott, J.M. (1984). Distraction and coping with pain. *Psychological Bulletin, 95*, 516-533.
- McCaul, K.D., Monson, N., & Maki, R.H. (1992). Does distraction reduce pain-produced distress among college students? *Health Psychology, 11*, 210-217.
- Meiran, N., Chorev, Z., & Sapir, A. (2000). Component processes in task switching. *Cognitive Psychology, 41*, 211-253.
- Miron, D., Duncan, G.H., & Bushnell, M.C. (1989). Effects of attention on the intensity and unpleasantness of thermal pain. *Pain, 39*, 345-352.
- Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., & Howerter, A. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100.
- Morley, S., Shapiro, D.A., & Biggs, J. (2004). Developing a treatment manual for attention management in chronic pain. *Cognitive Behaviour Therapy, 32*, 1-12.

- Nigg, J.T. (2000). On inhibition/disinhibition in developmental psychopathology: Views of cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin*, *126*, 220-246.
- Oosterman, J.M., Dijkerman, H.C., Kessels, R.P.C., & Scherder, E.J.A. (2010). A unique association between cognitive inhibition and pain sensitivity in healthy participants. *European Journal of Pain*, *14*, 1046-1050.
- Roberts, A.C., & Wallis, J.D. (2000). Inhibitory control and affective processing in the prefrontal cortex: Neuropsychological studies in the common marmoset. *Cerebral Cortex*, *10*, 252-262.
- Roelofs, J., Peters, M.L., van der Zijden, M., & Vlaeyen, J.W.S. (2004). Does fear of pain moderate the effects of sensory focusing and distraction on cold pressor pain in pain-free individuals? *The Journal of Pain*, *5*, 250-256.
- Rosselli, M., & Ardila, A. (2003). The impact of culture and education on non-verbal neuropsychological measurements: A critical review. *Brain Cognition*, *52*, 326-333.
- Schmitz, N., Arkink, E.B., Mulder, M., Rubia, K., Admiraal-Behloul, F., Schoonman, G.G., Kruit, M.C., Ferrari, M.D., & van Buchem, M.A. (2008). Frontal lobe structure and executive function in migraine patients. *Neuroscience Letters*, *440*, 92-96.
- Smith, E.E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science*, *283*, 1657-1661.
- Terkelsen, A.J., Andersen, O.K., Mølgaard, H., Hansen, J., & Jensen, T.S. (2004). Mental stress inhibits pain perception and heart rate variability but not a nociceptive withdrawal reflex. *Acta Physiologica Scandinavica*, *180*, 405-414.
- Tracey, I., & Mantyh, P.W. (2007). The cerebral signature for pain perception and its modulation. *Neuron*, *55*, 377-391.
- Van Damme, S., Crombez, G., & Eccleston, C. (2004). Disengagement from pain: The role of catastrophic thinking about pain. *Pain*, *107*, 70-76.
- Van Damme, S., Crombez, G., & Lorenz, J. (2007). Pain draws attention to its location: Experimental evidence for threat-related bias. *The Journal of Pain*, *8*, 976-982.

- Van Damme, S., Crombez, G., Van Nieuwenborgh-De wever, K., & Goubert, L. (2008). Is distraction less effective when pain is threatening? An experimental investigation with the cold pressor task. *European Journal of Pain, 12*, 60-67.
- Van Damme, S., Legrain, V., Vogt, J., & Crombez, G. (2010). Keeping pain in mind: A motivational account of attention to pain. *Neuroscience and Biobehavioral Reviews, 34*, 204-213.
- Vandierendonck, A., De Vooght, G., & Van der Goten, K. (1998a). Does random time interval generation interfere with working memory executive functions? *European Journal of Cognitive Psychology, 10*, 413-442.
- Vandierendonck, A., De Vooght, G., & Van der Goten, K. (1998b). Interfering with the central executive by means of a Random Interval Repetition Task. *The Quarterly Journal of Experimental Psychology, 51A*, 197-218.
- Vandierendonck, A., Liefoghe, B., & Verbruggen, F. (2010). Task switching: Interplay of reconfiguration and interference control. *Psychological Bulletin, 136*, 601-626.
- Verhoeven, K., Crombez, G., Eccleston, C., Van Ryckeghem, D.M.L., Morley, S., & Van Damme, S. (2010). The role of motivation in distracting attention away from pain: An experimental study. *Pain, 149*, 229-234.
- von Baeyer, C.L., Piira, T., Chambers, C.T., Trapanotto, M., & Zeltzer, L.K. (2005). Guidelines for the cold pressor task as an experimental pain stimulus for use with children. *The Journal of Pain, 6*, 218-227.
- Von Korff, M., Ormel, J., Keefe, F.J., & Dworkin, S.F. (1992). Grading the severity of chronic pain. *Pain, 50*, 133-149.
- Walsh, N.E., Schoenfeld, L., Ramamurthy, S., & Hoffman, J. (1989). Normative model for cold pressor test. *American Journal of Physical Medicine & Rehabilitation, 68*, 6-11.
- Wechsler, D. (2005). *WAIS-III Nederlandse bewerking: Technische handleiding*. Lisse: Harcourt Test Publishers.