Relationship between cardiovascular reactivity and the perception of the thermal grill illusion of pain

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Background and Aims

Alterations in blood pressure (BP) and concomitant changes in baroreceptor activation contribute to the modulation of pain sensitivity to warrant homeostatic regulation processes [1][2]. Numerous pain studies have described an inverse relationship between BP and nociceptive sensitivity [3][4][5]. It is not known whether a similar relationship plays a role in the framework of the induction of pain in the absence of noxious stimulation. The thermal grill (TG) paradigm is commonly used to trigger this type of paradoxical pain also termed thermal grill illusion of pain (TGI).

The goal of the present study was to explore the relationship between cardiovascular activity/reactivity and paradoxical pain sensitivity to get additional insight in the variability of responsiveness (responders and non-responders) to TG stimulation described in the literature [6][7]. We hypothesized that higher BP would be associated with stronger pain inhibitory effects in participants not perceiving the thermal grill illusion of pain (TGI). We moreover expected that the perception of paradoxical pain in the responder group would be paired with lower BP. We tested this hypothesis by comparing both groups with respect to their spontaneous cardiovascular activity (recorded in resting conditions) and their cardiovascular responses to TG stimulation.

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Methods

Participants:

We included 31 healthy and normotensive volunteers (Mean age: 24.2 years, *SEM* = 1.17, range: 19–51, *n* = 16 females) recruited at the University of Luxembourg in the final sample of this study. Exclusion criteria were previous or current psychological, cardiovascular, neurological, pain, and skin-related problems, as well as drug and pain medication intake 24 hours before the experimental session.

Thermal grill device and stimulation procedure:

We elicited the TGI with a custom-built and water-bath driven TG device [8] composed of eight alternating cooled and heated tubes of borosilicate glass (see Figure 3).

The stimulation procedure consisted in an experimental TG stimulation condition and two control conditions (CC1 and CC2) Details are shown in Figure 2.

Measures:

Psychophysical measures:

Participants used a 100 mm numerical rating scale (NRS) for the assessment of non-painful and painful sensations (i.e. sensory and affective component of pain) perceived during the TG stimulation conditions.

Psychophysiological measures:

Heart rate (HR, in beats per minute, bpm) and arterial BP (in mmHg) were continuously recorded with an MP150 Data Acquisition System (BIOPAC Systems Inc., USA) during the experiment.

Statistical analyses:

Pearson's correlation analyses were performed to study the relationship between cardiovascular activity and sensory resp. affective paradoxical pain ratings. General linear mixed model analyses were used for the investigation of between and within-subject effects in the responder and non-responder group.

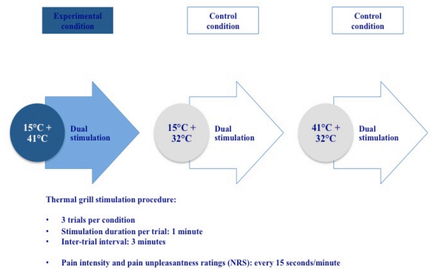

Figure 2: Thermal grill stimulation procedure

Figure 3: Custom-built thermal grill device. (W: warm tubes; C: cold tubes)

Conclusion

Like for classical nociceptive processing, we could find an inverse relationship between blood pressure reactivity and pain sensitivity in the present thermal grill paradigm. Participants displaying higher blood pressure responses in the experimental stimulation condition did not feel the illusive pain as compared to those with significantly lower blood pressure reactivity. These psychophysiological characteristics may be involved in the regulation of paradoxical pain sensitivity in addition to previously uncovered psychological factors [9] and hence explain part of the observed variance in the individual disposition to paradoxical pain perceptions.

Results

Based on paradoxical pain intensity ratings, we classified *n* = 13 participants as responders (*M* = 36.5, *SEM* = 3.16) and *n* = 18 as non-responders to TG stimulations (*M* = 15.9, *SEM* = 1.06).

Mean resting systolic and diastolic BP (SBP, DBP) did not significantly differ between groups (see Figure 1a and 1b). The correlation analyses did not show an association between resting BP and paradoxical pain sensitivity. However, a significant inverse relationship between SBP and DBP responses to TG stimulation and paradoxical pain perceptions could be found (see Table 1).

Table 1: Relationships between blood pressure and pain ratings

	Condition	NRS sensory	NRS affective[b]
Pearson correlation coefficient		*r*	*r*
Mean SBP [a]	BL	−.06	−.16
	TG mean	−.42*	−.33
	TG 1[c] (*N* = 26)	−.61**	−.53**
	TG 2 (*N* = 31)	−.30	−.18
	TG 3 (*N* = 30)	−.38*	−.27
Mean DBP [a]	BL	−.08	−.10
	TG mean	−.59**	−.09
	TG 1 (*N* = 24)	−.64**	−.44*
	TG 2 (*N* = 29)	−.33	−.05
	TG 3 (*N* = 28)	−.27	−.11

** $p < 0.01$, * $p < 0.05$ (2-tailed).
[a] Mean systolic blood pressure (SBP) and diastolic blood pressure (DBP).
[b] Mean NRS-related pain intensity and pain unpleasantness ratings assessed at 15 sec intervals in three separate 1-minute thermal grill stimulation phases.
[c] First thermal grill stimulation phase. etc.

Linear mixed model analyses revealed a significant group effect for SBP (*df* = 1, *F* = 9.21, *p* < .01) and for DBP (*df* = 1, *F* = 8.62, *p* < .01). The post hoc tests mainly uncovered that the SBP and DBP responses of the non-responders were significantly higher than those of the responders [SBP: *t* (23) = 4.70, *p* < .001, mean difference = 20.6, 95% CI: 11.5 to 29.7, η^2 = .59; two-tailed; see Figure 1a; DBP: *t* (23) = 3.71, *p* < .005, mean difference = 13.4, 95% CI: 5.9 to 20.9, η^2 = .37; two-tailed; see Figure 1b]. Mixed model results also showed a highly significant condition effect for SBP (*df* = 3, *F* = 15.92, *p* < .001) and DBP (*df* = 3, *F* = 7.96, *p* < .001). In both groups, SBP and DBP changed significantly throughout the distinct conditions, except the DBP in the responder group. The increase in SBP and DBP was significant from BL to the TG resp. the CC1 and CC2 condition. A significant decrease in DBP in CC1 as compared to BL was observed in the non-responder group (all *p* < .05).

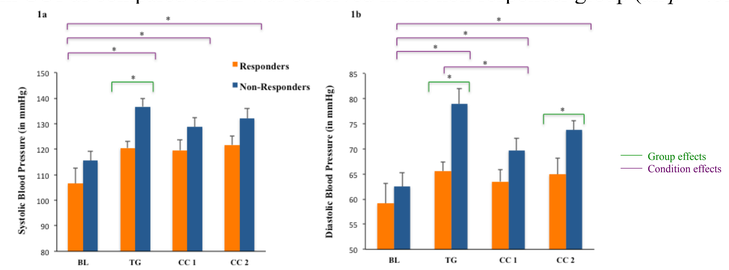

Figure 1: Systolic and diastolic blood pressure in responders and non-responders to thermal grill stimulation

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