The Influence of Pain Intensity and Executive Functioning on Facial Pain Expression

Juliane Traxler
Radboud University
julitraxler@yahoo.de

ABSTRACT
Facial pain expressions are frequently used to assess pain in populations that cannot verbally express their suffering. The present study aimed to investigate the usefulness of facial expressions as an assessment tool and the influence of executive functioning on facial pain expression. Pain ratings to mechanical nociceptive stimuli were obtained from 57 healthy elderly, facial pain expressions were filmed and coded, working memory and cognitive inhibition were assessed. Results showed a positive correlation between stimulus intensity and pain expressions which was moderated by cognitive inhibition. Pain intensity has a stronger effect on facial pain expression at low levels of inhibition.

Keywords
Facial expressions, pain, elderly, executive functioning, working memory, cognitive inhibition.

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INTRODUCTION
The strong subjectivity of the pain experience can pose a problem for its assessment and evaluation, making comparisons among people for scientific goals difficult or, worse, leaving some individuals undertreated. Especially the elderly and those who cannot verbally express their suffering in an adequate way may not receive sufficient analgesics. A study by Boerlage, van Dijk, Stronks, de Wit, and van der Rijt (2008) in Dutch residential homes demonstrated that more than two thirds of the residents had experienced pain within the past week, of which many received pain medication only on demand and 22% were not medically treated at all against their pain. Yet, it was repeatedly found that older people tend to be less communicative about their pain (e.g., Boerlage et al., 2008). Therefore, an alternative assessment to verbal pain reports may be useful for this subgroup.

One possible alternative is the assessment of people's facial expression as it is not compromised by language impairments and may be less dependent on the desire of expressing or hiding pain since facial expression is a rather automatic process (e.g., Blair, 2003). While several studies discovered small, but significant correlations between facial expressions and pain reports (e.g. Kunz, Mylius, Schepelmann, & Lautenbacher, 2004) it is likely that individual differences affect facial pain expressions (FPE) which can bias their interpretation. Previous research shows that executive functioning (EF) affects pain perception (Oosterman, Dijkerman, Kessels, & Scherder, 2010) and correlates negatively with pain report in the elderly (Hadjistavropoulos et al., 1998). Consequently, EF is likely to be involved in FPE as well, possibly moderating the effects of pain intensity on facial expressions. For example, two neuro-imaging studies by Kunz et al. (2009) and Kunz, Chen, Lautenbacher, Vachon-Presseau and Rainville (2011) detected that the suppression of FPE in low expressive individuals was related to activation in the medial frontal cortex which is known to be involved in behavioural inhibition.

Yet, up to now the relations between EF and FPE have not been investigated. Therefore, the current study examined the influence of stimulus intensity, EF, and their possible interaction on FPE in a group of healthy individuals. Besides, the relation between pain report and FPE was investigated because previous studies report contradictory results (Prkachin & Solomon, 2008). It is expected that (1) higher stimulus intensities will be accompanied by stronger FPE, (2) pain report will correlate positively with FPE, (3) EF will predict FPE, and that (4) EF functions as a moderator between stimulus intensity and FPE. A better understanding of mechanisms involved in FPE could yield more accurate evaluations of people's pain experience.

METHODS

Participants
Fifty-seven elderly subjects between the ages of 50 and 93 years (30 females; M = 65.9 years; SD = 11.7) were included in this study. Participants were recruited from a database of the university. Only subjects who did neither earlier nor currently suffered from chronic pain, depression, CVA, or any neurological disorder were included. Based on these criteria, one person was excluded for being dyslexic. All participants gave written informed consent prior to participation and received monetary compensation. The study protocol was approved by the ethics committee of the psychological faculty of the Radboud University Nijmegen.

Materials
Executive Functioning. Executive Functioning was assessed using the following two tests: The Digit Span backwards from the Wechsler Memory Scale – Revised (Wechsler, 1987) was used to test working memory; inhibition was assessed using the interference score of the Stroop task (Stroop, 1935; interference score: time Stroop Colour Word card/time Stroop Colour card). Global cognitive functioning was measured using the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and the Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, FitzGerald, & Parkes, 1982), but was only used for the purpose of population

description.

Mechanical Stimuli. Perception of noxious mechanical pressure was measured by using a Wagner FPXTM Algometer. Three pressure intensities (0.5 kilo, 2 kilo, 4 kilo) were applied in increasing order to both trapezius muscles alternating between the right and left side yielding a total of six measures. Pressure levels were built up rapidly and were continued for 5 s. In between stimulus applications, pain ratings were noted down, creating intervals of 10 – 20 s.

Procedure

A testing session took approximately 1 h and consisted of two measures of experimental pain and the Dutch versions of several cognitive tests and questionnaires. First, experimental pain was induced by using mechanical stimuli, during which the facial expressions were video-taped. Then, participants completed the Auditory Verbal Learning Test – recall and recognition, the zoo map test, and the Digit Span forwards and backwards. Hereafter, thermal stimuli were applied using the cold pressor test. After that, participants completed the story test of the Rivermead Behavioural Memory Test, the Stroop task, the Mini-Mental State Examination (MMSE), the Cognitive Failures Questionnaire (CFQ), a Meta-Cognition questionnaire and the Somatosensory Amplification Scale.

Facial Pain Expression. Facial expressions were video-taped during the mechanical pain test using a camera or a mobile phone that was located in front of the participant at a distance of 1.5 meters. Participants were instructed to focus on the camera in order to guarantee a frontal view and to avoid talking while pressure was applied. Participants rated their pain level on a scale from 0 to 10 before testing (baseline) and for the stimuli after each application. Facial pain responses were coded by four different observers by means of the Facial Expressions items of the Pain Assessment in Impaired Cognition (PAIC) meta-tool (Corbett et al., 2014a). For the analyses, a mean score of facial expression, consisting of the measure on both the right and left side, was computed for each of the three stimulus intensity levels.

Statistical Analysis

A repeated measures ANOVA with stimulus intensity (pressure: 0.5 kilo/2 kilo/4 kilo) as within-subject factor and pain report as dependent variable was conducted in order to check the effectiveness of the nociceptive stimuli. To test the hypothesis that stimulus intensity affects FPE a repeated measures ANOVA was conducted with stimulus intensity (0.5 kilo/2 kilo/4 kilo) as within-subject factor and FPE as dependent variable. The second hypothesis of a positive relation between pain report and FPE was analysed by means of a correlation analysis. A multiple regression analysis was used to evaluate the influence of EF on FPE. EF consisted of the total score on the Digit Span backwards, and of the interference score on the Stroop task which were entered as individual predictors. Finally, two moderation analyses using MODPROBE v2.0 by Hayes (http://www.afhayes.com/, 2015) were conducted to test a possible moderating effect of EF on the relation between stimulus intensity and FPE. Stimulus intensity (0.5 kilo/2 kilo/4 kilo) was entered as focal predictor, FPE (quantitative) as dependent variable and Stroop interference and Digit Span backwards were separately entered as moderators.

RESULTS

At first, the data were checked for missing values and outliers. Two missing values were detected for the variable FPE at the 2.0 kilo stimulus intensity and, consequently, for total FPE as well. Outliers were found on the variable total FPE and on Stroop interference. These were unlikely to be due to measurement error and were kept in the analysis. Among the subjects of the present study, 13 subjects showed a certain degree of cognitive impairment or subjective cognitive problems as they obtained a score of 43 or higher on the CFQ (Broadbent et al., 1982), scored below the cut-off score of 27 on the MMSE (O`Bryant et al., 2008) or both.

The pain ratings of the three stimuli (pressure: 0.5 kilo/2 kilo/4 kilo) differed significantly from each other ($F(2, 54) = 91.08$, $p < .001$, $\eta^2 = .77$) with increased pain ratings for increased pressure. On average, participants gave pain intensity ratings of $M = 1.14$ ($SD = .21$) for the 0.5 kilo stimulus, $M = 2.85$ ($SD = .29$) for the 2 kilo stimulus, and $M = 4.93$ ($SD = .35$) for the 4 kilo stimulus. Consequently, nociceptive stimulation was successful.

Relationship between stimulus intensity and facial pain expression

A repeated measures ANOVA was conducted to compare FPEs in the 0.5 kilo, 2 kilo and 4 kilo stimulus intensity conditions. Mauchly's test indicated that the assumption of sphericity has been violated, $\chi^2(2) = 57.93$, $p < .001$, therefore Greenhouse-Geisser corrected tests are reported ($\varepsilon = .598$). The results show that stimulus intensity has a significant effect on FPE ($F(1.20, 177.79) = 31.69$, $p < .001$, $\eta^2 = .374$). Specifically, higher stimulus intensities lead to increased FPE as the contrasts revealed that FPE in response to the 2 kilo stimulus, $F(1, 53) = 29.44$, $p < .001$., and to the 4 kilo stimulus, $F(1, 53) = 37.63$, $p < .001$, were significantly stronger than those on the 0.5 kilo level.

Correlation between pain report and facial pain expression

Pain report and FPE were positively correlated over all three stimulus intensities. According to Cohen (1992), correlations of .10, .30, and .50 can be considered as small, moderate, and large. The correlations on the 0.5 kilo and 4 kilo intensity levels were moderate and significant ($r = .325$, $p = .015$; and $r = .490$, $p < .001$, respectively), while those for 2 kilo were large and significant ($r = .519$, $p < .001$).

Relationship between EF and facial pain expression

Results of the Stroop interference ($M = 45.88$, $SD = 33.27$) and the Digit Span backwards test ($M = 5.77$, $SD = 2.26$) were entered as predictors of FPE in a regression analysis. Together, they were significantly related with overall FPE ($F(2, 50) = 5.26$, $p = .008$, $R^2 = .174$). However, when analysing the correlation between EF and FPE for each stimulus intensity separately, inhibition and working memory were significantly related with facial expression at the 2 kilo level ($F(2, 50) = 6.26$, $p = .004$) and the 4 kilo level ($F(2, 52) = 3.68$, $p = .032$) but not at 0.5 kilo. Individually, only cognitive inhibition was significantly related with FPE ($t = 2.239$, $p = .030$, ß = .302), while working memory did not correlate significantly with pain expression ($t = -1.568$, $p = .123$). Moreover, cognitive inhibition was a significant predictor only at the 2 kilo level, but non-significant at the 0.5 kilo level and marginally significant at the 4 kilo level.

Moderation analysis

Both cognitive inhibition and working memory were

examined as moderators of the relationship between stimulus intensity and FPE. The interaction between Stroop interference and stimulus intensity was significant (b = .012, 95% CI [0.002, 0.023], t = 2.26,
p = .0251, R^2 = .30), indicating that Stroop interference is a moderator of the relationship between stimulus intensity and FPE. When the Stroop interference is small (z = 0.41), this relationship is significant and positive (b = .84, p = .0012). At a moderate (z = 1.41) and large Stroop interference (z = 2.41), the relationship becomes highly significant and stronger (b = 1.24, p < .001; b = 1.64, p < .001; see Table 1). This implies that high interference scores, that is low cognitive inhibition, predict a stronger effect from stimulus intensity on FPE than low interference scores do.

Digit Span backwards displayed an interaction with stimulus intensity that was only marginally significant (b = -.16, p = .0586). Thus, it does not seem to moderate the relationship between stimulus intensity and FPE.

Table 1
EF as moderator between pain intensity and facial pain expression.

	b	SE	t	p
Constant	-.70	.670	-1.04	.300
Stimulus Intensity	.67	.310	2.16	.032
Inhibition	-.01	.012	-.71	.480
Stimulus Intensity x Inhibition	.01	.005	2.26	.025

DISCUSSION

In the present study, the influence of pain stimulus intensity and executive functioning on FPE was investigated. It was hypothesized that stimulus intensity and pain report would show a positive correlation with FPE, that EF would influence FPE, and that EF is a moderator of the relationship between stimulus intensity and FPE. As expected, both stimulus intensity and pain report were found to correlate positively with FPE. The stronger the stimulus was, the more an individual expressed pain via the face. Equally, subjects' FPE were in accordance with their pain ratings. Furthermore, a significant correlation between EF and FPE was confirmed: Together, cognitive inhibition and working memory predicted FPE at the 2 kilo and 4 kilo intensities. When examined separately, only inhibition predicted FPE at medium (2 kilo) and, by trend, at high (4 kilo) stimulus intensities. This suggests that high levels of cognitive inhibition go along with low facial expressiveness and that cognitive functioning has no influence on facial expressions in response to non-painful stimuli. Finally, inhibition but not working memory appears to be a moderator between stimulus intensity and FPE.

In replicating previous studies on the utility of FPE as an alternative pain assessment tool (e.g., Kunz et al., 2004), this study supports the general finding that FPE correlate positively with stimulus intensity and pain report. At least at higher pain intensities, the correlation between facial expressions and pain reports were larger than in the study by Prkachin and Solomon (2008). Consequently, this study further encourages the use of FPE to assess clinical pain, especially in the elderly.

The association between EF and FPE allows for several conclusions. First of all, the positive correlation of the Stroop interference with facial expressions shows that a higher interference score goes along with an increased FPE. Put differently, a good cognitive inhibition capacity enables subjects to suppress the open display of pain. This finding is in line with a study by Oosterman et al. (2010) who discovered a similar association between Stroop interference and pain sensitivity. In that study stronger cognitive inhibition led to longer immersion times on the cold pressor test, and reduced unpleasantness and pain intensity ratings. Secondly, with regard to working memory no effect on FPE was found. Again, this result supports findings by Oosterman et al. (2010) who reported no relationship between working memory and several pain correlates. In contrast, the results of another study suggest that "for older adults, increased pain perception [...] may be due to limited working memory capacity resulting from deterioration/degeneration of frontal cerebral networks" (Zhou et al., 2015, p.18). Zhou and colleagues (2015) explained their results through distraction from the nociceptive stimulus requiring more attentional resources and cognitive control, which would support the current findings. Apparently, this effect of working memory functioning on pain perception does not transfer to FPE.

The moderating role of cognitive inhibition between stimulus intensity and FPE shows that if an individual's cognitive inhibition is high stimulus intensity does predict FPE, but even more so at lower levels of inhibition. That means that people with high inhibition capacities do not strongly display their facial expressions, even at high stimulus intensities. In contrast, subjects with less effective inhibition mechanisms do express their pain via the face more strongly with increasing intensities of the nociceptive stimulation. This could have two contrasting implications: On the one hand, measuring pain through FPE might be best applicable in subjects who are not capable of effective inhibition, such as young children and cognitively impaired patients (e.g., Sheu et al., 2011). On the other hand, the lack of inhibition could also lead to an exaggeration of FPE with the consequence that clinicians could be misled when judging patients' pain based on their facial expression. As much research has found reasonable correlations between FPE and pain ratings in the elderly (Sheu et al., 2011), the earlier explanation is more likely and the present study can be considered as supporting the use of FPE as pain assessment in the designated populations. Nevertheless, further investigation is needed to rule out the possibility of exaggerated pain expression.

This study had several limitations. First, participants were instructed to refrain from talking and displaying any facial expressions that were unrelated to the nociceptive stimulation. This might have caused subjects to keep a still face in general and to consciously inhibit FPE. A second drawback of the current study might be that the assessments of FPE were conducted by four different observers which may have biased the ratings of pain expressions between participants. Third, because of ethical reasons the intensities of the applied stimuli were rather low so that some subjects might not have experienced any noteworthy pain. However, this limitation is unlikely to have biased the results of this study. Yet, to overcome this problem subsequent research could first measure individual pain thresholds and tolerances, and then adapt stimulus intensities to each subject so that stimuli are experienced as truly painful. Future studies could also examine possible age effects in the relationship between EF and FPE, as age was not analysed as a factor in this study. As EF is known to decline in older adults, age differences in pain perception might be explained by cognitive decline. This was suggested by Pickering, Jourdan, Eschalier and Dubray (2002) who found decreased pain tolerance in the elderly compared to young participants and, additionally, discovered a correlation between cognitive functioning and pain tolerance among the elderly. Like pain perception, FPE could increase with age, and this relationship might be influenced by EF as well. Additionally, the current study examined only elderly subjects that were not diagnosed with a neurodegenerative disorder. In order to generalize the results to other populations such as children or patients with dementia, a replication within these populations is necessary.

CONCLUSION

The present study indicates that stimulus intensity and pain ratings correlate positively with FPE, and that EF influences FPE in an elderly population. Specifically, decreased cognitive inhibition abilities predict stronger pain expressions in response to increasing stimulus intensity. These results warrant FPE as a clinical pain assessment tool among populations who may not verbally express their pain and cannot inhibit their facial pain reaction.

ROLE OF THE STUDENT

Juliane Traxler was an undergraduate student working under the supervision of Joukje Oosterman when performing the research in this report. The broader topic of the role of inhibition in pain perception in the elderly and the overall procedure were proposed by the supervisor. The more specific focus on FPE and the potential moderation through executive functioning was suggested by the student. Data collection was performed by the student and some fellow students; the analysis of the results, the formulation of the conclusions and the writing were done by the student.

Importantly, this study has been published previously as "Oosterman, J. M., Traxler, J., & Kunz, M. (2016). The Influence of Executive Functioning on Facial and Subjective Pain Responses in Older Adults. *Behavioural Neurology*, 2016."

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