

# Bittersweet - neither happy nor sad. An experimental comparison of the neural effects of bittersweet, negative and positive film clips using 7T fMRI

Frank P. Schulte<sup>1,2</sup>, Stefan Maderwald<sup>2</sup>, Nicole C. Kraemer<sup>3</sup>, and Matthias Brand<sup>1,2</sup>

<sup>1</sup>General Psychology: Cognition, University Duisburg-Essen, Duisburg, Germany, <sup>2</sup>Erwin L. Hahn Institute for Magnetic Resonance Imaging, University Duisburg-Essen, Essen, Germany, <sup>3</sup>Social Psychology: Media and Communication, University Duisburg-Essen, Duisburg, Germany

## Introduction:

Watching sad movies is a common leisure time activity although it has been described as awkward that people select stimuli that elicit sadness and tears. Media psychology explains this behavior by suggesting that such movies do not only include sad aspects, but also uplifting, positive messages, and rather elicit "bittersweet" feelings. However, it is still unclear how the brain responds to such bittersweet films. Inspired by recent functional imaging studies which show an involvement of the orbitofrontal cortex (OFC) in complex emotion integration [1], we argue that the OFC is the key structure which processes the "bittersweet effect". In more detail, we assume that the OFC integrates the bitter and the sweet component and that the limbic system, in particular the amygdala, should be additionally involved in processing the "simple" positive and negative emotions when watching bittersweet films.

## Materials and Methods:

Functional images were acquired on a 7 Tesla whole-body scanner (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) equipped with a custom-built 8-channel transmit / receive (Tx / Rx) head coil ([2]). 10 neurologically healthy female students took part in the study (mean age 24.80 years). Written informed consent was obtained prior to the examination and the examination was approved by the local ethics committee. Participants watched 5 negative, 5 positive and 5 bittersweet movies and rated their degree of sadness, funniness, and bittersweetness before scanning. The movies were shown again during scanning, and participants were instructed to relive the emotions they had experienced during the first presentation. 329 functional images were acquired with a BOLD contrast sensitive EPI sequence optimized for 7 T functional imaging (TR = 3000 ms, TE = 22 ms, flip angle = 86°, in-plane resolution = 3.00 x 3.00 mm<sup>2</sup>, GRAPPA R=2; [3]) using 87 contiguous 1.65 mm coronal slices. Imaging data was analyzed using SPM8. A general linear model was estimated in which the respective groups of the individual rated top 3 sad, funny and bittersweet movie clips were modeled to test our hypothesis. Based on prior hypotheses about key brain areas involved we conducted region-of-interest (ROI) analyses in the OFC and the amygdala. For these areas we defined respective anatomical ROIs within which we report effects at  $p < 0.001$  uncorrected.

Brain areas	Laterality	X	Y	Z	Peak t-score
<b>Bittersweet clips &gt; Positive clips</b>					
Medial/inferior frontal cortex (Brodmann areas 47, 11)	L	-35	37	-11	4.32
<b>Bittersweet clips &gt; Negative clips</b>					
Medial/inferior frontal cortex (Brodmann areas 47, 11)	L	-33	37	-11	5.46
Frontal cortex (Brodmann area 10)	R	5	58	-4	4.88
<b>Positive clips &gt; Bittersweet clips</b>					
Inferior frontal cortex (Brodmann area 47)	R	42	28	-4	4.41
<b>Negative clips &gt; Bittersweet clips</b>					
n.s.					
<b>Positive clips &gt; Negative clips</b>					
Medial/inferior frontal cortex (Brodmann areas 47, 11)	L	-29	34	-8	8.06
	L	-26	32	4	4.58
<b>Negative clips &gt; Positive clips</b>					
n.s.					

Table 1: Brain areas showing significant activation differences under the respective contrasts (thresholded at  $p < 0.001$  uncorrected;  $N=10$ ).

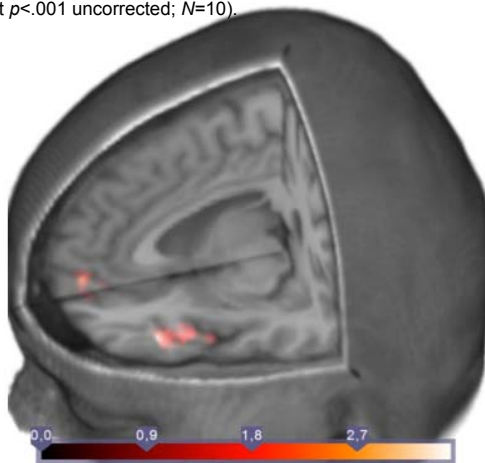


Fig. 1: Increased activation was found in left OFC and in frontopolar regions of the prefrontal cortex during reception of bittersweet movie clips compared to sad clips (Z-scores, thresholded at  $p < 0.001$  uncorr.).

n.s. = no significant neural activation differences in the second-level group analysis

## Results:

The left OFC (Brodmann areas (BA) 47, 11) is consistently activated when bittersweet clips are involved as table 1 shows: The left OFC is activated when contrasting bittersweet minus positive clips and also bittersweet minus negative clips, indicating that this might be the region representing the bittersweet component in contrast to the emotional processing elicited by positive or negative clips. Of the reverse contrasts, only the positive minus bittersweet contrast results in a significant albeit more lateral and right-sided activation (BA 47, only), indicating that the positive connotation of positive clips is stronger linked to the right hemisphere than the positive connotation of bittersweet clips. When concentrating on the contrasts for the simple emotional clips (positive minus negative clips and negative minus positive clips, respectively), the left OFC region is also activated when contrasting positive minus negative clips. Additionally, the frontal pole (BA 10) is also activated when contrasting bittersweet minus negative movies (Fig. 1). Although we found amygdala activation on the single subject level, this activation was interindividually rather different; hence it failed to reach statistical significance on the group analysis level.

## Discussion and Conclusion:

There seems to be a specific "bittersweet" region within the OFC, indicating that it might be a very specific emotion elicited that is different from the mere combination of positive and negative feelings. No distinct activations were found within the limbic system, indicating that the three categories of films seem to have induced emotional experiences equally strong resulting in no significant differential activations in the amygdala.

The OFC activation fits to theories which consider the OFC the expanded limbic system which is involved whenever different emotional aspects have to be integrated in higher cognitive processes, in most cases in strong interaction with the amygdala (e.g., [4],[5],[6]). However, it still has to be analyzed in future studies whether the specificity found here actually is a specificity with regard to emotion quality or whether bittersweet clips share another aspect of specificity concerning their processing. The result that in the contrast bittersweet minus negative films the medial frontal cortex was activated is in line with the argumentation that bittersweet films evoke a stronger personal engagement than simple negative films can (see references for brain correlates of self-referential processing and other forms of theory-of-mind, e.g., [7], [8]).

## References:

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