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## Research report

## How one's favorite song activates the reward circuitry of the brain: Personality matters!

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## ABSTRACT

The present fMRI study investigates individual differences in human brain activity during listening to one's favorite and one's most unlikeable song. In 33 participants, we found that the contrast of listening to pleasant versus unpleasant music revealed a robust activation of the ventral striatum, the caudate nucleus and the insula across a group of participants. Moreover, we could demonstrate that activity within the ventral striatum was modulated by the subscale 'self-forgetfulness' of the character dimension 'self-transcendence'.

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## 1. Introduction

Millions of people all over the world love to listen to music every day. One of the reasons for this passion is for sure the strong connection between music and its ability to elicit pleasant emotions [1].

Different approaches have been used to investigate the relationship between music and emotions in neuroscience: An early study by Blood and Zatorre [2] invited musicians to a PET experiment where they were confronted with their own chosen favorite classical music tune. This study pointed out the importance of the striatum when listening to one's favorite music. A study by Brown et al. [3] investigated non-musicians who listened to instrumental music by means of PET, whereby limbic and paralimbic activity could be observed. A study by Koelsch et al. [4] confronted eleven non-musicians with not self-chosen pleasant and electronically distorted unpleasant music in an fMRI setting. They reported among others brain activation in response to the pleasant song in the inferior frontal gyrus, the anterior superior part of the insula and the ventral striatum. A new study [5] linked nucleus accumbens activity to the peak of experienced positive emotionality and activity of the caudate nucleus to the anticipation of that emotional peak.

They also investigated non-musicians. Taken together, these studies indicate that the nucleus accumbens, which is known to be relevant for processing reward, plays a pivotal role during listening to pleasant music. Thus far, however, two important questions remained unresolved. First, no previous study compared brain activity during listening to a self-selected favorite song and the individually chosen most unlikeable song. This direct comparison is relevant because it directly modulates the dimension of subjective pleasantness. In fact, the study by Blood and Zatorre [2] contrasted the favorite song of each participant with the favorite song of another participant. Similarly, the investigation by Brown et al. [3] played music which was not selected by the participants. Second, no previous study explored how brain activations were inter-individually related to differences in personality traits. In the context of music enjoyment, traits like 'self-transcendence' [6] and absorption abilities [7] are arguably most relevant, because these constructs measure via self-report the tendency of humans to get absent-minded when listening to music or focusing on a piece of art. The absorption scales have been used widely in the context of meditation (e.g. [8]), susceptibility to hypnosis (e.g. [9]), but also music processing [10]. In fact, the latter study showed that high scores in the absorption scale were positively correlated with general arousal ratings while listening to classical music. The subscale 'self-transcendence' of the Temperament and Character Inventory (TCI) has often been used in the investigation of emotional well-being [11] and mental health [12]. Besides these behavioral or questionnaire studies, both scales have also been administered in

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**Table 1**  
Chosen song contrast (favorite vs. most unlikeable song) for each participant.

Favorite songs			Most unlikeable song		
Artist	Song	Genre	Artist	Song	Genre
Pink Floyd	Empty Spaces	Rock	Xavier Naidoo	Dieser Weg	Pop
Michael Bublé	Feeling good	Pop	Sido	Scheiss drauf	Hip-Hop/Rap
Gogol Bordello	Tribal connection	Rock	Rammstein	Ich will	Rock
Splash	Wünsch Dir was	Dance	Children of Bodom	Lake Bodom	Rock
Felix Mendelssohn-Batholdy	Klaviertrio D Moll, 1. Satz	Classic	Usher	Yeah	R&B/Soul
Silbermond	Das Beste	Pop	Mia	Tanz der Moleküle	Pop
Sam & Dave	Hold on – I'm comin	R&B/Soul	Jürgen Drews	Ein Bett im Kornfeld	Schlager
Metallica	Nothing else matters	Rock	Alanis Morissette	Uninvited	Rock
Madeleine Peyroux	Dance me to the end of love	Jazz	Alexander	Take me tonight	Pop
Metallica	Nothing else matters	Rock	Jürgen Drews	Ein Bett im Kornfeld	Schlager
Elton John	My father's gun	Pop	Kaoma	Lambada	Pop
Queen	I want to break free	Rock	Nintendo	Tetris Hardcore Happy Techno	Dance <sup>a</sup>
Tania Maria	Song title was not available	Jazz	Hipodil	Drugo Niama	Rock <sup>a</sup>
Shakespeare Sisters	Hello	Pop	Rihanna	Umbrella	Pop
The Lion King Cast	They live in you	Musical	Katy Perry	I kissed a girl	Pop
Alphaville	Forever Young	Pop	P. Diddy	Last night	Hip-Hop/Rap
Nickelback	If everyone cared	Rock	Eisregen	Leichenlager	Dark Metal
Yolanda Adams	I gotta believe	R&B/Soul	Tom Jones	Sex Bomb	Pop
Foo Fighters	Times like these	Rock	Bill Medley & Jennifer Warnes	The time of my life	Pop
Kid Rock	All summer long	Rock	Artist not available	Song title was not available	
Till Brönner	In my secret life	Jazz	Knorkator	Ich geh sowas von überhaupt nicht	Metal
Peter Gabriel	Solsbury Hills	Rock	Artist not available	Song title was not available	Dance <sup>a</sup>
Newton Faulkner	Dream catch me	Alternative	Korpiklaani	Väkirausta	Rock
Rihanna	Disturbia	Pop	Schnuffel	Ich hab' Dich lieb	Pop
Westlife	You raise me up	Pop	Tina Turner	Back where you started	R&B/Soul
Runrig	Hearts of olden glory	Rock	Waterdown	My hopeless and me	Alternative
The Whitest Boy Alive	Burning	Alternative	Alexander Marcus	Papaya	Dance
Candi Staton	You got the love	R&B/Soul	Geier Sturzflug	Bruttosozialprodukt	Schlager
David Gray	Sail away	Pop	Fettes Brot	Bettina	Hip-Hop/Rap
U2	With or without you	Rock	Alexander	Free like the wind	Pop
A-ha	Hunting high and low	Pop	Children of Bodom	Sixpounder	Rock
Shout out louds	Please, please, please	Alternative	Children of Bodom	Lake Bodom	Rock
Cali	Elle m'a di	Chanson	Rihanna	Umbrella	Pop

Genre appears as seen on iTunes®.

<sup>a</sup> Not available in iTunes®(own category after listening).

neuroscience research. Ott et al. [13] demonstrated an interaction effect of the COMT and 5-HT2a polymorphism on Tellegen's absorption scale. The character dimension Self-Transcendence of the TCI has been also shown to be of advance in recent molecular genetic studies [14,15]. Furthermore, it has been used in a prominent brain imaging study, recently: Urgesi et al. [16] investigated the spiritual brain in a pre-/postneurosurgical design and linked the left and right parietal lobes to self-transcendence. A good review on Tellegen's absorption construct can be found in Roche and McConkey [17]. More information on Self-Transcendence is described in the paper by Kose [18]. In general both scales are of rising importance also in the neurosciences.

### 1.1. Hypotheses

We expected a significant higher activity of caudate nucleus and nucleus accumbens in the contrast pleasant > unpleasant song analogue to Salimpoor et al. [5]. Moreover, we hypothesized that the activity of the nucleus accumbens (hence the peak of pleasure) would be modulated by Tellegen's absorption and/or Cloninger's 'self-forgetfulness' – a subscale of the mentioned trait 'self-transcendence' measuring absorption into music. As 'self-forgetfulness' and Tellegen's absorption scale are highly correlated (see [19] and also the following Section 2), we were also interested to investigate which of these two personality measures ('self-forgetfulness'/absorption) would represent a better predictor of the striatal activity. Based on the study by Kreutz et al. [10] reporting a positive correlation between the absorption score and arousal while listening to music, we hypothesized that high scores in trait absorption/'self-forgetfulness' would go along with higher striatal activity in the perception of one's favorite song.

## 2. Materials and methods

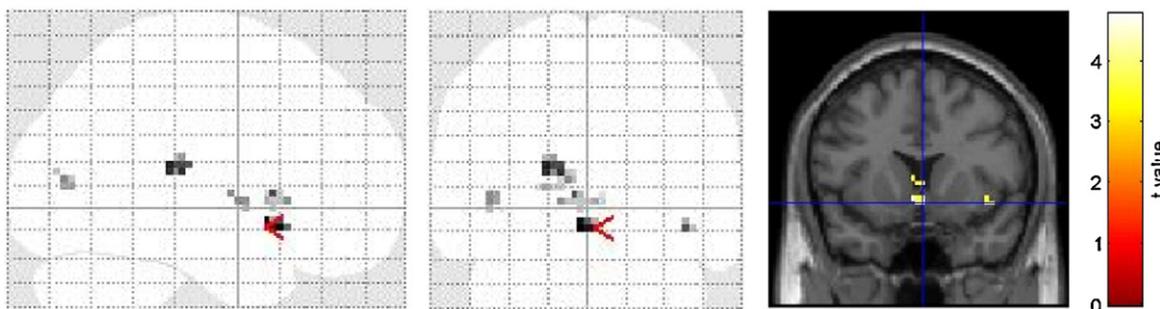
### 2.1. Participants and stimulus selection

33 undergraduate psychology students (27 = female, 6 = male; mean age = 23.55, SD = 5.04) participated in the present study. Each participant was instructed to bring along his or her favorite and most unlikeable song to the fMRI session. All participants were instructed at the recruitment stage of the study that upon participation they would have to listen to the chosen songs via earphones in the fMRI setup. Participants decided both in the pleasant and unpleasant music condition to listen to a vast range of music with songs from genres such as Pop, Rock, Heavy Metal, House and Techno. The participants did not rate the likeability of their self-chosen songs, because we expected that the rating of one's favorite song should be clearly at the positive end of such a scale, and the rating of one's most unlikeable song clearly at the other end. Participants were instructed to listen to the music they had brought along, which was presented alternately in the order pleasant-unpleasant and unpleasant-pleasant song. The song order was counterbalanced. Each song was presented for 3 min and then stopped. All song contrasts are presented in Table 1. A Chi<sup>2</sup> test revealed that the number of chosen songs in different music genres did not differ between the categories "favorite" and "most unlikeable songs". The participants did not know if they would listen to the pleasant or unpleasant song first. All participants gave written consent to participate in the study. The study was approved by the Medical Ethics Committee of the University of Bonn, Germany.

### 2.2. Personality assessment

Prior to scanning, participants filled in the Temperament and Character Inventory (TCI) [6]. This questionnaire consists of 240 dichotomous items measuring four temperaments (novelty seeking, harm avoidance, reward dependence, persistence) and three character dimensions (self-directedness, cooperativeness and self-transcendence). In the present study especially a subscale of self-transcendence called 'self-forgetfulness' was of interest, because it measures individual differences of absorption into music and art. High scorers on this scale are self-forgetful when concentrating on a certain task (flow experience), low scorers are in contrast very self-aware.

Another questionnaire of interest represents the Tellegen Absorption Scale consisting of 34 items with a 5-Likert scaling. Following Tellegen and Atkinson [7],



**Fig. 1.** Significant activations of the ventral striatum (bottom, left) and caudate nucleus (bottom, right) for the contrast pleasant > unpleasant song ( $p < 0.001$ , uncorrected; minimum cluster size of 5 contiguous voxels; activations remain after small volume correction).

absorption is associated with openness to self-altering experiences and hypnotizability. The construct 'absorption' and the subscale 'self-forgetfulness' of the character dimension 'self-transcendence' are highly correlated (in the present study  $r = .49$ ,  $p = .004$ ), showing an overlap of variance of approximately 25%.

2.3. Recordings and analyses

Thirty-five axial slices were collected at 1.5T (Avanto, Siemens, Erlangen, Germany). We collected 57 T2\*-weighted, gradient echo EPI-scans during the first song and 57 scans during the second song in two sessions. The songs were not presented in a single continuous block, but in two blocks (one block with the pleasant song, one block with the unpleasant song). The following parameters were used: thirty-five slices per volume; slice thickness: 3 mm; inter-slice gap: 0.3 mm; matrix size: 64 × 64; field of view: 192 mm; echo time: 40 ms; repetition time: 3200 ms. Preprocessing was done using FSL including realignment with three-dimensional motion correction, normalization onto the MNI-atlas (Montreal Neurological Institute), and spatial smoothing with an 8 mm Gaussian kernel (full width at half maximum). Afterwards, we used a general linear model in SPM5 to identify brain regions associated with processing preferred and non-preferred songs. Separate regressors were used to model linear scanner drift (removing low-frequency confounds of the data) and the mean activation across each of the two sessions. For a random effects analysis, we calculated contrasts for each subject (contrasting the mean activity during the two sessions corresponding to the preferred and the non-preferred song), which were then entered into a  $t$ -test against zero on the group level. All figures with fMRI results are displayed using neurological convention (left hemisphere on the left side of the figure). To identify significant activations, we used an uncorrected threshold of  $p < 0.001$  and a minimum cluster size of 5 contiguous voxels. Furthermore, based on the recent findings of Salimpoor and co-workers [5], we additionally conducted small volume corrections of activity in nucleus accumbens and caudate nucleus. Specifically, we used spheres of 9 mm diameter surrounding their peak activities in these regions (nucleus accumbens MNI coordinates: 8, 10, -8; caudate nucleus: -13, 11, 7).

3. Results

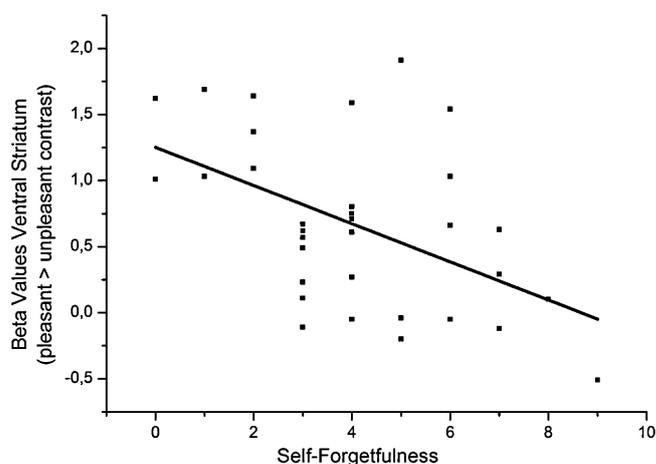
Statistical fMRI analyses showed significant activations of the nucleus accumbens, the caudate nucleus, the insula, and the cuneus for the contrast pleasant > unpleasant song (see Fig. 1). All significant activations including  $t$ -values can be found in Table 2. It should be noted that the "nucleus accumbens" activity was observed in a single medial cluster, possibly due to collapsing activity in the left and right nucleus accumbens. Similar findings have been reported previously [20–22]. Using smaller smoothing kernels (at 4 or 6 mm) in the preprocessing of the fMRI data yielded no activation in striatal

**Table 2**  
Significant brain activations in the contrast pleasant > unpleasant song (uncorrected threshold of  $p < 0.001$ ; a minimum cluster size of 5 contiguous voxels).

$t$ value	MNI coordinates				Structure
	$k_E$	$x$	$y$	$z$	
47,656	15	3	12	-9	Right nucleus accumbens
45,063	12	-18	-30	18	Left insula
42,345	14	-6	15	6	Left caudate nucleus
42,216	5	42	15	-9	Right insula
39,035	11	-9	-75	12	Left cuneus
38,942	6	-42	0	3	Left insula

areas for the same contrast, most likely due to an insufficient power in smaller subregions. As our results preclude precise anatomical localization to specific subregions of the ventral striatum, we will in the following only use the general term "ventral striatum". The activations within the ventral striatum remained significant after small volume correction (using either cluster of voxel threshold levels of  $p < 0.05$ , FWE-corrected). The contrast unpleasant > pleasant song revealed no significant activation.

In a next step, we examined inter-individual differences in activation of the ventral striatum and caudate nucleus related to personality traits. A strong negative correlation of the TCI subscale 'self-forgetfulness' (ST1) (subscales of self-transcendence) with ventral striatum activity in the contrast pleasant > unpleasant could be observed ( $r = -.50$ ,  $p = .003$ ; please see also Fig. 2). The two other subscales of self-transcendence ('transpersonal identification' (ST2) and 'spiritual acceptance' (ST3)) were not significantly correlated with ventral striatum activity. The reported correlation holds for multiple testing by means of Bonferroni correction. The Tellegen absorption score was also negatively correlated with ventral striatum activity ( $r = -.41$ ,  $p = .01$ ). Due to issues of multicollinearity, a stepwise regression model was calculated with both personality dimensions inserted in one block. The highly significant model ( $F_{(1,31)} = 10.129$ ,  $p = .003$ ) reveals that 'self-forgetfulness' alone explains 25% of the variance of the ventral striatum activity. The inclusion of Tellegen's absorption score could not improve the model. No significant correlations between caudate nucleus activity and personality measures could be observed. In a last step, beta values were extracted from insula activity in both hemispheres (centered around 42/15/-9 and -42/0/3). No correlations of insula activity with any personality measure could be observed.



**Fig. 2.** Correlation between 'self-forgetfulness' and ventral striatum activity for the contrast pleasant > unpleasant song ( $r = -.50$ ,  $p = .003$ ).

#### 4. Discussion

The present data shows the importance of the ventral striatum and the caudate nucleus for experiencing and anticipating pleasure while listening to one's favorite music supporting recent findings [5]. Replication of previous data is not trivial because our findings demonstrate that the activation of reward circuits can also be observed under the use of a different study design. The insula activation might appear surprising in the light of studies linking insula activity to negative emotions such as disgust [23]. On the other hand, newer studies question this direct link of insula activation and negative-emotionality, because this region is activated not only during anticipation of unpleasant, but also pleasant events [24], and generally during the coordination of external and internal information [25]. Interestingly, the music study by Koelsch et al. [4] also observed insula activity during processing of a pleasant music tune. Specially, they observed activations in the anterior superior insula and in the Rolandic operculum, which might reflect mental singing [26,27].

Moreover, our data can explain individual differences in the activation of the neuronal reward network while listening to music. Here, we show for the first time that a self-reported personality trait – the absorption scale of the TCI called 'self-forgetfulness' (ST1) – strongly modulates the ventral striatum activity in the contrast pleasant > unpleasant song. The activity of the ventral striatum was negatively correlated with 'self-forgetfulness', indicating that persons who describe themselves as easily getting absorbed by arts and music show lower activity of the ventral striatum when listening to their favorite songs. Due to the work by Kreutz et al. [10], we had expected the opposite effect, namely a positive correlation between ventral striatum activity and 'self-forgetfulness', however this was not the case. How can this be explained? Perhaps individuals describing themselves as very prone to absorption by music or other arts need another surrounding (not a noisy fMRI setting) or more intensity/closeness to arts (such as a certain mood, being alone or loudness of a music tune) to achieve a state of absorption. Moreover, the songs were only presented for a short time period of 3 min, which might be insufficient to get into a full state of absorption. This also fits nicely with the arousal idea of Eysenck [28] postulating that extraverted (outgoing) people need more stimulation to get to their hedonic peak than introverts. Post hoc analysis revealed a positive (but barely not significant) correlation between 'self-transcendence' and extraversion measured with the NEO-FFI questionnaire ( $r = .34$ ,  $p = .06$ ) supporting our idea. Further analysis showed that this correlation was mainly due to the subfacets ST2 and ST3 of 'self-transcendence' and not 'self-forgetfulness' (ST1) though. Moreover, extraversion did not correlate with ventral striatum or caudate nucleus activity. Nevertheless, the idea that a different stimulus intensity is required depending on the strength of the personality trait 'self-transcendence' and its subscale 'self-forgetfulness' represents a likeable explanation for the brain activity observed in our study. As 'self-forgetfulness' did not correlate with caudate nucleus activity, we conclude based on previous data [5] that this personality trait influences rather the pure joy experience but not the anticipation of the peak of enjoyment while listening to one's favorite song. This is in line with our hypothesis.

#### 5. Conclusions

In sum, the contrast pleasant > unpleasant song yielded a robust activation of the neuronal reward circuitry. The present study also

suggests a new design for the investigation of music – namely to contrast one's favorite song with one's most unlikeable song. Most importantly, this study shows the relevance of including personality traits for explaining individual differences in the neural response related to listening to one's favorite song.

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