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RESEARCH ARTICLE

# High resolution fMRI of subcortical regions during visual erotic stimulation at 7 T

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**Abstract**
*Object* Involvement of distinct subcortical structures during sexual arousal was shown in animals and functional imaging studies gave coarse evidence for a similar organisation in humans. In contrast to previous imaging studies at lower field strengths, we tried to investigate activation in distinguishable subcortical structures at high spatial resolution during a short stimulating paradigm to further account for potential effects of attenuation or adaptation.
*Materials and methods* Seven healthy subjects were investigated using functional magnetic resonance imaging (fMRI) on a 7 T scanner. High resolution EPI images of $1.4 \times 1.4\,mm^2$ inplane resolution were acquired in a single functional session of 13.6 minutes. During the session erotic and non-erotic pictures were presented in an event-related design.
*Results* In the unsmoothed data with preserved high spatial resolution significant effects were detected in relevant structures, including anterior caudate and mediodorsal thalamus. These effects were restricted to subcortical target structures and their anatomical boundaries.
*Conclusion* This study demonstrates that fMRI at high fields provides an ideal tool to investigate functional anatomy of subcortical structures. Due to an increased signal-to-noise ratio, functional scans of short duration can be acquired at high resolution without the need for further spatial smoothing.

**Keywords** High field MR · Functional MR · Subcortical structures · Neuroanatomy · Emotions and motivation · Neuroradiology

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## Introduction

Recent investigations have revealed a large network of both cortical and subcortical structures in erotic and emotional processing. Functional imaging showed involvement of cortical regions, such as the prefrontal cortex [1,2]. These studies also demonstrated involvement of subcortical regions e.g., caudate, specific thalamic nuclei, and the putamen, which, however, due to problems in spatial resolution must be considered rather preliminary [3–6]. The role of subcortical regions is further supported by animal studies [7,8]. This supports the need for reliable high spatial resolution imaging of subcortical regions during erotic and emotional processing in humans.

Studies using functional magnetic resonance imaging with field strengths up to 4 T suffer from several limitations which render detection of suspected neural activity in subcortical regions rather difficult. Erotic stimulus processing has recently been studied at field strengths of 1.5 T [2,9,10] 2 T [11] and 3 T [4]. At these lower fields scanning suffered from low effective spatial resolution by limited signal to noise ratios and in plane resolutions of $3 \times 3 \times 3$ mm or above. Further noise reduction (during preprocessing) normally requires additional smoothing with Gaussian kernels of 5–10 mm (Full with, Half maximum). Due to these limitations, reported peak locations of activation reflect not only

their true localization but also surrounding structures. This renders exact neuroanatomical localization as in specific subcortical regions rather difficult if not impossible. For example, structures as the claustrum or different subdivisions of the thalamus represent cell compounds with an extension of only a few millimetres, which may not be clearly distinguished functionally from adjacent structures. Such subcortical regions consequently require measurements at high spatial resolution without smoothing. A possible solution is to apply fMRI at high field of 7 T. The use of very high magnetic field strength results in a higher signal-to-noise ratio, in addition to the super-linearly increased BOLD effect [12]. Pioneering studies on fMRI at 7T provided evidences for a superiority over lower field strengths [13,14]. This superiority was supported by a more recent study [15].

Kruger et al. [16] and Triantafyllou et al. [17] have shown that physiological noise at high field can cause the time-course SNR of fMRI series to fall below the image SNR. Because this effect is more pronounced for high fields in combination with large voxel volumes the higher field discourages the use of large voxels. The higher image SNR due to the strong magnetic field can be exploited best when small voxel volumes of 8 µl or less are used. In combination with the stronger BOLD effect this makes high field imaging at 7 T a promising method to image neural activity in subcortical regions.

Another methodological problem in imaging subcortical regions is the high number of trials needed for obtaining reliable signals in low field scanning. The length of fMRI paradigms studying emotional or erotic arousal, and therefore the total number of stimuli applied, is restricted by adaptation and attention processes. This limits the ability to increase efficient HRF sampling and statistical power by using long runs with jittered onsets [18]. Using multiple shorter runs with extended pauses can keep subjects receptive for emotional stimuli. This may, however, resolve problems caused by adaptation only to a certain amount and further introduces other difficulties such as head movement between runs. Due to its higher effect-to-noise ratio, which is defined as the signal difference induced by the stimulation paradigm (effect) divided by the standard deviation of the temporal signal fluctuations which are not explained by the model (noise), a lower number of trials is needed to obtain reliable signals in high field imaging. Rather than using a high number of trials in multiple runs, effects could be investigated using shorter stimulation paradigms with a single run in high field imaging. This may be particularly suitable for subcortical regions that are otherwise rather difficult to image.

Functional MRI at 7 T could provide highly resolved functional data which do not need heavy smoothing or extended scan durations. The specific advantage of 7 T would therefore be the preservation of this high resolution and spatial specificity of observed activations while at lower field strengths, where highly resolved acquisitions are also possible [19], additional smoothing might be necessary to gain SNR, especially when scanning time is restricted.

The goal of this study was to test if activations in subcortical regions that were previously reported to host peak activations during erotic or emotional processing can be reliably detected in single runs in single subjects at 7T. Taking advantage of increased spatial resolution without additional smoothing of the data, we had the aim to show BOLD responses in specific subcortical regions as distinct from adjacent structures. We put a particular focus on the mediodorsal thalamus and the anterior caudate, which have previously shown activation during erotic processing [3,4,10].

## Methods

### Subjects

We scanned seven healthy, heterosexual male right handed subjects (mean age: 25,6 years SD: 1.51). All subjects had a partner at the time of scanning, were sexually active and recent or previous sexual dysfunctions were excluded in a standard clinical interview. Prior to the fMRI experiment all subjects were examined by an experienced neurologist. No subject had to be excluded for history of neurological or psychiatric disorders and all subjects performed within the normal range during neuropsychological assessment of individual attention and concentration performance using the d2 test of attention [20]. The study was approved by the local IRB. Research subjects participated after giving informed written consent.

### Paradigm

We adopted the stimulation paradigm described in Heinzel et al. [10] and Walter et al. [21], which has been reported to reliably induce sexual and emotional arousal by means of subjective self-assessment and which was found to effectively elicit neural responses in key structures relevant for sexual and emotional arousal [21]. To gain sufficient power for a single subject single-run analysis, the number of stimulus repetitions was increased, extending the total duration to 13.6 min. Picture sets consisted of 20 erotic and 20 non-erotic emotional pictures of humans, taken from the international affective picture system (IAPS) [22]. Picture sets were counterbalanced for standard values of arousal, pleasantness, and dominance as provided from the IAPS. Furthermore, the categories were balanced for mean ratings of perceived emotional and sexual intensity. These were rated separately to account for possible interaction between both aspects within general arousal. Together with a measure of pleasantness, the ratings were previously obtained from 32 healthy subjects.

After the scanning session our seven subjects were asked to rate erotic and non-erotic stimuli for induced sexual arousal as well as emotional intensity and perceived feeling of pleasure, to assure that stimuli indeed induced sexual arousal in our subjects.

Pictures were presented for 4 s and were projected to a screen mounted to the head coil via a LCD projector. After each picture presentation a white fixation cross appeared for a variable duration of 7.5–10.5 s and served as an experimental resting period. Further as described in Walter et al. [21], stimuli were preceded by short presentations of arrows at durations of 3–5 s. Arrows either indicated the type of the following picture (erotic picture: downward, non-erotic picture: upward arrows) or were oriented horizontally and thereby serving no information about subsequent stimuli. In this paper we concentrate on effects during the picture presentation.

### Image acquisition

All experiments were performed on a 7 T whole body MR system (Siemens, Erlangen, Germany). An eight-element array was used for signal transmission (RF power distributed to result in a pseudo CP excitation) and reception (eight independent receive channels). Anatomical reference data were acquired with 3D-MPRAGE (1 mm isotropic resolution, TI 1,000 ms, TR 2,300 ms, flip angle 5°). For high resolution functional imaging, single-shot EPI was optimized for 7 T. SAR was reduced by decreasing the nominal fat saturation flip angle. Imaging parameters were FOV 220*220 mm, matrix size 160*160, 17 slices, 1.5 mm slice thickness (width at 90% signal strength), 0.3 mm gap, TR 1,100 ms, TE 23 ms, 6/8 partial Fourier, GRAPPA factor 2, sinusoidal readout gradient. The small voxel extensions result in reduced dephasing across the voxel. Therefore, high spatial resolution allows a minimization of signal dropouts. During the online reconstruction, all data were motion corrected and distortion corrected based on a reference measurement of the local point spread function [23].

### Data preprocessing and analysis

Preprocessing and statistical analysis was performed using BrainVoyager QX [24,25]. Preprocessing of the functional scans included a more accurate offline correction of residual head motion, slice scan time correction and removal of linear trends [25]. A high pass filter of 0.0037 Hz was applied, corresponding to three replication cycles or less over the whole session to remove low frequency noise that could not be explained by our design. A low-pass filter, as would have been more useful for blocked designs, was not included to preserve power of high frequency components. Instead a first order autoregressive model (AR(1)) was preferred to correct for serial correlations, given the high autocorrelation of fMRI noise [26,27].

Functional images were co-registered with anatomical images and resliced to 3D data sets using a trilinear interpolation algorithm. This transformation resulted in isotropic voxels of $2 \times 2 \times 2$ mm, which was found to be a reasonable trade off between spatial resolution and the number of voxel-wise comparisons to correct for. No further smoothing was applied to preserve this resolution for further analysis.

Statistical analysis was performed creating three-dimensional statistical maps for each subject separately. Parameter estimates for our experimental conditions were calculated using a general linear model (GLM) [28] on 3D volume time courses. The GLM was further corrected for serial correlations that arise due to autocorrelation of noise and was refitted. Autocorrelation was estimated voxel-wise on the residuals ($e_t$) with the residuals of the following time-point ($e_{t+1}$). Autocorrelated noise was removed from measured voxel time courses and from regressor time courses of our model before re-estimation of the GLM to validate the assumption of independence of observations.

The expectancy period was entered as a regressor of no interest in our design matrix and was not further analyzed for the purpose of this study. The design matrix included two regressors of interest for the different types of picture presentation and one for the resting period. Activation as expressed by resulting beta weights greater than zero for the regressors for each picture type was tested. To control for multiple comparisons the standard false discovery rate (FDR) [29,30] method implemented in Brainvoyager QX was used. This thresholding method computes a single voxel threshold for the desired level of false positives according to the number of detected suprathreshold voxels. The false discovery rate was set to $q < 0.05$, which means that a total of 5% were accepted to be false positives. This method was chosen because it was previously shown to exceed other correction methods, such as Bonferroni correction, in sensitivity [31,32]. Further FDR does not require smoothing as opposed to other family wise error correction methods relying on Gaussian random field theory [33–35], which use the number of estimated unitless resolution elements (resells) to correct the original p-threshold.

Activations were defined by beta weights significantly greater for picture conditions than for the modeled rest condition.

Resulting 3D statistical maps were then overlaid on subjects anatomical high resolution images to relate activations to underlying structures which were identified using a standard anatomical atlas [36]. Effects were further validated by direct overlays on the original EPI data to account for possible susceptibility artefacts from neighbouring structures.

Following a standard protocol in Brainvoyager for anatomical overlays, statistical maps were interpolated to

correspond to the underlying anatomical resolution of 1 $mm^3$ and a minimum cluster volume threshold ($k$) of at least 10 voxels of 1 $mm^3$ (10 µL) was applied covering the volume of approximately one functional voxel.

For subject number 5 no distortion corrected data were available for technical reasons. Given the high resolution of the functional data (Fig. 2), identification of structures showing significant effects on an FDR level of $q < 0.05$ was still possible on the original 2D EPI slices.

One subject had to be excluded because the fMRI session was not completed by the subject.

## Results

On an FDR level of $q < 0.05$, significantly activated clusters of at least 10 µl were found at discrete subcortical anatomical locations within the structures of interest. Clusters were located and clearly restricted to anatomical boundaries of the underlying structures (see Fig. 1 and Table 1):

In five out of six subjects, significant right-sided or bilateral activations for erotic picture presentation were located in the mediodorsal thalamus and the head of caudate.

Non-erotic emotional stimulation lead to significant left-sided activations in the mediodorsal thalamus in four subjects and one left and one right-sided cluster in the head of the caudate.

Bilateral activations in the putamen for both conditions were detected in two subjects, and the claustrum was activated in three subjects showing left, right or bilateral localization for each erotic or non-erotic emotional conditions.

Except for the non-erotic condition in subject 4, bilateral activations in the corpus geniculatum laterale (CGL) were present in all subjects for both conditions. In addition, large activations were detected in the visual cortex for both visual conditions, i.e., erotic and non-erotic picture presentation in all subjects.

Additional subcortical clusters of significant activation were detected in the pallidum in two subjects and other thalamic subregions in one subject. In one subject, one activated cluster was located in the stria terminalis and one in the ventral tegmentum.

## Discussion

Using an optimized stimulation paradigm together with an optimized high resolution single-shot EPI acquisition method at 7 T, we isolated subcortical activations in the hypothesized regions of interest in five out of six subjects who completed the fMRI session. In contrast to prior studies which normally consisted of several runs over at least 30 [4] up to 90 min [10], significant activations were detected with a

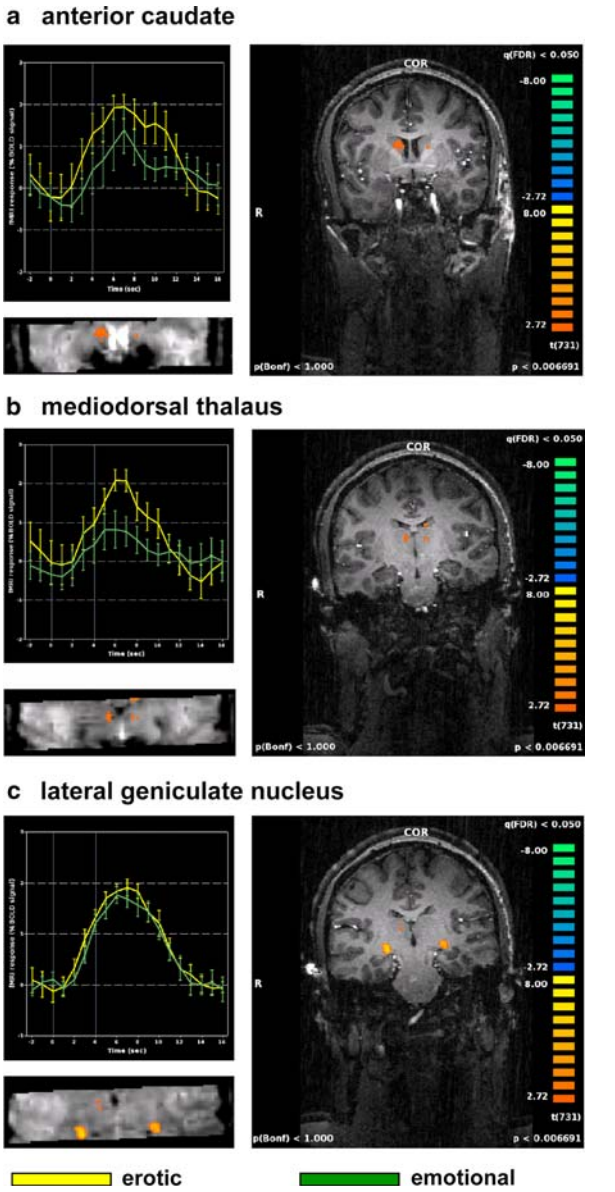


**Fig. 1** Regions with significant signal increases during erotic picture viewing. Coronary sections on the right show localization of significant clusters ($q < 0.05$ false discovery rate) overlaid on individual anatomical images at high resolution (1 mm isotropic). Images are in radiological orientation (the right hemisphere is shown on the *left*). On the *left*, activations are shown directly on functional images to assure correspondence of underlying structures. Note that functional images suffer from considerably weak signals in the ventral striatum which does however not boarder to signal changes in activated structures. Time courses of activations following onsets of erotic (*yellow*) or non-erotic, emotional (*green*) stimuli are plotted in means of percent signal changes. Activations were plotted over the next 16 s and were extracted for a right hemispheric cluster located in the anterior caudate nucleus (**a**), a right hemispheric cluster in the mediodorsal portion of the thalamus (MD, **b**), and for the right lateral geniculate nucleus (**c**). Note that, except for subject 5, right MD and right head of caudate did not show significant activations for non-erotic stimuli (Table 1). Individual data are shown for one representative subject (subject 1) and the corresponding $P$-value for a false discovery rate of 5% is indicated in the right lower corner ($P < 0.00691$ for subject 1). for activations in the other five subjects, see Table 1

**Table 1** Subcortical localization of clusters reaching an FDR controlled level of significance of $q < 0.05$

| Subject: | Subject 1 | | Subject 2 | | Subject 3 | | Subject 4 | | Subject 5 | | Subject 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition: | Erotic | non-erotic | Erotic | non-erotic | Erotic | non-erotic | Erotic | non-erotic | Erotic | non-erotic | Erotic | non-erotic |
| Region | | | | | | | | | | | | |
| Thalamus | | | | | | | | | | | | |
| Mediodorsal | Bilateral | Left | Right | Left | Right | Left | – | – | Right | – | Right | Left |
| Anteroventral | Left | – | – | – | – | – | – | – | – | – | – | – |
| Lateroposterior | Right | – | – | – | – | – | – | – | – | – | – | – |
| Intrlaminar | – | Right | – | – | – | – | – | – | – | – | – | – |
| Lateral geniculate | Bilateral | Bilateral | Bilateral | Bilateral | Bilateral | Bilateral | Bilateral | – | Bilateral | Bilateral | Bilateral | Bilateral |
| Pulvinar | – | – | – | Bilateral | – | – | – | – | – | – | – | – |
| Caudate nucleus | | | | | | | | | | | | |
| Head | Bilateral | – | Right | – | Right | Left | – | – | Right | Right | Bilateral | – |
| Body | Bilateral | – | – | – | Right | – | – | – | – | – | Right | – |
| Putamen | Bilateral | Bilateral | Bilateral | Bilateral | – | – | – | – | – | – | – | – |
| Claustrum | – | – | Bilateral | Bilateral | Right | Left | Left | – | – | – | – | – |

Structures were identified on co-registered high resolution images in the individual anatomical space separately for each subject. Note that due to technical reasons for subject 5, localization was performed on 2D functional slices (see "Methods"). Except for subject 1, thalamic activation was restricted to the mediodorsal part. Activations in the thalamus and the caudate nucleus during erotic picture viewing were detected preferentially on the right or bilaterally and predominantly left sided during non-erotic stimuli. For regions/conditions indicated by (–) no significant activation could be detected

short stimulation paradigm consisting of only one single run. Due to the fact that no additional smoothing was applied, activations restricted to distinct subcortical regions could be interpreted as actual peaks of activations irrespective of neighbouring signals. High field fMRI thus allowed detection of localized non-spread small clusters of activation in subcortical regions at an FDR controlled level of significance in single runs in single subjects. To exclude as much noise as possible a high statistical threshold, controlled for multiple comparisons using FDR, was applied, therefore explicitly benefiting from the higher effect to noise ratio provided at 7 T. In contrast to prior studies, including two studies of our own group [10,21], significant effects could therefore be restricted to their anatomical origin. As demonstrated in Fig. 2, analysis of high resolution functional MRI scans benefit from a large amount of anatomical information, given that this information was not blurred by additional spatial smoothing. This localization was further assured as the statistical level was set comparably high for a single subject single run analysis, therefore reducing widespread false positive effects in non-target regions. Convincingly, as a result of higher effect to noise ratio, no further clusters spreading over non-nuclear subcortical structures such as capsula interna or neighboring ventricles were detected (see also Fig. 3). This held true even when the false discovery rate was lowered to $q < 0.1$ for exploratory reasons.

Our findings can lend support to considerations of functional subdivisions for example within the thalamus. The mediodorsal thalamus was previously found to be activated in studies investigating sexual arousal [37] and effects of sexual preference [38] and is thought to be a crucial hub connecting ventral striatal structures to medial prefrontal cortex, therefore suggesting its involvement in basic processing of emotions [39] and reward. Interestingly, except for one subject, activations were found only in this part of the thalamus in both emotional and erotic stimulation which is consistent with its proposed role of mediating the emotional component of sexual arousal [37]. In contrast, no activations for either condition were observed in the adjacent centromedian nucleus of the thalamus (CM) which has stronger projections to dorsal and lateral parts of the prefrontal cortex [40,41] and dorsal striatum [42]. Our data, thus, indicate that high field scanning may offer the opportunity to functionally distinguish between various subdivisions within the thalamus with respect to its structural and functional connectivity.

Another region showing functional subdivision was the caudate as distinguished from adjacent putamen. The head of the caudate was confirmed to be especially activated during the erotic condition. This is in line with findings by Redoute et al. [3] as well as Bartels et al. [11] and Aron et al. [6], who reported peak locations of smoothed activations predominantly in the anterior part of the caudate. Activations in these regions are related to goal directed behavior and reward [43] during romantic and erotic love. Interestingly activations during erotic stimuli were predominantly lateralized to the right, which is in line with Aron et al. [6] who reported similar right hemispheric predominance, while the non-erotic stimuli elicited activations in left caudate. The

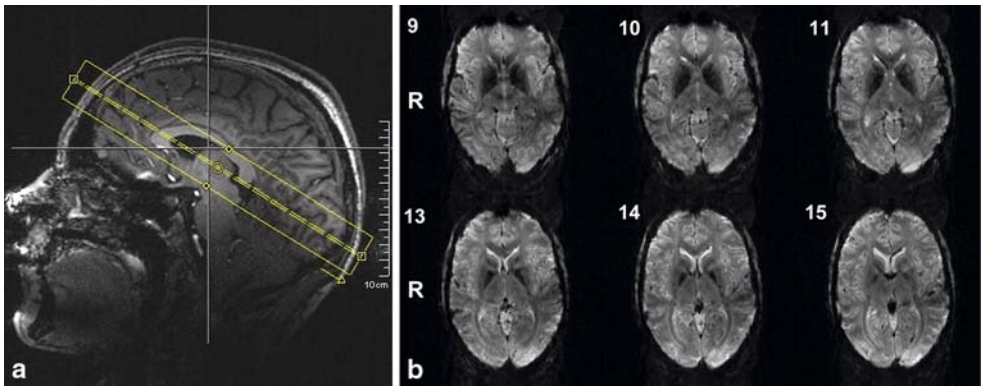


**Fig. 2** **a** Orientation of functional slices during fMRI session. Seventeen slices were acquired in an interleaved order. **b** Six representative slices (numbers 9,10,11 and 13,14,15) are shown for illustration. Note that spatial resolution and contrast allow the identification of anatomical structures. Difficulties persisted due to low signal intensities in the pallidum or due to frontal signal dropout (slice 11) but were absent in other subcortical structures, including thalamus

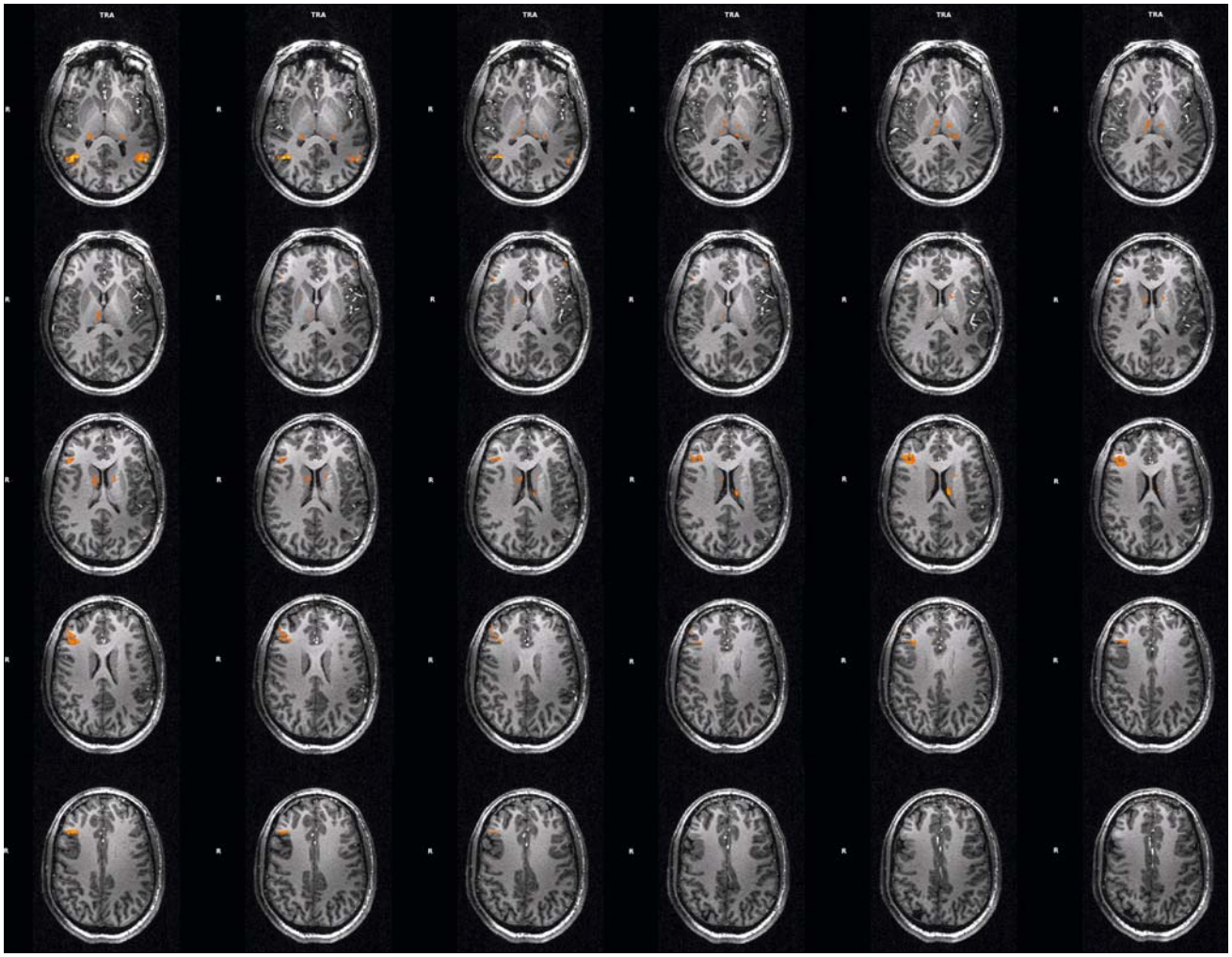

**Fig. 3** For the same subject as in Fig. 1, 30 contiguous transversal slices are shown ascending from as low as CGL (*upper left*) to dorsal frontal and parietal cortex (*lower right*) covering the whole region of interest. Please note that there are no additional clusters in white matter compartments such as internal capsule or corpus callosum. This held true when we applied a FDR level of $q < 0.1$ for exploratory reasons, while, depending on the individual subject, additional clusters appeared for false discovery rates from $q < 0.3$–$0.6$

caudate is located adjacent to the putamen which makes their exact functional distinction rather difficult. Our results show a different activation patterns for erotic and emotional conditions in the caudate, while they did not differ in the putamen (see also Table 1). This distinction is in accordance with the specific involvement of the anterior caudate as distinguished from other structures in the dorsal striatum such as the putamen in goal oriented behaviour during erotic stimulation as also suggested by Aron et al. [6]. The fact that we did not smooth the data makes it rather likely that the observed differential activation during erotic and emotional processing may reflect differential involvement of caudate and putamen rather than a common underlying region. Given the proximity between caudate and putamen, conservation of a high functional resolution of no more than 2 mm is thus highly desirable to account for possible functional differences between these two structures. This requires methodological improvements in both spatial and temporal resolution as provided in high field imaging to allow for optimal functional differentiation in subcortical regions like the caudate and the putamen, as shown in this study. While these results underline the possibility of anatomically distinguishing anterior caudate activations during sexual arousal, its functional specificity and potential differentiation from other processes like romantic love will have to be addressed in future studies focussing on this distinction and directly comparing these two processes that elicit activations in anterior caudate.

Arnow et al. [4] reported activation in the claustrum during visual erotic stimulation, which due to its close proximity to the insular cortex could not be isolated from insular activations at the applied spatial resolution. They used a 3.75 mm inplane resolution and additional smoothing with a 5 mm (FWHM) Gaussian kernel [4]. Stoleru et al. [44] reported similar activations, while at the time of the studies by Stoleru and Arnow technical limitations did not allow to anatomically differentiate claustrum from the insula. The reported activations in the claustrum in our study indicate that in the future this distinction may become possible. Scanning with voxel sizes that account for both the close vicinity of the two structures and the small diameter of the claustrum itself allows investigation of the claustrum as a distinct functional component of the neural network of sexual arousal. More critically it has to be acknowledged that claustrum activations were visible only in three out of six subjects. At the current stage it is impossible to state if the divergence of our results reflects a possible limitation of detectability by our approach, which might favour another trade off yielding an increased sensitivity. Annother possibility would arise from the problems previous studies had concerning the anatomical distinction of insula and claustrum. Both studies mentioned above presented visual erotic stimuli for a duration long enough to induce erectile responses in their subjects, which itself is associated with insula activity [1,2] while in our study visual stimuli were presented not long enough to produce stable erection. Future studies focussing on the difference of early and delayed (erectile) responses during SA should, therefore, try to differentiate effects in these two structures.

Activations in bilateral geniculate nuclei (CGL) and primary visual cortex were present and similar for erotic and non-erotic emotional stimuli in all subjects, except for subject 4, who did not show significant CGL activations during the non-erotic condition (Table 1). These activations can be seen in the context of processing visual properties which, in contrast to their induced level of sexual arousal, did not differ between stimulus categories. Strong activations for both conditions are therefore not surprising. Restriction to anatomical components known to constitute the visual system may serve as a sign of validity of the data and therefore support the observation of reliable effects in other areas.

Despite the above mentioned advantages of high resolution fMRI at 7T, considerable difficulties remained due to signal dropouts in ventral subcortical structures, including parts of nucleus accumbens, and hypothalamus caused by magnetic field ($B_0$) inhomogeneities due to tissue boundaries. As these structures have been shown to be involved especially during sexual arousal, functional imaging sequences reducing the signal loss in these structures are highly desirable. Solutions may include optimization of the slice angle with respect to the local susceptibility gradients or a further reduction of the voxel size. Other structures, i.e., ventral pallidum show extremely short native T2* at 7 T due to iron deposits [45,46] and correspondingly very low signal intensity. Even with further sequence optimization functional imaging of these structures remains challenging at very high field. In addition, higher acceleration factors of the parallel imaging technique could minimize the signal loss. However, with the eight-channel coil currently used, data acquisition with acceleration factors larger than two is compromised by significant noise amplification due to increased g-factors. A new coil design with a higher number of coil arrays should be very beneficial in this regard.

It is further acknowledged that apart from higher field strength, our setup benefits from other technical advances such as a modern eight-channel head coil. To quantify the described gain future investigations of high resolution fMRI should focus on comparing 3 and 7 T with identical high end setup. Spatial resolution and effective paradigm duration should be quantified separately. It has further to be acknowledged that although no additional spatial smoothing was applied, due to interpolation during correction of residual motion and to 2 mm isovoxel 3D volume timecourse files (VTC), at least a minimum amount of smoothing is introduced. The effects seem however limited as even on lower thresholds, activations do not smear into neighbouring regions and reported effects were reproduced for subcortical regions

even when no motion correction was applied and functional data were gridded to a 1 mm isovoxel VTC.

It should also be noted that by abandoning any additional smoothing we strongly emphasize our analysis on detection of small structures such as thalamic sub regions, while greater clusters of activation in bigger anatomical regions, such as dorsal striatum, when taken as one functional unit, or cortex regions would have benefited from larger smoothing kernels of up to 10 mm [19,47]. Our approach was, thus, aimed at high spatial specificity necessary for the investigation of small subcortical structures while taking into account that this leads to reduced sensitivity.

While at present our study size does not allow meaningful group analyses, so results should be regarded to be preliminary. However the results are promising in that questions concerning functional sub-specialization of certain subcortical structures such as dorsal striatum and thalamus were answered with high resolution fMRI at 7 T. Inference from the reported results to a general population has to be addressed by investigations using a larger sample of participants, and reproducibility within the same subject will have to be established by future investigations. Once this will be accomplished, investigation of distinct subcortical processes during sexual arousal in humans could provide new insights that, until recently were impossible due to limited spatial resolution.

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