DANCE

# D1.6 – Demonstrate the functional role of the occipital cortex in dance sonification in congenitally blind participants

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# Introduction

This study is part of the DANCE project which aims to investigate whether, by the understanding of movement and the analysis of its quality, we can translate movement into sounds (sonification). This would provide the possibility to help e.g. blind persons to “see” (experience) a dance choreography. An important aspect of dance experience is how the emotions are transferred by the dance movements. In this study we investigated how affective body expressions expressed through sound and touch are represented in the brain of blind compared to sighted persons. We also investigated the role of imagination in the representation of affective body expressions.

## Participants

Eight congenitally totally blind volunteers of Belgian and Danish nationality participated in this study (4 males, 4 females, mean age 39.3 years, range 27-48). The data from the congenitally blind participants were compared to a group of eight age- and gender-matched sighted control participants (4 males, 4 females, mean age 33.4 years, range 26-52). All participants gave their informed consent. Exclusion criteria were the institute’s MRI safety criteria. The study was approved by the local ethical committee.

## Stimuli

We used four 3D-printed figures, which consisted of two male identities expressing two emotions (anger, fear). We also created four audio files of human voices expressing two emotions (anger, fear) for 4.5 seconds each. During the experiment the seeing participants were blindfolded. Before the start of the fMRI session, the participants were trained on associating the four different 3D-printed figures with the four different voices. Afterwards, the participants entered a test phase in order to verify whether they could distinguish all stimuli. In the fMRI scanner the perception conditions were divided into blocks (auditory perception, tactile perception). Within these blocks, participants either imagined hearing the emotion and identity of the voice, or imagined perceiving the emotion and identity of the 3D figure through touch (see Figure 1, experimental design).

## MRI sequence

A 3T Siemens MR scanner (MAGNETOM Prisma, Siemens Medical Systems, Erlangen, Germany) was used for imaging. Functional scans were acquired with a multiband Gradient Echo Echo-Planar Imaging sequence with a Repetition Time (TR) of 1500 milliseconds (ms) and an Echo Time (TE) of 30 ms. For each functional run 687 volumes were acquired comprising 57 slices (FoV = 200x200, matrix = 100×100, 2 mm isotropic voxels, inter slice time = 26 ms, flip angle = 77°, multiband acceleration factor = 3). Between the two functional runs high resolution T1-weighted structural images of the whole brain were acquired with an MPRAGE with a TR of 2250 ms and a TE of 2.21, comprised of 192 slices (FoV = 256x256, matrix = 256×256, 1 mm isotropic voxels, flip angle = 9°).

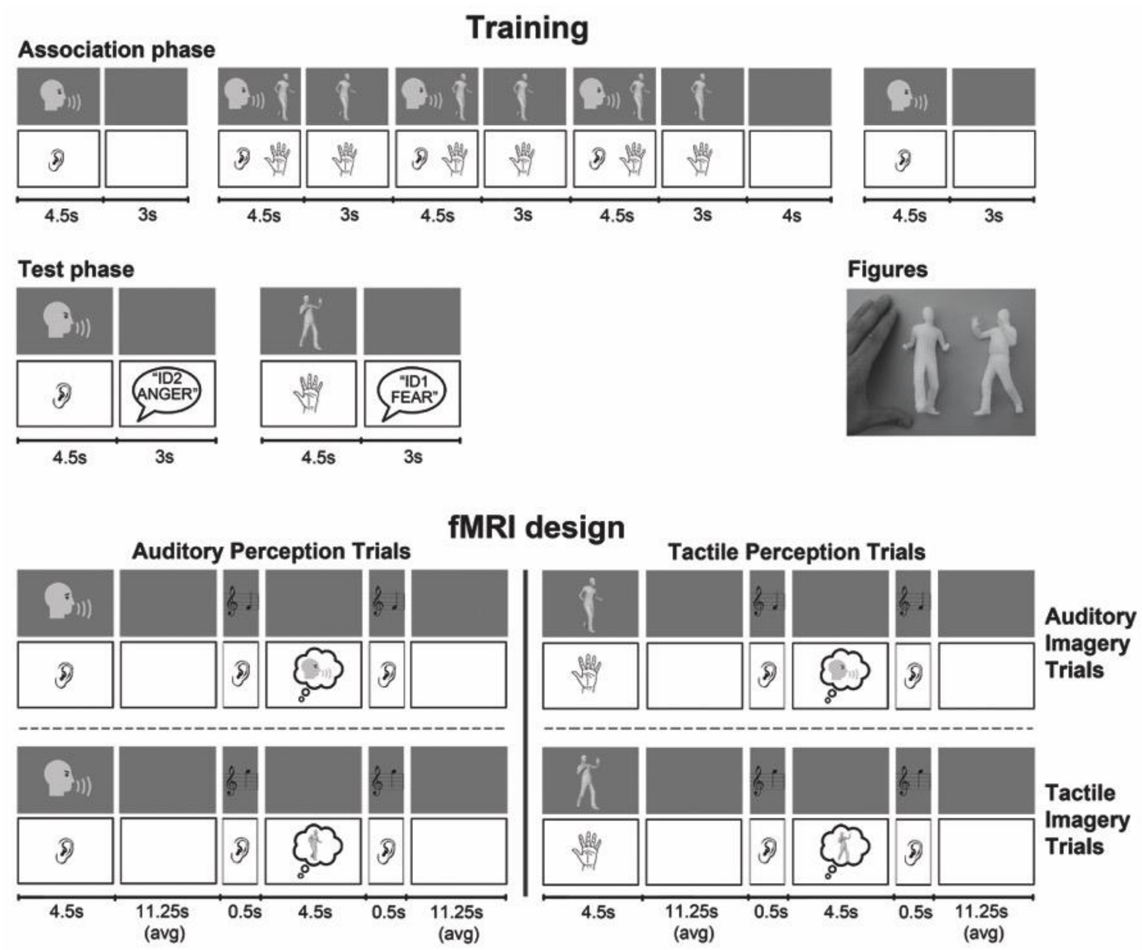


**Figure 1. Experimental Design**. Top: Training phase, in which participants were first familiarized with the stimuli and associated the auditory stimuli with the tactile stimuli (e.g. ID 1 angry voice with ID 1 angry body). Subsequently, they were tested on how well they could identify the stimuli (separate for auditory and tactile stimuli). Bottom: fMRI design, in which the auditory perception trials and the tactile perception trials are indicated on the left and right. On half of the trials the participants perform auditory imagery (top), while in the other half they perform tactile imagery (bottom), equally divided over both types of perception trials. The (average) duration of each stimulus is indicated below in seconds.

## Data analyses

For the main data analyses multivariate pattern analysis was performed on the whole brain level and in regions of interest. For the single trial estimation of the MVPA mean values were extracted in the perception and imagery intervals relative to baseline (Brainvoyager QX 2.8 MVPA Toolbox). On the estimated trials a whole-brain searchlight approach was applied to find the local patterns with the most discriminative voxels for the two classes. A leave-one-run-out strategy was then used for training and testing of the data using support vector machine (SVM) classification. The resulting search light maps were averaged over runs in each individual. We tested whether the average accuracy of a searchlight across subjects was significantly higher than chance using an exact permutation test. The correction for multiple comparisons was done using cluster threshold estimation based on the permutations. For the between-group analyses, we restricted our focus to those searchlights that showed a significant difference from chance in at least one of the two groups and we conducted a non-parametric one-way ANOVA (again via second level permutation tests) with group as a factor to highlight searchlights that showed a significant difference between the groups. We corrected for multiple comparisons using False Discovery Rate (FDR) correction with $p < 0.05$.

For the region-of-interest classification the same single trial estimations of the MVPA mean values in the perception and imagery intervals were used as during the WB-SLM analyses. The voxels were extracted within each ROI. On the estimated trials a ROI-based approach was applied to discriminate response patterns within specific brain regions. A leave-one-run-out strategy was used for training and testing of the data using SVM classification. A single classification accuracy was obtained for each region per subject and run. These accuracies were then averaged over runs. We tested whether the average accuracy of a region across subjects was significantly higher than chance using permutation testing and an FDR correction with $p < 0.05$. For the between-group analyses we again conducted a non-parametric one-way ANOVA (via second level permutation tests) with group as a factor to highlight regions that showed a significant difference between the groups. We employed random Monte Carlo permutations with $N = 1000$ and corrected for multiple comparisons using FDR correction with $p < 0.05$.

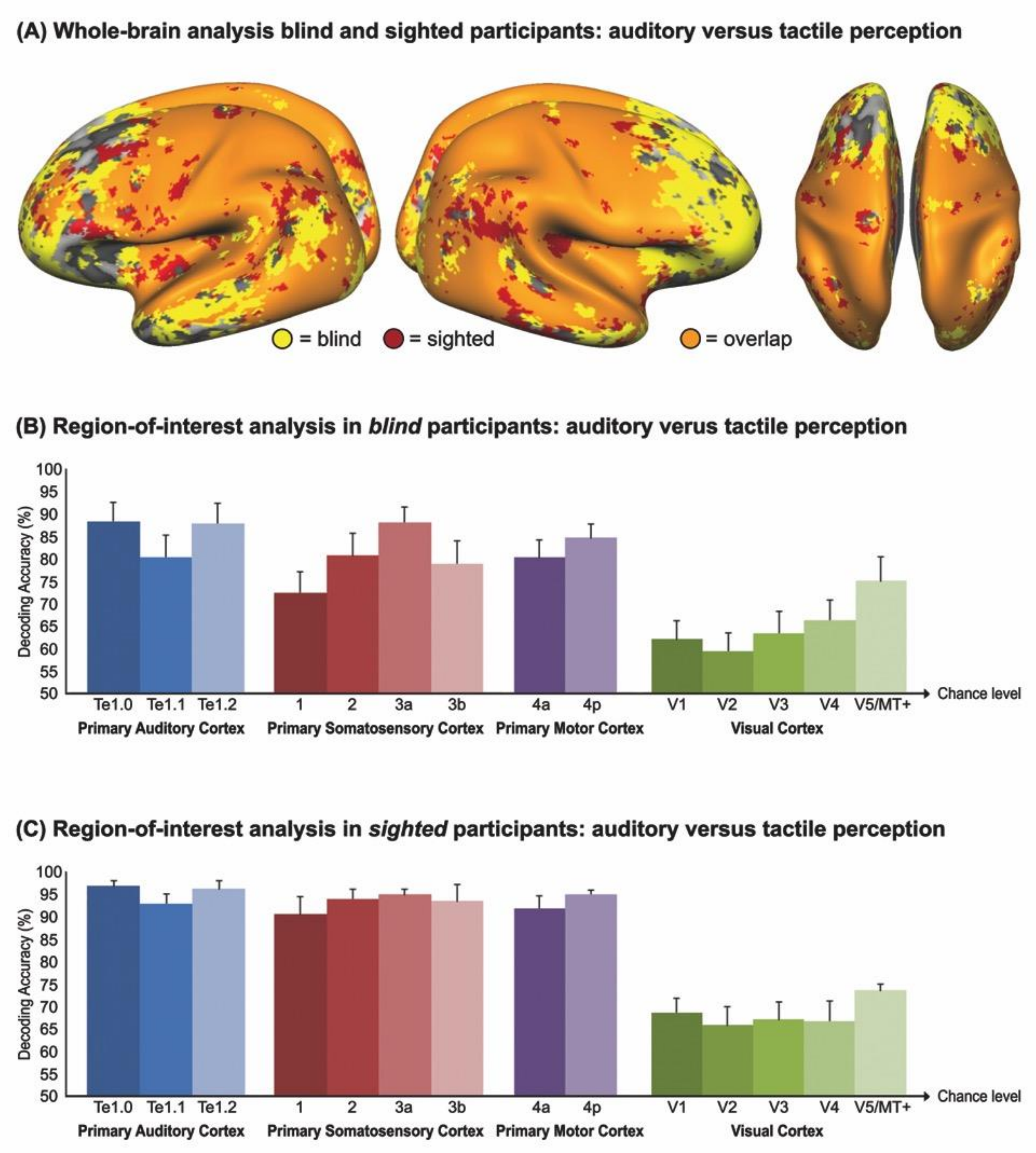
## Results

In order to understand what brain regions underlie the perception and imagination of affective body sound and touch, we investigated whether we could predict from brain activity whether:

1) the participants were *perceiving* auditory or tactile body expressions
2) the participants were *imagining* auditory or tactile body expressions

Figure 2 illustrates the brain regions that underlie the perception of auditory vs tactile body expressions. We found that most of the brain contains information about in which *modality* (sound or touch) the participants perceived the expressions of emotion (Figure 2A). Moreover, all of the primary sensory cortices (the areas where sound and touch are perceived) were discriminative for sound vs. touch. As one can see in Figure 2, the patterns are remarkably similar for blind and sighted participants. This indicates that blind and sighted participants perceive these stimuli in a similar manner. Interestingly, in both groups also the primary visual cortex (V1) is discriminative for sound vs. touch. For the blind people, this means that their brains reorganized after visual deprivation and that the visual cortex is now responsive to sound and touch. This is not the case for the seeing participants. They might activate the visual cortex during sound and touch because they use visual mental imagery during perception. For example, when you hear a barking dog, you do not only process the sound, but you might also imagine what the source of the sound, e.g. the dog, may look like.

For Figure 3 we conducted a similar analysis as in Figure 2, but we looked at brain activation during mental imagery rather than perception. We found that in the sighted participants, similar to perception, all of the primary sensory cortices (including the visual cortex) were discriminative for sound vs. touch. This suggests that mental imagery follows a similar organization and representation as perception in sighted people.


(A) Whole-brain analysis blind and sighted participants: auditory versus tactile perception

(B) Region-of-interest analysis in *blind* participants: auditory verus tactile perception

(C) Region-of-interest analysis in *sighted* participants: auditory versus tactile perception

**Figure 2. Classification of auditory versus tactile perception.** (A) Searchlights that contain significant information about perception modality on the group level are colour-coded in yellow for the group of blind participants and in red for the sighted participants. Orange indicates overlapping searchlights that were significant in both groups. The results are displayed on the group-aligned inflated average surface of the blind participants. (B) The classification accuracies and standard errors of anatomical regions that contain significant information about perception modality on the group level in blind participants are shown. (C) The classification accuracies and standard errors of anatomical regions that contain significant information about perception modality on the group level in sighted participants are shown.

In the group of blind persons however, we found that the primary visual cortex does not represent imagined sound vs. touch. This indicates that due to the functional reorganization of the brain that took place in blind people from birth the primary visual cortex is responsive to perception of sounds and touch, but it is not re-activated by mental imagery.

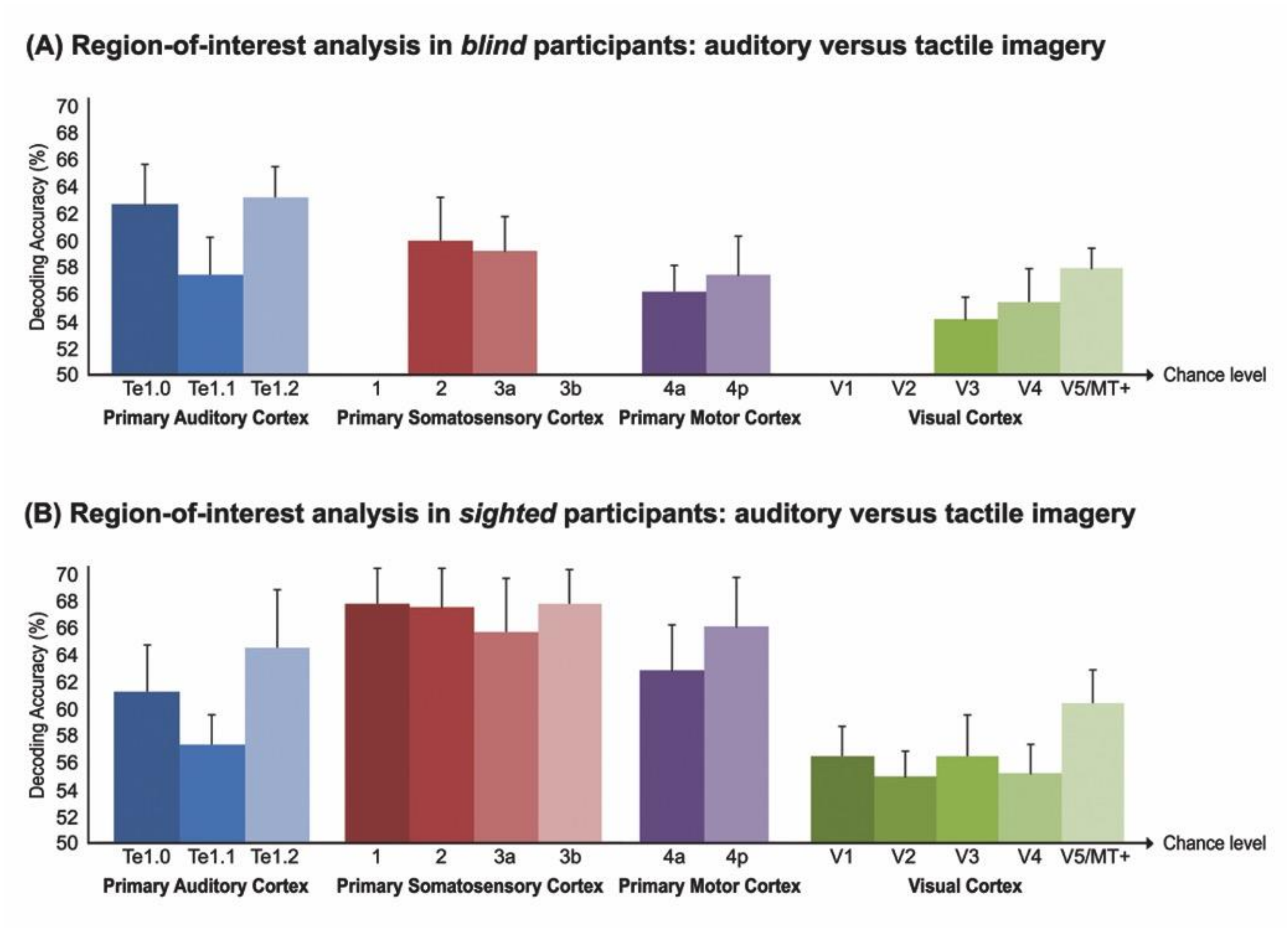


Figure 3. Classification of auditory versus tactile imagery. (A) Classification accuracies and standard errors of anatomical regions that contain significant information about imagery modality on the group level in blind participants are shown. (B) Classification accuracies and standard errors of anatomical regions that contain significant information about imagery modality on the group level in sighted participants are shown.

## Conclusions

These results showed that all primary sensory cortices of blind and sighted people are involved in decoding the perception of sound and touch. While mental imagery re-activates all primary sensory cortices in sighted people, it does not contribute to the involvement of early visual cortex in blind participants. This indicates that the primary visual cortex is not relevant for the imagination of sound and touch in blind people.

## References

de Borst, A.W. & de Gelder, B. (2017). fMRI-based multivariate pattern analyses reveal imagery modality and imagery content specific representations in primary somatosensory, motor and auditory cortices. Cerebral Cortex, 27, 3994-4009.

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