A novel paradigm for fMRI-based brain-computer interfacing using
selective somatosensory attention

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Introduction
For some time past, brain-computer interfaces (BCIs) based on (real-
time) functional magnetic resonance imaging (fMRI) implementing
sustained mental imagery tasks have been proposed as alternative
means for motor-independent communication and control in severely
paralyzed patients [1-4]. Several of these BCI systems require control
of eye gaze that might not be accomplished by certain patients. For
this reason, more recently, BCIs based on selective visuospatial [5,6]
and auditory attention [7] were suggested not involving any need of eye
movements. Here, we introduce a further eye gaze-independent fMRI-
BCI paradigm that exploits selective somatosensory attention [8] and
multi-voxel pattern analysis (MVPA) [9]. It allows for decoding the locus
of selective somatosensory attention (to the right hand or to the left
foot) from distributed brain activation.

Materials and Methods
Five participants (female, mean age: 26.8 years) were provided with
vibratoilex stimulation simultaneously applied to the right index finger
and to two toes (left, Fig. 1). Stimulation (25Hz) included randomized
(unsynchronized) interruptions and was controlled by a programmable
device (Piezostimulator, QuaeroSys, St. Johann, Germany). Participants
were audiotorily instructed to attend either to the right hand (50%) or to the left foot. To facilitate attention, participants counted the
interruptions occurring at the to-be-attended site (70.5±4.2 interruptions
across one run). Each of the six functional runs consisted of
18 16-s attention trials (9 per condition presented in pseudorandom
order) that were alternated with resting periods of 18-22s. Anatomical
and echo-planar images (TR=2s, 32 slices, no gap, 2-mm isovoxels,
350 measurements) were obtained by using a 3-T MRI scanner.

Using BrainVoyager QX (v2.8) functional data were motion-corrected,
high-pass filtered, slice-scan time corrected, coregistered to anatomical
images and spatially normalized (Talairach transformation). Based
on the 1st-run’s data, a cortical network comprising all brain regions
activated by task performance was defined per participant using an
individual cortex mask and univariate general linear model analysis. Statistical maps obtained by contrasting the mean fMRI response of
the two stimulation conditions vs. baseline were thresholded at p<0.05
(FDR; Fig. 2). All voxels within the cortical network were used to define
the features for the MVPA. Linear classifiers (support vector machines,
SVMs) were 'trained' based on t-values in a peri-onset window (-2s to
26s) for each single trial and voxel) combining data of a) 4 out of five
runs (run-level split analysis excluding 1st run; n=5) and b) of the first
1-5 functional runs (increasing amount of training data; n=5).

For testing these classifiers, data from the (for each case) remaining
functional run(s) were used following the same procedure for
calculating t-values. For each single trial, the classifier’s prediction
was compared to the condition supposed to be performed by the
participant. Classification accuracies resulting from all training/testing
run combinations were obtained for each participant and respective
group means were calculated.

Results

Obtained individual classification accuracies considerably varied across
participants ranging from 63.3% to 75.6% (run-level split analysis;
mean: 70.4%), but were significantly above chance level (being 50%) in
all participants (p<0.05) as assessed by running permutation tests to
obtain a distribution of accuracy values under the null hypothesis
(Fig.3, left panel). When increasing the amount of training data (1-5
runs), obtained classification accuracies increased accordingly (Fig.3,
right panel). Voxels with the most well-learned discriminative classifier
weights corresponded nicely to the putative primary sensory right-hand
and left-foot areas (Fig.4). Looking at classification accuracies separately for right-hand (75.6%) and left-foot trials (71.1%) did not
reveal any significant differences.

Conclusions
We suggest a novel 2-class fMRI-based BCI paradigm employing a
selective somatosensory attention task that requires only little pre-
training and effort. It might allow for basic communication (e.g.,
"yes"/"no" answers) in severely motor-disabled patients. Moreover, it
might serve as a procedure to detect conscious awareness in non-
responsive patients. As the proposed system does not require eye
movement control, it might be especially suited for patients that show
responding impairments.

References
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