D1.3 - Quantify connectivity/overlap of regions processing dance movement and sonified dance movement

Version	Edited by	Changes
1.0	UM, UNIGE	

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Introduction

The DANCE project aims to investigate whether, by the understanding of movement and the analysis of its quality, we can translate movement into sounds (sonification). To face this translation, we first need to understand how a healthy individual perceives dance and its respective aesthetic properties. To investigate how the human brain is affected when individuals watch dance choreography, we will use a functional Magnetic Resonance Imaging (fMRI) scanner to measure brain activity.

Experiment with visual stimuli

Stimuli

We asked several dancers to perform two aspects of dance, which are "Fragility" and "Lightness" (Camurri et al. 2016). Fragility has been defined as: "*A sequence of non-rhythmical upper body cracks and leg releases. It emerges, for example, when moving at the boundary between balance and fall, resulting in short movements with continuous interruption of motor plans. The resulting movement is non-predictable, interrupted, and uncertain*", whereas lightness can be defined as: "*A series of body movements that are smooth, fluid and elegant and therefore result in predictable, continuous and certain movement, with no or limited accelerations of body parts towards the ground"*. In total, 10 dancers have been recorded on video while measuring breathing and movement with accelerometers. The videos have been edited into six ~10 sec. fragments for each dancer and dance type, resulting in 120 videos. Next, the faces in the videos have been blurred to reduce the strong effect of face recognition in the human brain. In the fMRI scanner participants watch the videos passively in a randomized order with a ~12 sec. interval between videos. To reduce fatigue the experiment is split into three sessions of ~15 min. with breaks in between.

MRI sequence

The anatomical data were acquired in the Maastricht Brain Imaging Center, Maastricht University (Netherlands), with a 3T MAGNETOM Prisma fit scanner (Siemens, Erlangen, Germany), with a 64-channel whole-brain coil. We acquired two anatomical scans, a T1 weighted image (3D MPRAGE, FOV = 224 mm, matrix = 320, 256 sagittal slices in a single slab), TR = 2400 ms, TE = 2.14 ms, TI = 1000 ms, FA = 8°, GRAPPA=2) and a T2 weighted image (SPACE, same matrix, FOV, and slices as in the T1w, TR = 3200 ms, TE = 565 ms, GRAPPA=2). Functional images were acquired with a T2*-weighted gradient echo EPI sequence, covering the whole brain with a resolution of 2*2*2 mm3 (64 slices without gaps, TR=1330 ms, TE=30 ms, flip angle=67, multi-band acceleration factor=3, FOV=200x200, matrix size=100x100, phase encoding direction: anterior to posterior). To correct for EPI distortion, an extra run of 5 volumes with phase encoding direction posterior to anterior was acquired before each functional run.

Image analysis

We have adapted a specialized and high quality pre-processing pipeline from the Human Connectome Project (HCP, https://www.humanconnectome.org/, Glasser et al. 2013) to preprocess our fMRI data. This pipeline consists of a set of state-of-the-art tools to allow accurate comparison of brain anatomy and functional activation across subjects as well as noise reduction. Briefly, the anatomical images are aligned to a standard space (MNI) template through a series of optimized processes. This allows intra-individual comparison of anatomical locations. During this process the brain is also segmented into the main tissue types and a 3D model of the cortical surface is generated to allow an even more accurate comparison of cortical areas between subjects. The functional images are first corrected for MRI sequence induced anatomical distortions (Andersson et al. 2016), corrected for between image head motion, and then made to match the anatomical and MNI space images very accurately. These final fMRI images are then used to perform the statistical analysis on. Here, we used a general linear model approach to test for differences in voxel level brain activations between the two dance conditions. For each scanned participant a regression model was made including predictors representing the timings of the videos and the different measures of head movement of each session against the dependent voxel level fMRI time signals.

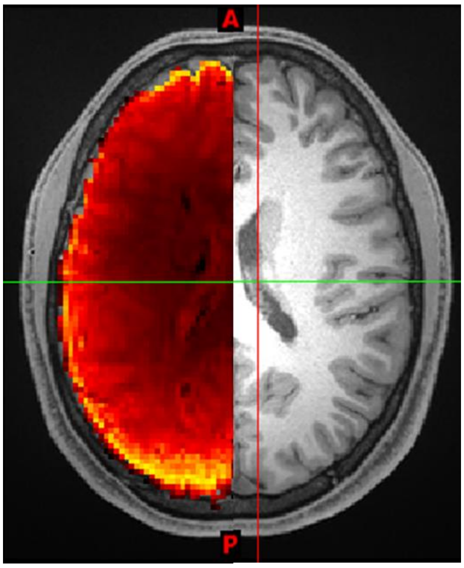

Figure 1: example output of the anatomical alignment of the structural (background greyscale) and the fMRI (red-yellow) images.

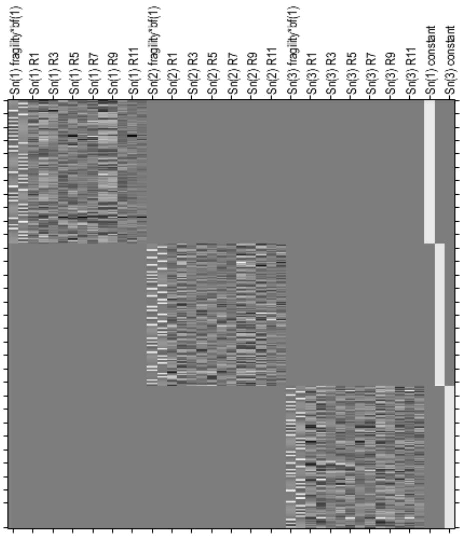

Figure 2: the design matrix for the linear model used to analyze a single subject's data.

Results

We contrasted the two dance conditions to reveal brain regions that responded stronger to one of the two conditions. In Fig. 3 results are displayed on the cortical surface for 3 participants for the contrast Fragility>Lightness. This contrast revealed stronger activation in inferior parietal, supramarginal and central sulcus regions, which are well known to be related to action observation.

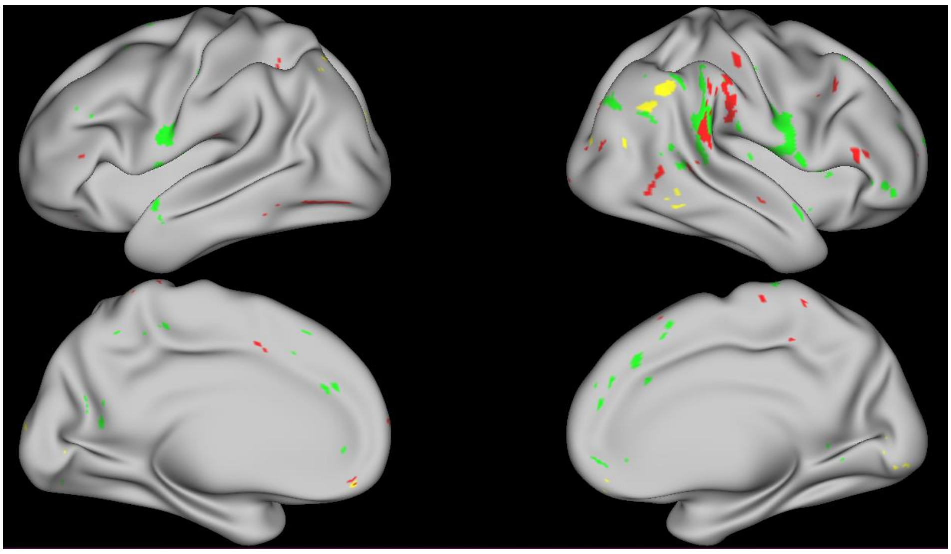

Figure 3: Fragility > Lightness displayed on the cortical surface. Colors represent the three different participants in this analysis.

Figure 4 displays the results for the Lightness>Fragility contrast. Here we observe greater activation for Lightness in inferior parietal, precentral sulcus and superior parietal regions.

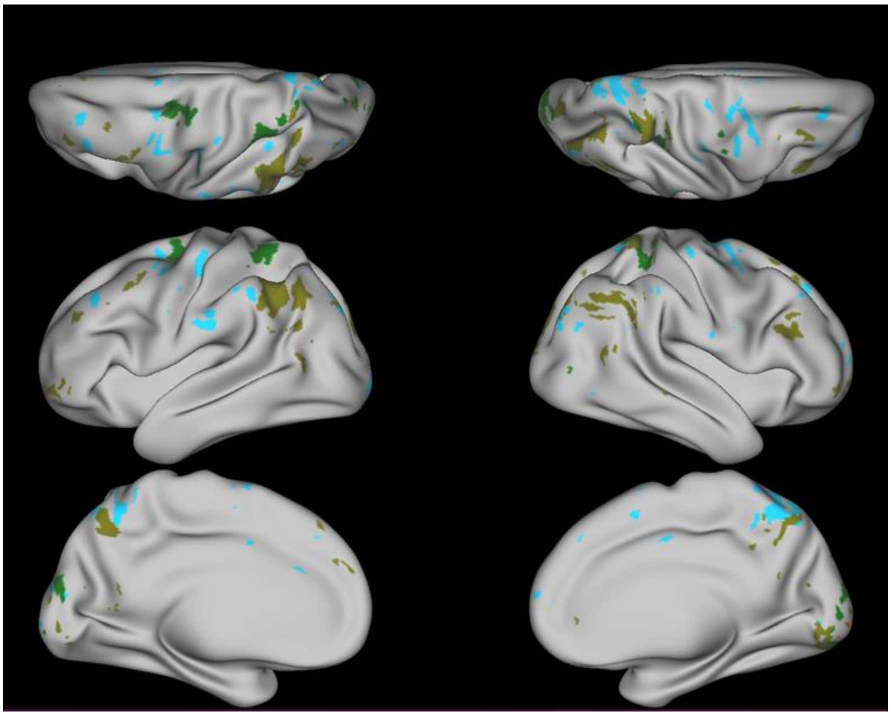

Figure 4. Lightness > Fragility displayed on the cortical surface. Colors represent the three different participants in this analysis.

Experiment with sonification of visual stimuli

Two sonification models of Fragility and Lightness were developed, in collaboration with artists (Kolykhalova et al 2016; Camurri et al. 2016). These sonification models were adopted for a scientific experiment addressing the following research question: **can we communicate a Light or Fragile movement only by means of an interactive sonification?**

This experiment is the premise to a further experiment where brain imaging responses to sonfications of fragility and lightness, to create a validated set of audio stimuli that will be later exploited in the ongoing experiment involving fMRI scanning to compare the brain response to visual stimuli Vs their sonifications.

Hypotheses

The aim of this experiment is to check 2 hypotheses:

- H1a) the degree of Perceived Lightness differs between the sonifications of Lightness and Fragility segments. In particular, we expect that our participants will perceive more Lightness from the sonifications of Lightness movements compared to the sonifications of Fragile movements;
- H1b) the degree of Perceived Fragility differs between the sonifications of Lightness and Fragility segments. We expect that our participants will perceive more Fragility in the sonifications of Fragility movements compared to sonifications of Lightness movements;
- H2a) The degree of Perceived Lightness is higher than the degree of Perceived Fragility for Lightness segments: when listening a sonification of a light movement, participants will perceive more lightness than fragility.
- H2b) The degree of Perceived Lightness is lower than the degree of Perceived Fragility for Fragility segments: when listening the sonification of a Fragility movement, participants will perceive more fragility than lightness.

Procedure

Twenty participants (18 females) were invited to our laboratory: 13 participants had some prior experience with dance (12 at amateur, and 1 at professional level). 6 out of 20 participants had some prior experience with music creation (4 at amateur level and 2 being professionists). Before the starting the experiment, the participants watched short video-examples of the performances of professional dancers expressing both qualities, prepared for this experiment. Videos were selected in order to maintain the movement quality (lightness or fragility) at the highest degree for the whole duration of the video.

As a first step, participants were asked to fill personal questionnaires. Next, they listened 20 audio files. For each audio segment, they were asked to rate the global level of Fragility and Lightness they perceived using two independent 5-point Likert scales (from "absent" to "very high"). The audio segments are sonifications of the two qualities: they are automatically generated as the result of the application of the computational models of the sonification of the two qualities applied to the videos adopted in the fMRI experiment. We started from the 120 video stimuli (duration each 10s) of the fMRI experiment. Sonifications were played in the random order using Latin Square Design.

Stimuli

Ten segments displaying the Lightness and ten displaying the Fragility were chosen for the experiment by 4 experts (professional dancers and movement experts) out of the 120 described in the previous section on the fMRI study. Each segment was sonified, the results of the sonification process were stereo audio files (WAV file format, 48KHz sampling rate).

Results

The experiment design introduces two dependent variables: Perceived Lightness (PL) and Perceived Fragility (PF). Figure 5 and Table 1 report the average values of the Perceived Lightness and Fragility for each type of stimuli (Lightness segments vs Fragility Segments).

	Perceived Lightness	Perceived Fragility
Lightness segments	2.75 (1.106)	0.96 (1.090)
Fragility segments	1.05 (0.991)	2.79 (1.078)

Table 1. Average values of the Perceived Lightness and Fragility

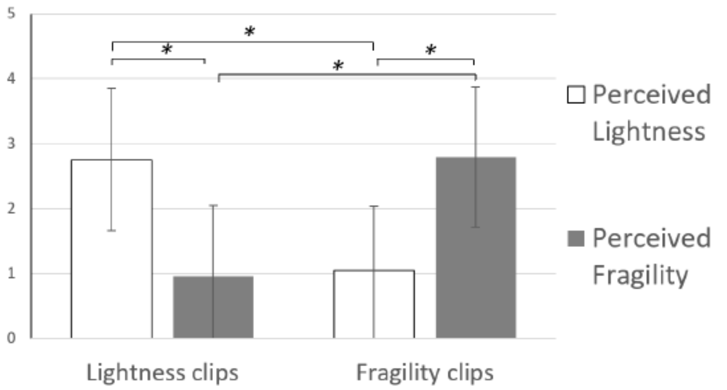

Figure 5. Summary of the results: significant differences signed with "*" (p<.05)

Conclusions

These results indicate that the stimuli and study design were successful in eliciting relevant brain activations and made a first step in disentangling the brain regions involved in decoding different qualities of movement.

The preliminary evaluation of audio stimuli also demonstrated that participants were able to perceive correctly the expressive qualities of the movement only from their appropriate sonifications. Indeed, strong differences in the perception of the Lightness and Fragility were observed between the sonifications of the Fragility and Lightness Segments.

References

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