# 2. Methods

## 2.1 Participants

For the experiment Thirteen healthy, right-handed medicine students from the University of Marburg (7 males and 6 females) were recruited. Each of them took part in an MRI introduction course to familiarize themselves method and to experience having an MRI scan performed on themselves. Subjects were additionally offered to participate in an fMRI experiment. If they agreed, subjects were asked permission to have an EEG recording added to the experiment. In exchange, they were provided an anatomical scan of their brain. Subjects were excluded from the experiment if they were not between 18 and 35 years old, reported impaired vision, left-handedness, prior experience with the task, current use of prescription drugs and acute or a history of neurological or psychiatric disorders. All subjects were between 18 and 32 years old (M = 23.23, SD = 4.28). Participants provided informed consent after they were given a summary of the risks and requirements involved as well as a rough outlet of the experimental procedure. This study was approved by the local ethics committee at the Department of Psychology.

## 2.2 Experimental Design and Setup

### 2.2.1 General Procedure

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All experiments were performed on the premises of the section for brainimaging located at the clinic for psychiatry and psychotherapy at the Department of Medicine in Marburg. When subjects arrived at the clinic, they were greeted and asked to take a seat in front of a desk in a comfortable office chair in a light-attenuated room. The desk was empty, except for a few sheets of paper, a stop watch and a pen. Starting from this point, all experimental procedures were documented on the standardized protocol (see Appendix 1).

Next, subjects were provided an oral overview of the following proceedings (i.e., conditions for participation, informed consent, etc.) and the study’s background. Then, they were handed the written version of the informed consent as well as a metal anamnesis to assess risk factors for the application of fMRI and to ensure the subject’s safety (see Appendix 2 and 3). The latter was used to ensure that there were no pieces of metal or electrical devices permanently attached to the subject’s body. On request subjects could receive a written report, describing the study’s background, risks and conditions of participation in detail.

If the subject had filled out all forms and had no further questions, the interviewer conducted pre-experimental interview (see Appendix 4), in order to assess demographic and personal data (i.e., age, highest academic degree, average grades). Further, to control for the influence of stable capacities for informational load, the Digit Symbol Coding Test from the German version of the Wechsler Intelligence Scale for Adults (WAIS-IV, fourth eidition; Petermann, 2012) was administered as a pretest (see Appendix 5). This measure was also included to enrich the battery of behavioral and self-report variables, which should be predictable by brain activation, with a cognitive test.

Afterwards, subjects were brought into the MRI control room, where they could change into a hospital gown. This was offered to prevent soiling the participants’ private clothing with gel from the EEG and ECG electrodes at the head and upper back. While subjects sat in a chair in front of the computer running the EEG and ECG recording software, the experimenter could check the signal quality (i.e., electrical impedance, voltage at each electrode). Two sizes of EEG caps were available (size 56-58 cm and 58-60 cm) with mounts for 31 ring electrodes plus one grounding (AFz) and one reference channel (FCz) on the fronto-anterior and fronto-central scalp positions, respecitvely.

Before the EEG cap was put on, skin portions that would be covered were cleaned with Isopropanol (70%), followed by measuring the subject’s head circumference. By assessing the distances between the left and right preauricular points as well as between the nasion below the forehead and the inion at the back of the head, the central vertex point (Cz) was marked as the intersection of the two axes (Klem, Lüders, Jasper, & Elger, 1999). The EEG cap was then put on at this central position. An elastic chin band prevented the cap from sliding.

Electrical impedances were reduced with a conductive electrolyte gel, containing pumice, as this gel component aids roughening the skin and removes detrimental elements to the electrical conductance such as callus skin or fat. The gel was distributed across the electrode sites, starting with the reference and grounding electrodes. For this purpose blunt plastic syringes were used, after slightly roughening the skin with cotton swabs. These were also applied for pushing away hair blocking the contact of the electrodes to the scalp. All impedances were kept at or below 5 kΩ. At last, the ECG electrode integrated in the EEG system was placed on the upper back. Before the electrode was attached and the impedance was optimized, subjects were asked if they preferred a person of the same sex to execute this step.

When the EEG and ECG signal were optimal, subjects were lead into the scanning room to the MRI bore. Here, several measures, as can be read in protocols from Ritter and Villringer (2006) or Mullinger, Castellone, & Bowtell (2013), were met to achieve optimal data quality. For a detailed description on these measures specific for simultaneous recordings, see section 2.3.2. During the entire time in the scanner, subjects were able to communicate with the experimenter via a two-way intercom system connecting the two adjacent rooms.

Following an anatomical T1-weighted scan, subjects were introduced to the DPX (see section 2.2.2) on ten slides with written instructions. When they felt confident, they could start with 18 practice trials. As opposed to the subsequent four experimental blocks, subjects received feedback on their performance (‘correct’, ‘incorrect’, ‘too slow’, ‘too early, please wait for the probe’). The feedback was initially given to make sure subjects had properly understood the task. Before the experiment and the functional data acquisition was started, subjects were asked one last time if they were well and ready to begin. From that point on, not counting practice trials and instructions, the experiment lasted approximately 32 minutes.

Finally, when the task was over, subjects were moved out of the scanner, freed of all EEG equipment and provided the opportunity to wash their hair and back. When they had cleaned themselves, all subjects participated in a post-experimental interview (see Appendix 6). Among other questions, they were asked how they rated their task performance on a scale of one to ten and which ideas they had on the purpose of the task. Concluding the experiment, subjects were informed about the background of the task and the complete purposes of the study (i.e., psychological mechanisms involved in DPX, clinical applications). In case they were interested, subjects could indicate if they wanted to be notified of the results of the study.

### 2.2.2 DPX Paradigm

The DPX task is a continuous performance task with four different trialtypes (AX, BX, AY, BY) repeated across experimental blocks. Each block consisted of 52 trials with four different trialtypes (AX, BX, AY, BY). Blocks were separated by one minute breaks and preceded by 18 practice trials. One trial consisted of two stimulus types. Stimuli consisted of dot patterns highlighted within a square of nine equidistant, blue dots. The first dot pattern (i.e., the cue) was presented in light blue for 100 ms on a white background, followed by a jittered interstimulus interval of 3 to 5 seconds. The second dot pattern (i.e., the probe) was presented in grey. As soon as the probe appeared, subjects had a time window of 800 ms to respond. After 300 ms the probe disappeared. A jittered intertrialinterval of 2.5 to 4.5 seconds separated the probe from the next cue. Thus, the minimum duration of each trial was 6.4 s and the maximum duration 10.4 s.

Subjects were instructed to respond with a right button push after a correct cue-probe combination and with a left button push after an incorrect combination. In the correct combination (AX) there was a vertical line of three blue dots on top of one another as a cue. The corresponding probe had the two upper dots of the vertical line and one on the right in the middle in white. Any deviation in the cue, probe or in both was considered incorrect. All patterns were constructed starting with of nine equidistant dots arranged in a square.

ISI 2.5 to 4.5 s

maintenance interval

**Right button**

Correct cue-probe combination **AX**

**BX**

**AY**

**BY**

Fig. 4. Illustration of the DPX task adapted for simultaneous EEG-fMRI recordings. One trial consists of a cue lighting up within in the square, followed by a mask and then the probe appearing in grey (left side of the figure). A correct combination is presented on the left and all incorrect combinations on the right side.

Incorrect cue-probe combinations

**Left button**

Across the four blocks 208 trials were presented with 136 AX (65%) and 24 trials (11.6%) for BX, AY and BY respectively. However, due to an error in the programming the fourth block consisted of 33 AX and 7 BX trials. Therefore, the actual amount is 135 AX, 25 BX and 24 AY and BY trials. An overview of the paradigm is given in Figure 3.

As often found in EEG paradigms, this design was intentionally unbalanced. For the paradigm to work, the correct trialtype AX had to have the highest frequency of occurance. Of the 52 trials per block, 33 were AX (65%) and 8 trials were each of the remaining trialtypes (11.6%). Thus, subjects developed a dominant response tendency towards AX to push the right button. However, in a small amount of trials (i.e., AY trials) the expectation to see a correct probe after a correct cue was violated. An AY trial required subjects to correct their behavioral planning by updating WM in a reactive control style. They had to integrate the unexpected information, since the last stimulus and not the context was imperative to their behavior.

By contrast, when subjects saw a wrong cue (B), a strong proactivity was triggered. Regardless of the probe, in a trial starting with a wrong cue there is only one possible response, since both cue and probe have to be correct in order for the trial to be correct. The wrong cue has to be maintained in WM, because in this case it is the imperative stimulus. As soon as subjects saw the correct probe, they had to inhibit the dominant response tendency to push the right button by having the context direct their behaviour. The last combination BY was a control condition and presumably did not require noteworthy cognitive control efforts.

Across the four blocks 564 trials were presented with 384 AX and 60 trials for BX, AY and BY respectively. Both the baseline and the dual demand blocks with cognitive reappraisal consisted of 282 trials. Hence, both conditions had 192 AX and 30 BX, AY and BY trials.

## 2.3 Data acquisition

### 2.3.1 Materials and software

### 2.3.2 Experimental protocol for simultaneous recordings

First, subjects were once more instructed about how to behave during the expriment. They were asked to abstain from any unnecessary movements of the head, torso or shoulders and to avoid crossing their limbs, as this would cause severe artefacts for both the EEG and fMRI. Furthermore, they were given a brief oral explanation of the experimental task. The participant’s head was then placed on a pressure-insensitive cushion and further stabilized with pads to minimize head movements. Electrode leads were passed through the head coil above the subject. Before moving the subject into the scanner bore, they were given an emergency control to be able to abort the experiment at any time they felt in danger. Inside the bore electrode leads were connected to the amplifier positioned behind the subject’s head. All cables and leads between electrodes and the amplifier were fastened with adhesive tape to either the head coil or the

### 2.3.3 Recording parameters for EEG and fMRI

## 2.4 Unimodal data analysis

### 2.4.1 Behavioral Data

### 2.4.2 fMRI pre-processing

### 2.4.3 EEG pre-processing

## 2.5 Multimodal data analysis

### 2.5.1 Asymmetric data integration

### 2.5.2 Joint and Parallel ICA

### 2.4.6 Multiway Partial Least Squares regression

### 2.4.7 Multilevel modeling