fMRIAT Functional Magnetic Resonance Imaging
Windischberger Lab

MR Centre of Excellence Vienna

MPBE

MEDICAL UNIVERSITY OF VIENNA

ULTRA-HIGH FIELD FMRI INSIGHTS ON INSIGHT
NEURAL CORRELATES OF THE "AHA!"-MOMENT

M Tik[A,B], R Sladky[A,B], CDB Luft[C], A Hoffmann[A,B], A Hummer[A,B], MJ Banissy[C], J Bhattacharya[C], C Windischberger[A,B]

A. MR CENTRE OF EXCELLENCE, MEDICAL UNIVERSITY OF VIENNA, LAZARETTGASSE 14, 1090 VIENNA, AUSTRIA
B. MR PHYSICS DIVISION, CENTER FOR MEDICAL PHYSICS AND BIOMEDICAL ENGINEERING, MEDICAL UNIVERSITY OF VIENNA, WÄHRINGER GÜRTEL 18-20, 1090 VIENNA, AUSTRIA
C. DEPARTMENT OF PSYCHOLOGY, GOLDSMITHS, UNIVERSITY OF LONDON, NEW CROSS, SE146 NW, LONDON, UK

The "Aha!"-moment, characterized as a sudden moment of insight is a common psychological phenomenon. It is signified as the process of linking old knowledge in an original way and is thought to be an important component of creative problem solving.

One of the most commonly used tasks to study creative problem solving is the Remote Associates Task, RAT (Mednick & Mednick, 1967). To date, reported neural correlates of the "Aha!" moment are mainly restricted to cortical areas such as the temporal lobes (Kounis & Beeman, 2014) while some weak activation changes (not exceeding strict statistical thresholds) were reported in a few subcortical areas such as bilateral hippocampi, parahippocampal gyri, and anterior and posterior cingulate (Subramaniam et al. 2009).

However, no study so far has investigated insightful problem solving using state-of-the-art 7T fMRI methods.

SUBJECTS AND METHODS Twenty-four healthy subjects (12 female, age mean ± standard deviation [min, max]: 27.24 ± 3.54 [23, 38] years) were examined with 7T fMRI during a German version of the RAT (Jung-Beeman, et al., 2004; Sandkühler & Bhattacharya, 2008). Participants were instructed to press a button as soon as they reached a solution and were asked to provide the last letter of the solution word (Figure 1). The perceived level of insight was indicated by the subject on a 5-point Likert-like scale after each trial.

Data were acquired on a Siemens MAGNETOM 7T MR scanner with a 32-channel head coil using a multiband EPI sequence (MB=3, TR=1.4 s, TE=23 ms, flip angle 62°, bandwidth 1447 Hz, 78 slices, resolution: 1.5×1.5×1 mm^3, FOV=192×192×97.25 mm^3). Data were slice-timing corrected (FSL) (Sladky, et al., 2011), bias-field corrected (ANTs), realigned (FSL), normalized (ANTs), and spatially smoothed (FSL, 6mm). Data analyses were performed in SPM12 using GLM analysis.

RESULTS About a quarter of the items were solved insightfully (subjective rating of insight > 3). The comparison of TASK (whole period in which the participants were trying to solve the problems) activity during trials solved with versus without insight revealed two main clusters (see Figure 2): one located around the Broca's area, inferior frontal gyrus and DLPFC indicating preparation for lexical/semantic processing. Also activated were medial pre-frontal areas (including the ACC), which are associated with performance monitoring or the evaluation/processing of the solutions (Anderson et al., 2009).

Comparing the event of insight vs. non-insight revealed strongest activation in language areas (i.e., Broca's and Wernicke's), right anterior temporal regions (e.g., right insula, inferior frontal gyrus, and superior temporal lobe), medial areas (e.g., PCC and ACC), and subcortical structures (e.g. hippocampus, substantia nigra and thalamus). Additionally, activation in the nucleus accumbens (NAcc) was associated with solved items and was further increased when the solution was found with insight (Figure 4).

CONCLUSIONS This is the first study to show insight-related neural activation patterns using fMRI at 7 Tesla. Our results not only corroborate former findings (Subramaniam et al. 2009, Jung-Beeman, et al., 2004, Kounis & Beeman, 2014), but also extend cortical activation patterns to task-related language areas. Due to our carefully developed task design and the increased signal to noise ratios at ultra-high magnetic field strengths, we found robust effects in a number of subcortical areas that are particularly related to insight (see Figure 3 and 4), which have not been reported by previous studies.

The results of this study further indicate a relationship between increased activity in the NAcc and increased activity in task-related brain areas during insight. Our results thus suggest that the "Aha!" event is a formative situation that goes along with learning processes and increased involvement in creating solutions.

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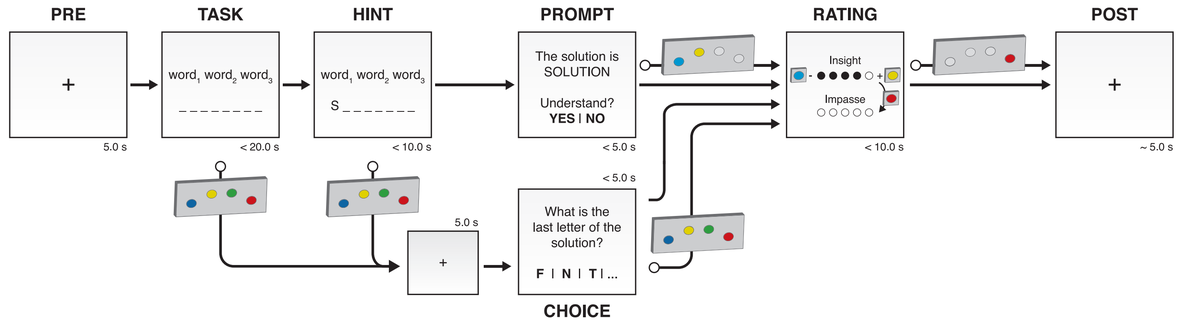

Figure 1. Flow chart of a RAT trial. The goal of the task is to find a word that can form compound nouns with three given stimulus words. For example, the three words 'river', 'note' and 'account' constitute three compound words when combined with the common target or solution word bank (river bank, bank note, bank account). Each trial consists of 7 phases, with fixed and variable durations. Response box indicates the situations in which the participant could press a button to report a solution (during TASK or HINT), select one of the presented options (PROMPT, CHOICE), and provide a subjective insight rating on a discrete scale (RATING).

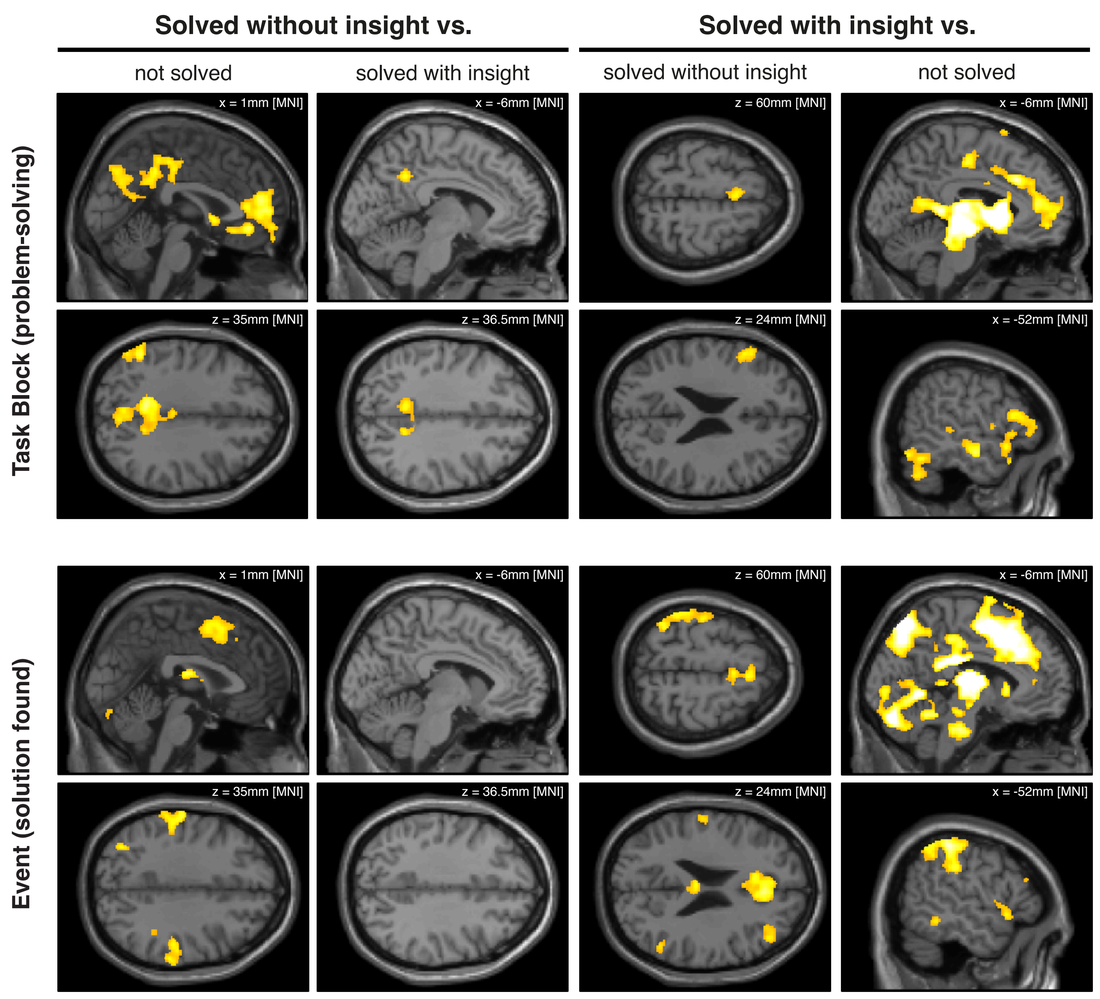

Figure 2. Solutions without (left) or with insight (right). Significant brain activations for the TASK period (top, i.e., the total length of the RAT task block) and the EVENT at the end of the TASK period (bottom). p<0.05 FWEc

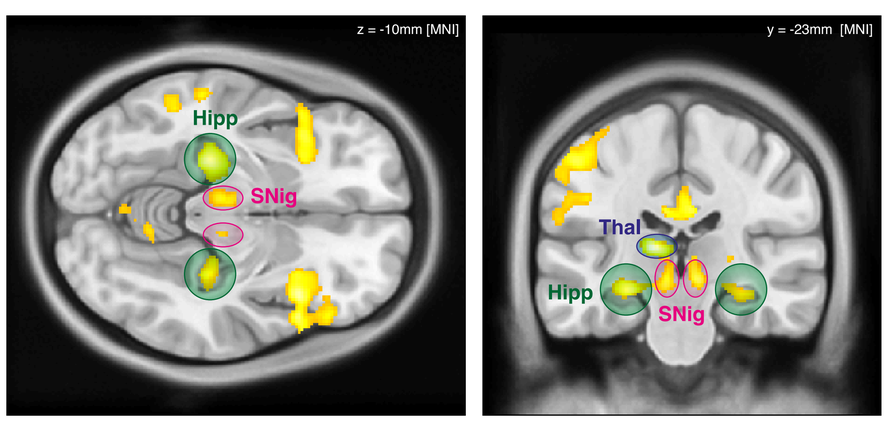

Figure 3. Subcortical activation for insight events (INSIGHT>NO INSIGHT). Locations of hippocampus (green), substantia nigra (magenta), and thalamus (blue) highlighted.

Figure 4. Condition-dependent activation of left and right nucleus accumbens. Nucleus accumbens activation was significantly higher for solved vs. unsolved trials and even more increased for solutions, where participants experienced an "Aha!"-moment.