*John Kounios, Jennifer L. Frymiare, Edward M. Bowden, Jessica I. Fleck, Karuna Subramaniam, Todd B. Parrish, and Mark Jung-Beeman.* **The Prepared Mind: Neural Activity Prior to Problem Presentation Predicts Subsequent Solution by Sudden Insight.**

Psychological Science (in press).

ABSTRACT—Insight occurs when problem solutions arise suddenly and seem obviously correct, and is associated with an ‘‘Aha!’’ experience. Prior theorizing concerning preparation that facilitates insight focused on solvers’problem-specific knowledge. We hypothesized that a distinct type of mental preparation, manifested in a distinct brain state, would facilitate insight problem solving independently of problem-specific knowledge. Consistent with this hypothesis, neural activity during a preparatory interval before subjects saw verbal problems predicted which problems they would subsequently solve with, versus without, self-reported insight. Specifically, electroencephalographic topography and frequency (Experiment 1) and functional magnetic resonance imaging signal (Experiment 2) both suggest that mental preparation leading to insight involves heightened activity in medial frontal areas associated with cognitive control and in temporal areas associated with semantic processing. The results for electroencephalographic topography suggest that noninsight preparation, in contrast, involves increased occipital activity consistent with an increase in externally directed visual attention. Thus, general preparatory mechanisms modulate problem-solving strategy.

Резюме.

После того, как человек стал решать задачи,  иногда достигая ясного и внезапного решения через инсайт - так называемый Ага! опыт. Из-за различного опыта происхождения и характеристик инсайт исторически получил значительное внимание в психологическом исследовании. Однако, несмотря на значительный прогресс характеристик инсайта, основные механизмы остаются таинственными. Мы обсуждаем исследование об инсайте, которое может  быть наиболее ярким, добавляя к традиционному исследованию инсайта, которое зависит от нескольких сложных проблем, с парадигмами, обычными в других областях познавательной науки. Мы описываем большой набор мини-инсайтных задач, к которым могут быть применены различные методы, вместе с субъективными сообщениями выделения инсайта, при решении задачи. Поведенческое начало и методы нейроизображения обеспечивают доказательство того где, и как возникает

мозговая активность во время инсайта. Такое доказательство ограничивает сложные теории процессов, и поможет демистифицировать инсайт.

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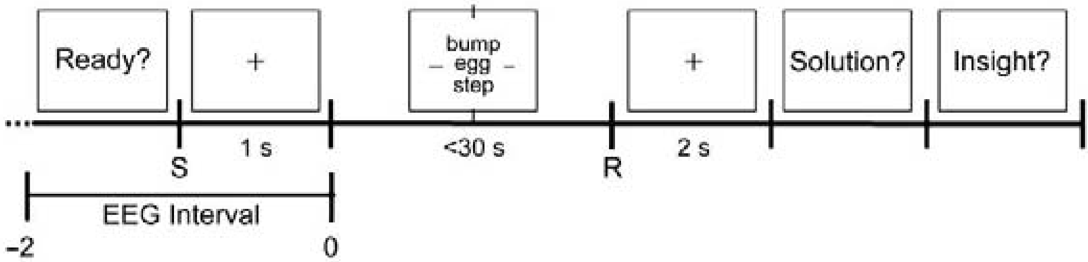


Fig. 1. Time line of events on a trial in Experiment 1. A "Ready?" message was displayed on a monitor, and the subject made a bimanual button press ("S") when he or she was prepared to start the trial and view the three words constituting a problem. The problem was displayed after a 1-s visual fixation mark. The subject responded with another button press ("R") as soon as he or she had solved the problem. This initiated a prompt to verbalize the solution (in this case, *goose*), followed by another prompt to make a button press to indicate whether the verbalized solution was accompanied by an experience of insight. This report presents electroencephalography (EEG) results for the bracketed preparatory interval consisting of the 2 s prior to the display of the problem.

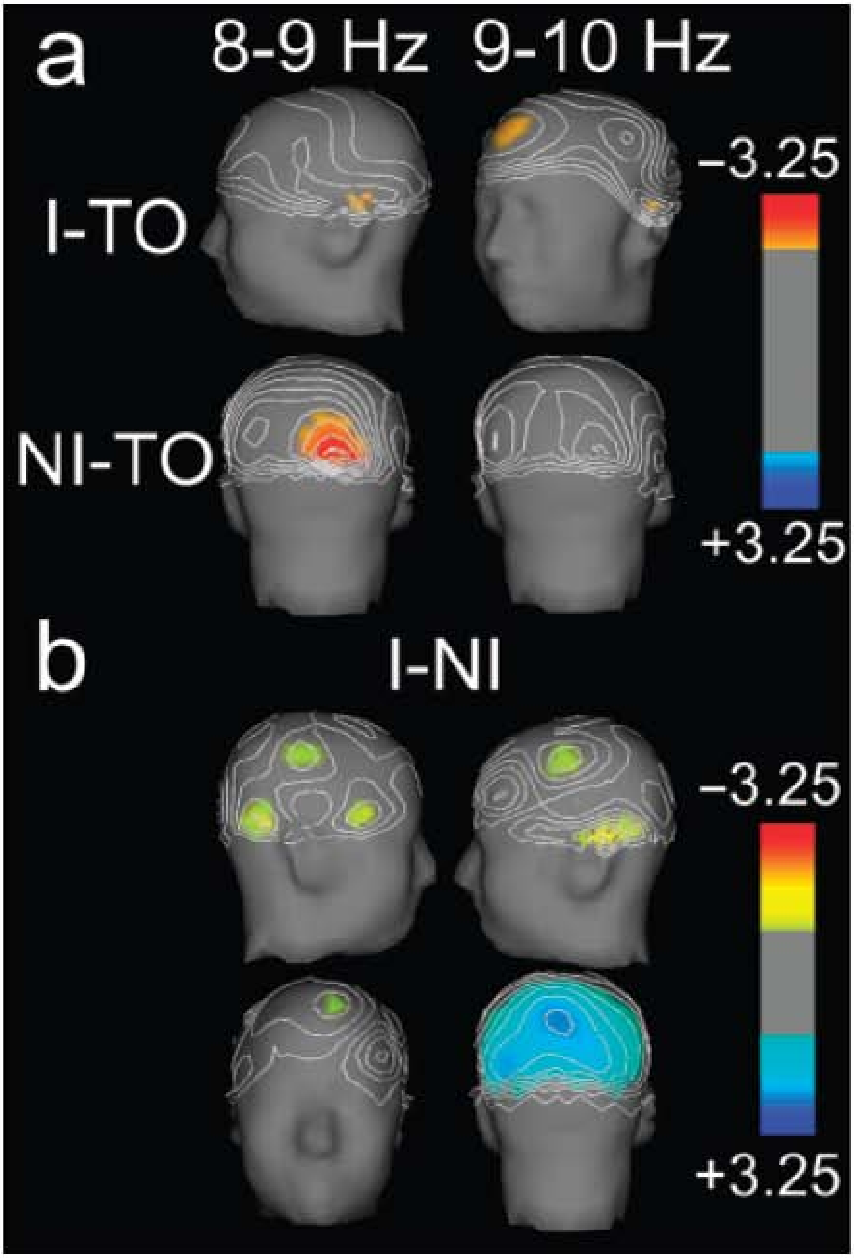


**Fig. 2.** Results from Experiment 1: alpha-band electroencephalographic (EEG) topography during the 2-s preparatory interval before the problem was displayed. Plotted values are *t* scores of electrode-by-electrode comparisons. The maps in (a) show results for comparisons between unsolved problems (time-outs, or TOs) and problems solved with insight processing (I) or with noninsight processing (NI); the left column shows maps for comparisons in the 8- to 9-Hz frequency band, and the right column shows maps for comparisons in the 9- to 10-Hz band. Red and orange regions indicate electrode sites at which I or NI trials exhibited less alpha power (i.e., more neural activity) than TO trials; the middle 66% of the color scale is grayed out. The maps in (b) show comparisons between insight preparation at peak power (9–10 Hz) and noninsight preparation at peak power (8–9 Hz; insight preparation minus noninsight preparation). Yellow regions show electrode sites at which insight preparation exhibited less alpha power than noninsight preparation. Blue regions show electrode sites at which noninsight preparation exhibited less alpha power than insight preparation. The middle 33% of the color scale is grayed out.

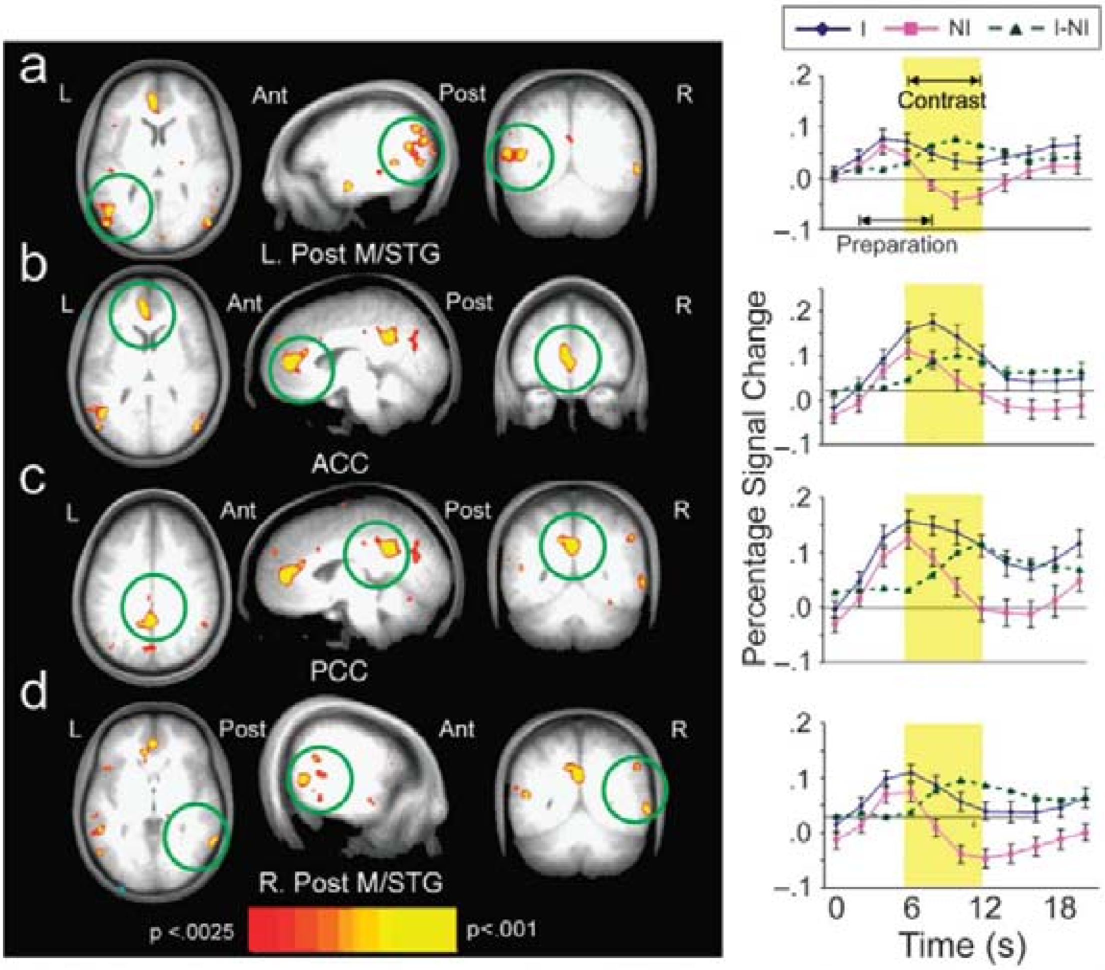


Fig. 3. Results from Experiment 2: structural images averaged across all 25 subjects, showing all voxels with stronger functional magnetic resonance imaging (fMRI) signal, $t(24) = 3.375$, $p < .0025$, uncorrected, for preparation periods that led to insight solutions than for preparation periods that led to noninsight solutions. Each row shows (left to right) axial, sagittal, and coronal images (with the left hemisphere on the left of axial and coronal images) centered on clusters (circled) of significant size (i.e., larger than 1,000 $mm^3$; no clusters of significant size showed the reverse pattern). For each circled region, the graph on the right shows the average percentage signal change during the shaded 6- to 12-s interval associated with neural activity during the 2- to 8-s preparatory interval (the offset between these intervals being due to the lag of the hemodynamic response). The blue line shows signal related to insight (I) preparation, the pink line shows signal related to noninsight (NI) preparation (both with standard error bars), and the green line shows the subtraction (I − NI). Analyses identifying significant voxels tested the contrast within the four TRs (times to repetition) highlighted in the yellow shaded region (i.e., TR ending at 6 s through TR ending at 12 s), which corresponds to the expected peak signal for the preparation period. (The preceding button press elicited peak signal in motor cortex at 4 s in these graphs.) Results are shown for four clusters: (a) left posterior middle/superior temporal gyri (L. Post M/STG), (b) anterior cingulate cortex (ACC), (c) posterior cingulate cortex (PCC), and (d) right posterior middle/superior temporal gyri (R. Post M/STG). Ant = anterior; Post = posterior; L = left; R = right.

**TABLE 1**

***Brain Areas Showing Significantly Different Functional Magnetic Resonance Imaging Signal for Insight Preparation Versus Noninsight Preparation***

| Gyrus or structure | Brodmann Area | Volume ($mm^3$) | Center coordinates |  |  | Signal change (%) |  | Mean $t$ | Max $t$ | Effect size ($d$) |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | $x$ | $y$ | $z$ | Mean | Max |  |  |  |
| Insight preparation > noninsight preparation |  |  |  |  |  |  |  |  |  |  |
| Left posterior M/STG | 39, 37, 22 | 2,031 | −49 | −62 | 15 | 0.06 | 0.08 | 3.6 | 4.7 | 0.98 |
| Anterior cingulate | 32, 24 | 1,922 | −4 | 41 | 8 | 0.08 | 0.10 | 3.8 | 4.8 | 0.94 |
| Posterior cingulate | 31 | 1,594 | −3 | −47 | 32 | 0.08 | 0.11 | 4.0 | 5.6 | 0.96 |
| Right posterior M/STG | 37, 39, 22 | 1,266 | 52 | −62 | 9 | 0.07 | 0.10 | 3.7 | 4.8 | 1.00 |
| Left amygdala | — | 438 | −25 | −7 | −9 | 0.07 | 0.10 | 3.8 | 4.6 | — |
| Left middle temporal gyrus | 21 | 438 | −62 | −32 | −6 | 0.07 | 0.10 | 3.7 | 4.6 | — |
| Noninsight preparation > insight preparation[a] |  |  |  |  |  |  |  |  |  |  |
| Left middle and inferior occipital gyrus | 18 | 375 | −30 | −98 | 2 | −0.09 | −0.12 | −3.1 | −3.7 | — |

Note. We used a strict threshold for significance, requiring a cluster size of 1,000 $mm^3$ and requiring that all voxels show a consistent effect across subjects, $t(24) = 3.374$, $p < .0025$. For thoroughness, all clusters down to 300 $mm^3$ are listed. For each cluster listed, we report the signal difference between insight and noninsight preparation as a percentage of the average signal within the cluster, as well as the average and maximum $t$ score for all voxels within the cluster. For significant clusters, we include the cluster-wise effect size, $d$. M/STG = middle and superior temporal gyri.

[a]No clusters showed significantly greater signal for noninsight preparation than for insight preparation, so we list the largest area at a lower threshold, 375 $mm^3$ at $t(24) = 2.795$, $p < .01$.