The Cognitive Neuroscience of Insight

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Abstract

Insight occurs when a person suddenly reinterprets a stimulus, situation, or event to produce a nonobvious, nondominant interpretation. This can take the form of a solution to a problem (an "aha moment"), comprehension of a joke or metaphor, or recognition of an ambiguous percept. Insight research began a century ago, but neuroimaging and electrophysiological techniques have been applied to its study only during the past decade. Recent work has revealed insight-related coarse semantic coding in the right hemisphere and internally focused attention preceding and during problem solving. Individual differences in the tendency to solve problems insightfully rather than in a deliberate, analytic fashion are associated with different patterns of resting-state brain activity. Recent studies have begun to apply direct brain stimulation to facilitate insight. In sum, the cognitive neuroscience of insight is an exciting new area of research with connections to fundamental neurocognitive processes.

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INTRODUCTION

In an article in the *Annual Review of Astronomy and Astrophysics*, William Wilson Morgan (1988) summarized several of the groundbreaking scientific contributions he made over his long career. One of these was the discovery of the structure of the Milky Way galaxy. What isn't obvious from his article is how he came to make this discovery (Sheehan 2008).

In 1951, Morgan had been calculating the distances of OB associations, which are groups of hot, bright stars. OB associations are considered "star nurseries" because these stars are young. One evening, he finished his work for the night and started to walk home from the Yerkes Observatory. He glanced up at the sky to observe the stars that he had been studying and had what he called a "flash inspiration . . . a creative intuitional burst": These stars are organized in a three-dimensional, strand-like structure. Galaxies come in a variety of forms, but he knew that in spiral galaxies OB associations reside in the galactic arms. Morgan understood that the strand-like form was a galactic arm and that he had directly apprehended the spiral structure of the Milky Way, a realization that he substantiated with data that he presented at a conference a few months later.

Morgan's breakthrough realization was an insight, colloquially known as an "aha moment"—a sudden, conscious change in a person's representation of a stimulus, situation, event, or problem (Kaplan & Simon 1990). Awareness of this kind of representational change, though abrupt, takes place after a period of unconscious processing (van Steenburgh et al. 2012). Because insights are largely a product of unconscious processing, when they emerge, they seem to be disconnected from the ongoing stream of conscious thought. In contrast, analytic thought is deliberate and conscious and is characterized by incremental awareness of a solution (Smith & Kounios 1996).

Although Morgan's insight was literally on a cosmic scale, the phenomenon of insight, in a more modest guise, is a common experience that occurs in perception, language comprehension, problem solving, and other domains of cognition (van Steenburgh et al. 2012). It is therefore of interest to ask what happened in Morgan's brain and in the brains of many other people when they have had an insight. This article reviews relevant cognitive neuroscience research and an emerging theoretical framework that is progressing toward an answer to this question. Before describing this work, we circumscribe the insight phenomenon to specify the domain of this review.

WHAT IS INSIGHT?

Insight is often defined as a sudden change in or the formation of a concept or other type of knowledge representation, often leading to the solution of a problem. These changes are thought to have certain attributes. For example, insights are frequently accompanied by a burst of emotion, including a highly positive surprise at either the content or manner of the realization. In contrast, analytic solutions are not typically accompanied by an emotional response except perhaps for a sense of satisfaction resulting from completing the task. However, though not an unusual concomitant, a conscious emotional response is not a necessary feature of insight. Participants in many studies have solved dozens of verbal puzzles with insight (e.g., Jung-Beeman et al. 2004, Smith & Kounios 1996) without reports of multiple bursts of emotion.

Another feature is that insights often break an impasse or mental block produced because a solver initially fixated on an incorrect solution strategy or strong but ultimately unhelpful associations of a problem. The breaking of an impasse is accompanied by the reinterpretation or restructuring of a problem to reveal a new, often simple, solution or solution strategy. Some researchers implicitly consider problem restructuring and the breaking of an impasse to be defining features of insight (e.g., Cranford & Moss 2012). However, this view excludes prominent types of insights, such as those that occur (*a*) when the solution suddenly intrudes on a person's awareness when he or she is not focusing on any solution strategy, (*b*) when an insight pointing to a solution occurs while a person is actively engaged in analytic processing but has not yet reached an impasse, and (*c*) when a person has a spontaneous realization that does not relate to any explicitly posed problem. We therefore do not consider the breaking of an impasse to be a precondition for insight.

Thus, there are a number of potential definitions of insight, depending on which combination of features one selects. Very narrowly defined, insight could be thought of as a sudden solution to a problem preceded by an impasse and problem restructuring and followed by a positive emotional response. In contrast, the broadest definition of insight is the common nonscientific one in which an insight is any deep realization, whether sudden or not. Within cognitive psychology and cognitive neuroscience, inconsistency exists concerning what we consider to be a basic criterion for insight, namely, suddenness. For example, a number of purported insight studies do not specifically isolate and focus on solutions that occurred suddenly (e.g., Luo & Niki 2003, Wagner et al. 2004).

Another broad use of the term insight can be found in clinical psychology, in which insight refers to self-awareness, often of one's own symptoms, functional deficits, or other kind of predicament. The clinical and nonscientific uses of the term do not require suddenness of realization or any accompanying emotional response. Indeed, in clinical psychology, the lack of an emotional response could itself be considered a symptom signifying a lack of insight.

The issue of defining insight is not an exercise in pedantry. When insight is defined too broadly, it includes so many diverse, loosely related phenomena that it becomes virtually impossible for researchers to draw general conclusions. For example, one recent review of cognitive neuroscience research on creativity and insight lumps together widely diverse studies characterized by a variety of definitions, assumptions, experimental paradigms, empirical phenomena, analytical methods, and stages of the solving process (and inconsistent experimental rigor). Unsurprisingly, because of such indiscriminate agglomeration, that review failed to find much consistency across studies, leading the authors to pronounce a negative verdict on the field (Dietrich & Kanso 2010). In contrast, going to the other extreme by adopting an overly narrow definition of insight can lead one to miss important large-scale generalizations that cut across particular experimental paradigms.

Thus, progress in studying insight can be facilitated or enhanced by "carving nature at its joints" and adopting a middle-path definition of insight to guide the selection of empirical phenomena and the development of experimental paradigms for its study. Specifically, we define insight as any sudden comprehension, realization, or problem solution that involves a reorganization of the elements of a person's mental representation of a stimulus, situation, or event to yield a nonobvious or nondominant interpretation. Insights are not confined to any particular domain of understanding, but we do not include all sudden realizations within this definition. For example, the reading of an isolated word starts with unconscious processing, which is followed by a sudden conscious realization of the word's meaning. But this is not an insight, because it doesn't involve reorganizing a mental representation to arrive at a nonobvious or nondominant interpretation. Insights may be especially salient when they follow an impasse, but impasse is not a necessary precondition for insight; otherwise, spontaneous sudden realizations would be excluded because they are not associated with an explicit problem whose solution is blocked by another idea. Insights are often accompanied by surprise and a positive burst of conscious emotion, but we do not consider these to be defining features because individual insights in a sequence of insights, as occur in many experimental studies, don't all elicit such conscious affective responses. (Of course, this doesn't exclude the possibility that all insights may be accompanied by unconscious affective responses; cf. Topolinski & Reber 2010.) Phenomena such as impasse and emotion play important roles in problem solving and are worthy of study. However, isolating the core processes of insight is a prerequisite for investigating it. To accomplish this, we adopt a "Goldilocks" approach—neither too much nor too little—and argue that this strategy can, and has, enabled progress in understanding insight's neurocognitive substrates.

It is also critical to recognize that insight involves several component processes working together and unfolding over time. Experimental paradigms that emphasize one process over another will reveal different parts of this network. Such results may appear complex but actually paint a richer picture of insight, just as studying encoding and retrieval, or implicit and explicit learning, paints a more complete picture of how the brain supports memory.

SCOPE OF THE REVIEW

This review discusses the current state of cognitive neuroscience research on insight. Though we also discuss selected behavioral cognitive studies that inform the neuroscientific framework we describe, we do not provide an overall review of the relevant cognitive literature here. Recent reviews of the cognitive literature are available elsewhere (e.g., van Steenburgh et al. 2012). Moreover, our discussion of neuroscientific studies is not exhaustive. We focus on those that meet several methodological criteria.

The first desideratum is that a study must demonstrably isolate the insight phenomenon. Some studies present problems to participants and simply assume that the solutions are the result of insight rather than analytical thought. However, as described below, many types of problems can be solved by either insight or analysis (Bowden et al. 2005). Therefore, with some exceptions, we do not discuss studies that do not demonstrate that participants' solutions were, in fact, a product of insight. One exception to this criterion is studies that use classic insight problems, such as the Nine-Dot Problem, that have been used by researchers for many decades and for which a consensus has been tacitly reached—though perhaps not yet with sufficient justification—that solutions to these problems are usually achieved by insight (e.g., Chi & Snyder 2012).

A number of studies examine brain activity when people recognize rather than generate solutions (e.g., Ludmer et al. 2011, Luo et al. 2011, Metuki et al. 2012). People may feel a sense of insight upon recognizing solutions, but these postsolution recognition processes differ from the processes responsible for generating the solutions. Once people see a solution word, they can perform a directed semantic memory search to connect the solution to the problem rather than an open-ended search for associations that might lead to the solution. Although solution recognition is itself interesting, it differs from pure insight.

A second criterion is that a candidate study must use an appropriate control or comparison condition. For example, in studies that use remote associates problems or anagrams, insight solutions can be directly compared to analytic solutions for the same type of problem because this comparison controls for all factors except for the cognitive solving strategy—insight versus analytic processing—that is the factor of primary interest. We therefore do not focus on studies that directly compare neural activity for sets of problems that differ in complexity, solving duration (e.g., Aziz-Zadeh et al. 2013), visual content, working-memory load, and so forth (e.g., Sheth et al. 2008) because differences in cognitive strategy are confounded with these ancillary factors. We wish to highlight how insight solving differs from analytic solving when other factors are held relatively constant.

Other studies are not discussed here due to methodological issues that cannot be addressed on a study-by-study basis in an article of this scope, such as problematic baselining of neural activity (e.g., Sandkühler & Bhattacharya 2008). Another type of methodological issue involves the integration over time of functional magnetic resonance imaging (fMRI) signal. One study attempted to use both subjective (self-report) and objective measures to distinguish insight from analytic solving (Aziz-Zadeh et al. 2009). Unfortunately, the objective measure was speed of solution: It was assumed that fast solutions were achieved with insight and slow solutions were achieved analytically. Not only is this assumption questionable, it also completely confounds the experimental contrast with the duration of solving effort. Because fMRI signal is integrated over time—the longer an area is active, the more the measured signal will increase—it is very sensitive to such confounds. Thus, it is impossible to know which effects were real and which were confound related.

It is important to note that the studies that are not discussed here due to methodological issues are not entirely uninformative. However, careful consideration must be given to each of these issues in the context of interpreting the results.

COGNITIVE PSYCHOLOGY OF INSIGHT

Much of the cognitive psychology research on insight done over the past three decades aimed to clarify the relationship between insightful and analytic thought (Sternberg & Davidson 1995). Early gestalt studies distinguished insight and analysis almost solely on the basis of the informal conscious experience of a problem solution emerging suddenly versus gradually. To extend this research, cognitive psychologists attempted to uncover more formal evidence to distinguish these two types of processing. A prominent example is a pioneering series of studies done by Janet Metcalfe during the 1980s. For example, Metcalfe & Wiebe (1987) focused on metacognitive characteristics of insight such as participants' feelings of "warmth" (i.e., closeness to solution) while working on insight and analytic problems. Participants reported a gradual increase in feelings of warmth leading up to analytic solutions, but little or no warmth preceding insights until shortly before they solved the problem. Moreover, insight problems that were accompanied by feelings of warmth usually elicited incorrect solutions.

Metcalfe & Wiebe's (1987) study was groundbreaking in showing a behavioral difference between insight and analytic solving beyond factors that differentially affected solution rates for these two types of problems. However, because Metcalfe's study sampled participants' feelings only once every 15 seconds, it did not directly address one of the central characteristics thought to distinguish insight and analytic solving, namely, the suddenness of solution. Rather, her procedure was designed to examine changes over time in participants' feelings about their closeness to solution.

However, it is possible to measure the accrual of solution information with higher temporal resolution using the speed-accuracy decomposition procedure (Kounios et al. 1987, Meyer et al. 1988). This technique revealed no discernable partial response information preceding the solution when people solve insight-like anagrams (Smith & Kounios 1996). Thus, insight solving occurs in a discrete transition from a state of no conscious information about the solution to the final complete solution, with no intermediate states. In contrast, for similar speed-accuracy decomposition studies of other (noninsight) tasks, such as lexical decision, semantic verification, short-term recognition memory, and long-term recognition memory, people show evidence of substantial partial information (Smith & Kounios 1996). This finding objectively validated the conscious experience of the abruptness of insight.

The conscious experience of insight directly relates to unconscious processing that precedes it. When people solve problems (anagrams), they solve better and experience their solutions as more insight-like when, prior to solution, solution-related words are presented to them subliminally (Bowden 1997). The fact that a subliminal prime can spark a later insight supports the hypothesis that insight solutions are preceded by substantial unconscious processing rather than spontaneously generated. Similarly, when people respond to solution words before solving a problem, the amount of semantic priming for solution words—an index of related unconscious processing—is directly related to how they experience the recognition of the solution. Specifically, people show more solution priming when they recognize solution words with a feeling of sudden insight than when they recognize the words without an insight experience (Bowden & Jung-Beeman 2003b).

These studies are also notable for a methodological innovation. Much of the insight literature compares performance on so-called insight problems with performance on analytic problems, a distinction based largely on researchers' intuitions or introspections about sudden versus gradual solution. This phenomenological difference had rarely been measured and quantified in a rigorous way. Furthermore, applying the monikers "insight" and "analytic" to specific problems assumes that all participants will always solve insight problems insightfully and analytic problems analytically—hardly a safe assumption. To put insight research on a firmer empirical foundation, Bowden (1997) developed a procedure for soliciting participants' trial-by-trial judgments of whether a solution had been derived by insight or analysis. This technique has been validated by subsequent studies that have shown that the number of insight solutions and analytic solutions to a series of problems varies independently as a function of factors such as mood (Subramaniam et al. 2009) and meaningfully with respect to cognitive strategies (Kounios et al. 2008) and brain activations (Jung-Beeman et al. 2004, Kounios et al. 2006, Subramaniam et al. 2009). The insight judgment procedure has thus provided a foundation for subsequent neuroimaging studies of insight because it allows researchers to isolate the insight phenomenon by controlling for ancillary differences between problems that were solved insightfully and analytically (Bowden et al. 2005, Kounios & Beeman 2009).

The development of short problems solvable by insight (Bowden & Jung-Beeman 2003a) has also proved useful in later neuroscience studies. Early studies of insight typically posed a small number of complex problems to participants. Most participants take many minutes to solve such problems, when they are able to solve them. However, neuroimaging and electrophysiological methods require many trials to accurately record brain activity. An alternative approach uses a relatively large number of structurally identical verbal problems, called remote associates problems, modeled after one type of problem developed by Mednick for his remote associates test of creativity (Mednick 1962). Bowden & Jung-Beeman (2003a) developed a set of compound remote associates problems that consist of three words (e.g., pine, crab, sauce). The participant's task is to think of a single solution word (apple) that will form a compound or familiar phrase with each of the three problem words (pineapple, crabapple, applesauce).

Remote associates problems are well suited to neuroimaging and electrophysiological studies. Large numbers of these problems have been developed, allowing for neuroimaging and electrophysiological studies with a sufficient number of trials per condition. Other types of short problems can serve this function as well. For example, anagrams have also been used with the insight judgment procedure (Bowden 1997, Kounios et al. 2008).

NEURAL BASIS OF INSIGHT

Hemispheric Asymmetry

Much of the research on the neural basis of insight has been framed by hemispheric differences, namely, that the right hemisphere contributes relatively more to insight solving than to analytic solving, whereas the left hemisphere contributes more to analytic solving than to insight solving. This hypothesis particularly influenced the experimental methods and predictions of early cognitive neuroscience studies of insight. For instance, several studies used visually lateralized probe words to detect and compare semantic processing in the hemispheres while participants worked on remote associates problems. On trials for which participants failed to solve problems within a time limit, they still showed semantic priming for the solution words by responding to solution word probes more quickly than to unrelated word probes. Importantly, this solution priming was especially pronounced when the solution word probes were presented to the left visual field, thus being directed initially to the right hemisphere (Beeman & Bowden 2000, Bowden & Beeman 1998). Furthermore, enhanced priming in the right hemisphere occurred only when participants reported that they recognized a solution word probe with a feeling of insight (Bowden & Jung-Beeman 2003b).

This rightward asymmetry of insight processing was predicted (Bowden & Beeman 1998) on the basis of prior evidence of right hemisphere involvement in integrating distant semantic relations in language input (e.g., St George et al. 1999) as well as a theoretical framework that describes the right hemisphere as engaging in relatively coarser semantic coding than the left hemisphere (Jung-Beeman 2005). This framework incorporates neuropsychological and neurological evidence of subtle comprehension deficits following right hemisphere brain damage with neuroanatomical findings of asymmetric neuronal wiring.

According to the coarse semantic coding framework, when readers or listeners encounter a word or concept, they activate a semantic field related to the word: a subset of features, properties, and associations of that word. Evidence suggests that the left hemisphere strongly activates a relatively smaller semantic field of features, those most closely related to the dominant interpretation or the current context; in contrast, the right hemisphere weakly activates a relatively broader semantic field, including features that are distantly related to the word or context (Chiarello 1988, Chiarello et al. 1990). Despite some obvious limitations, coarser semantic coding in the right hemisphere has one big advantage: The less sharply each word's meaning is specified, the more likely it is to connect to other words and concepts. This is a key ingredient for drawing inferences (Virtue et al. 2006, 2008), extracting the gist (St George et al. 1999), comprehending figurative language (Mashal et al. 2008), and for insight.

The coarse semantic coding notion is more than a metaphor. Rather, it potentially links asymmetric semantic processing to asymmetric brain wiring. Aside from some size asymmetries in particular regions of cortex (such as Broca's area and Wernicke's area), lateralized cytoarchitectonic differences also influence how neurons integrate inputs (for a review, see Hutsler & Galuske 2003). In brief, pyramidal neurons collect inputs through their dendrites. Differences in synaptic distributions along dendrites influence the type of inputs that cause these pyramidal neurons to fire. The range of cortical area over which neurons collect inputs could be termed their input fields. In association cortices in or near language-critical areas, such as Wernicke's area, Broca's area, and the anterior temporal cortex, right hemisphere neurons have larger input fields than do left hemisphere neurons (e.g., Jacob et al. 1993, Scheibel et al. 1985, Seldon 1981). Specifically, right hemisphere pyramidal neurons have more synapses overall and especially more synapses far from the cell body. This indicates that they have larger input fields than corresponding left hemisphere pyramidal neurons. Because cortical connections are spatially organized, the right hemisphere's larger input fields collect more differentiated inputs, perhaps requiring a variety of inputs to fire. The left hemisphere's smaller input fields collect highly similar inputs, likely causing the neuron to respond best to somewhat redundant inputs. Outputs from neurons appear to show similar asymmetry; for example, axons in superior temporal cortex are longer in the right hemisphere than in the left hemisphere, favoring more integrative processing in the right hemisphere (Tardif & Clarke 2001).

These neuroanatomical asymmetries could contribute to the right hemisphere's bias to engage in coarser semantic coding and the left hemisphere's bias to engage in finer (i.e., less coarse) semantic coding. As previously noted (Jung-Beeman 2005), there is a huge gap between descriptions of dendritic branching and modes of language processing or problem solving. However, the asymmetries that exist in neuronal wiring almost certainly influence information processing, and the asymmetries that indisputably exist in language processing must have some neuroanatomical basis. The coarser semantic coding framework attempts to bridge that gap. In so doing, it also provides an avenue for future research on the relationship between neural microcircuitry and higher cognitive functions.

Neural Correlates of Insight Solving

Further specification of the neural bases of insight can be achieved through neuroimaging studies. These studies have identified a number of distinct components of insight and have generally supported the idea that the right hemisphere contributes relatively more to insight than to analytic solving.

One early neuroimaging study of insight isolated neural correlates of the insight experience with both fMRI and high-density EEG in separate experiments matched as closely as possible for procedure (Jung-Beeman et al. 2004). EEG has excellent temporal resolution but limited spatial resolution. It is therefore good at circumscribing a neural process in time. fMRI has excellent spatial resolution but limited temporal resolution and is therefore best suited to localize a neural event in space. Together these techniques were able to isolate insight's neural correlates in both space and time. This combination of methods was crucial, because fMRI's power to localize insight-related neural activity would have been less informative without knowing whether these neural correlates occurred before, after, or at the moment of solution. A neural correlate of the insight experience itself would have to occur at, or immediately prior to, the moment of conscious awareness of a solution.

At the moment when people solve problems by insight, relative to solving identical problems by analytic processing, EEG shows a burst of high-frequency (gamma-band) EEG activity over the right temporal lobe, and fMRI shows a corresponding change in blood flow in the medial aspect of the right anterior superior temporal gyrus (Jung-Beeman et al. 2004) (**Figure 1**). In the initial fMRI experiment, this right temporal area was the only area exceeding strict statistical thresholds, but weak activity was detected in other areas, including bilateral hippocampus and

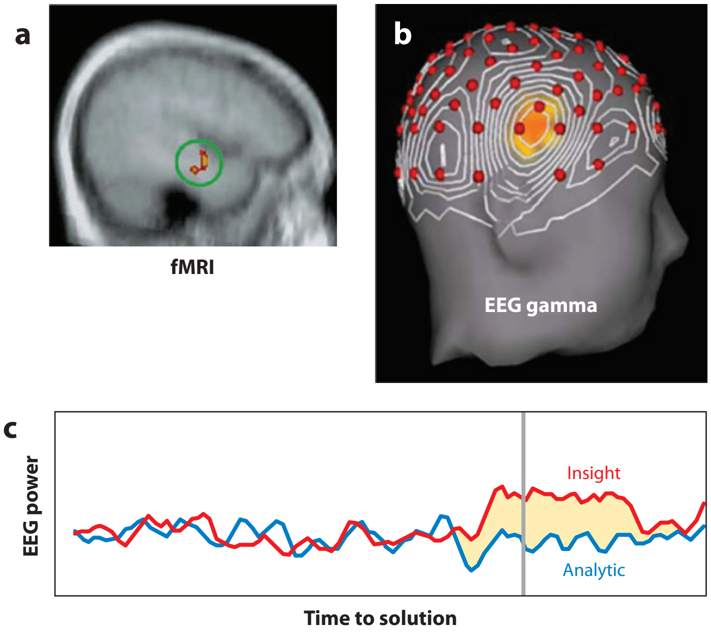

Figure 1

Neural correlates of insight. (*a*) Insight-related blood oxygen–level dependent (BOLD) activity in the right anterior superior temporal gyrus recorded by functional magnetic resonance imaging (fMRI). (*b*) Insight-related gamma-band oscillatory activity recorded by electroencephalogram (EEG) over the anterior right temporal lobe. (*c*) Time course of insight- and analysis-related gamma-band EEG power recorded at a right anterior electrode. The vertical gray line marks the point in time at which participants made a bimanual button press to indicate that they had solved a problem. EEG power leading up to insight and analytic solutions diverges at approximately 300 ms before the bimanual button press. Taking into consideration that a button press requires about 300 milliseconds to initiate and execute (Smith & Kounios 1996), the insight-related burst of gamma activity occurred at approximately the time at which the solution to the problem became available to participants. Adapted from Jung-Beeman et al. (2004), with permission.

parahippocampal gyri and anterior and posterior cingulate cortex. In a later replication with more participants and stronger imaging methods (Subramaniam et al. 2009), the same network of areas all far exceeded critical statistical threshold, with the right anterior temporal region again being the strongest. The close spatial and temporal correspondence of the fMRI and EEG results obtained by Jung-Beeman et al. suggested that they were produced by the same underlying brain activation. This right temporal brain response was identified as the main neural correlate of the insight experience because (*a*) it occurred at about the moment when participants realized the solution to each of these problems, (*b*) the same region is involved in other tasks demanding semantic integration (St George et al. 1999); and (*c*) gamma-band activity has been proposed to be a mechanism for binding information as it emerges into consciousness (Tallon-Baudry & Bertrand 1999). Alternative interpretations of this finding were rejected based on considerations of timing, functional neuroanatomy, etc.

The burst of gamma-band EEG activity in the right temporal lobe was not unexpected, given earlier visual half-field studies (Beeman & Bowden 2000, Bowden & Beeman 1998, Bowden & Jung-Beeman 2003b). However, the EEG results revealed another, totally unexpected, finding. The insight-related gamma-band activity was immediately preceded by a burst of alpha-band activity (10 Hz) measured over right occipital cortex (Jung-Beeman et al. 2004) (see **Figure 2**).

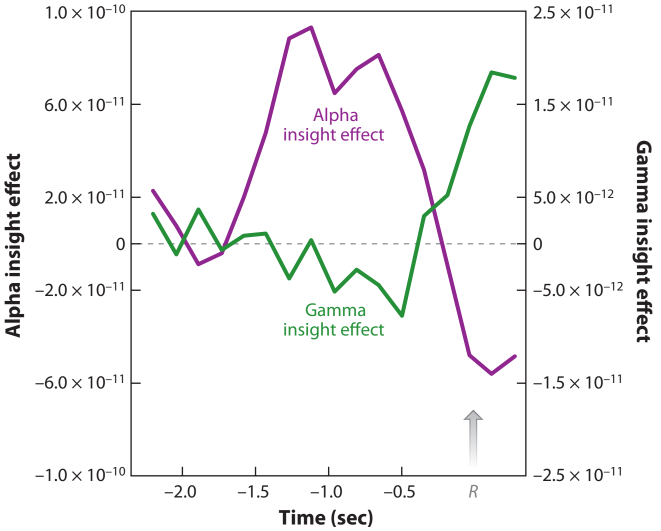

Figure 2

The time course of the insight effect. Alpha power (9.8 Hz at right parietal-occipital electrode PO8) and gamma power (39 Hz at right temporal electrode T8) for the insight effect (i.e., correct insight solutions minus correct noninsight solutions, in v^2). The left *y*-axis shows the magnitude of the alpha insight effect (*purple line*); the right *y*-axis applies to the gamma insight effect (*green line*). The *x*-axis represents time (in seconds). The gray arrow and *R* (at 0.0 sec) signify the time of the button-press response. Note the transient enhancement of alpha on insight trials (relative to noninsight trials) prior to the gamma burst.

Alpha-band oscillations reflect neural inhibition; occipital alpha reflects inhibition of visual inputs, that is, sensory gating (Jensen & Mazaheri 2010). It appears likely that the preinsight alpha burst reflects transient sensory gating that reduces noise from distracting inputs to facilitate retrieval of the weakly and unconsciously activated solution represented in the right temporal lobe (Jung-Beeman et al. 2004; cf. Wu et al. 2009). This idea is analogous to the common behavior of closing or averting one's eyes to avoid distractions that would otherwise interfere with intense mental effort.

The discovery of transient sensory gating immediately preceding the insight-related burst of gamma-band activity suggested a promising research strategy. Previous behavioral research had demonstrated the discrete, all-or-nothing nature of insight solutions (Smith & Kounios 1996). On the other hand, visual hemifield solution-priming studies showed that insight, though consciously abrupt, is preceded by unconscious processing, primarily in the right hemisphere (e.g., Bowden & Beeman 1998). So, an insightful solution is a discrete phenomenon in terms of its availability to awareness, but it is preceded by unconscious neural precursors. It should therefore be possible to trace these neural precursors backward in time from the gamma burst at the moment of insight to reveal the brain mechanisms that unfold to produce an insight.

Preparation for Insight

Before people even start to tackle a problem, their state of mind—and their brain activity—predisposes them to solve either by insight or analytic processing. Participants' neural activity, assessed with both EEG and fMRI during a task-free preparation phase prior to each remote associates problem, shows that such predispositions do occur: Distinct patterns of neural activity precede problems that people eventually solve by insight versus those that they solve by analysis

(Kounios et al. 2006). EEG showed that preparation for analytic solving involves increased neural activity (i.e., decreased alpha-band activity) measured over visual cortex, hypothesized to reflect outward focus of attention directed to the computer monitor on which the next problem in the sequence was to be displayed. Both EEG and fMRI revealed that preparation for insight solving involves activation of the anterior cingulate and bilateral temporal cortices. The temporal lobe activation suggests that cortical regions involved in lexical and semantic processing are prepared to respond. Previous research implicates anterior cingulate cortex in monitoring other brain regions for conflicting action tendencies (Botvinick et al. 2004). Kounios et al. (2006) expanded on this notion of conflicting action tendencies to propose that the anterior cingulate's role in problem solving is to detect the activation of conflicting solution possibilities or strategies. If the anterior cingulate is sufficiently activated at the time a problem is presented, then it can detect the weak activation of nondominant solution possibilities, enabling attention to switch to one of these weakly activated ideas. Switching attention to a nonobvious solution brings the idea to awareness as an insight. However, when the anterior cingulate is relatively deactivated prior to the presentation of a problem, attention is dominated by the more obvious associations and solution possibilities afforded by the problem.

Thus, the transient state of one's attentional focus, varying from trial to trial, helps to determine the range of potential solutions that a person is prepared to consider when a problem is presented: Outwardly directed attention coupled with low anterior cingulate activity focuses processing on the dominant features or possibilities of a situation; inwardly directed attention and high anterior cingulate activity heightens sensitivity to weakly activated remote associations and long-shot solution ideas.

One important, but unresolved, issue is to what extent such preparatory activity is under voluntary control and to what extent spontaneous shifts of attention may be involved. Kounios et al. (2006) found no evidence of any trial-to-trial sequential clusters of insight or analytic solutions that would suggest slow spontaneous shifts of attention. However, this kind of analysis would not be capable of showing attention shifts on a timescale shorter than the duration of a single trial (i.e., approximately 10 sec.). Identifying any neural correlates of possible strategic or spontaneous attention shifts is therefore an important focus for future investigations. Progress in elucidating the role of attention shifts would suggest practical techniques for controlling or enhancing cognitive style.

Resting-State Brain Activity and Individual Differences

Given that transient shifts in attention influence whether people solve by analysis or by insight, do any longer-lasting states or traits influence this preparatory activity and the corresponding predisposition to solve by insight or analysis? One approach is to examine whether individual differences in resting-state brain activity while people have no task to perform or any particular expectation about what will follow may influence their subsequent problem-solving style. In one study, we recorded participants' resting-state EEGs before tasking them with solving a series of anagrams (Kounios et al. 2008). Participants were classified as high insight or low insight based on the proportion of problems they solved with insight. These groups exhibited different patterns of resting-state EEGs, suggesting that the insightful and analytic cognitive styles have their origins in, or are at least related to, distinct patterns of resting-state neural activity. The differences between these patterns highlighted two general phenomena.

Insightful individuals show greater right hemisphere activity at rest, relative to analytic individuals, consistent with the idea of insight-related right hemisphere bias described above. The fact that an insight-related hemispheric difference can be found in the resting state suggests that the functional hemispheric asymmetry occurring during problem solution (Jung-Beeman et al.

2004) may have its origin in structural hemispheric differences among people, such as the cytoarchitectonic differences described above (Jung-Beeman 2005) or in asymmetries of structural or functional connectivity.

Insightful individuals also showed greater diffuse activation of visual cortex compared to analytical individuals, even when resting-state EEGs were measured while participants' eyes were closed (Kounios et al. 2008). This finding mirrors earlier behavioral research showing that highly creative individuals tend to have diffuse attention when at rest or when cognitive resources are not dominated by a task (e.g., Ansburg & Hill 2003, Carson et al. 2003).

Resting-state EEG can be perturbed by stimuli but otherwise is relatively stable; in fact, behavioral genetics studies show that individual differences in resting-state EEG have a substantial genetic loading largely attributable to individual differences in gray matter and white matter volume (Smit et al. 2012). It is not yet known whether insight-related individual differences in resting-state EEG are a subset of the genetically loaded individual differences in EEG or brain volume, but if so, this would be a promising avenue of investigation into the stability and origins of cognitive style.

Studies of insight-related resting-state brain activity may also provide a link to recent social psychological research on construal level. According to construal level theory, psychological "distance"—thinking about things that are far away in space or time, or about people that are different from oneself—engages abstract thinking (Trope & Liberman 2010). Based on this idea, Förster et al. (2004) predicted that priming people to think about the distant future would bias them to think abstractly, which in turn would induce a person to think more insightfully and creatively; conversely, priming people to think about the near future would bias them to think concretely and therefore analytically. Their studies supported these predictions: Participants primed by asking them to think about the distant future subsequently did better on insight and creativity tasks; those asked to think about the near future did better on analytic tasks. These results are particularly interesting because construal-level priming may influence task-related cognition by transiently altering the resting-state brain activity from which task-related brain activity emerges. A potentially fruitful line of research would be to examine how various types of priming might influence the tendency to solve problems insightfully or analytically by imposing transient changes in resting-state brain activity.

Thus, distinct patterns of neural activity are associated with insight versus analytic solving at the moment of insight, in the last two seconds leading up to that moment, in the preparation phase prior to presentation of a problem, and even in resting-state brain activity of individuals who tend to solve by insight contrasted with those who tend to solve analytically. These findings objectively substantiate an abundance of behavioral evidence that indicates insight solving differs from analytic solving and that these solving styles result from different tunings of the network of brain areas involved in problem solving. Moreover, the specific areas associated at each distinct stage of solving (or preparation) help inform theories of how insight is different from analysis. Compared to analytic solving, insight requires greater input from and integration of relatively coarser semantic processing of right hemisphere temporal areas, greater sensitivity to competing responses in cognitive control mechanisms supported by the anterior cingulate cortex, and a relative emphasis on internal processing and de-emphasis on external stimuli.

ATTENDING IN, OUT, AND AROUND

A prominent theme in insight and creativity research is the role that attention deployment plays in cognitive style. Though a number of behavioral studies have observed that highly creative individuals have diffuse attention, taken as a whole, neuroimaging and electrophysiological studies of insight suggest that attention plays a more nuanced role. Neural activity during the preparatory phase suggests that attention can also be focused outwardly on external objects or inwardly on internal knowledge in memory (see Chun et al. 2011), which influences the likelihood that people will solve with insight (Kounios et al. 2006, Wegbreit et al. 2012).

Occipital alpha-band EEG activity reflects visual cortex inhibition that protects fragile internal processing from potentially interfering or distracting perceptual inputs (Ray & Cole 1985). Levels of occipital alpha during the different phases leading up to the solution of a problem suggest that (*a*) during the resting state, insightful individuals have more externally oriented attention than do analytical individuals (Kounios et al. 2008); (*b*) during the preparation phase prior to the presentation of a problem that will be solved by insight, there is greater internal focus of attention (Kounios et al. 2006); and (*c*) just before the emergence of an insight, there is another brief burst of inward focus (Jung-Beeman et al. 2004).

Thus, the notion that insight is associated with diffuse attention appears to be an oversimplification. Insightful individuals may generally have more diffuse and outwardly directed attention, but successful insight solving involves transiently redirecting attention inwardly during the preparation for and solving of a problem. It therefore appears that the tendency to solve problems insightfully is associated with broad perceptual intake as the default mode of resting-state attention deployment, coupled with the tendency to focus inwardly in preparation for, and during, solving. In contrast, analytical people's resting-state attention is less outwardly focused during the resting state and less inwardly directed during preparation and solving.

FACTORS THAT INFLUENCE THE LIKELIHOOD OF INSIGHT

Understanding the factors that can increase or reduce the likelihood of experiencing insight is important for both theoretical and practical reasons. Besides contributing toward the development of a theoretical model of insight, understanding these factors also suggests strategies for its enhancement outside the laboratory. Here we focus on the interrelated factors of mood, attention, and cognitive control.

Mood

Positive affect enhances insight and other forms of creativity, both when the mood occurs naturally and when it is induced in the laboratory (e.g., Ashby et al. 1999, Isen et al. 1987). Though some aspects of creative production may be impeded by positive mood or aided by other moods such as depression (Verhaeghen et al. 2005), insight and related processes seem to benefit from greater positive mood (or reduced anxiety) either when participants enter the lab in a relatively positive mood or after they watch funny film clips (H. Mirous & M. Beeman, manuscript submitted; Subramaniam et al. 2009). Facilitation of insight by positive mood has also been demonstrated in the workplace, as documented by diaries and self-reports (Amabile et al. 2005).

Mood influences other cognitive abilities that are related to insight and creativity. For example, positive mood facilitates intuition, the ability to make decisions or judgments about stimuli without conscious access to the information or processes influencing their behavior. When people are working on remote associates problems, they show better-than-chance judgment about whether individual problems are solvable before they are able to state the solution; such intuitive judgments are improved after people recall happy autobiographical events and are impeded after recalling sad autobiographical events (Bolte et al. 2003).

Finding or intuiting the presence of a solution to a remote associates problem requires a person to access weak associations of the problem words because the solution is typically not a strong associate of all three problem words. Thus, the presentation of the problem will evoke only weak activation of the solution's representation. Positive mood seems to broaden the scope of semantic processing to make such weak associations more accessible (Isen & Daubman 1984, Isen et al. 1985). For instance, the amplitude of the N400 component of the event-related potential (ERP) is inversely proportional to the relatedness of a word to its semantic context (Kounios 1996), and N400 semantic relatedness effects are modulated by mood. When a positive mood is induced, target words that loosely fit their semantic context elicit a smaller N400 than when the participant is in a neutral mood (Federmeier et al. 2001). This indicates that a positive mood makes a word seem less incongruent with its semantic context. Additionally, when people listen to stories that imply specific causal events without stating them explicitly, they show sensitivity to semantic information that is related to the implicit inference. Specifically, they read or respond to probe words that are related to an implicit inference more quickly than they read or respond to unrelated probe words. Such inference-related priming normally occurs earlier and more strongly for words presented to the right hemisphere (left visual field) than for words presented to the left hemisphere (right visual field) (Beeman et al. 2000). But people show stronger inference-related priming to inference-related words presented in the middle of the visual field while listening to stories after watching funny film clips than after watching emotionally neutral films; they show no inference-related priming after watching scary film clips that induce anxiety (H. Mirous & M. Beeman, manuscript submitted).

Recently it has also been argued that the relation between broad associations and positive mood is bidirectional, making it possible to induce a positive mood by instructing or otherwise inducing participants to process remote associations (Bar 2009, Brunyé et al. 2013). According to this idea, a positive mood both facilitates insight and is enhanced by it. This shows deep integration of cognitive and affective processes and relates to many everyday behaviors, such as peoples' enjoyment of verbal puzzles, especially those with surprising solutions.

The fact that people engage in coarser semantic coding when they are in a positive mood compared to when they are in neutral or anxious mood raises the possibility that positive mood may selectively activate right hemisphere semantic processing. However, as of yet, there is no evidence to support this hypothesis. For example, the neuroimaging study of insight and mood by Subramaniam et al. (2009) found no evidence of lateralized differences in brain activity that were attributable to mood.

Mood and Attention

A more likely hypothesis is that mood influences the likelihood of insight by modulating attention or cognitive control, which in turn modulates semantic processing. For example, anxiety narrows the scope of attention by eliciting excessive focus on the center of one's field of vision—which usually includes the source of the threat—to the exclusion of peripheral information (Easterbrook 1959). From the evolutionary standpoint, this makes great sense: Early humans spotting a lion on the African savannah would not want to be distracted by less important stimuli. In contrast, positive mood appears to broaden attention. It increases the perception and utilization of global and peripheral perceptual features at the expense of the local details of complex stimuli by spatially broadening the "spotlight" of attention (Gasper & Clore 2002). For example, in a task that requires participants to respond to a centrally located target stimulus and disregard other stimuli that flank it, a positive mood increases both facilitation and interference of target processing attributable to the flanking stimuli (Rowe et al. 2007). Beyond visual processing, positive mood seems to broaden the processing of novel and varied stimuli, stimulating exploratory behavior (Fredrickson & Branigan 2005).

Models of Attention

One possibility is that mood affects the balance between two brain systems: an anterior attention network that maintains top-down control over perceptual processing in the service of goals and a posterior network involved in bottom-up attentional capture by salient stimuli. According to attentional control theory, anxiety shifts the balance away from the top-down system toward the bottom-up system (Derakshan & Eysenck 2009), leading to enhanced distractibility by task-irrelevant stimuli, especially threatening stimuli (Bar-Haim et al. 2007). This view suggests that anxiety shifts attention toward external stimuli and away from internal representations, states, and goals; positive affect may have the opposite effect.

In practice, attentional control theory makes predictions that are similar to those of the spotlight model of attention. Moreover, it links positive mood with internally focused attention in a way that is consistent with research implicating both of these factors in preparation for insight (Kounios et al. 2006, Subramaniam et al. 2009). Attentional control theory is therefore a promising direction for future insight research.

One important question is why changes in the breadth of perceptual attention due to mood and other factors should be related to changes in the breadth or narrowness of thought to include or exclude remote associations, what Rowe et al. (2007) called conceptual attention. Rowe et al. demonstrated that a positive mood both increases the breadth of visual attention to include stimuli that flank a target and enhances performance on remote associates problems that, as noted, require access to distant associations of the problem words. Rowe et al. (2007) argued that perceptual and conceptual attention are closely linked.

Current attention theory can be expanded to include both phenomena. The biased competition model of attention characterizes the neural computations subserving vision as a process of competition between the representations of the stimuli in the visual field (Desimone 1998). This competition can be biased to favor a particular stimulus by a variety of factors, including externally driven (bottom-up) and internally driven (top-down) processes. Such biasing is manifested as an increase in the neural activity subserving one of the representations.

A similar mechanism may underlie the conceptual processing that occurs during problem solving. According to this idea, the presentation of a problem activates a number of associations in a person's memory. Dominant associations are strongly activated; nondominant ones are weakly activated. All of these associations compete for processing resources, though under normal circumstances, the dominant associations win the competition for further processing. However, top-down mechanisms can bias this competition toward weak associations by actively selecting nondominant representations; by expanding the scope of attention to boost activation of nondominant representations; or, simply, by not suppressing the less dominant associations when the dominant ones capture the spotlight. Dominant associations are already as activated as they can be, so expanding the scope of attention would benefit weak associations more than it would do for strong ones, giving weak associations a greater opportunity to capture attention and spark an insight. Bottom-up processes can also bias the competition between ideas. Stimuli in the surrounding environment that are related to the solution can intervene to bias processing toward a weak association by acting as a hint that triggers an insight (Bowden 1997, Seifert et al. 1995). Thus, the biased competition model may be generalized to explain the role of conceptual attention in problem solving by insight.

Cognitive Control

Other research has focused on the role of cognitive control, especially the ability to maintain or switch between different thoughts, actions, and goals. People often focus on a task or goal to shield it from distraction. In other cases, especially in creative tasks, people need to flexibly switch between different processes, associations, or goals. These two functions, task shielding and task switching, appear to be in direct competition: The need for flexible switching demands relaxation of task shielding and leaves processing open to distraction (Dreisbach 2012). Positive affect enhances task switching but yields increased distractibility (Dreisbach & Goschke 2004).

As noted above, preparation for insight involves increased activity in the anterior cingulate during the preparatory period preceding a problem (Kounios et al. 2006). Anterior cingulate activation is hypothesized to be a sign that problem solvers are sensitized to competing, nondominant associations that they can switch to, resulting in an insight. When a person is in a positive mood, the preparation period shows stronger anterior cingulate activation than occurs for people not in a positive mood. In fact, the anterior cingulate was found to be the only brain area whose activation varies with mood, preparation for insight versus analytic processing, and later insight versus analytic solving (Subramaniam et al. 2009).

The anterior cingulate has long been recognized as a critical component of the cognitive control network. One hypothesis, backed up by substantial evidence, is that this brain region monitors other regions for competing action tendencies or stimulus representations (Kerns et al. 2004, Weissman et al. 2005). It has been proposed to be an interface between emotion and cognition (Allman et al. 2001, Bush et al. 2000, Lane et al. 1998) in part because some (ventral) regions of the cingulate are important for emotional processing (Mayberg et al. 1999).

Another brain area implicated in insight-related cognitive control is prefrontal cortex. Considerable evidence supports the idea that prefrontal cortex exerts control over other brain regions in response to input from the anterior cingulate signaling the presence of cognitive conflict (Miller & Cohen 2001). According to this idea, modulation of insight solving due to changes in anterior cingulate activity should be mediated, at least in part, by control signals originating in prefrontal cortex that limit the range of possibilities that a person considers when working on a problem. This limiting function is ordinarily helpful because it focuses the solver on a small number of the most viable solution paths to avoid computational overload. However, it can be a hindrance when a person tries to solve a problem whose solution lies on a nonobvious solution path. In support of this idea, patients with damage to lateral prefrontal cortex were better able to solve matchstick insight problems than were healthy control participants (Reverberi et al. 2005).

STIMULATING INSIGHT

One limitation of neuroimaging and electrophysiological studies is that they are inherently correlational—they don't directly show that the recorded patterns of brain activity cause the measured changes in behavior or experience. But the advent of brain stimulation techniques now affords the opportunity to treat brain activity as an independent variable rather than a dependent one.

Recent efforts have applied one brain-stimulation technique, transcranial direct current stimulation (tDCS), to attempt to enhance insight solving. Two recent studies have yielded promising results (Chi & Snyder 2011, 2012). Researchers tested the hemispheric hypothesis of insight by applying facilitatory (anodal) stimulation to right frontal-temporal cortex and inhibitory (cathodal) stimulation to left frontal-temporal cortex. This pattern of stimulation, but not the reverse hemispheric pattern, significantly enhanced solution rates for the nine-dot problem and for an insight matchstick problem. This stimulation protocol yielded especially dramatic enhancement for the classic nine-dot problem, increasing the solution rate from 0% to 40%. Additional studies have found that stimulation interfering with left dorsolateral prefrontal cortex facilitates solving compound remote associates problems (Metuki et al. 2012) or flexibly generating unusual uses for objects (Chrysikou et al. 2013). These studies suggest that such tasks benefit from the release of cognitive control that would otherwise maintain focus on fine semantic coding in the left hemisphere; however, neither of these studies specifically contrasted insight versus analytic performance.

Such stimulation studies are encouraging initial efforts that provide striking support for the claim that insight depends relatively more on right than on left temporal lobe processes. They also raise the alluring possibility that someday brain stimulation techniques will be refined to the point at which individuals grappling with difficult problems may have the option of donning a "thinking cap" that will increase their ability to find solutions. However, it should be kept in mind that these early studies—similar to other groundbreaking studies—raise as many questions as they answer. For example, this stimulation protocol simultaneously stimulated right frontal-temporal cortex and inhibited left frontal-temporal cortex (Chi & Snyder 2012). It is not yet known whether it was the right frontal-temporal stimulation, the left frontal-temporal inhibition, or the combination of the two that facilitated solving these insight problems. Moreover, it is not yet known whether this tDCS protocol actually increased the probability that participants solved these problems insightfully or whether it increased the probability that they solved the problems analytically. As we have noted, most problems can be solved by either strategy. The fact that researchers have considered the nine-dot and matchstick-type problems to be insight problems doesn't preclude the possibility that they can be solved analytically. These studies did not assess the strategies that their participants employed, so all that is known is that the solution rates for these problems increased rather than how or why they increased. Thus, much foundational work must be done before tDCS can be considered a realistic possibility for adaptively modifying people's cognitive strategies.

Pharmacological intervention is another route to insight enhancement. To date, we are aware of no studies that use drugs to attempt selective facilitation of insight solving. However, the recent demonstration that alcohol can enhance insight, but not analytic, solving of remote associates problems shows that pharmacological promotion of insight is achievable (Jarosz et al. 2012).

FUTURE DIRECTIONS

Neuroimaging and electrophysiological techniques have begun to reveal neural substrates of insight that were invisible to behavioral research. This has led to progress in understanding how insight emerges from more basic cognitive mechanisms. Technologies for stimulating insightful thought are becoming available, including intervention by direct brain stimulation.

Nevertheless, from our current vantage point, it is important to keep in mind that the surface has barely been scratched. Research has shown that multiple component processes and corresponding neural substrates are involved, and some of these are susceptible to subtle shifts in attention, mood, and other factors. Refined methods will expand on the research we have described and contribute new findings from connectivity and network analyses. And one can only guess what will be uncovered by future studies of insight-related individual differences in neuroanatomy, cytoarchitectonics, and genetics. The psychopharmacology of insight and creativity, currently virtually unexplored, holds out the promise of contributing both to our scientific understanding of insight and to methods for enhancing it. Further research will reveal the limits and applicability of brain stimulation, neurofeedback, and cognitive training techniques for enhancing insight and, more generally, influencing and optimizing cognitive styles to suit different circumstances. The study of insight began in the early twentieth century, but a century from now, researchers may look back at the early twenty-first century as the beginning of a golden age of insight research.

SUMMARY POINTS

1. Insight is any sudden comprehension, realization, or problem solution that involves a reorganization of the elements of a person's mental representation of a stimulus, situation, or event to yield a nonobvious or nondominant interpretation. Insight is sudden, but it is preceded by substantial unconscious processing.
2. Some critical components of insight are preferentially associated with the right cerebral hemisphere. Insight culminates with a sharp increase in neural activity in the right anterior temporal lobe at the moment of insight.
3. Insights are immediately preceded by a transient reduction of visual inputs that apparently reduce distractions and boost the signal-to-noise ratio of the solution.
4. Neural activity immediately before the presentation of an expected problem predicts whether that problem will be solved by insight or analytically. Such preparation for insight involves inwardly directed attention; preparation for analysis involves outwardly directed attention.
5. Resting-state neural activity biases later processing to favor insight or analytical problem solving.
6. Positive mood facilitates insight by increasing attentional scope to include weakly activated solution possibilities.
7. Direct stimulation of right frontal-temporal cortex coupled with inhibition of left frontal-temporal cortex enhances solving of insight problems.
8. Cognitive neuroscience methods have contributed exciting new results and theories of insight; nevertheless, insight research is still in a very early stage. Continuing applications of new methods, paradigms, and models hold much promise for additional substantial progress.

FUTURE ISSUES

1. How and when can insight be facilitated? People often ask how they can foster more insightful thinking, even though in many situations and for many problems, analytic processing would be more effective. At the least, problems must be deeply analyzed [what Graham Wallas (1926) termed immersion] before an insight solution can be achieved. So the question becomes when insight should be facilitated. We suggest that the right time to facilitate insight is when semantic integration processes activate the representation of a potential solution to a level just below the threshold for consciousness, setting the stage for an aha moment. Thus, honing intuition to sense the presence of a subthreshold solution may be the first step toward facilitating insight. At this time, inducing a positive mood and broadening attention through various means, and not directly focusing on the problem, is likely to increase the chance of achieving insight.

2. What individual differences in attention or cognitive control are most conducive to insight? Recent work shows that while in the resting state and not engaged in any task, individuals who tend to solve by insight deploy attention differently from individuals who are more analytic. What is the best way to characterize this pattern of differences? Do high-insight individuals deploy attention externally at rest and internally during solving? Or do they just deploy their attention in a less-focused manner? Do these differences primarily occur in bottom-up attention or primarily in top-down attention and cognitive control? How tightly coupled are insight-related individual differences in visual cortex and those in the anterior cingulate? Do individual differences in insightfulness have a genetic basis?
3. How do individual differences in processes that support insight interact? In general, positive mood facilitates insight by encouraging broader or less selective attention. However, a greater tendency or ability to solve problems with insight may also be associated with individual differences in other factors that cause broad associative thinking, such as schizotypy (Folley & Park 2005). It is possible that for individuals who typically think more broadly, anxiety would facilitate solving by focusing their attention to harness their broader associative processes toward a useful solution.
4. How does insight problem solving relate to other creative behavior? Insight is considered a critical facet of creative cognition. However, creativity is a highly complex behavior. Although aspects of creativity may be entirely unrelated, others are likely linked, perhaps sharing similar patterns of attention. How do insight, intuitive decision making, divergent thinking, and creative achievement relate to each other, and to attention and cognitive control?

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