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Mary Vitello and Carola Salvi *

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Review

Gestalt's Perspective on Insight, a Recap Based on Recent Behavioral and Neuroscientific Evidence

Mary Vitello [1] and Carola Salvi [2,3,*]

[1] University of California, Los Angeles, Department of Psychology
[2] John Cabot University; carola.salvi@johncabot.edu
[3] University of Texas at Austin; carola.salvi@austin.utexas.edu
* Correspondence: carola.salvi@austin.utexas.edu;

Abstract: The Gestalt psychologists' theory of insight problem-solving was based on a direct parallelism between perceptual experience and higher-order forms of cognition (e.g., problem-solving). Similarly to the sudden recognition of an ambiguous figure, they contended that problem-solving involves a restructuring of one's initial representation of the problem's elements, leading to a sudden leap of understanding phenomenologically indexed by the "Aha!" feeling. Over the last century, different scholars discussed the validity of the Gestalt psychologists' perspective foremost using the behavioral measures available at the time. However, in the last 2 decades, scientists gained a deeper understanding of insight problem-solving due to the advancements in cognitive neuroscience. This review aims to provide a retrospective reading of Gestalt theory based on the knowledge accrued by adopting novel paradigms and investigating their neurophysiological correlates. Among several key points that the Gestalt psychologists underscored, we focus specifically on the role of the visual system in marking a discrete switch of knowledge into awareness, as well as the perceptual experience and the holistic standpoints. While the main goal of this paper is to read the previous theory in light of new evidence, we also hope to initiate an academic discussion and encourage further research about the points we raise.

Keywords: insight problem-solving; Aha! moment; pupillometry; Gestalt; perception; attention; creativity

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1. Introduction

The scientific understanding of insight problem-solving originates from the Gestalt psychologists in the early 20th century. Before them, the prevailing theory on problem-solving suggested its genesis through iterative experimentation of preexisting responses. This viewpoint posited that individuals inherently establish associations during trial-and-error learning, leading to a mode of reproductive thinking. When confronted with commonplace problems, individuals would merely reproduce solutions they had previously correlated with successful outcomes by expanding, or modifying, their existing associations, implying the absence of genuinely novel creations (Thorndike, 1911). Gestalt psychologists, instead, theorized that insight problem-solving unfolds through a paradigm of productive thinking. Within this framework, problem solvers would overcome conventional associations and perceive problems through an entirely novel lens (Kohler, 1925; Wertheimer, 1945; 1959). These novel solutions emerge together with an abrupt sensation of apprehending, also termed an "Aha!" moment. For Gestalt psychologists, insight manifests as the transition from a state of uncertainty regarding the achievement of a problem's objective to an in-depth comprehension of the problem itself and thus its attendant solution (Maier, 1940) in an off-on matter, as a whole, or a "Gestalt."

In his seminal work, Wolfgang Kohler (1925) documented a chimpanzee's attempts to access out-of-reach bananas. Fortuitously, the chimpanzee managed to see the crates in his cage as potential building blocks for a makeshift staircase. By stacking and ascending the assembled crates, the chimpanzee successfully accessed the bananas. Kohler concluded that the chimpanzee's cognitive reorganization of information in his visual field is what permitted the emergence of an insightful

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solution. The sudden off-on switch into awareness aligns with phenomena like figure-ground reversals, where "elements at one moment are seen as one unity, and at the same moment, another unity appears with the same elements " (Ellen, 1982, p. 324). This perspective underscores the interplay between Gestalt's problem-solving outlook and the foundational principles of Gestalt perceptual experience. Indeed, Gestalt psychologists argued that perceptual experience is an active and dynamic process involving the mind's inherent tendency to organize sensory information into coherent forms. To them, this process is not restricted to perception but expands also to the way we solve problems and how we experience the emergence of a solution as a whole (Kohler, 1925; Wertheimer, 1945; 1959).

Until recently, most of the academic discussions in support of, or in contrast to, the Gestalt theory on insight problem-solving have been based on behavioral studies. Those studies have allowed fundamental steps forward in the cognitive understanding of problem-solving. However, considering a renewed interest in their theory (e.g., Mungan, 2023) in this review, we aim to retroactively interpret some core points of Gestalt psychologists on insight based on what we learned from its study in the field of cognitive neuroscience. We will focus on three main points that were raised by Gestalt theorists: *First,* the role of perceptual experience in problem-solving cognition: Was the parallelism between ambiguous figures and insight problem-solving warranted? *Second,* the holistic approach: What has recent research discovered about the idea that solutions to problems sometimes come to mind in an off-on manner? *Third,* while not explicitly, the Gestalt psychologists did assume that the solution to problems comes "with sudden clarity" (Kohler, 1925; Wertheimer, 1945). Can we see in this statement a proto-assumption that insightful solutions might be characterized by higher accuracy and confidence?

2. The visual cortex

Insightful ideas are often more creative than non-insightful ideas. This is because they draw upon information that might initially seem distantly connected to the original problem, as well as on the retrieval of unconventional interpretations of elements within the problem (Bowden & Beeman, 1998). While it is not possible to definitively establish a direct correspondence between creativity and insight problem-solving, as not all creative ideas emerge as insights, having an insight involves a fundamental reorganization of concepts or "representational change" (Duncker, 1945; Ohlsson, 1983; Wertheimer, 1945), leading to fresh and less obvious interpretations of the problem scenario. This type of thinking is frequently recognized as a manifestation of creativity (Friedman & Förster, 2005). The emergence of a creative idea, indeed, stems from a search, whether it is a conscious or unconscious (i.e., via insight), and is conceived as the outcome of a process aimed at solving a problem (Salvi, 2023).

Results from the fields of neuroscience show how insight solutions present a specific brain activation that differs from those generated via step-by-step analysis (for a review see Kounios and Beeman, 2014; Salvi, 2023). Among these studies, numerous investigations corroborate the evidence that a distinct visual-attentional pattern characterizes insight problem-solving (e.g., Aziz-Zadeh, Kaplan, & Iacoboni, 2009; Elston, Croy, & Bilkey, 2019; Jung-Beeman et al., 2004; Kounios et al., 2008; Litchfield & Ball, 2011; Salvi et al., 2015; Thomas & Lleras, 2009; Wegbreit, Suzuki, Grabowecky, Kounios, & Beeman, 2012). For instance, eye-tracking and EEG studies suggest that prior to insight experiences, our attentional system suppresses visual input: EEG results show increased alpha-band activity over the visual cortex, and eye tracking results show an increased frequency and duration of blinks (Kounios et al., 2006; Jung-Beeman et al., 2004; Salvi et al., 2015; Salvi & Bowden, 2016). Conversely, the period preceding step-by-step analytic solutions is marked by heightened eye movements, reduced blinking, and gamma-band activity over the visual cortex which implies an outward-directed focus of attention (Kounios et al., 2006; Jung-Beeman et al., 2004; Salvi et al., 2015; Salvi & Bowden, 2016). These distinct patterns are explained as either internally oriented cognition (for solutions via insight) or externally to reinforce or acquire additional environment information in the case of solutions via analysis. Further, it is known that during periods of intense cognitive engagement, such as problem-solving or creative ideation, individuals frequently direct their gaze

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toward vacant spaces or blank surfaces. This phenomenon of "looking at nothing" is commonly recognized as a way to enhance concentration on inner thoughts by disengaging from external distractions (Salvi & Bowden, 2016).

Taken together, multiple studies attest to a distinct activation pattern within the attentional system characterizing insight problem-solving. This suppression of incoming sensory information suggests that inwardly oriented attention reduces competition for cognitive resources as a type of "sensory gating" (Kounios et al., 2006; Kounios and Beeman, 2014; Salvi et al., 2015). This alpha increase has been found overall during creative ideation and it is characterized by the absence of external bottom-up stimulation and, thus, a form of top-down activity (for a review, Fink and Benedek, 2012).

3. Pupil dilation

A critical link between perceptual experience and the physiological markers of insight problem-solving is provided by the study of pupil dilation. As we mentioned, one of the central ideas of Gestalt psychologists was that the recognition of ambiguous figures, in terms of object interpretation, can rise suddenly following a reconfiguration of the visual constituents into a new, integrated Gestalt. Analogously, during problem-solving, a solution can unexpectedly emerge holistically, triggered by a reinterpretation of the constituent elements of the problem (Köhler, 1921). Both instances entail a restructuring of the problem's elements or figures, facilitating the emergence of a solution, or perception, into conscious awareness. This restructuring is phenomenologically marked by a sensation of surprise, satisfaction, and pleasure often articulated through the exclamation "Aha!" (Danek & Wiley 2017). When exposed to instances of perceptual and conceptual ambiguity, such as when confronted with ambiguous figures or attempting to unravel the solution to a problem, individuals tend to seek a recognizable structure within their perceptual or imaginative frameworks, akin to deciphering "connecting the dots" puzzles (Salvi, Simoncini, Grafman, & Beeman, 2020). Undergoing an insight experience involves an underlying, top-down subconscious reorganization of stimulus attributes, wherein the coherence of this configuration promptly engages conscious awareness (Salvi, 2023).

Crucially, the question that arises pertains to whether this parallelism between perceptual experience and insight problem-solving is merely an illustrative analogy or if the two share deeper commonalities. Nearly a century after Köhler's investigations, research has unveiled that this parallel between visual perception and insight problem-solving is, indeed, grounded in markedly similar behavioral proxies as physiological correlates. Laukkonen and Tangen (2017) demonstrated that individuals who exhibit enhanced proficiency in discerning alternative perspectives within ambiguous figures, such as Necker's cube, are more inclined to report insight experiences while solving verbal problems requiring reorganization. Notably, they established a connection between these two tasks; specifically, the number of puzzles solved via insight was higher when participants were initially presented with the conflicting version of the ambiguous figure, thereby fostering perceptual rivalry. This transfer appears to happen not only from perception to problem-solving conception but also from the conception of spatial relationship to problem-solving. Bianchi and colleagues, indeed, found that prompting individuals to "think in opposites" in visuospatial problems encouraged insights over an overt hint at the problem (Bianchi et al., 2019). Specifically, the authors showed how the prompt to think in terms of opposites fosters a representational change in problem-solving by extending the search space.

Further studies have indicated that participants' pupil diameter increases just before they declare engaging in perceptual or conceptual reorganization (Einhäuser, Stout, Koch, & Carter, 2008; Salvi, Simoncini, Grafman, & Beeman, 2020). Specifically, investigations have observed a rise in average pupil diameter above baseline prior to the conscious recognition of ambiguous visual stimuli (Einhäuser et al., 2008; Kietzmann, Geuter, & Konig, 2011). Salvi and colleagues (2020) demonstrated that pupil size increased with a 60.5% likelihood in trials that were resolved through insight (with peak dilation occurring around 200 milliseconds before individuals declared experiencing an insight, i.e., during the "Aha!" moment).

While further exploration is needed (and encouraged as a purpose of this review) to fully elucidate the implications of this physiological response in both perceptual and problem-solving tasks, so far these studies substantiate Gestalt psychology's conceptualization of insight problem-solving being akin to the structural top-down reorganization of visually ambiguous figures. Moreover, it provides evidence that the experience of insight is characterized by a non-continuous process, as the pupillary response could serve as an indicator of the transition from the unconscious to conscious awareness (Laeng & Teodorescu, 2002). While the outcomes of Salvi et al. have already been replicated by Becker, Kühn, & Sommer (2020), capturing the precise instant an idea materializes remains a multifaceted endeavor. Thus far, it is established that the shift in pupil size is observed approximately 200 milliseconds before individuals press a button to signify the occurrence of an "Aha!" moment. The variation in pupil size likely represents a physiological marker that may precede, follow, or coincide with the transition into awareness of the outcomes of unconscious processes (Salvi, 2023).

4. Holistic perspective

The Gestalt School of Psychology was grounded in the idea that perceptual experiences are holistically organized, meaning that sensory stimuli are spontaneously organized into meaningful and holistic patterns rather than perceived as isolated elements. Using Koffka's (1935, p. 176) words: "The whole is something else than the sum of its parts, because summing is a meaningless procedure, whereas the whole-part relationship is meaningful". Similarly, during insight problem-solving, individuals do not have immediate access to information since it is processed in a discrete off-on manner and when solutions to problems emerge, they do it as a "whole." Further, insight solutions tend to be more accurate than those via analysis, similar to pattern recognition in ambiguous figures (Danek, et al., 2014; Danek & Salvi, 2018; Hedne et al., 2016; Kounios et al., 2008; Metcalfe; 1986; Salvi, et al., 2016; Laukkonen et al., 2020, 2021; 2022; 2023; Webb et al., 2016). When people see the alternative image, it is foremost the correct one. On the other hand, analytical problem-solving involves a stepwise analysis of partial information processing that occurs above awareness (Smith & Kounios, 1996). Thus when investigating the types of errors committed when solving problems via insight vs. analysis, separate patterns of errors emerge. For example, when solving analytically, individuals commit more errors of commission (inaccurate guesses), while insight problem solving is associated with higher rates of errors of omission (timing out with no response given; Kounios et al., 2008; Salvi et al., 2016).

Metcalfe (1986) monitored the evaluation of participants regarding their proximity to arriving at a solution, measured as "warmth." The findings revealed that in the context of insight problems, the perception of warmth did not escalate until the final 10 seconds before the solution was reached. In contrast, when dealing with analytic solutions, the warmth ratings demonstrated a more gradual increase over time. Additionally, Metcalfe investigated the types of responses participants provided based on whether warmth ratings increased incrementally or suddenly. It was observed that responses connected to abrupt surges in warmth (indicative of insights) were more frequently correct compared to responses associated with gradual increments in warmth (representative of analytical problem-solving).

Further evidence of this all-or-none rise of the problem solution is provided by Laukkonen et al., 2021 who used a dynamometer to track the intensity of the insight experience. Their results show that participants instinctively (i.e., without explicit instruction) exerted greater pressure on the dynamometer during more intense Aha! experiences and the magnitude of the Aha! experience corresponded to the accuracy of the solutions. This result was in accordance with the consistent findings across numerous prior studies such as (Danek, et al., 2014; Danek & Salvi, 2018; Hedne et al., 2016; Kounios et al., 2008; Metcalfe; 1986; Salvi, et al., 2016; Laukkonen et al., 2020, 2021; 2022; 2023; Webb et al., 2016), which strongly emphasize that sensations of Aha!, including their intensity, carry valuable information regarding the accuracy of solutions in problem-solving contexts (see final section).

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Though it is challenging to capture the shift into awareness that characterizes an insight, researchers have been able to utilize advancements in techniques to identify physiological measures that might overlap with insight emerging into awareness. As mentioned above, during both a perceptual and conceptual associated with having an insight the pupil dilates (Einhauer et al. 2008; Salvi et al., 2020), and pupil dilation has been argued to be a proxy for the switch from unconscious to conscious states (Bijleveld, Custers, & Aarts, 2009; Chapman, Oka, Bradshaw, Jacobson, & Donaldson, 1999). This result is further bolstered by EEG studies which have identified gamma activity over the temporal lobes before a button press 560msec prior to a reported Aha! (Jung-Beeman et al., 2004; Salvi et al., 2020). That said, insights are ineffable; capturing the exact instance of when the ideas burst into awareness might be ambitious at this time, and with the current techniques, it is worth posing this question to encourage future investigation.

5. Accuracy and the Law of Pragnanz?

The finding that insight solutions tend to be more correct (compared to those without insight), bears on important questions about the adaptive nature of insights (Salvi et al., 2023; Laukkonen et al., 2023). When confronted with a question, a natural inclination might be to think step-by-step about problem elements to obtain a solution (Danek, 2018). However, in cases of insight, this effortful strategy is absent, and a solution springs to mind with clarity and conviction about its correctness (Danek and Wiley, 2017). Why should we trust such thoughts that have no accessible preceding information steps? In this last section, we discuss insights in terms of their adaptive function to select the most simple and fitting solution, and how this might be captured by a neurocomputational theory of insight (Laukkonen et al., 2023).

The hallmark of insight, according to Gestalt theory, is its suddenness and clarity. People experience a sudden shift in understanding, often accompanied by a feeling of certainty that they have found the correct solution (Danek & Wiley, 2017; Webb, Little & Cropper, 2016). These feelings of conviction are not simply superficial: a validated line of research has demonstrated that insights tend to be more accurate (Danek et al., 2014; Danek & Salvi, 2020; Salvi et al., 2016; Webb et al., 2018), and this holds across several different task domains: Compound Remote Associates problems (CRAs; Salvi et al., 2016; Laukkonen et al., 2021), anagrams (Salvi et al., 2016), rebus puzzles (Salvi et al., 2016), line drawings (Salvi et al., 2016), and magic tricks (Danek et al., 2014; Hedne, Norman & Metcalfe, 2016).

When considering the affective experience of insight, "correct solutions bring about a sensation of closure and satisfaction" (Salvi & Danek, 2018 p. 485). Conversely, in the case of incorrect solutions, certain elements might be absent or fail to harmonize, leading to an incomplete sense of the Gestalt. This divergence is also evident in the subjective assessments of solvers' solution experiences: Danek and Wiley (2017) demonstrated that correct solutions elicit a more pleasurable feeling compared to incorrect ones. This experience of achieving a Gestalt followed by pleasure bears similarity to comprehending jokes and metaphors. Analogous to grasping a joke, gaining insight involves delving into alternative meanings and concepts that then suddenly align into a unified whole, triggering the Aha! moment (or a burst of laughter). Notably, neuroscientific investigations reveal that the brain circuitry implicated in insight is also pivotal for recognizing remote semantic relationships, metaphors, and alternate meanings (for review, see Kounios & Beeman, 2014).

The Gestalt school noted the proclivity for humans to perceive complex sensory information in the simplest, meaningful, and complete way. In simple terms, the Law of Pragnanz is a case of cognitive parsimony: a principle asserting that our cognitive systems prefer economical and elegant representations of reality (Wertheimer, 1938). Sudden insights exemplify this principle, as they succinctly encapsulate the most pertinent and likely solution. A recent experiment supports this conclusion. Korovkin et al. (2021) demonstrated that solutions to the ten-penny problem that form a symmetrical (holistic) Gestalt are also perceived as more correct and have a higher subjective rating of Aha! experience, compared to a solution that is correct as well but does not form a holistic Gestalt. As Danek and Kizilirmak put it "Essentially, Korovkin et al. (2021) demonstrate that the Aha! experience is determined by features of the solution – and not by features of the problem. Although

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the problem remained the same, the resulting solution experience, measured by a number of rating scales […], differed, depending on which type of solution was found" (Danek & Kizilirmak, 2021).

Further, fact-free learning has been introduced as a conceptual framework for understanding insight (Friston et al. 2017; Laukkonen et al., 2023). This framework is predicated on the idea that the optimization of cognitive models of knowledge systems can occur autonomously without external informational input. Essentially, this view challenges the conventional view that knowledge refinement and updating is contingent upon the acquisition of new, incoming information from external sources. This holds particular significance for instances of abrupt perspective or belief change, such as insights, wherein novel realizations can manifest during apparently unrelated contexts (Ovington et al., 2018).

As we have seen previously, behavioral and physiological markers of insight indicate a reduction in externally oriented attention. Therefore, candidate processes that may underlie the neurophysiological and computational mechanisms of insight would require minimal influence of external environmental input. One way to elucidate the processes involved in insight is through the purview of the predictive processing. In simple terms, this perspective takes that the brain does not have unlimited access to the information in the external environment and instead must create a cognitive model based on inferences (Friston, 2009). Correction on false inferences - prediction errors - is important for model updating to refine beliefs and expectations (Feldman & Friston, 2010). Crucially, in the context of the sudden rise of an insight into awareness, Bayesian model reduction may be involved in the identification of the most parsimonious and best-fitting solution to a problem as argued by Laukkonen and colleagues (2023). This notion finds resonance in physiological processes, where the minimization of model error is mediated by neurotransmitters such as dopamine (Feldman & Friston, 2010; Haarsma et al., 2020). In this way, a sudden insight might arise when the amalgamation of previously separate and loosely related pieces of information is selected as a coherent and parsimonious solution. The feelings of pleasure and confidence immediately after insight is realized (grounded in dopamine involvement during insight, e.g., Tik et al., 2018; Yong et al., 2022; Salvi et al., 2015 and 2021) may also be captured by the dopaminergic signaling that occurs during prediction errors. The moment of insight is associated with increased activation in brain networks relating to salience signaling (Kounios et al., 2006; Kounios & Beeman, 2009; Becker et al., 2020). In this way, dopamine signaling may be integral to the heightened confidence and affective experience in the emerging insight (Danek & Wiley, 2017; Laukkonen et al., 2023; Salvi, 2023).

These findings complement the behavioral and neurophysiological literature discussed in the previous sections. On the observational level, individuals demonstrate behaviors such as gaze aversion, pupil dilation, increased frequency and duration of eye blinks (Salvi et al., 2015; 2020; Salvi & Bowden, 2016). This disengagement of external attentional processing encourages the integration of conceptual disparate thoughts, allowing for an insight to emerge. Nevertheless, until recently, neurocomputational perspectives to explain the processes by which the brain can integrate information into a previously unsolved problem have been lacking. Implicit reorganization via a reduction in prediction errors, in the absence of new visual inputs, provides an apt framework to understand the behavioral, neurocomputational, and phenomenological experience of insight problem-solving (Laukkonen, et al., 2023).

6. Conclusions and future directions

The Gestalt psychologists introduced a novel perspective on problem-solving conception. In lieu of the prevailing view by which learned associates dictate the success of solution finding, they advanced the notion that solutions can arise from a sudden and holistic restructuring of problem elements, similar to the way ambiguous figures are holistically recognized. However, the extent to which these parallels between perceptual experience and problem-solving provided a useful comparison, or instead illuminated something more critical about how information is processed more generally has been debated for a long time (e.g., Weisberg and Alba, 1981; Weisberg, 1986). In recent years, advancements in cognitive neuroscientific techniques have begun to provide further evidence to unravel these questions. This integration of phenomenologically inspired observations (such as

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those of Gestalt Psychologists, but also of recent developments discussed in the previous sections of this article) and cognitive neuroscience has illuminated the multifaceted nature of insight problem-solving and its underlying cognitive and neural processes.

Both the recognition of ambiguous figures and the sudden rise of insight into awareness are associated with an increase in pupil dilation. This marker is diagnostic of insights, and thus we could use it to study insight also when self-reporting of Aha! experiences are possible (for example with children or primates) (Salvi et al., 2023). Further, results of eye movement and EEG studies have led to the proposal that insights require a sensory-gating process to pull attention from the external environment towards internally oriented cognition. What is the role of crowded and uncrowded visual environments in insight problem-solving? Can this knowledge help us in finding ways to facilitate insight occurrence? Further, does this physiological response signify a pivotal temporal juncture in the shift to conscious awareness? Is this small temporal window the instant when an idea switches into awareness? Can we draw deeper conclusions from what is, so far, just a speculation?

We tried to highlight how insights embody the concept of cognitive parsimony, integrating complex information into coherent and succinct solutions. Recent neurocomputational perspectives have advanced knowledge of how, in the absence of further visual or external input, a holistic reconfiguration of information emerges as a sudden insight. This harkens back to the Gestaltist principle of Pragnanz: humans prefer simple and recognizable forms of information. While the Gestaltists primarily focused on visual forms, we extended this understanding to the conceptual level. Insights carry with them feelings of certainty, clarity, reward, and satisfaction (Danek & Wiley, 2017; Webb, Little & Cropper, 2016), which poses interesting questions about why we trust these insights with such conviction. They spring to mind without any conscious effort or awareness, yet we are confident about their accuracy. By integrating neurocomputational perspectives (Laukkonen et al., 2023; Friston et al., 2017) with behavioral and physiological indicators of insight problem-solving, researchers are granted a deepening understanding of the phenomena along levels of analysis. In the absence of new information, is the brain capable of integrating extant knowledge into new configurations to encourage insightful solutions?

As we navigate this juncture of century-old theories and modern cognitive neuroscientific evidence, several promising avenues for future research emerge. For example, while much evidence points towards its involvement, the particular role of dopamine and its associated circuits remain unclear. Along these lines, the parameters for which a solution is selected are underspecified and computational models could address this with normative models of decision making.

In sum, we have traced the influence of Gestalt psychologists on modern conceptions of insight problem-solving. This synthesis between historical tenets of Gestalt psychology and contemporary cognitive neuroscience underscores the multifaceted nature of insight problem-solving, hopefully, encouraging interdisciplinary approaches, they hold the potential to illuminate the intricate interplay between perception, cognition, and insight problem-solving.

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