# Rethinking Intelligence: What if Intelligence is Just Pattern Matching?

**Egil Diau**
Department of Computer Science
National Taiwan University
Taiwan, Taipei
egil158@gmail.com

## Abstract

Recent advances in large language models have challenged long-held assumptions about the nature of intelligence, showing that behaviours once thought to require symbolic reasoning or abstract planning can emerge from large-scale pattern matching. We argue that this is not an artifact of artificial systems, but a reflection of how human intelligence itself operates. We support this view with two converging lines of evidence. First, cognitive biases—such as stereotyping and base-rate neglect—reflect systematic misalignments in pattern recognition, rather than logical errors. Second, intuition, creativity, and sudden insight often stem from rapid alignment with stored patterns, enabling flexible responses without explicit reasoning. We revisit core cognitive functions—language, causal reasoning, planning, and social inference—and show that they can be unified under a single mechanism: memory-driven pattern matching. This reframing suggests that many forms of intelligent behavior can be explained as pattern matching over stored experience, rather than abstract computation.


Figure 1: **Bias and creativity as outcomes of pattern matching.** Bias reflects failures of pattern matching—when surface similarity misguides retrieval. Intuition and creativity arise when contextual cues trigger useful patterns from memory. Both suggest that intelligent behavior often depends not on rules, but on matching and reusing prior structure.

# 1 Introduction

What is intelligence? Despite decades of research across cognitive science, psychology, and artificial intelligence, the answer remains deeply contested. Some view it as logical reasoning, others as abstract planning or symbolic manipulation. But recent advances in large language models (LLMs) Achiam et al. [2023], Team et al. [2024], Guo et al. [2025] have disrupted this landscape. Without explicit rules, goals, or world models, these models achieve performance once thought to require human-level cognition—simply by scaling pattern matching.

This empirical shift echoes a growing recognition in cognitive science: much of human intelligence is not computed from abstract rules, but retrieved through pattern matching. People rarely construct optimal solutions from first principles. Instead, they recognize familiar configurations and respond based on prior matches. Even the most celebrated forms of thought—intuition, insight, creativity—often emerge not from deliberate reasoning, but from sudden resonance between new input and stored patterns.

Crucially, the same mechanism explains our most common cognitive failures. Decades of research on cognitive biases have shown that human reasoning is systematically flawed—not randomly, but predictably. Errors like stereotyping, base-rate neglect, and post hoc fallacy are not lapses in logic; they are predictable outcomes of pattern matching driven by superficial resemblance rather than structural fit.

In this paper, we argue that intelligence—both biological and artificial—is best understood not as abstract reasoning, but as pattern matching. We revisit key cognitive biases through this lens, then show how intuition and creative insight rely on similar mechanisms. Finally, we examine core cognitive functions—including language, planning, and social reasoning—and demonstrate how pattern-based retrieval offers a unified account. This reframing highlights a core strength of intelligent systems: the ability to generalize by recognizing and reapplying structural patterns across domains.

**Our contribution.** This paper rethinks the foundations of intelligence by proposing a pattern-based account of human cognition. Our key contributions are:

- Present a unified framework in which core cognitive abilities—such as language, planning, causal reasoning, and social inference—emerge from structural pattern matching rather than symbolic rules or logical computation;
- Reinterpret cognitive biases not as irrational exceptions, but as systematic misalignments in pattern retrieval—revealing a shared mechanism behind both intuitive success and predictable error;
- Show that phenomena like insight, intuition, and expert decision-making can be parsimoniously explained by rapid structural resonance between current input and stored configurations;
- Argue that the recent performance of large language models is not anomalous, but rather evidence that pattern matching at scale can replicate behaviors traditionally viewed as hallmarks of intelligence;
- Challenge the long-standing assumption that intelligence depends on abstract reasoning, and offer a biologically grounded, computationally demonstrable alternative based on pattern matching.

# 2 Related Work

## 2.1 Existing Accounts of Intelligence

Traditional accounts of intelligence fall into a few dominant camps. Symbolic models Newell and Simon [2007] define intelligence as rule-based manipulation of abstract symbols. Connectionist models Rumelhart et al. [1986] focus on learned distributed patterns, while probabilistic models Tenenbaum et al. [2011] treat cognition as Bayesian inference. Embodied views Tenenbaum et al. [2011] emphasize interaction with the environment. Despite their differences, these views share a common assumption: that intelligence requires computation, abstraction, or logic. In contrast, we explore a simpler possibility—pattern recognition and structural reuse—as the common thread behind intelligent behavior.

These frameworks offer valuable modeling paradigms, but they often remain computational ideals or philosophical intuitions—rarely grounded in mechanisms observed in actual biological systems. Few provide direct empirical support from animal or human experiments, particularly regarding how cognition emerges or how errors systematically arise.

### 2.2 Pattern Matching as a Biological Substrate

While symbolic, connectionist, and probabilistic models define intelligence in terms of computation, pattern matching has long served as a biologically grounded alternative. Hebbian learning Hebb [2005], the core principle of neural adaptation, encodes associations through repeated co-activation—effectively building structural templates from experiential regularities. In both animals and humans, perception, categorization, and motor control emerge from the reactivation and recombination of such patterns Sio and Ormerod [2009], Fiser et al. [2010]. Even higher-order cognition, including abstraction and imagination, may reflect structural reuse of stored sensorimotor traces Barsalou [2008].

Unlike symbolic reasoning, which presumes flexible manipulation of rules, biological systems tend to generalize by similarity, not logic. This view aligns with behavioral findings that seemingly rational errors—such as conjunction fallacies or causal illusions—are predictable consequences of compressive, context-dependent pattern matching. In this light, pattern matching is not a side effect of neural processing; it is the mechanism by which intelligence operates under resource constraints.

### 2.3 LLMs as a Mirror of Human Cognition

The rise of large language models (LLMs) Achiam et al. [2023], Team et al. [2024], Guo et al. [2025] has reignited debate over the nature of intelligence. These systems, trained on massive text corpora, exhibit capabilities once thought to require symbolic reasoning: analogical thinking, problem solving, planning, and even creativity. Yet they achieve this not through logic or explicit world models, but through high-dimensional pattern matching across linguistic sequences.

Rather than proving that machines are becoming human-like, LLMs suggest that much of human cognition may itself rely heavily on pattern matching. Their success echoes psychological evidence that human thought depends primarily on matching new inputs to familiar patterns stored in memory—not on symbolic reasoning or abstract inference. Far from undermining intelligence, LLMs highlight how much can be achieved simply through large-scale pattern matching.

## 3 Pattern-Based Computation in Human Intelligence

### 3.1 Biases, Heuristics, and the Myth of Rational Thought

Prevailing cultural and philosophical notions of human intelligence typically portray individuals as fundamentally rational agents—capable of logical reasoning, systematic evidence evaluation, and structured decision-making. Empirical research from cognitive science, however, consistently challenges this view. Decades of studies demonstrate that human reasoning frequently deviates from logical consistency, revealing pervasive biases and systematic errors.

Importantly, these cognitive biases are not arbitrary or isolated. Instead, they reflect predictable patterns: human inference often depends heavily on superficial similarity rather than on deeper causal or structural analysis. Many cognitive errors thus represent misapplications of pattern-matching processes, where surface-level resemblances are erroneously treated as indicative of deeper structural or causal equivalence.

Five representative examples illustrate this phenomenon:

- **Stereotyping:** Individuals are judged based on superficial resemblance to familiar social categories, reflecting overgeneralized pattern matching rather than case-specific evaluation Macrae et al. [1994].

- **Base-Rate Neglect:** Generalizations ignore background frequencies in favor of salient patterns, reflecting a preference for vivid resemblance over structural accuracy Tversky and Kahneman [1974].
- **Representativeness Bias:** Probabilities are estimated by judging how closely an event resembles a prototype, disregarding critical statistical information such as base rates Kahneman and Tversky [1972].
- **Post Hoc Fallacy:** Causal relationships are inferred solely from temporal sequence, erroneously interpreting temporal proximity as causal connection Einhorn and Hogarth [1986].
- **Fundamental Attribution Error:** Observers disproportionately attribute others' behaviors to stable dispositional traits, neglecting situational influences and contextual constraints Ross [1977].
- **Teleology Bias:** A pervasive tendency to interpret natural or random processes as purposeful or intentional, assuming outcomes have underlying reasons or intentional designs, even when such interpretations are unfounded Kelemen [1999].

Collectively, these biases indicate a systematic reliance on resemblance-based generalization rather than logical inference or structured causal analysis. Across diverse cognitive domains, human reasoning appears fundamentally driven by associative pattern matching, underscoring the limitations of conceptualizing intelligence solely as a form of rational, structured thought.

A similar pattern emerges in large language models. Their most salient failure—hallucination—is not a random flaw, but a predictable outcome of extending surface-level or high-frequency associations into unfamiliar contexts Maynez et al. [2020], Ji et al. [2023]. Like human biases, these errors arise from the same underlying mechanism: reliance on resemblance rather than structural understanding. In both biological and artificial systems, misalignment is not an exception—it is a natural outcome of pattern-based generalization.

### 3.2 Intuition and Insight as Pattern-Based Cognition

While much attention has been given to the errors and biases arising from flawed pattern matching, the same mechanism also underlies many of the most remarkable features of human cognition. Intuition, insight, and creativity—often treated as mysterious or uniquely human capacities—can be understood as efficient forms of pattern-based inference.

What we call a "gut feeling" or a "flash of insight" often arises not from abstract reasoning, but from the rapid alignment of current input with stored structural patterns. These moments feel sudden not because the underlying computation is special, but because the matching happens below the level of conscious deliberation. Intuition is speed, not depth Kounios and Beeman [2009], Schooler et al. [1993].

Importantly, insight is rarely self-generated in a vacuum. Whether it's an artist visiting a particular landscape, a musician improvising with new sounds, or a scientist scanning through recent papers or engaging in lively discussion—creative breakthroughs are typically triggered by external cues. These cues activate latent structures accumulated over time, allowing the brain to reorganize known patterns in novel ways. Insight is not invented; it is elicited.

Critically, this pattern-based process is not limited to trivial or low-level domains. In expert reasoning—from chess Chase and Simon [1973] to physics Chi et al. [1981]—snap judgments often outperform slow deliberation precisely because the mind has encoded relevant structure through experience. The "aha" moment is not a leap beyond logic, but a shortcut built by repeated exposure to hidden regularities.

This view reframes intuition as a form of high-efficiency pattern recognition. It explains why insight often comes with a feeling of inevitability or coherence—because the matched pattern fits so well that it feels self-evident. But this also explains why intuition can fail: when the wrong pattern is activated, even confident insight can mislead.

# 4 A Rethinking: Intelligence as Pattern Matching

Across domains of reasoning—from persistent cognitive biases to sudden flashes of insight—one mechanism keeps reappearing: pattern matching. As shown in the previous sections, human errors often arise from treating superficial similarity as functional equivalence, while human intuition often results from context-driven retrieval of familiar patterns. These are not separate quirks or mysterious faculties, but expressions of the same core process.

Despite long-standing beliefs that intelligence depends on rule-based reasoning Newell et al. [1972] or abstract planning Rips [1994], decades of cognitive science—and now large-scale AI systems—point to a more unified account: humans excel not by computing optimal solutions, but by recognizing patterns and reapplying prior structure.

Whether in language, decision-making, or creative thought, performance often hinges not on formal logic, but on alignment: mapping current input onto stored configurations that capture structural regularities from experience. Intuition is not magic—it is memory, compressed and redeployed.

This view reframes intelligence as high-efficiency generalization. The mind does not construct new answers from first principles; it recognizes when a new situation feels like an old one, and uses that similarity to act fast.

Crucially, this mechanism is not limited to humans. Modern language models Achiam et al. [2023], Team et al. [2024], Guo et al. [2025]—trained solely on next-token prediction—have achieved a surprising range of reasoning, planning, and creative abilities without explicit symbolic rules. Their success offers converging evidence: pattern-based inference alone can scale, generalize, and even surprise.

## 4.1 A Pattern-Based Account of Intelligence

The idea that human intelligence depends on pattern recognition has deep roots in cognitive science. Early work on chess expertise showed that grandmasters do not calculate exhaustively, but retrieve familiar board configurations from memory De Groot [2014], Chase and Simon [1973]. Schema theory proposed that comprehension and memory operate by matching inputs to pre-encoded conceptual structures Rumelhart [2017]. Even insight and intuition, long viewed as mysterious, have been reinterpreted as sudden recognitions of structural similarity across contexts Kaplan and Simon [1990], Klein et al. [1993].

Yet despite this body of work, pattern matching has often been treated as peripheral—relevant to perception, expertise, or heuristics, but not to reasoning or general intelligence. Our goal is to reconsider this assumption. Viewed broadly, a wide range of cognitive phenomena—from perception and intuition to abstraction and decision-making—can be understood as variations of the same underlying mechanism: aligning current inputs with structured patterns from experience.

## 4.2 Pattern Matching as a Cross-Domain Mechanism

The power of pattern matching lies in its generality. From language PINE [2005] and planning Klein et al. [1993] to perception Biederman [1987] and creativity Kaplan and Simon [1990], the same mechanism—recognizing structure and projecting it forward—operates across domains. A sentence is completed not by grammar trees, but by resemblance to stored fragments; a plan is formed not by logic trees, but by recalling analogous past configurations.

Expertise offers a striking example: chess masters Chase and Simon [1973], musicians Sloboda [1991], and physicists Chi et al. [1981] often act on intuition, not calculation. Their fluency stems from exposure to deep regularities—structures stored through repetition and reactivated on demand. These domains differ in surface rules but converge on the same core substrate: pattern-based inference, tuned by experience Klein et al. [1993].

## 4.3 Beyond Rules: Why Symbolic Models Fall Short

Traditional symbolic models treat intelligence as a logical process: applying rules, manipulating symbols, and computing valid conclusions from explicit premises. But this framework reflects the structure of mathematics, not of minds. It prioritizes precision and completeness—properties prized in formal systems, yet often irrelevant in real-world cognition.

Human reasoning is rarely deductive. People tolerate ambiguity, rely on incomplete information, and often favor answers that feel right over those that are logically sound. Classic cognitive biases—such as conjunction errors, base rate neglect, and causal illusions—reveal a consistent pattern: we are drawn to what looks plausible, not what follows from rules. In this light, symbolic models do not merely fail to scale; they mischaracterize the nature of thought.

Pattern-based cognition offers a better fit. It explains both the efficiency and the systematic errors of human reasoning: we reuse structure, not derive it. This mechanism is not a byproduct of formal logic, but a widely observed cognitive strategy—found in humans and other animals, and replicated in neural systems trained without symbolic rules. Intelligence, in this view, emerges not from deduction, but from structured resemblance—fast, flexible, and grounded in experience.

| Cognitive Function | Corresponding Bias (Structural Residue) |
|---|---|
| Abstraction | Conjunction Fallacy Tversky and Kahneman [1983] |
| Counterfactual Thinking | Hindsight Bias Fischhoff [1975] / Outcome Bias Baron and Hershey [1988] |
| Planning | Planning Fallacy Buehler et al. [1994] / Typicality Bias Tversky and Kahneman [1974] |
| Decision Making | Availability Heuristic Tversky and Kahneman [1973] / Representativeness Heuristic Kahneman and Tversky [1972] |
| Language Understanding | Pragmatic Inference Grice [1975] / Suggestibility Loftus and Palmer [1974] |
| Causal Reasoning | Post Hoc Fallacy Kelley [1973] / Illusory Causation Alloy and Abramson [1979] |
| Social Cognition | Fundamental Attribution Error Jones and Harris [1967] / Stereotyping Macrae et al. [1994] |
| Generalization | Overgeneralization Marcus et al. [1992] / Confirmation Bias Wason [1960] |

Table 1: Although the internal workings of intelligence are difficult to observe directly, its failures are not. Each high-level cognitive function, often praised as "intelligent," exhibits systematic biases. These biases are not random—they reflect structured, reproducible errors. We argue that these regularities are not noise, but the predictable failure modes of a pattern-matching system.

## 5 Revisiting Cognitive Abilities through Pattern Association

Across domains traditionally treated as requiring deep reasoning—language, causality, planning, abstraction, and social cognition—a common mechanism recurs: the ability to align present inputs with structured patterns from past experience. This section reinterprets core cognitive capacities through the lens of pattern association, revealing a shared substrate behind seemingly distinct abilities.

### 5.1 Language Understanding

Language is often viewed as a combinatorial system governed by syntactic rules. But fluency arises not from computing grammar, but from rapidly aligning phrases with familiar structures. Listeners predict upcoming words based on frequency, co-occurrence, and contextual frames—not logic.

Neural and behavioral studies show that comprehension depends heavily on prior exposure: ambiguous sentences are resolved by context-dependent pattern activation, not syntactic analysis alone PINE [2005], MacDonald et al. [1994]. Modern language models Achiam et al. [2023], Team et al. [2024], Guo et al. [2025] trained on prediction replicate this capacity without rules, supporting the idea that language understanding is, at its core, a form of statistical pattern alignment.

### 5.2 Causal Reasoning

Causality is often treated as the pinnacle of rational thought: inferring unseen mechanisms from observation. Yet human causal judgments frequently rely on surface similarity, temporal proximity, and covariation—heuristics that reflect structural resemblance, not deep inference.

Classic fallacies like post hoc reasoning Tversky and Kahneman [1974], causal illusions Alloy and Abramson [1979], or correlation-as-causation Sloman and Sloman [2009] illustrate how the mind substitutes matching patterns for mechanistic explanation. Rather than simulating causal models, people align present observations with past cause–effect templates.

### 5.3 Planning and Goal Pursuit

Planning is typically framed as forward simulation: computing action sequences to maximize reward. But in real-world behavior, plans often emerge from analogy, not optimization. People reuse prior solutions that resemble the current situation, adjusting familiar paths to fit new contexts.

This process is iterative pattern matching: the mind recalls similar episodes, adapts them incrementally, and evaluates progress by similarity to known outcomes. Rather than search from scratch, agents "recognize their way forward."

### 5.4 Abstract Thinking

Abstraction is often assumed to involve higher-order reasoning—deriving structure from variation. But abstraction can also emerge from pattern matching: identifying recurring structural similarities across contexts and reapplying them without explicit derivation or formal definition.

Children generalize without rules; experts intuit structure without constructing logic trees. The core operation is not deduction, but the selective recognition and reuse of patterns that align with prior experience.

### 5.5 Social Inference

Social cognition is often attributed to "mindreading" or theory of mind. But many inferences about others—goals, beliefs, emotions—arise from recognizing familiar behavioral templates. People use tone, gaze, context, and history to match the present interaction to stored patterns of social roles and intentions.

Rather than simulating mental states, we align observed behavior with memory-based prototypes: "this looks like when someone was angry," or "this resembles a betrayal." Social inference, like other forms of cognition, depends on resonance more than reconstruction.

### 5.6 Expert Thinking

Expertise is sometimes portrayed as superior reasoning. But empirical studies—from chess Chase and Simon [1973] to medicine Norman [2005], Eva [2005]—show that experts rarely reason from first principles. Instead, they instantly recognize patterns that map new problems to known solutions.

Expertise is fast because it is compressed: years of experience are restructured into retrievable patterns. Deliberation fades as matching becomes automatic. What looks like insight is often rapid pattern retrieval.

## 6 Theoretical Implications

### 6.1 Biases Reflect Surface-Level Pattern Confusion

Many cognitive biases are not random mistakes or innate flaws, but systematic misjudgments driven by surface-level similarity. When different situations appear similar on the surface—whether in language, form, or co-occurrence—they are often treated as equivalent, even when their underlying structures differ. The result is not noise, but a patterned form of error.

People mistake correlation for causation, match faces to stereotypes, or ignore base rates when intuitive resemblance dominates. These errors are consistent and predictable. They reveal not a failure of logic, but a system that treats partial similarity as sufficient—and often gets it wrong.

### 6.2 Beyond Rules: How Pattern Matching Enables Generalization

Pattern matching is often regarded as a shallow heuristic, yet it supports some of the most robust and flexible forms of generalization. Apparent instances of symbolic reasoning, logical inference, and abstract planning can frequently be reinterpreted as higher-order pattern alignment—across contexts, modalities, and levels of abstraction. From analogical mapping to structural extrapolation, intelligent behaviour often reflects not the application of rules, but the resonance of relational patterns between superficially dissimilar inputs.

In contrast to symbolic and Bayesian approaches, which rely on predefined representations and fully specified models, pattern-based systems accommodate ambiguity, sparsity, and open-ended variability. They do not require complete formulations to act; instead, they operate by identifying partial structural correspondence, even under noise and uncertainty. This affords rapid generalization, contextual adaptability, and the capacity to navigate ill-structured environments where formal reasoning falters.

This perspective also reframes the capabilities of large-scale neural models. Despite lacking explicit reasoning modules or symbolic structures, such systems demonstrate behaviours once thought to require abstract rule manipulation. Their capacities emerge not through logical derivation, but through the cumulative reuse of relational structure. In both biological and artificial systems, generalization is not grounded in universals—it is scaffolded by distributed similarity.

### 6.3 Why Pattern Matching Can Resemble Rules—But Still Go Wrong

Many intelligent behaviors—such as grammar, logic, or causal reasoning—appear rule-based, but can emerge from large-scale pattern matching. Rather than applying explicit symbolic rules, cognition often reuses prior structural alignments across similar contexts. When these alignments succeed, behavior looks systematic and principled. When they fail, the errors are not random—they reflect surface-level similarity masking deeper structural mismatches.

This explains why human reasoning can feel rule-like, yet break down in predictable ways. Pattern matching enables flexible generalization, but it also overextends when structural constraints differ beneath superficial resemblance. The result is not flawed logic, but misapplied structure.

### 6.4 Recursive Thinking Is Not the Core of Human Intelligence

In computer science, recursive solutions are elegant—but fragile. Without careful memory management, they quickly lead to stack overflow or untraceable logic. The same holds for human cognition: while people can reason recursively, their capacity to do so is sharply limited. Beyond a few levels of nesting, most individuals lose track—unless the structure is externalized through writing or diagrams.

This is not a failure of logic, but a structural constraint. Recursive reasoning places a heavy burden on working memory, making it inherently unstable in natural cognition. What appears to be recursive thought is often reconstructed linearly, step by step, rather than maintained as a nested whole. Human intelligence, at its core, is not hierarchical—it is shallow, reconstructive, and context-driven.

## 7 Future Directions

This framing invites a shift in how we study and build intelligence. If reasoning and abstraction emerge from pattern reuse rather than symbolic rules, then future work should focus less on designing deeper logic, and more on understanding how structure is stored, matched, and reapplied.

Both cognitive science and AI stand to benefit from this view. We need better models of how pattern alignment succeeds, when it fails, and how it scales. Intelligence may not lie in computing truth, but in compressing experience into forms that can generalize.

## 8 Conclusion

This paper reframes intelligence as large-scale pattern matching: the retrieval and reuse of structured experience across domains. Drawing on evidence from cognitive science and the capabilities of large language models, we show that core cognitive functions—including language, planning, causal reasoning, and social inference—emerge not from rule-based construction, but from context-sensitive alignment with prior structure.

This account offers a unified perspective on phenomena traditionally viewed as distinct. Cognitive biases appear as systematic misalignments; intuition and creativity, as rapid resonance triggered by contextual cues. Rather than deriving solutions from abstract principles, intelligent behavior emerges from matching current inputs to patterns stored from past experience.

In this view, intelligence is grounded not in inference, but in recognition—flexible, scalable, and attuned to the structure of past experience. Understanding this mechanism offers a concrete basis for rethinking both cognitive architecture and the design of intelligent systems.

## Declaration of LLM Usage

The authors used OpenAI's ChatGPT to assist in refining phrasing and improving clarity. All theoretical arguments and interpretations are original and authored by the researchers.

## References


J. Achiam, S. Adler, S. Agarwal, L. Ahmad, I. Akkaya, F. L. Aleman, D. Almeida, J. Altenschmidt, S. Altman, S. Anadkat, et al. Gpt-4 technical report. *arXiv preprint arXiv:2303.08774*, 2023.

L. B. Alloy and L. Y. Abramson. Judgment of contingency in depressed and nondepressed students: Sadder but wiser? *Journal of experimental psychology: General*, 108(4):441, 1979.

J. Baron and J. C. Hershey. Outcome bias in decision evaluation. *Journal of personality and social psychology*, 54(4):569, 1988.

L. W. Barsalou. Grounded cognition. *Annu. Rev. Psychol.*, 59(1):617–645, 2008.

I. Biederman. Recognition-by-components: a theory of human image understanding. *Psychological review*, 94(2):115, 1987.

R. Buehler, D. Griffin, and M. Ross. Exploring the" planning fallacy": Why people underestimate their task completion times. *Journal of personality and social psychology*, 67(3):366, 1994.

W. G. Chase and H. A. Simon. Perception in chess. *Cognitive psychology*, 4(1):55–81, 1973.

M. T. Chi, P. J. Feltovich, and R. Glaser. Categorization and representation of physics problems by experts and novices. *Cognitive science*, 5(2):121–152, 1981.

A. D. De Groot. *Thought and choice in chess*, volume 4. Walter de Gruyter GmbH & Co KG, 2014.

H. J. Einhorn and R. M. Hogarth. Judging probable cause. *Psychological bulletin*, 99(1):3, 1986.

K. W. Eva. What every teacher needs to know about clinical reasoning. *Medical education*, 39(1): 98–106, 2005.

B. Fischhoff. Hindsight is not equal to foresight: The effect of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human perception and performance*, 1 (3):288, 1975.

J. Fiser, P. Berkes, G. Orbán, and M. Lengyel. Statistically optimal perception and learning: from behavior to neural representations. *Trends in cognitive sciences*, 14(3):119–130, 2010.

H. P. Grice. Logic and conversation. In *Speech acts*, pages 41–58. Brill, 1975.

D. Guo, D. Yang, H. Zhang, J. Song, R. Zhang, R. Xu, Q. Zhu, S. Ma, P. Wang, X. Bi, et al. Deepseek-r1: Incentivizing reasoning capability in llms via reinforcement learning. *arXiv preprint arXiv:2501.12948*, 2025.

D. O. Hebb. *The organization of behavior: A neuropsychological theory*. Psychology press, 2005.

Z. Ji, N. Lee, R. Frieske, T. Yu, D. Su, Y. Xu, E. Ishii, Y. J. Bang, A. Madotto, and P. Fung. Survey of hallucination in natural language generation. *ACM computing surveys*, 55(12):1–38, 2023.

E. E. Jones and V. A. Harris. The attribution of attitudes. *Journal of experimental social psychology*, 3(1):1–24, 1967.

D. Kahneman and A. Tversky. Subjective probability: A judgment of representativeness. *Cognitive psychology*, 3(3):430–454, 1972.

C. A. Kaplan and H. A. Simon. In search of insight. *Cognitive psychology*, 22(3):374–419, 1990.

D. Kelemen. Function, goals and intention: Children's teleological reasoning about objects. *Trends in Cognitive Sciences*, 3(12):461–468, 1999.

H. H. Kelley. The processes of causal attribution. *American psychologist*, 28(2):107, 1973.

G. A. Klein et al. A recognition-primed decision (rpd) model of rapid decision making. 1993.

J. Kounios and M. Beeman. The aha! moment: The cognitive neuroscience of insight. *Current directions in psychological science*, 18(4):210–216, 2009.

E. F. Loftus and J. C. Palmer. Reconstruction of automobile destruction: An example of the interaction between language and memory. *Journal of verbal learning and verbal behavior*, 13(5):585–589, 1974.

M. C. MacDonald, N. J. Pearlmutter, and M. S. Seidenberg. The lexical nature of syntactic ambiguity resolution. *Psychological review*, 101(4):676, 1994.

C. N. Macrae, A. B. Milne, and G. V. Bodenhausen. Stereotypes as energy-saving devices: A peek inside the cognitive toolbox. *Journal of personality and Social Psychology*, 66(1):37, 1994.

G. F. Marcus, S. Pinker, M. Ullman, M. Hollander, T. J. Rosen, F. Xu, and H. Clahsen. Overregularization in language acquisition. *Monographs of the society for research in child development*, pages i–178, 1992.

J. Maynez, S. Narayan, B. Bohnet, and R. McDonald. On faithfulness and factuality in abstractive summarization. *arXiv preprint arXiv:2005.00661*, 2020.

A. Newell and H. A. Simon. Computer science as empirical inquiry: Symbols and search. In *ACM Turing award lectures*, page 1975. 2007.

A. Newell, H. A. Simon, et al. *Human problem solving*, volume 104. Prentice-hall Englewood Cliffs, NJ, 1972.

G. Norman. Research in clinical reasoning: past history and current trends. *Medical education*, 39 (4):418–427, 2005.

J. M. PINE. Tomasello, m., constructing a language: a usage-based theory of language acquisition. cambridge, ma: Harvard university press, 2003. pp. 388. hardback,£ 29.95. isbn 0-674-01030-2. *Journal of Child Language*, 32(3):697–702, 2005.

L. J. Rips. *The psychology of proof: Deductive reasoning in human thinking*. Mit Press, 1994.

L. Ross. The intuitive psychologist and his shortcomings: Distortions in the attribution process. In *Advances in experimental social psychology*, volume 10, pages 173–220. Elsevier, 1977.

D. E. Rumelhart. Schemata: The building blocks of cognition. In *Theoretical issues in reading comprehension*, pages 33–58. Routledge, 2017.

D. E. Rumelhart, G. E. Hinton, J. L. McClelland, et al. A general framework for parallel distributed processing. *Parallel distributed processing: Explorations in the microstructure of cognition*, 1 (45-76):26, 1986.

J. W. Schooler, S. Ohlsson, and K. Brooks. Thoughts beyond words: when language overshadows insight. *Journal of experimental psychology: General*, 122(2):166, 1993.

U. N. Sio and T. C. Ormerod. Does incubation enhance problem solving? a meta-analytic review. *Psychological bulletin*, 135(1):94, 2009.

J. A. Sloboda. *Musical expertise*. na, 1991.

S. Sloman and S. A. Sloman. *Causal models: How people think about the world and its alternatives*. Oxford University Press, 2009.

G. Team, P. Georgiev, V. I. Lei, R. Burnell, L. Bai, A. Gulati, G. Tanzer, D. Vincent, Z. Pan, S. Wang, et al. Gemini 1.5: Unlocking multimodal understanding across millions of tokens of context. *arXiv preprint arXiv:2403.05530*, 2024.

J. B. Tenenbaum, C. Kemp, T. L. Griffiths, and N. D. Goodman. How to grow a mind: Statistics, structure, and abstraction. *science*, 331(6022):1279–1285, 2011.

A. Tversky and D. Kahneman. Availability: A heuristic for judging frequency and probability. *Cognitive psychology*, 5(2):207–232, 1973.

A. Tversky and D. Kahneman. Judgment under uncertainty: Heuristics and biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *science*, 185(4157):1124–1131, 1974.

A. Tversky and D. Kahneman. Extensional versus intuitive reasoning: The conjunction fallacy in probability judgment. *Psychological review*, 90(4):293, 1983.

P. C. Wason. On the failure to eliminate hypotheses in a conceptual task. *Quarterly journal of experimental psychology*, 12(3):129–140, 1960.