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Interliminal Design: Understanding cognitive heuristics to mitigate design distortion

Abstract

Cognitive heuristics are mental shortcuts adapted over time to enable rapid interpretation of our complex environment. They are intrinsic to human cognition and resist modification. Heuristics applied outside the context to which they are best suited are termed cognitive bias, and are the cause of systematic errors in judgment and reasoning. As both a cognitive and intuitive discipline, design by individuals is vulnerable to context-inappropriate heuristic usage. Designing in groups can act positively to counterbalance these tendencies, but is subject to heuristic misuse and biases particular to social environments. Mismatch between desired and actual outcomes– termed here, design distortion – occurs when such usage goes unnoticed and unaddressed, and can affect multiple dimensions of a system. We propose a methodology, interliminal design, emerging from the Program in Collaborative Design at Pacific Northwest College of Art, to specifically address the influence of cognitive heuristics in design. This adaptive approach involves reflective, dialogic, inquiry-driven practices intended to increase awareness of heuristic usage, and identify aspects of the design process vulnerable to misuse on both individual and group levels. By facilitating the detection and mitigation of potentially costly errors in judgment and decision-making that create distortion, such metacognitive techniques can meaningfully improve design.

Keywords: cognitive heuristics, design methodology, cognitive bias, design distortion, wicked problems

Introduction

Our globally interconnected and information-rich world is comprised of complex systems operating under vast uncertainty. Our most pressing societal problems are now considered wicked, or even super wicked (e.g., climate change) (Levin et al., 2012); they frequently have incomplete, continuously changing, intricately interdependent yet contradictory requirements, urgent or emergency status, no central responsible authority, and caused by the same entities charged with solving them (Rittel & Webber, 1973). It is becoming increasingly clear that to take substantive action in today's wicked problems, design thinking (Nelson & Stolterman, 2003) must be directed by lucid, purpose-driven intention that is rooted in a deep appreciation of complex system dynamics and inter-relationships.

Originating from anthropological study of human ritual, the concept of liminality (from *limen*, threshold) refers to periods between stages of transition, implicit with an experience of intense and disorienting ambiguity; people or constructs are "at once, no longer classified and not yet classified" and "neither one thing nor another, or maybe both" (van Gennep, 1960; Turner, 1967). The term has been more broadly applied in diverse societal, political, and cultural contexts (Thomassen, 2009) to describe the frequently chaotic states of unlimited potential that accompany large-scale dismantling of outmoded structures, institutions, and world-views as their replacements have yet to take shape. In its most general sense, to occupy liminal space is to be at, between, or on both sides of a boundary, unable to claim or identify with anything beyond the dividing line itself. Designers in today's world face not only the challenge of addressing wicked problems within larger transitional or liminal states, but must also do so in a space of imperfect information and apparent human irrationality replete with arbitrary definitions, conflicting stakeholder motivations, and outcomes that are moving targets. Thus, we believe that the awareness of patterns of human

reasoning, motivation, and behavior, particularly in the face of problem-solving and decision-making challenges, is a powerful and underutilized resource for improving contemporary design.

As a result of its intrinsic reliance on heuristics (see below), human cognition is highly vulnerable to distortions of perception and reason, i.e., cognitive biases, which result from the unconscious use of heuristics in suboptimal or inappropriate contexts. Since personal and group heuristics are involved in all design processes, multiple dimensions of a design may be inadvertently affected. During the design process, including system modeling, iteration, and prototyping, unacknowledged and uncompensated biases may lead to accumulation of errors which cause the resultant design to diverge in various degrees from the intended outcome. Constraints on time, resources, communication, competing cognitive tasks, and overly strict adherence to arbitrary or artificial boundaries compound this effect. We refer to the unintended mismatch between desired and actual design outcomes as "design distortion," a feature distinct from unanticipated consequences, yet similar in that it typically becomes apparent only after completion of the design. Furthermore, we propose interliminal design as both a mindset and methodology that can specifically address the contributing factor of inappropriate use of heuristics in human thought process and decision-making, as well as more skillfully manage the high levels of uncertainty inherent to contemporary design.

Personal Heuristics in Design

"Our mind is strongly biased toward causal explanations and does not deal well with mere statistics" — D. Kahneman

On an individual level, cognitive heuristics are mental shortcuts adapted to enable rapid interpretation of the complex environment in which we evolved and live (Tversky & Kahneman, 1974). Heuristics are simple decision rules; innate, inevitable, and necessary, generating both routine behavior (inference, choice) and more consequential decisions (morality). Importantly, cognitive heuristics resist modification, i.e., they require attention and energy to recognize and alter. Heuristics are instinctive and reflexive, occurring below and more rapidly than conscious thought in much the same way that visual illusions, e.g., perspective drawing, persist despite the viewer's awareness that the image is only two-dimensional.

The use of cognitive heuristics has evolved over time and is observable in a wide variety of circumstances in humans and animals. The neurobiological substrate for heuristics is hard-wired, present at birth, and primed for ready shaping by life's exposures, in a manner that is at least partly coordinated with memory and sensory perception (Real, 1991). While a general explanation of many aspects of apparently irrational human behavior (Kahneman, 2011), heuristics can also be considered ecologically rational (Goldstein & Gigerenzer, 2002) cognitive tools that exploit the structure of environmental information to allow good-enough judgment and action in real time. Thus, use of a heuristic in its appropriate context typically affords alignment of an action with its desired outcome, and is a crucial mechanism underlying the often valuable intuitive judgment of experts and novices alike.

As an example, the *availability heuristic* is used to assess frequency or probability of events, or plausibility of information, based on the availability of examples of the event or information in memory. Recalled information is weighted subjectively in favor of that which is recent, common, easily-remembered. Consequently, this information is considered more reliable and influential (Tversky & Kahneman, 1973; Schwarz et al., 1991). The *availability heuristic* is often sensible, as when recall fluency corresponds to an objective, fact-based relationship in the external world, but can be easily manipulated, e.g., in modern-day marketing and advertising.

There is no guarantee, however, that recall fluency correlates with objective probability. Dramatic, vivid, or emotionally salient events or information often actually occur less frequently (e.g., an airplane crash), but leave a strong and lasting impression on memory nonetheless. Evolutionarily, the advantages of such an adaptation are clear; survival depends on successfully learning to avoid what is likely to harm and seek out what is likely to nourish. While true threats to survival are relatively rare in our lives today, this fundamental machinery is still continually active during all kinds of judgment and decision-making, leaving us vulnerable to the overutilization or application of heuristics in contexts for which they are inappropriate. Misapplied heuristics, termed 'cognitive biases,' are a major source of systematic errors in human reasoning (Tversky & Kahneman, 1974).

In addition to *availability*, other fundamental decision-making heuristics include: *anchoring and adjustment* - the estimation or prediction of an unknown by incremental adjustments to a known; *representativeness* - the prediction of likelihood based on similarity to a (most salient) known; and *affect* (Slovic et al., 2007) - the influence of emotion on the assessment of information. Biases in judgment associated with these heuristics occur as people tend to make insufficient adjustments to an anchor, are unconsciously influenced by entirely unrelated stimuli, are neglectful or ignorant of base rates (pure probabilities), and are unaware of the strength or prevalence of emotionality to drive motivation and behavior. Unfortunately, these examples are just a few of the myriad ways in which heuristics may be used in a context-inappropriate manner, and cause errors in judgment. As such, frequently misapplied heuristics warrant specific attention if design process and outcomes are to be meaningfully improved.

The concept of cognitive heuristics and their (mis)application is depicted in **Figure 1**. The archer has honed her skills while shooting in a cross-wind, thereby developing a technique that accommodates for an external force that deflects her aim. If the wind were to suddenly cease or blow from the other direction, and she continues to use the identical technique, she will certainly miss the target, and in a predictable way. If, however, she can both detect the environmental change and appropriately adapt her technique to the new conditions, she may very well hit the target exactly as intended.

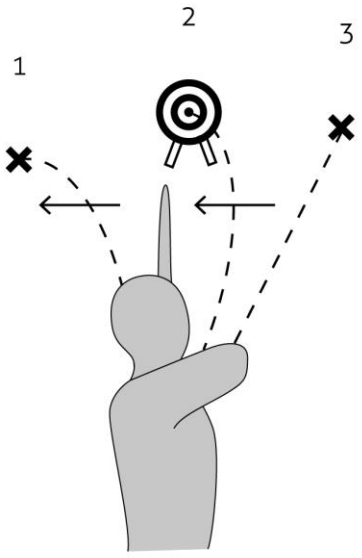

Figure 1. The archer learns to shoot in a cross-wind (left-pointing arrows). In a cross-wind, shooting directly at (2) will hit (1). To hit the target, she must fire at (3). However, if the wind shifts or ceases, firing at (3) will, predictably, miss the target. Image courtesy of Danielle Olson, MFA.

By nature, design is largely an intuitive judgment and experience-based discipline. Design problems are often ill-defined and open-ended, with starting goals as only incomplete or vague mental representations. As such, designers typically explore tasks from a particular perspective, i.e., framing, so that solution concepts may emerge. A designer decides what to do (and when) on the basis of a personally perceived and constructed design task, which includes the design problem, the design situation, the resources (time or materials) available, as well as the designer's own goals (Yilmaz et al., 2010). Thus, design thinking is strongly influenced by personal heuristics at each of these decision points and is particularly vulnerable to heuristic misuse when undertaken as a solo, unexamined practiced, even by experts.

Structural Heuristics in Design

The physical design space and design team infrastructure, including interpersonal and group process navigation dynamics, are considered structural elements that together form a higher-ordered system. In an ideal scenario, design team members come from diverse backgrounds, collectively possess a wide spectrum of skills and expertise, and communicate with optimal openness, clarity and efficiency. Differing perspectives are valued, encouraged, and given equal opportunity for consideration and integration into design decisions. Importantly, the group as a whole maintains an unwavering commitment to act according to the needs and priorities of the design, over those of any individual agenda. Such perfectly balanced collaboration can be considered a type of structural (group) heuristic that promotes increased cognitive complexity and group rationality (Curşeu et al., 2013). In the right conditions, collaboration itself can act to counterbalance individual tendencies to misuse heuristics.

Social heuristics, including collaboration, have adapted in both humans and animals, and contribute to cognitive synergy and consensus decision-making. Synergy describes cognitive competencies, particularly rationality and task-related demands, that emerge from interpersonal interactions and transcend individual cognitive competencies (Larson, 2007; Sasaki & Pratt, 2012). From an evolutionary perspective, survival of an individual is contingent upon group survival; achieving consensus is often crucial to maintaining group cohesion, and the risk of isolation far outweighs the choice to dissent. Recent evidence indicates that prosociality and cooperation are mostly intuitive behaviors (Rand et al., 2014), especially in social environments with mutually agreed upon values (e.g., transparency, fairness, speed), and may have distinct advantages over selfishness. Indeed, a combination of *"imitate-the-successful"* and *"take-the-best"* may be an optimal heuristic for sound decision-making in groups (Meslec et al., 2014).

While group-based strategies are often employed under the assumption that their collective rationality or performance reliably exceeds that of individual members, little evidence exists in support of this as the general case. More commonly, the pitfalls of personal heuristics do not "average out" in group decision-making, and may become negatively reinforcing. Indeed, several types of biases are common across populations, emerging as a result of social heuristics gone awry. Group decisions require individuals to balance personal information (e.g., heuristics, beliefs, memories, habits) with potentially conflicting social information acquired by observing other members. In this context, and with the high stakes of isolation risk, biased decisions not based solely on information about option quality can easily arise (Miller et al., 2013).

Groupthink, an extreme result of imbalanced or dysfunctional group dynamics and conformity pressures, is a useful example of the harmful effects of unchecked social heuristics. In this case, even highly competent individuals may together arrive at a poor decision, due in large part to strong group identity, belief in group morality, authoritative leadership, and insulation from outside information, all of which are worsened by time

pressures (Janis, 1982; Baron, 2005). If acknowledgment of discrepant or unsettling information is not encouraged, or worse, even mildly punished, and contradictory or outside opinions not solicited, the group may begin to see itself as overly important, valuable, and invulnerable. Decision-making in such contexts will almost certainly be erroneous, often with dire consequences. Indeed, *groupthink* has been cited as a potential factor in several major well-known business and government decision mishaps, including the 2003 Iraq invasion, NASA space shuttle incidents in 1986 and 2003, U.S. involvement in the 1962 overthrow of Fidel Castro, and the recent global financial crisis (see below).

Collaborative design can counterbalance the distortion caused by an individual's tendency to misuse heuristics, but intra-group communication appears key to ensuring that social heuristics benefit, rather than harm, a group process (Bahrami et al., 2010). Indeed, collaborative efforts are vulnerable to their own set of biases resulting from unrecognized and uncompensated heuristics that can easily weaken cognitive synergy, undermine sound consensus decisions, and severely distort design outcomes. Thus, continual evaluation of the appropriateness of the habits, practices, and values of the collaborative group as a whole, and effortful action toward mitigation, is required to reduce the likelihood of design distortion.

The 2008 Financial Crisis: An illustration of heuristics and negative impacts of cognitive bias

Unacknowledged or inappropriate use of cognitive heuristics may result in design distortions of any magnitude. While difficult to prevent entirely, awareness and understanding of the influence of cognitive heuristics can facilitate the detection of potentially costly errors. Additionally, the intentional application of a context-appropriate heuristic may be leveraged to improve design. Here, we use the 2008 global financial crisis to illustrate how context can distort the utility of cognitive heuristics, and discuss the resultant biases that skew otherwise reasonable decision-making and resultant outcomes. Like economic behavior, design behavior, particularly that involving social, institutional, or organizational systems, is a microcosm of psychological dynamics; as people, designers seek to understand and find meaning in the world (cognitive), are driven by emotions and motives (affective), and interact with other people doing the same (social) (Montgomery, 2011).

The financial crash of 2008 was the most dramatic worldwide economic crisis since the 1930's Great Depression. Extensive subprime U.S. mortgage lending triggered financial system malfunctions around the globe, with stock loss estimates averaging $8 trillion in the U.S. and about 40% in other countries. The crisis has been described as a perfect storm (Norberg, 2012), in which severe imbalances caused by increasing dependence on borrowed money rather than the production of goods and services, combined with an increasingly complex financial savings market and other systemic factors, led to a rapid deterioration of global economic stability. Unsound judgment and poor decision-making on the part of numerous parties, including lax lending in the housing market, inaccurate risk rating by agencies, excessive leveraging by institutions and individual households, and dilution of regulatory oversight, have been identified as critical contributions to the widespread financial disaster.

As described by Montgomery (2011), dramatic price shifts occur commonly in the stock market with little apparent rationale; only after the shift does the cause become clear. News of shifts, however, is instantly available and frequently elicits strong reactions from players (*overreaction*) as they overweight and rapidly respond to this readily available information. While the shift-causing events are generally economically relevant, the price changes themselves may not accurately reflect the underlying market forces. Similarly, economically relevant information may be less available and is thus neglected in participants' decisions (*underreaction*). These dynamics were at play for several years leading up to the

crisis, and the associated warning signs were recognized by many economists. Far more attention was paid, however, to news that the economy continued to develop well year after year, leading to an endemic belief in further growth. This belief was likely reinforced by the general human tendency to be erroneously optimistic about the likelihood of future positive events, while underestimating the likelihood of future negative events (*optimism bias*; Sharot, 2011); financial analysts predict growth more accurately in poor times, but tend to overestimate forecasts when times are good (Lee et al., 2008).

An overarching theme of heuristic misuse is that it leads to bias-induced distortions of judgment. Bias emerges so readily in large part due to the instrinsic tendency of human cognition to search for, detect, or attribute meaning to patterns which are, in reality, entirely random. In many instances, such pareidolia, apophenia, or patternicity (Shermer, 2011) plays an adaptive role, e.g., both human and animal survival necessitates an extremely high sensitivity for facial recognition (reviewed in Liu et al., 2014). However, as alluded to above, randomness is the rule in stock markets, and past movements have almost no relevance to the accurate prediction of future movements. Furthermore, randomly fluctuating phenomena, including markets, will *regress to a mean* over time, i.e., extreme events in one direction are more likely to be directly followed by movement in the opposite direction, resulting in an averaging of the effects. As with uncertainty, it appears quite difficult for human cognition to accept randomness on its own terms, creating fertile ground for distortions in perception that better fit the pre-existing internal construct. Instead, we instinctively seek out, remember, and favorably interpret information that confirms what we already know or believe (*confirmation bias*), and retain an inflated and unjustified conviction that this information is accurate (*overconfidence bias*). We systemically discount the impact or consequences of future actions or events, and will be less likely to change our behavior the more removed an event is from its related consequences (*remoteness of impact bias*). We tend to value immediate more than delayed payoffs, and with even greater magnitude the closer the payoffs are to the present (*hyperbolic* or *temporal discounting*; Strotz, 1955). In highly volatile environments, "cashing out" as soon as possible is a rational choice, even in the face of substantial long-term risks. Although these psychological mechanisms cannot entirely explain the degree of financial disaster which ensued, they clearly made major contributions to the contagion, escalating poor judgment, risky behavior, and fueling the rapid growth of a bubble that would inevitably burst.

While not causal in itself, *herding*, or the adoption of the opinions, beliefs, or behaviors of the perceived majority, likely set the stage for the ensuing crash and magnified growing dysfunctional group dynamics as increasing numbers of inexperienced players entered the market. As a source of inflation, such behavior is often viewed as a significant threat to healthy market function; players systematically respond more actively to perceived positive signals and are more skeptical or neglectful of negative signals, leading to information inefficiency, increased volatility, and bubbles. Frequently more malignant, the prevalence of *groupthink*, with its suppression of dissent, self-censorship, and enhanced risk-taking associated with perceived invulnerability, at least partly explains the remarkable behavioral synchronization of previously opposing groups (e.g., rating agencies, regulators, legislators, lenders, borrowers, mortgage brokers, securities dealers) that led to unwarranted trust in experts, an illusory consensus, and ultimately, the crash (Montgomery, 2011). Disturbingly, while warning signs were plentiful in retrospect, the IMF has since acknowledged the contribution of *groupthink* to its hindered ability to correctly identify risks, inadequate analytics, and discounting of poor outcomes in favor of promoting the vision of a healthy economy.

Perhaps most frustratingly, while indicators of potential crisis were prevalent for some time, and much of the resulting losses preventable, the crash itself was not knowable with any

certainty — many contributing factors became obvious only in retrospect. Similar to the difficulties with uncertainty and randomness, human cognition does not readily accommodate unpredicted events; instead, we immediately adjust our worldview and attempt to explain them causally with any information that comes to mind. We do not reliably reconstruct past beliefs, and thus underestimate the extent to which past events were surprising (*hindsight bias*). Ultimately, our assessment of decision quality is based not on whether the process was sound, but whether the outcome was good or bad (Kahneman, 2011). Especially pertinent to design, agents acting on the behalf of others get less credit when the outcome is positive and receive more blame when the outcome is negative, regardless of the quality of the decision-making process *("shoot the messenger" effect*), and this is amplified in worse consequences. Evaluation of decisions and their outcomes is critical to transcending past mistakes; unawareness of these tendencies can greatly hinder effective learning and preclude implementation of future safeguards.

Interliminal Design: A Framework for Appropriate Heuristic Usage and Bias Mitigation

Built on the premise that every design task occurs within an evolving ecology of individual and group systems in both conscious and subconscious relationship, interliminal design is particularly well-suited for complex systems and wicked problems. In dynamic environments, learning, emergence and adaptation are frequent and non-linear; success of the design process relies heavily on maintaining clear intention, flexibility and creativity in response to actively changing circumstances. A basic understanding of how the intrinsic cognitive tendencies underlying judgment and decision-making influence the design process, and active efforts to counteract or prevent the negative consequences of unrecognized influence, are potent remedies to avoid, or at least ameliorate, design distortion. Here we provide a general framework and some specific techniques that may be used to effectively mitigate context-inappropriate heuristic usage and associated cognitive bias in systems design, particularly that involving collaboration and wicked problems.

Conceptually, interliminal design leverages several critical aspects of a systems approach, including the core recognition that as cognitive heuristics are active on both personal and structural levels, multiple levels of any design process may be affected. Heuristic misapplication on personal levels frequently become magnified in group settings. Critical evaluation of heuristic appropriateness to the current design context is imperative, regardless of how familiar or similar to those of the past, and best undertaken simultaneously by individuals and the group as a whole. Awareness of those identified as incongruous or potentially misaligning for design goals can then be redirected. At all levels, primary tools include intentionally reflective and dialogic methods that enhance deliberate and corrective thought processes, and focused interaction strategies addressing the ideas and insights that emerge through interpersonal or collaborative activity.

We recommend that specific mitigation techniques and ideas for inquiry be revisited continuously throughout the design process, with contemplation at major decision points being particularly critical. Similarly, we emphasize the importance of flexibility among different techniques to maintain a position of equanimity between systems and boundaries, as well as building in continual reassessment of current design conditions as the process unfolds. Our suggestions are based on evaluations of experts, personal experience, and the limited available empirical evidence, but are intended only as a starting point and certainly not exhaustive of potentially useful strategies. We have made a general distinction between strategies as more personal or structural, though many are beneficial at both levels.

Personal

- Utilize multiple, diverse information-gathering techniques. Question and rank the quality of sources.
- Perform evidence-based research to gather the most relevant, accurate, and current statistical information as possible.
- Invite the user to participate directly in the design conversation or process.
- Identify and label anecdotal evidence as such. Gather additional non-anecdotal evidence, and estimate rational probabilities, i.e., base rate calculations.
- If predictions are necessary, factor in regression to the mean over time.
- Question the diagnosticity of evidence.
- Seek out drastically differing expert opinions.
- Identify sources of physiological and emotional influence or stress. When possible, take immediate action to ameliorate before making a decision.

Structural

- Perform a contrarian group role-exchange exercise, e.g., Red Team-Blue Team.
- Construct a genuine argument directly opposed to the preferred stance/opinion.
- Construct emergence maps of the adjacent possible.
- Create plans for a variety of different scenarios, including multiple versions of complete failure or worst imaginable outcomes.
- Repeat multiple cycles of iteration and prototyping. Combined with reassessment of stated goal/outcome.
- Use personas to help understand stakeholders. Try to defy the stereotypes associated with each.

Ideas for Inquiry

- What are the main drivers or leverage points of the primary system(s) in question?
- What are the possible outcomes of altering these drivers?
- What are the worst outcomes we can imagine?
- What might we do to arrive at our worst imaginable outcome(s)?
- What is the source of the information (factual, explanatory, deontic, etc.)? How was it acquired?
- What motivation(s) might be at play for all of the various stakeholders?
- What first-hand experience do we have?
- What evidence refutes what we believe to be true?
- Is there physical or emotional stress? What are the sources (both external and internal)?

Heuristic utilization is fundamental to human cognition, and serves a highly valuable role during intuitive judgment when used in the appropriate context. While difficult to prevent entirely, heuristic misapplication and the resulting errors in judgment can be more readily detected and ameliorated using techniques that enhance metacognition in both individual and group design processes.

Interliminal design in Action

As part of the elective curriculum in the Collaborative Design MFA program at Pacific Northwest College of Art, we developed and taught a novel course entitled "Design Thinking and Cognitive Biases." Coursework was directed toward an exploration of cognitive heuristics and associated biases, and their influence in design thinking, process, and outcomes. An additional goal was to formulate specific techniques that could readily illuminate heuristics

and biases commonly acting on personal and structural levels in design. Students in the course developed two projects as potentially effective interliminal design approaches: The Designer's Bias Lounge, a physical space to hold constructive, interactive dialogues with fellow designers and facilitate challenging self-assessment and inquiry; and the board game "BIAS!" for play in small design groups to increase the ability to rapidly detect heuristic misuse and cognitive bias in humorous, but accurate, real-world examples.

Conclusion

Interliminal design seeks to illuminate and understand the influence of cognitive heuristics to improve intention, decision-making, and outcomes in design. Those revealed as inappropriate for design goals through reflective and interactive evaluation can then be compensated for, or substituted with a superior cognitive model or analysis technique. This inquiry-driven approach furthers the evolution of design thinking by adding a metacognitive dimension, i.e., thinking about design thinking, and increases accessibility of corrective or rational thought. The resulting ability to flexibly shift between states, perspectives and mental models, while maintaining equanimity and clear focus on a desired outcome, is a potent tool for minimizing distortion in both individual and collaborative design processes.

> ... it would be wrong to conclude...that having biases, values and interests is an impediment to sound reasoning that we'd be better off without. It is one of the conditions of human being, after all, that we care about things and that caring colors our attempts at logical judgment. It is just something that always needs to be taken into account when the stakes are high and we are not, as we so rarely are, entirely detached from a problem or situation. — Alva Noe

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References

Bahrami, B., Olsen, K., Latham, P. E., Roepstorff, A., Rees, G., Frith, C. D. (2010). Optimally interacting minds. *Science*, *329*(5995), 1081-5.

Baron, R. S. (2005). So right it's wrong: Groupthink and the ubiquitous nature of polarized group decision making. *Advances in Experimental Social Psychology, 37*, 219–253.

Curşeu, P. L., Jansen, R. J., Chappin, M. M. (2013). Decision rules and group rationality: cognitive gain or standstill? *PLoS One*, *8*(2), e56454.

Gennep, A. van (1960) [1909]. *The rites of passage*. Chicago: Chicago University Press.

Goldstein, D. G., & Gigerenzer, G. (2002). Models of ecological rationality: the recognition heuristic. *Psychological Review*, *109*(1), 75-90.

Janis, I. L. (1982). *Groupthink* (2nd ed.). Boston: Houghton Mifflin.

Kahneman, D. (2003). A perspective on judgment and choice: mapping bounded rationality. *American Psychology, 58*(9), 697-720.

Kahneman, D. (2011). *Thinking, fast and slow*. New York: Macmillan.

Larson, J. R. (2007). Deep diversity and strong synergy: Modeling the impact of variability in members' problem-solving strategies on group problem-solving performance. *Small Group Research, 38*, 413–436.

Lee, B., O'Brien, J., & Sivaramakrishnan, K. (2008). An analysis of financial analysts' optimism in long-term growth forecasts. *The Journal of Behavioral Finance*, *9*(3), 171-184.

Levin, K., Cashore, B., Bernstein, S., Auld, G. (2012) Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. *Policy Sciences*, *45*(2), 123–152.

Liu, J., Li, J., Feng, L., Li, L., Tian, J., Lee, K. (2014). Seeing Jesus in toast: Neural and behavioral correlates of face pareidolia. *Cortex, 53*, 60-77.

Meslec, N., Curşeu, P.L., Meeus, M. T., Iederan Fodor, O. C. (2014) When none of us perform better than all of us together: the role of analogical decision rules in groups. *PLoS One*, *9*(1), e85232.

Miller, N., Garnier, S., Hartnett, A. T., Couzin, I. D. (2013). Both information and social cohesion determine collective decisions in animal groups. *Proceedings of the National Academy of Sciences U S A*, *110*(13), 5263-8.

Montgomery, H. (2011). *The Financial Crisis - Lessons for Europe from Psychology*. Swedish Institute for Policy Studies. Retrieved from http://www.sieps.se.

Nelson, H., & Stolterman, E. (2003). *The design way: Intentional change in an unpredictable world*. Cambridge, MA: The MIT Press.

Norberg, J. (2012). *Financial fiasco: How America's infatuation with homeownership and easy money created the financial crisis.* Wahington D.C.: Cato Institute.

Rand, D. G., Peysakhovich A., Kraft-Todd G. T., Newman G. E., Wurzbacher O., Nowak M. A., Greene J. D. (2014). Social heuristics shape intuitive cooperation. *Nature Communications, 22*(5), 3677.

Real, L. A. (1991). Animal choice behavior and the evolution of cognitive architecture. *Science*, *253*(5023), 980-6.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169.

Sasaki, T., Pratt S. C. (2012). Groups have a larger cognitive capacity than individuals. *Currrent Biology, 22*(19), R827-9.

Schwarz, N., Bless, H., Strack, F., Klumpp, G., Rittenauer-Schatka, H., Simons, A. (1991). Ease of retrieval as information: Another look at the availability heuristic. *Journal of Personality and Social Psychology, 61*(2), 195-202.

Sharot, T. (2011). The optimism bias. *Current Biology*, *21*(23), R941-R945.

Shermer, M. (2011). The believing brain. *Scientific American*, *305*(1), 85.

Slovic, P., Finucane, M., Peters, E., & MacGregor, D. (2007). The affect heuristic. *European Journal of Operational Research*, *177*(3), 1333-1352.

Strotz, R. H. (1955). Myopia and inconsistency in dynamic utility maximization. *The Review of Economic Studies*, *23*(3), 165–180.

Thomassen, B. (2009). The uses and meaning of liminality. *International Political Anthropology*, *2*(1), 5-28.

Turner V. (1967). The forest of symbols – Aspects of Ndembu ritual, Chapter IV - *Betwixt and between: The liminal period in rites de passage*.

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

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131.

Tversky, A., & Kahneman, D. (1985). The framing of decisions and the psychology of choice. *Behavioral Decision Making* (pp. 25-41). Boston, MA: Springer US.

Yilmaz, S., Seifert, C. M., & Gonzalez, R. (2010). Cognitive heuristics in design: Instructional strategies to increase creativity in idea generation. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *24*(03), 335-355.