Special Issue

Intuitive Cognition

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In the naturalistic decision-making literature, intuitive cognition is at the heart of a pattern recognition–based decision model called the *recognition-primed decision* model. Given the importance of intuitive cognition in naturalistic decision-making theory, we explore the question of what makes intuitive cognition effective for decision making and, in so doing, present an extended empirical and theoretical foundation for the intuitive component in naturalistic decision making. We theorize that intuitive cognition is effective because it (1) possesses a capability for grounded, situational meaning making (sign interpretation); (2) is operative over extended work intervals involving interruptions; and (3) is instrumental in handling situated complexities of everyday living. Other characteristics of intuitive cognition and its foundations are discussed. We propose that intuitive cognition represents the core of cognition—grounded, situational meaning making—whereas analytical cognition represents a form of an intellectual exoskeleton that provides added capabilities (e.g., working memory).

Keywords: intuitive cognition, meaning making, sensemaking, reasoning, dual-process model

INTRODUCTION

Decision making based on unconscious situational pattern recognition is called *intuitive* (Klein, 1998, 2008; Lopes & Oden, 1991; Westcott, 1968; Zsambok & Klein, 1997). Skilled intuitive decision making occurs in many domains of expertise, such as fighting fires, diagnosing infants with disease, and engaging an enemy during combat (Klein, 1998). In the naturalistic decision making (NDM) literature, intuitive cognition is at the heart of a pattern recognition–based decision model called the *recognition-primed decision* model (e.g., Klein, 1997, 1998, 2008; Klein, Wolf, Militello, & Zsambok, 1995). According to this model, intuitive decision making involves an unconscious comparison between the current situational pattern and situational patterns stored in memory from previous experiences. A match between current and remembered situational patterns generates responses based on previous successes adapted to the current situation (the potential outcome of a given course of action may be mentally simulated before action).

Given the importance of intuitive cognition in NDM theory, we explore the question of what makes intuitive cognition effective for decision making and, in so doing, present an extended empirical and theoretical foundation for the intuitive component in NDM. We theorize that intuitive cognition is effective because it (1) possesses a capability for grounded, situational meaning making (sign interpretation); (2) is operative over extended work intervals involving interruptions; and (3) is instrumental in handling situated complexities of everyday living. These ideas are discussed at length throughout the remainder of this paper. Other characteristics of intuitive cognition (information integration) and its foundations (implicit learning, procedural memory, and embodiment) are also covered. This theory of intuitive cognition is our main scientific contribution to the literature.

The background and theoretical context of intuitive cognition are covered next. The characteristics and foundations of intuitive cognition are discussed in subsequent sections. The last section offers discussion and concluding remarks.

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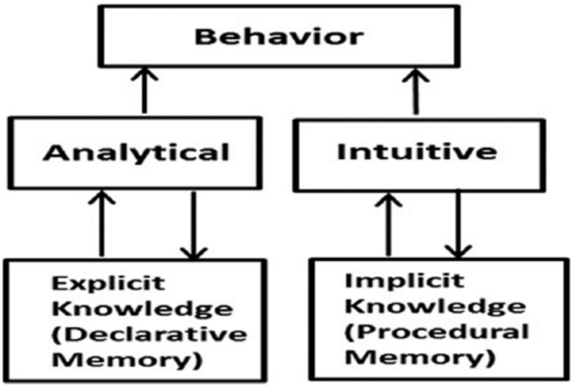

Figure 1. Depiction of two sets of cognitive processes, or two systems (i.e., analytical and intuitive), for human reasoning and decision making. There is much evidence in support of some form of dual-process model. The current paper links analytical cognition to declarative memory and intuitive cognition to procedural memory.

BACKGROUND AND THEORETICAL CONTEXT: DUAL-PROCESS OVERVIEW

Dual Process

Intuitive cognition is one of two types of cognition deployed in reasoning and decision making (see Figure 1; Reyna & Brainerd, 1995; Evans, 2003, 2008, 2010; Evans & Stanovich, 2013; Kahneman, 2011; Kahneman & Klein, 2009; Sloman, 1996; Stanovich & West, 2000). *Analytical cognition* involves conscious deliberation that draws on limited working memory resources (Baddeley, 2003; Baddeley & Hitch, 1974; Miyake & Shah, 1999). Analytical cognition is voluntary, effortful, limited in capacity, and slow. *Intuitive cognition* involves unconscious situational pattern synthesis and recognition unconstrained by working memory limitations. Intuitive cognition is independent of conscious "executive" control, large in capacity, and fast. Simon (1992, p. 155) defined skilled intuition as situational cue recognition that primes retrieval of an answer from memory. These two types of reasoning and decision making can be dissociated experimentally (De Neys, 2006a, 2006b) and neurologically (Funahashi, 2006; Goldman-Rakic, 1995; Horr, Braun, & Volz, 2014; Owen, 1997; Volz & von Cramon, 2006).

A framework similar to Figure 1 was presented by Hammond and colleagues (Hammond, 2007; see also Hammond, Hamm, Grassia, & Pearson, 1987, 1997). These authors proposed the existence of a cognitive continuum, with analysis at one end and intuition at the other end; *quasi-rational decision making* referred to a blending of the two types and was positioned in the middle of the continuum. Hammond and colleagues suggested that analysis and intuition were parallel systems that functionally interacted when reasoning about a problem. Effective decision making required flexibility on the cognitive continuum—oscillation between analysis and intuition (see Hamm, 1988).

Emotion. Intuitive cognition, in particular, is linked to emotion. For example, Damasio (1994) proposed that the memory of situations involving positive or negative emotions may trigger reactions that guide decision making, a form of "somatic marker." Bechara, Damasio, Tranel, and Damasio (1997) found evidence of a somatic marker: Individuals playing a gambling task learned to choose successfully and generate anticipatory skin-conductance responses to risky choices, without conscious awareness. The somatic marker works outside conscious working memory (Damasio, 1994) and may be a component of intuitive cognition.

Tasks involving intuitive cognition have produced activation in brain regions (e.g., ventromedial prefrontal cortex; Horr et al., 2014; Volz & von Cramon, 2006) implicated in emotion and social interaction (Bar et al., 2001; Gazzaniga, Ivry, & Mangun, 2002). This emotional underpinning of intuitive cognition means that the output of intuitive cognition's processing—which is unconscious—is posted to consciousness as a gut feeling (for related ideas, see Bowers, Regehr, Balthazard, & Parker, 1990).

Intuitive Cognition Domination

There are many instances of intuitive cognition dominating responding when humans make decisions. This domination, however, does not necessarily imply effective or rational decision making, as many studies seem to present mixed results in terms of the appropriateness and accuracy of intuitive cognition. There are three factors to consider when judging the appropriateness, accuracy, or rationality of human decision making. This three-factor approach can be used to better understand the task situation confronting the decision maker and thereby provide deeper insight into the sometimes confusing extant human decision-making literature.

First, one must consider the standards by which decision making is judged. One standard involves the adoption of some formalized framework of concepts (whose choice is arbitrary), as in logic and mathematics. This approach has been called *coherence* by Hammond (1990, 1996, 2007; see also Dunwoody, 2009)—decisions are considered rational when they fit into, or are coherent with, a given framework. According to Vicente (1990), the coherence approach entails a form of relativism—the status of a statement can vary according to the concepts against which it is evaluated. Standards based on coherence are found in the literature on rational choice theory (e.g., Bernoulli, 1738/1954; von Neumann & Morgenstern, 1944).

A different standard entails the consideration of empirical reality. This approach has been called *correspondence* (Dunwoody, 2009; Hammond, 1990, 1996, 2007)—decisions are considered accurate when they are correct for, or correspond to, empirical reality. According to Vicente (1990), the correspondence approach involves a form of realism—an observer-independent, objective reality is assumed to exist.

Vicente (1990) embraced this coherence-correspondence framework as a means for classifying two kinds of work domains, and Mosier (2009) adopted this coherence-correspondence framework in the discussion of cockpit instrumentation. Thus, in addition to dominance, one can ask to what degree intuitive decision making is appropriate, accurate, or rational and by what standard.

Second, one must consider the type of task that must be performed. Hammond and colleagues (Hammond, 2007; Hammond et al., 1987, 1997) proposed that the precise blend of analytical and intuitive decision making adopted at a given point in time depends on factors such as the structure, complexity, ambiguity, and form of presentation of a given task. Specifically, the relative weight given to processing in one or the other system depends on the number of cues (intuition: many, analysis: few), measurement of cues (intuition: perceptual, analysis: objective), redundancy among cues (intuition: high, analysis: low), degree of task certainty (intuition: low, analysis: high), display of cues (intuition: simultaneous, analysis: sequential), and the available period (intuition: short, analysis: long).

Thus, at one end of the task continuum, an intuition-inducing (correspondence-driven) task would entail speeded judgments about perceptual material with multiple cues and no symbolic calculation. At the other end of the task continuum, an analysis-inducing (coherence-driven) task would entail deliberative judgments involving symbols, rules, and/or algorithms (e.g., mathematical expressions). As noted by Hammond et al (1987), the relation between task properties and the type of cognition induced is not fully determined. These authors mention that analytical cognition can respond to intuition-inducing tasks (e.g., if there is sufficient time), and intuitive cognition can respond to analysis-inducing tasks (e.g., if time is limited). When a single task includes both intuitive and analytical properties, presumably both modes of cognition can be induced ("quasi-rationality").

Hammond and colleagues also distinguished between the depth features of a task (covert relationships among underlying variables) and its surface features (overt display of task variables). Hammond, Hamm, and Grassia (1986; see also Hammond et al., 1987) found that, in a study involving highway engineers, the task properties did induce the corresponding cognition ($r^2 = 0.26$). However, the degree of congruence between surface and depth characteristics of tasks had only a negligible positive relation to performance (r^2 = 0.03).

Third, one must consider whether the decision maker has the needed cognitive resources for bearing on the task at hand. For example, one type of resource would be any necessary experience and/or formal training. Much has been written about the need for domain expertise, in terms of exposure to situational cues, for appropriate and effective intuitive decision making (Kahneman & Klein, 2009; Klein, 1997, 1998, 2008; Shanteau, 1992). Domain expertise of a different nature, such as exposure to formal rules of logic, would be needed for accurate and effective analytical decision making.

The issue of cognitive resources is important because there is evidence that intuitive cognition is the default system whenever analytical cognition is faced with tasks it cannot accomplish (see below). Thus, in many cases, intuitive cognition is left to generate the (pattern-based) response, which can be correct or appropriate if the individual can process the meaningful gist found in a given task and/or has relevant domain expertise; otherwise, the response may be incorrect or inappropriate.

Putting together these three factors—standards, type of task, and cognitive resources—we have coherence-based standards applying to coherence-driven, analysis-inducing tasks (deliberative judgments, symbols, rules) and correspondence-based standards applying to correspondence-driven, intuition-inducing tasks (perceptual judgments, multiple cues, no symbols or rules). In each case, good performance would depend on having the necessary cognitive resources (e.g., experience and/or training).

Turning back to the issue of intuitive cognition domination, evidence of such domination comes from the heuristics and biases literature in which participants judged probabilities under uncertainty (Kahneman & Tversky, 1972, 1973; Tversky & Kahneman, 1973, 1974). One hallmark of this research is that, in many cases, "uncertainty" was created by presenting participants with tasks for which they would likely not know the correct answer. For example, in a study of the representativeness heuristic, Kahneman and Tversky (1972) had participants estimate the probability of the birth order (boys and girls) of "B G B B B" relative to the birth order of "G B G B B G" (the birth sequences were about equally probable). In a study of the availability heuristic, Tversky and Kahneman (1973) had participants judge whether the letter K appeared more frequently in the first or third position in words chosen randomly from English text (a typical text contains twice as many words with K in the third position). See Gilovich and Griffin (2002) for further discussion. For a recent review of this literature, see Kahneman (2011).

Performance on these kinds of coherence-driven, analysis-inducing tasks would be compared with probability theory or some other norm. Most participants' responses were intuitive and presumably based on heuristics that violated statistical norms. However, it is likely that few participants in these studies had the necessary experience and/or training (e.g., formal probability theory; knowledge of the frequency of positions of all letters in all English words) for correctly performing these analysis-inducing tasks using analytical cognition. Intuitive cognition generated most of the (usually incorrect) responses to the tasks.

Further evidence of intuitive cognition domination comes from the dual-process literature. In this literature, participants attempted to solve a deductive-logic "selection" task (e.g., Evans, 2008; Evans & Stanovich, 2013; Wason & Evans, 1975) or a syllogism task (e.g., Evans, Barston, & Pollard, 1983). Performance on these analysis-inducing tasks was compared with rules of logic. Most participants' responses were intuitive, not logical: Incorrect responses called *pattern matching* occurred 80% of the time on the selection task, and believability of the conclusion had a larger effect than logic on the syllogism task. However, it is likely that few participants in these studies had the necessary experience and/or training (e.g., formal rules of logic) for performing the analysis-inducing tasks using analytical cognition. Intuitive cognition again generated most of the (incorrect) responses to the tasks.

Other evidence of intuitive cognition domination comes from the fuzzy trace literature in which children attempted to solve transitivity reasoning problems (Brainerd & Kingma, 1984, 1985; see also Reyna, 2012; Reyna & Brainerd, 1995). Performance on the analysis-inducing reasoning tasks was compared with formal rules of logic. Most responses by the children were correct despite a lack of declarative memory for the premises. Thus, the children in these studies did not have the necessary cognitive resources (declarative memory) for solving the analysis-inducing task using analytical cognition. Intuitive cognition generated correct responses to the task by recognizing and remembering the gist of the problem solution as a global pattern in the ordering of elements (smallest on the left, largest on the right) without conscious recollection of specific relationships among elements.

Intuitive cognition domination can clearly be seen in the NDM literature in which professionals with expertise (e.g., firefighters, neonatal nurses) performing in their work domains were studied (Klein, 1997, 1998, 2008; Zsambok & Klein, 1997). Performance on the correspondence-driven, intuition-inducing tasks was examined for efficacy in the real world. The professionals engaged in intuitive decision making 80% of the time or more, with varying degrees of success, which entailed situational pattern recognition. All participants had significant training and experience in their domain of expertise—the necessary resources for successfully performing the intuitive-inducing tasks using intuition.

Final evidence of intuitive cognition domination comes from the automatic process literature, in which the effects of information presentation on reasoning, the development of preferences, and decision-making strategies were investigated (e.g., Betsch, 2008; Betsch & Glöckner, 2010; Betsch, Plessner, Schwieren, & Gutig, 2001; Glöckner, 2006; Glöckner & Betsch, 2008). For example, in one study (Betsch et al., 2001, as reviewed by Betsch & Glöckner, 2010), participants used working memory to memorize videotaped advertisements ("primary task") while 140 numbers scrolled—one at a time—across the bottom of the display ("secondary task," the task of interest). The numbers were to be grouped into five categories, and then each category was to be summed, which represented an analysis-inducing secondary task. Yet participants could not perform the secondary task consciously (analytically), because their working memory was taken up with memorizing the videotaped advertisements (primary task). The participants did not possess the necessary cognitive resources for performing the secondary task using analytical cognition. But the participants could correctly perform the secondary task—categorize and sum numbers—intuitively when measured by an affective (good, bad) scale, a capability consistent with intuitive cognition's so-called organizing principle (Hammond et al., 1987).

In the NDM literature, intuitive cognition generated most responses on the correspondence-driven tasks (e.g., fighting fires), which involved participants possessing high domain expertise (e.g., firefighters). However, in the heuristics and biases, dual-process, fuzzy-trace, and automatic process literatures, intuitive cognition also generated most responses (correct and incorrect) on coherence-driven tasks—judging probabilities under uncertainty, solving logic and reasoning problems, or categorizing and summing numbers. This occurred when the participants did not have the necessary experience, training, or other cognitive resources to accomplish the tasks using analytical cognition (in the successful cases, intuitive cognition recognized gist or calculated sums). These results are consistent with Hammond and colleagues' (1987) statement that there are times when intuitive cognition can respond on analysis-inducing tasks.

We conjecture that the reason why intuitive cognition dominated under conditions that should have favored analytical cognition is that intuitive cognition is the default system whenever analytical cognition is faced with tasks it cannot accomplish. Hammond and colleagues' cognitive continuum is a necessary but insufficient concept for specifying the conditions under which intuitive versus analytical cognition can be elicited. What also matters is whether intuitive or analytical cognition possesses the necessary resources to accomplish the task at hand. If analytical cognition does not, then intuitive cognition will be the default system that generates the response, for better or worse.

Summary

Intuitive cognition, one of two types of cognition for decision making, involves judgments and decisions based on unconscious situational pattern recognition. This kind of cognition exhibits large capacity and fast responses and is independent of conscious "executive" control. Intuitive cognition dominates responding by generating most of the responses on various reasoning and decision-making tasks. In some cases, intuitive cognition is not productive (tasks requiring logic). In other cases, intuitive cognition is highly productive (tasks benefiting from exploiting environmental cues). In many studies, intuitive cognition dominated under conditions that should have favored analytical cognition because analytical cognition was faced with tasks it could not accomplish and intuitive cognition was likely the default system.

In following sections, characteristics and foundations of intuitive cognition are discussed. Tables 1 and 2 summarize some of the key concepts covered under the characteristics and foundations sections, respectively.

CHARACTERISTICS

This section on "characteristics" begins with the topic of meaning making, which we conjecture is a key characteristic of intuitive cognition. After the discussion of meaning making, we present several other characteristics of intuitive cognition.

Meaning Making

The ability of people to make meaning of events in the world is crucial for their survival. But exactly what is meaning making? In this section, we explore the idea that meaning making is *sign interpretation* brought about by intuitive cognition. Before proceeding to a discussion of sign interpretation, we first note that meaning making can also be called *sensemaking*, a term that has been conceptualized variously as (1) the process of encoding data in a given representation to answer task-specific questions (Russell, Stefik, Pirolli, & Card, 1993), (2) constructing mental sense of one's own world (Dervin, 1983), or (3) mentally fitting data elements into contextual frames (Klein, Moon, & Hoffman, 2006a, 2006b). Due to the varied definitions and conceptualizations of the term *sensemaking*, we have elected to use the phrase *meaning making* throughout the remainder of this paper.

In what follows, we explore our core theory that meaning making is sign interpretation—which is called *semiosis* and which entails the intuitive synthesis of situated patterns via memory recombination.

Meaning making as semiosis. Our approach to conceptualizing meaning making is to view it as sign interpretation. The study of meaning making as sign interpretation is called *semiotics* (e.g., Bains, 2006; Hoffmeyer, 1996; Sebeok, 1994, 1996; von Uexkull, 1982), a field originating in the 19th century (de Saussure, 1916/1972; Peirce, 1960). For example, the seminal writings of Peirce (1960) provided original analysis of the issues of thinking and meaning making. Peirce treated meaning making during thinking as sign interpretation—the meaning of a given thought occurs due to a triadic relation among the thought, the interpretation ("interpretant") of the thought as a sign (meaning), and a determining thought that the sign denotes (Hoopes, 1991, p. 7). In simpler terms, the meaning of an object or event is found in its interpretation as a sign denoting some other (determining) object or event. For example, the meaning of a traffic jam during a morning commute would be found in its interpretation as a sign denoting that the person will be late for work. Evidence that intuitive cognition engages in semiosis comes from the NDM literature where Klein and colleagues (e.g., Klein, 1997, 1998, 2008; Klein et al., 1995) have shown that most decisions made by professionals (e.g., firefighters) were intuitive and based on meaningful recognition of situational patterns as signs.

Intuitive meaning making, pattern synthesis, and memory recombination: Insight literature. Meaning is found in sign interpretation. This interpretation of something as a sign—its assigned meaning—involves the mental operation of pattern synthesis (and, by implication, memory recombination). This role of pattern synthesis in meaning making can be seen by an examination of studies from the insight literature.

Insight refers to the sudden realization of a problem solution following a period of impasse (e.g., Broderbauer, Huemer, & Riffert, 2013;

TABLE 1: Characteristics of Intuitive Cognition: Key Concepts

Meaning making: Semiosis	
Description	Interpreting a stimulus or event as a sign denoting a determining stimulus or event
Key articles	Bains (2006), Hoopes (1991), Peirce (1960), de Saussure (1916/1972)
Summary of studies	Philosophical discourse on meaning making as sign interpretation
Meaning making: Pattern synthesis	
Description	Mentally combining elements into a meaningful, holistic pattern
Key articles	Broderbauer et al. (2013), Maier (1931)
Summary of studies	Participants solved insight problems via an intuitive pattern-synthesis operation
Pattern recognition	
Description	Recognition of stimuli and cues as belonging to patterns unfolding in space and time
Key articles	Brainerd and Kingma (1984, 1985), Reyna and Brainerd (1995), Evans and Lynch (1973), Kahneman and Tversky (1973), Klein (1997, 1998, 2008), Klein et al. (1995), Reyna (2012), Watson and Evans (1975)
Summary of studies	Participants unconsciously recognized patterns based on past experience
Extended intuitive cognition	
Description	Intuitive cognition over extended work intervals involving interruptions (insight problem solving)
Key articles	Broderbauer et al. (2013), Duncker (1945), Maier (1931), Moss et al. (2011), Reverberi et al. (2005), Schooler et al. (1995), Sternberg and Davidson (1995), Wallas (1926)
Summary of studies	Participants intuitively solved insight problems that lasted over extended durations and involved interruptions.
Information integration	
Description	Integrating information for purpose of analysis
Key articles	Betsch and Glöckner (2010), Betsch et al. (2001), Glöckner (2006), Glockner and Betsch (2008), Lohse and Johnson (1996)
Summary of studies	Participants integrated and categorized information for decision making very quickly or while working memory was distracted by a secondary task.

Duncker, 1945; Maier, 1931; Moss, Kotovsky, & Cagan, 2011; Sternberg & Davidson, 1995), which typically occurs with nonroutine problem solving. Wallas (1926, p. 38) gave the original description of the phenomenon and suggested four stages of insight, which he called *illumination*: (1) preparation—conscious investigation of a problem, (2) incubation—unconscious processing, (3) illumination—"Aha" experience or sudden insight due to unconscious processing during incubation, and (4) verification—conscious assessment of the insight. Helie and Sun (2010) suggested that the first and fourth stages (conscious preparation and verification) entail analytical cognition whereas the second and third stages (unconscious incubation and illumination) involve intuitive cognition.

In particular, incubation is where intuitive cognition generates a problem solution. Support for the idea that insight problem solving is intuitive

TABLE 2: Foundations of Intuitive Cognition: Key Concepts

Implicit learning	
Description	Learning without intention and without full awareness of what has been learned
Key articles	Berry and Broadbent (1984, 1988), Brady and Oliva (2008), Cleeremans et al. (1998), Hayes and Broadbent (1988), Patterson et al. (2013), Perruchet and Pacton (2006), A. Reber (1967), Saffran et al. (1996)
Summary of studies	Participants unconsciously learned sequences, some of which were categorical or situational
Procedural memory and knowledge	
Description	Unconscious memory of invariant, relational, knowledge supporting skill and behavioral dispositions acquired through experience.
Key articles	N. J. Cohen and Squire (1980), Knowlton et al. (1992), Knowlton and Squire (1993), Squire (2004, 2009)
Summary of studies	Amnesic participants displayed normal learning of sequences and categories despite lack of conscious recollection
Embodied cognition	
Description	"Central" cognitive processes mediated by same neural substrate as that which mediates perception and action
Key articles	Barsalou (1999, 2005, 2008), Clark (1998), Glenberg (1997), Lakoff and Johnson (1980)
Summary of studies	Theoretical discourse on cognition being directly linked to perceptual-motor systems

comes from studies revealing that (1) cognitive processing leading to the problem solution during incubation was largely unconscious (e.g., Broderbauer et al., 2013; Maier, 1931), (2) performance on insight problems was not linked with executive functions typically associated with working memory (Gilhooly & Fioratou, 2009), and (3) participants with impaired neurology in a region of cortex typically associated with working memory solved 50% more insight problems than healthy participants (Reverberi, Toraldo, D'Agostini, & Skrap, 2005). Disconnection from consciousness and working memory is a feature of intuitive cognition.

In a field study, Klein and Jarosz (2011) found that insight as a sudden phenomenon occurred in only a minority of the cases. However, Klein and Jarosz defined insight as a shift in a person's mental model of a given problem (Kaplan & Simon, 1990; Weisberg, 1995). Note that this idea of a shifting mental model is a theoretical explanation of the phenomenon, not its operational definition. Given that there are other theories of insight (e.g., schema completion; Mayer, 1995), Schooler, Fallshore, and Fiore (1995) argued that the operational definition of insight should be independent of the theories used to explain it: Insight should be defined as the sudden "Aha" enlightenment experience after an impasse (e.g., Broderbauer et al., 2013; Duncker, 1945; Gick & Lockhart, 1995; Maier, 1931; Schooler et al., 1995). This is the definition we use in the present paper.

Turning back to the topic of sign interpretation (meaning making) and pattern synthesis, consider a classic study of insight by Maier (1931). In Maier's problem, participants had to tie the ends of two long cords hung from the ceiling of a room and separated by a large distance. The solution was to make one cord a pendulum by tying an object (pliers) to its end and swinging it close to the other cord so the person could grab both cords simultaneously. Some participants discovered the pendulum solution unaided, whereas others discovered it only after seeing the experimenter casually bump into and sway one of the cords while walking across the

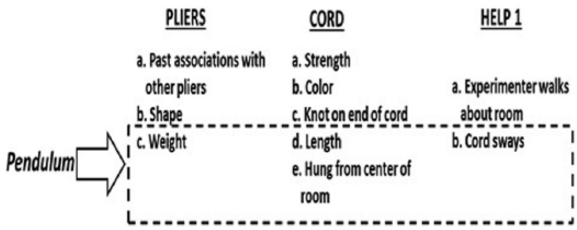

Figure 2. A listing of qualities of the pliers, cord, and help 1, which were elements of the "pendulum problem" (from Figure 1 of Maier, 1931). For 85% of participants who solved the problem (with or without the help), the pendulum solution was found by intuitive conceptual reorganization (pattern synthesis) of the qualities of the pliers, cord, and—for those who needed the help—the help 1, as shown by the dashed line.

room ("help 1"). For 85% of the successful participants (with or without the help), the pendulum solution was discovered suddenly, unconsciously, and with insight ("Aha" experience) via intuitive cognition. For the successful participants, the meaning of the pendulum would be in its interpretation as a sign denoting a solution to the two-cord problem.

Maier noted that the pendulum solution was derived from a meaningful conceptual reorganization (pattern synthesis) of the weight of the pliers, length and position of the cord, and—for those who needed the help—the cord-swaying aspect of "help 1" (see dashed line grouping the lower elements in Figure 2). Such synthesis of pattern to derive meaning likely entailed memory recombination: knowledge about (1) what a pair of pliers would weigh and (2) how a length of cord behaves when weighted on one end would be retrieved and recombined from procedural memories—unconscious relational knowledge that supports skill development and behavioral tendencies tuned through experience (Squire, 2004, 2009). According to our theory, memory recombination supporting intuitive situational pattern synthesis was fundamental to the insightful creation of the pendulum and its interpretation as a sign (its meaning) denoting a solution to the two-cord problem. Other studies on insight problem solving (e.g., Broderbauer et al., 2013) can be interpreted in analogous fashion.

We conjecture that pattern synthesis should be a common operation during the meaning-making process because people live in a dynamic world and they never encounter the same situation twice. Differences between current and previous situations can be quite significant, and meaning making may require the synthesis of different memories of various situations rather than retrieval of a single memory of a given situation.

In our theory, meaning making entails intuitive pattern synthesis, which in turn implies the process of pattern recognition as well. That is, the meaning-making process involves having the synthesized pattern recognized as a sign, as revealed by the insight literature (note that pattern recognition can also involve analytical cognition and analysis as well). Accordingly, we now turn to the topic of intuitive pattern recognition.

Pattern Recognition

Meaning making by intuitive cognition is assumed to entail pattern recognition as part of the process. It is therefore not surprising that there is abundant evidence that intuitive cognition involves a process of meaningful, situational pattern recognition—the recognition of stimuli and cues as belonging to meaningful patterns (signs) unfolding in space and time. The strongest evidence comes from the NDM literature and studies by Klein and colleagues (Klein, 1997, 1998, 2008; Zsambok & Klein, 1997), who investigated how professionals with high levels of expertise (e.g., firefighters) made decisions (Klein, 1997, 1998, 2008; Klein et al., 1995). The evidence collected showed the such professionals made most of their decisions (80%) by meaningful, intuitive situational pattern recognition.

Evidence of intuitive cognition involving pattern recognition can be found in other literatures, discussed previously. When judging probabilities under uncertainty, intuitive heuristics that violated statistical norms were thought to be used by participants most of the time (Kahneman & Tversky, 1972, 1973; Tversky & Kahneman, 1973, 1974)—although the results of a number of these studies can be interpreted as reflecting nonheuristic pattern-based reasoning (Lopes & Odom, 1991). On a deductive-logic ("selection") task, incorrect responses called *pattern matching* occurred ≥80% of the time (Evans, 2008; Evans & Stanovich, 2013; Wason & Evans, 1975), and on a syllogism task, the believability of the conclusion had a larger effect than logic (Evans et al., 1983). Both kinds of responses can be interpreted as reflecting intuitive situational pattern matching. Additionally, reasoning problems were solved by children using intuitive recognition of "gist," or pattern information (Brainerd & Kingma, 1984, 1985; see also Reyna & Brainerd, 1995; Reyna, 2012).

Lopes and Oden (1991) discussed the advantages of pattern recognition–based reasoning and remarked,

> Rather than involving content-less rules . . . a pattern-based system makes use of rich encodings of situation specifics gleaned from direct prior experience and tends to go relatively directly from data to conclusion. . . . This type of reasoning mostly involves simply being able to categorize the current situation into which of the many known situations it belongs to. . . . Pattern-based reasoning substantially reduces the inference problem to . . . identification. (pp. 213–214)

Intuitive Cognition at Work Over Extended Work Intervals

Consideration of the insight literature, discussed above, reveals that intuitive cognition can operate over extended work intervals involving interruptions—that is, during the interval called *incubation*. (Work over an extended period does not contradict the idea of *fast responding*, which refers to the initiation of a response.) Wallas (1926) discussed how the great physicist Helmholtz was speaking at an 1891 banquet on his 70th birthday and stated that his most important new ideas came to him unexpectedly and without effort, particularly during walks in wooded hills (p. 37). Wallas also discussed how Henri Poincare stated in his book *Science and Method* that ideas related to two of his great mathematical discoveries came to him suddenly after a period of incubation during which no conscious mathematical thinking was done. Many participants in Maier's (1931) study, discussed previously, solved the two-cord problem only after 10 minutes had elapsed and a hint had been provided.

In sum, the existence of an incubation period during insight problem solving shows that intuitive cognition can function over extended work intervals involving interruptions. This extends the descriptions of intuitive decision making in the NDM literature (e.g., Klein, 1997, 1998, 2008; Klein et al., 1995).

Information Integration

Certain kinds of information can be categorized and integrated by intuitive cognition. For example, Glöckner and Betsch (2008) investigated participants' ability to integrate and analyze information about multiple attributes of cues and their relationships to multiple decision options. Participants quickly and intuitively integrated the information based on a "feeling in the gut" when deciding, with an average decision time of 1.53 seconds. Conscious deliberation of attributes, cues, and options proceeded more slowly when deciding, with average decision times of 20.5 seconds (Glöckner, 2006) or 29.1 seconds (Lohse & Johnson, 1996). In a dual-task paradigm, participants' working memory was engaged by a memorization task while 140 values were each successively scrolled across a visual display. The participants were able to correctly and intuitively categorize and sum the values when indexed by ratings of affect; the participants were not able to integrate the values consciously (analytically) under comparable conditions (Betsch et al., 2001; Betsch & Glöckner, 2010).

Summary

Intuitive cognition can be characterized as a process for meaning making involving sign interpretation ("semiosis") via pattern synthesis and memory recombination. Intuitive cognition can also operate over extended work intervals involving interruptions and perform information integration and analysis.

FOUNDATIONS

We begin this section on foundations with the topic of implicit learning, which is one of three foundations covered in this section—the other two are (1) procedural memory and knowledge and (2) embodiment.

Implicit Learning

Implicit learning refers to learning without conscious intention and without full awareness of what has been learned (e.g., Berry & Dienes, 1991; Cleeremans, Destrebecqz, & Boyer, 1998; Mathews et al., 1989; Perruchet & Pacton, 2006; Stanley, Mathews, Buss, & Kotler-Cope, 1989). In his seminal studies, A. Reber (e.g., 1967; A. Reber, Kassin, Lewis, & Cantor, 1980) found that participants could implicitly learn series of elements that contained statistical dependencies. Broadbent and colleagues reported that individuals could implicitly learn to control computer-implemented systems (e.g., Berry & Broadbent, 1984; Broadbent, 1977; Hayes & Broadbent, 1988), with salience of the input-output relationship determining whether the learning was implicit or explicit (Berry & Broadbent, 1988). Aslin and colleagues reported that individuals could implicitly learn raw frequencies, joint probabilities, and conditional probabilities (Aslin, Saffran, & Newport, 1998; Fiser & Aslin, 2001, 2002; Saffran, Aslin, & Newport, 1996). Implicit learning can exhibit generalization and abstraction (Turk-Browne, Junge, & Scholl, 2005; Turk-Browne, Scholl, Chun, & Johnson, 2009) as well as be accessed lexically (Brady & Oliva, 2008). For possible evidence of implicit learning in an applied setting, see Woods and Hollnagel's (2006, pp. 15–16) description of the actions taken by control room operators in a nuclear power plant who were handling simulated faults.

Over the years, several authors have proposed that the situational patterns recognized by intuitive cognition can be implicitly learned (Hammond, 2007; Hogarth, 2001; A. Reber, 1989). This idea has been supported by Patterson and colleagues (Patterson et al., 2013; Patterson, Pierce, Bell, Andrews, & Winterbottom, 2009), who showed that intuitive decision making can be developed by an implicit learning process that is likely engaged by the meaning inherent in naturalistic scenes. Finally, Patterson and colleagues proposed that implicit learning can be used for training intuitive decision making. This is not to say that implicit learning is the only kind of learning that can support situational pattern recognition. Situational training programs for expertise often include explicit learning experiences that can later be drawn on via recognition. But it does seem that implicit learning is a key cognitive process that undergirds intuitive cognition.

Neurophysiological research has shown that implicit learning and explicit learning are mediated by distinct neural systems. Implicit learning is mediated by a frontal lobe–basal ganglia (neostriatal) network, whereas explicit learning is governed by a hippocampus–temporal cortex–parietal cortex network (N. J. Cohen, Eichenbaum, Deacedo, & Corkin, 1985; Eichenbaum, 1999; Heindel, Salmon, Shults, Walicke, & Butters, 1989; Packard & Knowlton, 2002; P. J. Reber & Squire, 1994; Yang & Li, 2012).

Intuitive cognition is likely developed, in part, by an implicit learning process, which extends the description of how professionals such as firefighters learn to make decisions in the NDM literature (e.g., Klein, 1997, 1998, 2008; Klein et al., 1995).

Procedural Memory and Knowledge

Information about statistical regularities and patterns acquired in implicit learning is consolidated in procedural memory. *Procedural memory* refers to the unconscious memory of invariant, relational knowledge that supports skill development and behavioral dispositions and is acquired and tuned through experience (Squire, 2004, 2009; Sherry & Schacter, 1987). N. J. Cohen and Squire (1980) found that amnesic patients could learn a pattern-analyzing skill at a normal rate, despite having amnesia for the stimuli and task. The unconscious memory underlying the pattern-analyzing skill was called *procedural memory*, as opposed to the declarative memory (conscious recollection) affected by amnesia. Amnesics can also learn to categorize visual patterns via procedural memory (Knowlton, Ramus, & Squire, 1992; Knowlton & Squire 1993, 1994; Knowlton, Squire, & Gluck, 1994). Procedural memory can be dissociated neurologically from declarative memory (N. J. Cohen & Squire, 1980; Knowlton, Mangels, & Squire, 1996; Poldrack et al., 2001; Squire, 2004, 2009). Finally, procedural memory may be a component of intuitive cognition (Patterson et al., 2013), whereas declarative memory, of which working memory is a part (e.g., Hannula, Tranel, & Cohen, 2006), is a component of analytical cognition (e.g., Evans & Stanovich, 2013).

In sum, intuitive cognition is likely supported by procedural memory, which extends the description of how professionals such as firefighters make decisions in the NDM literature (e.g., Klein, 1997, 1998, 2008; Klein et al., 1995).

Embodied Cognition

In an amodal cognitive system, perceptual and motor systems would not be playing any significant role in "central" cognitive processing (Wilson, 2002). Abstract mental representations would arise from the transduction of perceptual states into amodal representations (Barsalou, 1999). However, the problem with amodal cognitive systems is that their symbols are arbitrary and lack grounding in the natural world—and grounding may be a necessary precondition for meaning making (Harnad, 1990, 2003). One solution to the problem of symbol grounding is to make cognition embodied. With embodied cognition, the same neural substrate that underlies perception and action also underlies central cognitive processing (Barsalou, 1999, 2005, 2008; see also Clark, 1998). Embodied cognitive processes can be conceptualized as high-level "simulators" operating within modal systems of representation (Barsalou, 1999, 2005). This kind of system may make cognition situated (Glenberg, 1997; Wilson, 2002).

We conjecture that the characteristics of intuitive cognition—meaningful, situated, pattern recognition–based processing—fit well with the properties of a modal cognitive system. Specifically, we propose that meaning making by intuitive cognition entails embodied simulation of synthesized situational patterns drawn from procedural memory. This conjecture, in turn, would extend the description of intuitive decision making in the NDM literature (e.g., Klein, 1997, 1998, 2008; Klein et al., 1995) by proposing the characteristics of embodiment, pattern synthesis, and procedural memory.

We also propose that analytical cognition is not embodied or grounded, an idea supported by the fact that—discussed earlier—analytical cognition generates slow responses and entails effort. Slow and effortful responding suggests the existence of an amodal cognitive system in which abstract mental processing arises from the transduction of perceptual states into amodal representations (Barsalou, 1999). Transduction would likely take extra time and effort relative to modal system processing that does not involve transduction (e.g., intuitive cognition).

Summary

The foundations of intuitive cognition include implicit learning of meaningful situational patterns that are consolidated in procedural memory and embodiment.

DISCUSSION

Our essential conjecture is that intuitive cognition can be very effective for decision making because it possesses a capability for meaning making via sign interpretation. Such meaning making is derived from the grounded, embodied simulation of synthesized, situational patterns. Intuitive cognition is also operative over extended work intervals involving interruptions.

These characteristics of intuitive cognition motivate our next conjecture: intuitive processing represents the core of cognition whose foundation is grounded, situational meaning making. Analytical cognition, however, is likely not grounded, and it serves as a form of an intellectual exoskeleton that provides the added capabilities of cognitive decoupling (e.g., counterfactual thinking), working memory, consciousness, and language. Such additional capabilities support intuitive cognition's foundation (Figure 3).

One may ask, however, how intuitive processing can represent the core of cognition when

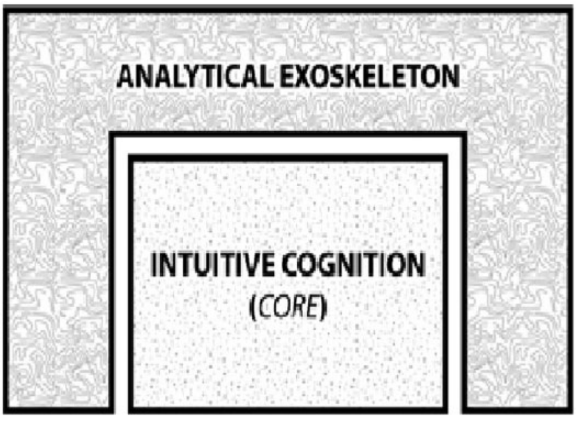

Figure 3. Intuitive cognition represents the core of cognition in terms of grounded, situational meaning making. Analytical cognition represents a form of an intellectual exoskeleton to intuitive cognition and provides support capabilities of cognitive decoupling (e.g., counterfactual thinking), working memory, consciousness, and language.

we have not explicated the role of expertise, a key issue in the NDM literature. The expert has a base of experiences stored in long-term memory that enables successful decision making. It is thought that this experience base is what differentiates expert intuition from the misguided naïve intuition reported in the heuristics and biases literature (Kahneman & Klein, 2009), discussed earlier. To address this issue, we unpack further what is meant by *expert intuition*, on one hand, and the misguided naïve intuition often found in the heuristics and biases literature, on the other. We begin with the latter.

The notion of misguided naïve intuition in the heuristics and biases literature derives from the concept of "heuristic," a cognitive shortcut that can lead to bias and judgment error. Recall that, in this literature, performance on various coherence-driven, analysis-inducing tasks was compared with a standard such as probability theory. Most participants' responses were presumably based on intuitive heuristics that violated probability theory (e.g., Kahneman, 2011; Kahneman & Tversky, 1972, 1973; Tversky & Kahneman, 1973, 1974, 1981). Human judgments were seen as basically flawed and leading to "serious errors," "predictable biases," "systematic errors," and "fallacies" (Tversky & Kahneman, 1974).

However, these claims of biased and error-prone decision making are undercut by the likelihood that few participants in the heuristics and biases studies would have had the necessary training and/or experience to successfully perform the coherence-driven tasks using analytical cognition, as discussed previously. Intuitive cognition, by default, engendered most responses that were usually incorrect when judged by statistical norms. Due to these methodological problems, the heuristics and biases literature does not actually demonstrate misguided intuition. For other criticisms of the heuristics and biases literature, see L. J. Cohen (1981), Cosmides and Tooby (1996), Einhorn and Hogarth (1981), Gigerenzer (1996), Gigerenzer and Hoffrage (1995), Lopes (1991), and Lopes and Oden (1991).

Turning now to unpack what is meant by *expert intuition*, in the NDM literature, the development of expert intuition derives from having statistical regularities in the environment (cues) indicating predictable outcomes, experience in learning the relevant cues, and feedback (Kahneman & Klein, 2009; Shanteau, 1992). Such factors promoted expertise development in the firefighters, nurses, and combatants mentioned previously. However, we conjecture that it would be incorrect to think that skilled, competent intuitive cognition can be achieved only by experts at very high levels of professional development.

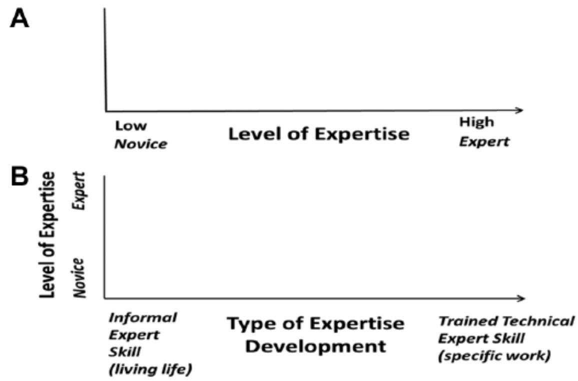

Figure 4. Panel A depicts the typical conception of expertise in the naturalistic decision-making literature, with high levels of expertise differentiating expert intuition from misguided naïve intuition (Dreyfus, 2004). Panel B depicts our conception of expertise. Two types of expertise development exist, one involving skills needed for everyday living (i.e., informal expert), whereas the second involves skill development in a technical field (i.e., formal or technical expert). Level of expertise shown on the ordinate.

Predictability of outcomes, experience, and feedback are present in many, if not most, areas of everyday life. Through people's experiences interacting with the world as they grow up, they have implicitly learned a vast array of situational patterns and developed varying degrees of intuitive expertise in, for example, driving a vehicle and navigating in all sorts of traffic, negotiating social situations involving family or professional coworkers, and avoiding dangerous situations of various kinds. In these instances and many others, we posit that people are engaged in intuitive situational pattern synthesis and recognition most of the time, exactly analogous to Klein's (1998) firefighters, nurses, and combatants. This includes participants in the studies in the non-NDM literatures discussed above, which involved intuitive cognition even though they did not study so-called expert intuition. The studies in the non-NDM literatures give validity to the idea that people are engaged in grounded, situational meaning making via intuitive cognition most of the time despite not having achieved expert-level expertise through formal training in a given domain.

For example, consider an individual driving to work in the morning who sees debris in his lane of the highway a short distance ahead of his vehicle. Before he can change lanes, he sees a slight breeze blow the debris several feet and instantly decides it is no threat and runs over it. His intuitive situational pattern recognition was honed through years of driving experience and was able to correctly infer that the debris was paper. Alternatively, consider an observer who is witness to a conversation between two colleagues who have not seen each other in years and are discussing persons they both knew previously. When one of the colleagues asks about the well-being of a particular person and the other colleague answers "not doing well," the observer leaves the room to avoid hearing bad news. His intuitive situational pattern recognition was honed through years of socializing with others, and he was able to infer that the assessment of someone else "not doing well"—when given to a colleague who has not been seen in years—would likely be a reflection of something serious.

In the current NDM literature, the base of experience is what differentiates expert intuition from the so-called misguided naïve intuition of the heuristics and biases literature (Kahneman & Klein, 2009). This concept can be depicted through a "level of expertise" scale, with "novice" marking one end and "expert" denoting the other (panel A, Figure 4; see Dreyfus, 2004). Instead, we argue that the experience base defining "expert" intuition exists in all of us in everyday life, to varying levels, and that the heuristics and biases literature does not actually demonstrate misguided intuition (i.e., due to flawed methodology). Accordingly, our concept could be depicted by using a "type of expertise development" scale, with "informal expert" marking one end and "trained technical expert" denoting the other; level of expertise would be depicted on the ordinate (panel B, Figure 4).

In short, the notion of skilled, competent intuitive cognition applies not just to professionals with high levels of expertise but also to people engaged in everyday living. The intuitive expertise of everyday living may be underappreciated even though our daily successes can serve as instances of expert decision making in the wild. This view extends the current conceptualization of intuitive cognition in the NDM literature (e.g., Klein, 1997, 1998, 2008; Klein et al., 1995).

Concluding Remarks

We conclude that what makes intuitive cognition so effective for decision making is that it engenders people's ability to make meaning of events in the world (sign interpretation), which is crucial for survival. Intuitive cognition's meaning-making capability is based on embodied representations (i.e., embodied simulation of synthesized situational patterns), which makes this kind of cognition grounded and situated. Intuitive cognition—which represents the core of human cognition—is instrumental in handling the situated complexities of everyday living.

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