**Extending Cognitive Continuum Theory: CCT II**

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Abstract

This extension of Kenneth Hammond’s Cognitive Continuum Theory (CCT) brings together into a single theory some of the methodological, theoretical and philosophical contributions of Egon Brunswik and Kenneth Hammond. We do so by conceptualizing these apparently disparate contributions as they are understood by social judgment theory (SJT) scientists who are planning or evaluating an investigation. That is, this extension of CCT, which we will call Cognitive Continuum Theory II (CCT II) is a theory of the thinking of SJT researchers, not of the subjects (judges) in SJT research. A major attribute of CCT II is that the methodological, theoretical and philosophical contributions of Brunswik and Hammond are not viewed as dichotomous concepts but as cognitive continua, similar in many ways to a key concept in CCT, the *intuitive-analytic* continuum. A version of the *intuitive-analytic* continuum is a core premise in CCT II. The other four premises of CCT are assumed to be part of CCT II. These four premises deal with quasirationality, the role of task structure, dynamic cognition, pattern relations, and functional relations. Two other premises are added, each of which plays a critical role in CCT II. One is that coherence and correspondence are cognitive continua. The other is that representative design is a cognitive continuum. Implications for how idealized and perhaps real SJT investigators think about research and for graduate education are discussed.

Note: A previous version of this paper was included in the 2023 Brunswik Society Newsletter.  This update was written after consideration of insightful comments from colleagues during and after the 2023 meeting of the Brunswik Society.  We are grateful to the many colleagues who took the time to comment on our paper.

Our objective is to unite two metatheories of truth (coherence and correspondence) with Ken Hammond’s original cognitive continuum theory (CCT) and Egon Brunswik’s principle of representative design of scientiﬁc research. We add two premises to the original ﬁve CCT premises and reinterpret several key concepts as continua. The *intuitive-analytic* continuum, of course, is the foundation of CCT. We propose that the coherence and correspondence truth criteria are also best conceptualized as continua. Furthermore, we argue that representative design in research should also be conceptualized as a continuum. The three proposed continua are similar to Hammond’s *intuitive-analytic* continuum in that they are continua, but there are fundamental differences. One difference is that the *intuitive-analytic* continuum may have on it a virtually infinite variety of objects, from hunches to ideas about research. Another difference is that Hammond’s *intuitive-analytic* continuum has two positive poles, whereas the proposed continua will range from a negative pole to a positive one. The proposed continua are each devoted to the evaluation of potential research studies.

Our domain of interest in this paper is the design and evaluation of research within the framework of social judgment theory (SJT), although our argument applies to some other judgment and decision making (JDM) research. The *intuitive-analytic* continuum has just been characterized as potentially describing a great variety of psychological phenomena. The proposed continua have special purpose in that they describe possible SJT investigations. We describe all four continua — coherence, correspondence, representative design and *intuitive-analytic* continua— as continua that describe the cognitive processes of SJT scientists at every stage of research and theory. We believe that consideration of our proposed CCT II may help SJT researchers think about design and evaluation of research.

**Cognitive Continuum Theory**

Cognitive Continuum Theory (CCT) evolved through the 1980s and 1990s (Hammond, 1980, 1981, 1986, 1987, 1988, 1990а, 1990b) and is detailed in a book by Hammond (1996) that was chosen by the awards committee of Division I of the American Educational Research Association (AERA) “for Outstanding Research Publication of 1996 focusing on education for the professions” (AERA, 1997, p. 39).

The essence of Hammond’s original CCT is its ﬁve basic premises, listed below (also see Hammond, 2000). Page references are from Hammond (1996). Our proposed extension of CCT, which we call CCT II, consists of the five premises of CCT plus two additional premises. We believe the additional premises are fully consistent with the spirit of Hammond’s approach to theory. Hammond’s insights into the development of SJT and CCT were profound, and we believe it will be useful to reexamine and build upon those insights.

***Premise 1: A Cognitive Continuum***

*Various modes, or forms, of cognition can be ordered in relation to one another on a continuum that is identified by intuitive cognition at one pole and analytical cognition at the other.* (p. 147)

Premise l rejects the dichotomous view of analysis and intuition (also known as dual systems theory). According to Hammond (1996, p. 149), “The idea of a cognitive continuum challenges the age-old tradition of a dichotomy between intuition and analysis; in fact, it denies the validity of that dichotomy.” Acknowledgment of a continuum between intuition and analysis permits discussion of modes of cognition lying between the two poles.

The *intuitive-analytic* continuum is a core concept in CCT. Our proposed coherence, correspondence, and representative design continua will be discussed with respect to the *intuitive-analytic* continuum. We noted above the centrality of the *intuitive-analytic* continuum to CCT. In CCT II we limit the *intuitive-analytic* continuum in one way and extend it in another way. Our proposed limitation of the *intuitive-analytic* continuum is that in CCT II it is limited to efforts to understand scientific research and theory. This is not to deny other myriad cognitive activities to the continuum; It is to say that they are outside the domain of CCT II. The basic extension that we propose concerns completed or partially completed investigations that a SJT scientist wishes to understand. Examples range from research ideas a scientist is considering implementing to the work of refereeing the research of others. In the remainder of this paper we focus strictly on research proposed by a SJT scientist.

We have one more necessary comment about the expansion of *intuitive-analytic* continuum. The potential investigations must be multifaceted so that the principles and knowledge in the three proposed continua can be used to modify the planned investigation. We note that the principle of quasirationality implies that the representations on the *intuitive-analytic* continuum and the other continua involved are in essence multifaceted. In order for the scheme to work, the representations of the proposed study are assumed to be multifaceted, or better, to have multiple components. Such proposals can be more easily modified and improved by reference to the continua introduced in CCT II. Note also that the various components of the proposed studies may be differentially intuitive or analytic, as seems likely in proposals that would qualify as quasirational.

***Premise 2: Common Sense***

*The forms of cognition that lie on the continuum between intuition and analysis include elements of both intuition and analysis and are included under the term quasirationality. This form of cognition is known to the layperson as “common sense.” (p. 150)*

Quasirationality (common sense) is cognition incorporating elements of both intuition and analysis. The term quasirationality was used by Brunswik (1952, pp. 23–24) in discussing the system that a person uses to perceive the environment. In the context of CCT, quasirationality is a blend of intuitive and analytical cognition, having neither greater nor lesser importance than pure analytical or intuitive cognition. The issue of importance or status among modes of cognition is a major consideration within CCT. For those who would claim superiority of analytical cognition over intuition, we agree with Cooksey (1996, p. 16) who says that “analytical cognition should not automatically or necessarily be considered the normative model for all of cognition and that in order to completely understand human cognition, we must understand the relationships between cognition and the task ecology within which it must operate.”

The term *quasirationality* is precise. It refers to a key concept. Unfortunately, it seems to us that the term sounds like it refers to something inexact and not quite right when it refers to an ability of the organism. But it means that the organism, including a SJT scientist, brings two important cognitive powers to bear on understanding an aspect of the ecology (the powers of intuition, rationality and combinations thereof).

***Premise 3: Theory of Task Structure***

*Cognitive tasks can also be ordered on a continuum with regard to their capacity to induce intuition, quasirationality, or analytical cognition. (p. 180)*

Serious consideration of the structure of the environment or ecology in which organisms’ function is a major tradition within the area of research on perceptual and social judgment processes known as lens model functionalism or SJT (see *The essential Brunswik: Beginnings, explications, applications* by Hammond & Stewart, 2001). This tradition began with Brunswik (1952, 1956) when he insisted that ecological systems be studied in parallel with cognitive systems, using a research methodology called representative design. The idea that cognitive tasks can be ordered on a continuum with regard to their capacity to induce intuitions, quasirationality, or analytical cognition is an outgrowth of Hammond’s earlier work within the Brunswikian tradition and has serious implications for research efforts in the entire field of judgment and decision processes.

***Premise 4: Dynamic Cognition***

*Cognitive activities may move along the intuitive-analytic continuum over time; as they do so, the relative contributions of intuitive and analytical components to quasirationality will change. Successful cognition maintains constancy with the task environment and inhibits movement; failure and loss of constancy stimulate movement. (p. 192)*

People oscillate along the cognitive continuum over time, with the relative contributions of analysis and intuition shifting according to changing circumstances and tasks. Failure to solve a cognitive problem stimulates a shift toward either the analytical or intuitive pole of the continuum. According to Cooksey (1996, p. 21), Premise 4 moves “in direct opposition to the traditional view of intuition and analytical cognition as relatively stable cognitive styles.” According to Hammond (1996, p. 196), “Although the empirical basis for oscillation is almost nonexistent, the rationale for its presence is intuitively compelling.” In the discussion of CCT II Premise 6, we note that the truth criteria of coherence and correspondence share the property of dynamic cognition.

In a thorough treatment of Hammond’s CCT, Hogarth (2001, p. 261) adds:

*my amendment to the Hammond model would be to stress the role of learning. The fact that a task induces intuitive (i.e., tacit) processing does not mean that this will necessarily be more effective than deliberate thought. For example, many stimuli or tasks can induce stereotypic reactions. But it takes active thought to question whether stereotypes are justified and to correct initial impressions if these are misguided (p. 261).*

Learning influences oscillation along the *intuitive-analytic* continuum. So also do pattern recognition and use of functional relations.

***Premise 5: Pattern Recognition and Functional Relations***

*Human cognition is capable of pattern recognition and the use of functional relations. (p. 196)*

The ability to learn and utilize functional relations among indicators has long been studied and recognized as essential to correspondence competence. Hammond describes the seldom recognized relation between pattern recognition and coherence competence:

*Pattern recognition has barely been touched by judgment and decision-making researchers. The present theory, however, asserts that cognition alternates between coherence-seeking (pattern-seeking) and correspondence-seeking explanations—that is, seeking functional relations between indicators and targets. (p.201)*

*Pattern seeking and pattern recognition are useful cognitive activities when employed in appropriate circumstances—that is, on tasks that offer coherence either through our natural capacities or through our training capacities to do so. (p. 198)*

At this juncture it is worth noting that Hammond’s five premises can be conceptualized as psychological continua. In commenting on quasirationality above, we said that the organism, including a SJT scientist, brings two important cognitive powers to bear on understanding an aspect of the ecology. Now we assert that these five premises constitute Hammond’s more complete conception of the set of cognitive powers the organism brings to bear on understanding an aspect of the ecology. The remainder of this paper extends that set.

***Premise 6 (proposed): Coherence and correspondence are psychological continua***

*Coherence and correspondence criteria for truth are psychological continua that affect research design and interpretation.*

Coherence refers to principles. Correspondence refers to observations. Coherence is defined by the agreement among principles that govern the investigation at hand and the agreement with those principles that constitute the received view in the field. Correspondence is defined by the agreement between predicted observations and actual observations.Hammond brought these metatheories to the attention of JDM scientists in *Human Judgment and Social Policy: Irreducible Uncertainty Inevitable Error, Unavoidable Injustice* (Hammond, 1996). He wrote that “*Two grand metatheories have been persistent rivals in the history of science in general and in the history of research in judgment and decision making”* (p. 95). He argued that tasks used in JDM studies can be easily classified as those evaluating human performance according to coherence or correspondence principles, and that classification helps us understand their methods and results. We will quote extensively from Hammond’s 1996 book.

*Correspondence theory focuses on the empirical accuracy of judgments, irrespective of whether the cognitive activity of the judge can be justified or even described. Although correspondence researchers may be interested in describing the processes that produce the judgments, they rarely inquire into the question of whether these processes are rational, that is, conform to some normative, or prescribed, model of how a judgment ought to be reached. (p. 106)*

*Coherence theorists have opposite interests; they examine the question of whether an individual’s judgment processes meet the test of rationality -- internal consistency -- irrespective of whether the judgment is empirically accurate. Indeed, no test of empirical accuracy may be available in principle or fact. (p. 106)*

*In short, correspondence theorists are interested in the way the mind works in relation to the way the world works, while coherence theorists are interested in the way the mind works in relation to the way it ought to. (p. 106)*

Hammond clearly saw coherence and correspondence as a dichotomy, that is, research programs and studies can be classified as one or the other, but not both. However, he also stressed the importance of complementarity. For example:

*The tension between coherence and correspondence, however, cannot be resolved by compromise; one replaces the other in entirety. But these two meta theories can enjoy peaceful coexistence, and that coexistence can be, and should be, constructive. Each may compete for our attention and our energy even our treasure (as they have), but given the successful history of each, there is no need for researchers or policymakers to deny the value of one or the other and although compromise cannot be achieved, there is always the grand goal of* ***complementarity*** *but that would require that the researcher and policymaker alike be able to comprehend which meta theory is being proposed on which occasion. (p. 218, emphasis in original)*

We disagree with Hammond’s view that studies can use one or the other, but not both. Scientists are capable of using both coherence and correspondence in their research, and often do. Furthermore, complementarity can only be achieved using both. Complementarity is a complex concept, and we will not attempt to address it fully here, but we will reject his “one or the other” view and replace it with the recognition that correspondence and coherence should both play important roles in any study, and usually do. Furthermore, we argue below that each can be present to a degree and therefore must be considered continua.

There are discussions of coherence and correspondence in philosophical and scientific literature (e.g., Dunwoody, 2009; Dawson & Gregory, 2009; Polonioli, 2015). There is considerable consensus in the literature that coherence and correspondence are fundamental concepts, that both are important in the science of SJT, and that coherence is often crucial in achieving correspondence. According to Collins et al. (2023, p. 2), recent findings “show that coherence and correspondence may, in fact, be strongly related. More importantly, decision makers can exploit knowledge of the former to improve the latter.”

Mosier (2009) considers both coherence and correspondence as goals of cognition and also as strategies used to achieve both of these goals. She writes:

*The goal of correspondence is empirical, objective accuracy in human judgment. A correspondence strategy entails the use of multiple fallible indicators to make judgments about the natural world.* *A pilot, for example, uses a correspondence strategy when checking cues outside the cockpit to ﬁgure out where he or she is, or judging height and distance from an obstacle or a runway. Correspondence competence refers to an individual’s ability to correctly judge and respond to multiple fallible indicators in the environment (e.g., Brunswik, 1956; Hammond, 1996, 2000, 2007), and the empirical accuracy of these judgments is the standard by which correspondence is evaluated. (p. 154)*

*The goal of coherence, in contrast, is rationality and consistency in judgment and decision making. Using a coherence strategy, a pilot might evaluate the information displayed inside the cockpit to ensure that system parameters, flight modes, and navigational displays are consistent with each other and with what should be present in a given situation. Coherence competence refers to the ability to maintain logical consistency in judgments and decisions. Coherence is not evaluated by empirical accuracy relative to the real world; what is important is the logical consistency of the process and resultant judgment (Hammond, 1996, 2000, 2007). (pp. 154-155)*

We propose reconceptualizing the two philosophical theories of truth in psychological terms and including them in CCT II as two psychological continua. We label two poles of the coherence continuum *Chaos* and *Coherence*. The two poles of the correspondence continuum we label *Irrelevance* and *Correspondence*. We believe this is well within the spirit of Hammond’s conception. We add here that tasks may elicit activation on truth (coherence and correspondence) continua in different ways.

What is the rationale for asserting that the theories of truth are best conceptualized as continua? If you assume that the metatheory of coherence is all or none, how can you explain how often you have felt “*I’m almost there*” when working on understanding something about reality? How often have you thought “*That’s it I have it*” – only to realize an hour, day, or later that you never did have it? How often have you been convinced that you had understood something until you started to put it on paper and found that you just couldn’t do it? These behavioral phenomena implicate movement on the coherence continuum even as they trigger movement on the *intuitive-analytic* continuum. They describe a thinker who understands a conception to be true and then realizes that it may be or is incorrect. That means that a scientist’s criterion for truth in this case has changed. It means that his or her metatheory of truth in this case is not fixed and immutable. It is a continuum.

There is a technical argument supporting the idea that the two theories of truth as they relate to judgment and decision research are continua. It is that the criteria used by judgment researchers to evaluate research results are themselves continua. Ward Edwards conducted decades of elegant decision analysis and research, both theoretical and applied (see Weiss & Weiss, 2009). A basic theoretical underpinning of decision analysis study design is Bayes’ theorem, which is intrinsically continuous. SJT investigators typically employ correlation coefficients to measure coherence and correspondence (using Rs and ra to assess coherence and correspondence of a study participant). Of course, correlation coefficients are intrinsically continuous.

We make one final point on this issue. Perfect coherence, for example, is impossible. But conceptualizing the truth criteria as continua rather than as all or none allows us to see an investigation with less than a perfect level of coherence or correspondence as a good one rather than as having a fatal flaw.

We don’t claim that working scientists *explicitly* consider coherence and correspondence when they design studies and interpret results. Rather, we consider them psychological continua that implicitly or explicitly influence how SJT scientists do their work. We have limited (and mostly introspective) access to the way scientists think (see Tweney et al., 1981), our evidence is limited to the research designs and interpretations of results produced by such thinking.

***Premise 7 (proposed): Representative design is a continuum***

*The representative design continuum refers to the ability of a design to support generalizations to a specific environment of interest by representing important characteristics of that environment.  It is based on a central tenet of Brunswik's probabilistic functionalism.*

The two poles of the continuum are *Environment Ignored* and *Environment Represented*. By environment we mean the environment to which the investigator intends to generalize. At one pole (end) of this continuum (environment ignored), scientists specify a phenomenon with no attention to the environment. At the other pole (environment represented), scientists specify the environment and include all the important features of that environment in their study. Representation means that the study is a model of the environment. At one end, there is no model. At the other, the model is a “good” match to the environment. “Good” is a judgment about whether the properties of the environment that influence the phenomenon being studied (judgment, in our case) are included.

For a thorough review of representative design, see Dhami, Hertwig, and Hoffrage (2004; Dhami, 2011), see also Katsikopoulos (2009),Kirlik (2010, 2012, 2018), and Mosier (2009) for details concerning pros and cons of representative design. We will summarize two examples below.

An invited editorial in *Simulation in Healthcare* by Alex Kirlik concerns a research paper by Nadler et al. (2010) about clinicians’ abilities to accurately and reliably make judgments of Apgar scores (measures of clinical conditions of newborns). The article was the ﬁrst to introduce readers of *Simulation in Healthcare* to Egon Brunswik’s theory of probabilistic functionalism and methodology of representative design (2010, p. 255). Authors of the research were meticulous in designing, producing, and validating 50 video recordings of neonatal resuscitation scenarios generated by a simulator (Laerdal SimNewB) and based upon computerized (representative) birth records of the five cues comprising an Apgar score (heart rate, breathing, blood saturation, muscle tone, and vocal sound). In each video, a neonate patient (mannequin) was provided treatment by a professional medical team. Each video recording lasted approximately 2 minutes (see Nadler et al., 2010, for details). Intended Apgar scores generated by the simulator were verified by judgments of expert clinicians before use in the research project. In the actual study, 17 clinicians (doctors and nurses) viewed and judged 30 of the original 50 scenario recordings, with rest breaks after sets of 10. Results were quite positive. Kirlik (2010, p. 258) strongly endorsed the representative design of the Nadler et al. research and concluded that “ﬁnding that ***increased levels of representativeness*** [emphasis added] allowed clinicians to demonstrate their competence adds another data point conﬁrming Egon Brunswik’s insights into the importance of representative design in psychological research.” Kirlik appears to acknowledge that representative design is a continuous variable.

*Importantly, representative design is not a silver bullet: it does not tell us how to design an experiment or simulation (i.e., it does not specify what aspects of a clinical situation are important to preserve in the research or training context). Instead, as a methodology, it is a process toward which a scientific community can collectively learn, from empirical evidence, to discover what those aspects are. In research, if findings relating to clinical judgment intended to generalize to some particular class of situations (e.g., making Apgar ratings) are found not to generalize to another situation in that class, then one has discovered information on the inadequacy of the original research and a need to refine the relevant situational aspects accordingly. In training, if learning does not effectively transfer from the training context to the target, clinical context of performance, one has similarly gained information on the inadequacy of the original training context and a need to refine (typically enrich, but in some instances impoverish) the relevant situational aspects to improve training effectiveness. (Kirlik, 2010, p. 257)*

Mosier (2009) traces the evolution of the aircraft cockpit as an example of the transformation of a probabilistic environment into an ecological hybrid. She defines ecological hybrid as an environment characterized by both probabilistic and deterministic features and elements. Mosier (2009) claims that:

*As technology has changed the nature of cues and information available to the pilot, it has also changed the strategies and tactics pilots must use to make judgments successfully. I make the case that judgment and decision making in a hybrid ecology requires coherence as the primary strategy to achieve correspondence, and that this process requires a shift in tactics from intuition toward analysis. The recognition of these changes carries implications for research models in high-technology environments, as well as for the design of systems and decision aids. (p. 154)*

*Because the hybrid ecology functions in and is subject to the constraints of the physical world, correspondence is still the ultimate goal of judgment and decision making. However, because the hybrid ecology is characterized by highly reliable deterministic systems, strategies and tactics to achieve correspondence will be different than those in a probabilistic ecology. (2009, p. 159)*

*If correspondence in judgment and decision making in the hybrid ecology is accomplished primarily through the achievement of coherence, then it is important to examine whether the features and properties of the environment elicit the type of cognition required. (2009, p. 160)*

This is precisely why representative design of research is important for research, development, and training. According to Dhami et al. (2004 p. 963), “Brunswik (1944) himself proposed that it is ‘generally possible’ and ‘practically often very desirable’ (p. 42) to use a hybrid design in which the researcher introduces certain elements of systematic design into an experiment in which a representative design is used.”

**Implications for research design and evaluation**

***The coherence continuum.*** The coherence continuum is a specialized memory that provides comparisons among possible proposals and research projects with examples of related research studies, especially examples that a scientist has judged as excellent and worth knowing. The rigorous processes of becoming a scientist and doing science leads to the development and internalization of a graduated and flexible set of criteria for good science. The coherence continuum is concerned with how research under consideration makes sense (coheres) both internally and externally with respect to the larger scientific enterprise.

An important question to be asked here is what is supposed to cohere with what? That question has answers at multiple levels. A good scientific theory or research contribution ought to cohere with all the received knowledge in the field and related fields. As Dunwoody (2009, p.117) put it “Theories must be coherent. That is, theories cannot be self-contradictory and generally, they must be consistent with other widely held beliefs within that scientific community.” We certainly agree, but that statement was not meant as a measurable cognitive goal. Dunwoody’s assertion that theories must be consistent with other widely held beliefs might be termed *global coherence*, which we believe is typically a desired characteristic of contemporary science. Scientific theory and research take advantage of millennia of progress not only in the sense of the vast amount of scientific knowledge accessible with current information technology, but also in the sense of the very modes of thought that we call scientific thinking, including the metatheories of truth. Much of today’s science has global coherence largely because science is a set of social enterprises knit together by marvels of technology. What we are mainly concerned with in this paper might be called *local coherence*. The assumptions and principles defining a scientist’s work must agree among themselves and with those of the received view in the area in which a scientist is working. Of course, the received view may be wrong. Scientific revolutions do occur (Kuhn, 1962).

Another level of local coherence involves the agreement among all the attributes of the research or theory at hand. As noted above, we assume that an individual scientist has internalized a set of principles defining or describing the principle of coherence as it applies in his or her field. Today’s scientist does not start out at the chaos end of the truth continuum, even if the problem is new. In some fields a mathematical model may already be available to be adapted or exploited. It is not news to any reader of this paper that scientists often struggle for a considerable time to come up with coherent theories and good experiments. Efforts may be assessed by comparing possibilities on the coherence continuum. Easily dismissed are scientific claims that rest on propositions that are not coherent. The coherence continuum stretches all the way from chaos to formal mathematical or logical models.

***The correspondence continuum.*** The correspondence continuum serves as a standard of successful science. Potential research projects on the *intuitive-analytic* continuum, or completed research being read or even refereed, can be compared with projects that have demonstrated high correspondence. As with the coherence continuum, we attribute the development of this continuum to the rigorous processes of becoming a scientist and practicing one’s craft. That is, a scientist has internalized a set of examples with acceptable outcomes that support the expectation that the proposed project may well be worth doing.

A proposed experiment may be based on theory, on similar experiments in the relevant literature, on pilot studies, etc. The conditions of the research and the hoped for results can be matched to the relevant study or studies. Possible studies that appear to fall near the extreme irrelevance end of a scientist’s correspondence continuum are easily dismissed as not worth doing. The other extreme end of the continuum involves a situation in which the evidence of potentially important outcomes is overwhelmingly positive. Much interest in scientific thinking lies between the two ends of the continuum, nearer the upper end. It is there that most of the work of science is done and that science progresses.

We have quasirational mixes of analysis and intuition on the *intuitive-analytic* continuum, and we may also have quasirational mixes of analytic and intuitive cognition on the correspondence continuum. That is, we may have quasirational cognition on what is and on what makes science to start with and what makes a study worth doing.

We believe that it is almost self-evident that correspondence is a matter of degree. As we argued above, the statistical tools for analyzing JDM research yield continuous results. The very notion that science progresses means that at one time the scientific community holds that the criterion for truth has been met, but then new kinds of thinking or new information surfaced, and revision of understanding on the *intuitive-analytic* continuum begins. Movement on one or both of the truth continua (coherence and correspondence) may commence. The concept of continua leaves open the idea that a potential solution may be good or very good yet not perfect. A widely accepted statement about the nature of science is that all scientific knowledge is tentative. Conceptualizing coherence and correspondence as continuous is consistent with that maxim.

***The representative design continuum.*** Every SJT researcher considers the degree of representativeness appropriate for his/her research design. With the objectives of coherence and correspondence in mind, hybrid designs mentioned above (Kirlik, 2010; Mosier, 2009) may enable us to address more complex research questions. Mosier and Fischer (2010) comment:

*Because “good” decision making in hybrid ecologies must be both coherent (in the electronic world) and accurate (in the physical world), proficient decision making in these environments involves knowing which strategy is appropriate in a given situation. As yet, the optimal combinations of recognition and analysis, and of coherence and correspondence strategies, are not known. The proliferation of hybrid ecologies in decision domains (particularly those domains in which teams operate) offers perhaps the greatest future challenge in decision-making research. (p. 184)*

*Decision making in human factors must be studied in context. Laboratory studies, the traditional approach in early work, can give insights on specific microaspects of judgment and decision making, but they alone cannot provide viable predictions of how operators will perform in dynamic environments. Rather, as exemplified by the research cited in this chapter, a range of methodological tools for investigating decision making should be employed with the goal of converging results at varied levels of context fidelity. These include lab studies in which factors and variables replicate aspects of the environment, archival analyses of accidents and incidents, simulations of varying fidelity, synthetic environments, and field studies. At all levels, it is important to match the features of the tasks as closely as possible to the formal properties of the environment (Hammond, 1993).* (Mosier and Fischer. 2010, p. 176)

*A body of literature exists in the area of engineering design to aid decision making, including several chapters in Reviews of Human Factors and Ergonomics volumes … Technological innovations to enhance decision making must be based on correct assumptions about human judgment processes and about how people think (Maule, 2009), and they should provide support for both coherence and correspondence as well as for requirements at the front and back ends of decision making. (*p. 236)

Lynn Miller and colleagues (2019a) introduced a hybrid *systematic representative design* that takes advantage of virtual reality. Miller et al. (2019b), in a reply to commentaries to their earlier introduction suggest that, in virtual environments,

*we might expect that top-down processes will play particularly significant roles in social interaction, but proximal cues could as well, especially if they are incompatible with top-down predictions. Imagine we had highly representative environments that allowed us to ascertain (e.g., via eye tracking) when people were considering what cues; we might begin to see patterns of a given participant’s proximal cue attention, use (and weights) as predictive of “top down” and “bottom up” cue utilization following, for example, prediction surprise.* (p. 252)

**Using All One’s Cognitive Powers**

CCT II is a proposed theory extending Hammond’s conceptions to how SJT scientists think and how SJT scientists should think. We propose that a SJT scientist brings all of his or her cognitive powers to bear in acts of creativity or understanding. The cognitive processes on the *intuitive-analytic* continuum are a major source of creative progress as a SJT scientist brings both intuition and analysis to bear on the research design problem. A SJT scientist’s understanding of the task structure may change substantially as he or she explores the task pattern and investigates possible functional relations. Memory searches along the coherence and correspondence continua shape new possibilities for investigation. As such possibilities arise potential avenues of exploration are suggested and perhaps rejected in light of a scientist’s understanding of the representative design continuum. All of this involves significant changes in the idea that had, perhaps, arisen on the *intuitive-analytic* continuum. At some point, a SJT scientist, if he or she is to be successful, has to say “enough.” It is time to act.

We do not wish to leave the reader with the idea that the proposed process is neat or linear. A SJT scientist may return repeatedly to one or more continua. For example, he or she may assess and reassess coherence as considerations of correspondence and representative design lead to modifications of the proposed research. Oscillation between continua is easy to imagine.

**Evaluation of CCT II**

An important form of evaluation of CCT II would involve methods rarely ever used in SJT research, that is, think aloud protocols (Ericsson & Simon, 1980, 1993; also see Hamm, 1988). Such research is normally time and labor intensive, but in this case it could well be part of students’ master’s and doctoral research, with the students as subjects. We speculate that explicitly thinking and verbalizing about the issues on coherence, correspondence and representative design may have a positive impact on research design. Interestingly, it is in this activity that the potentially symbiotic relation between description of research and prescription for research becomes most clear.

**Summary and Conclusion**

We opened this paper by saying that our objective is to unite two metatheories of truth (coherence and correspondence) with Ken Hammond’s original cognitive continuum theory (CCT) and Egon Brunswik’s principle of representative design of scientiﬁc research. We have done so by incorporating these key principles into a theory of investigators’ thinking. In the above pages we present an expanded version of Hammond's cognitive continuum theory (CCT). We call this expanded version Cognitive Continuum Theory II (CCT II). It includes Hammond's CCT but has additional features. The additional features include two new premises. CCT II also redefines as psychological continua certain ideas that have traditionally been conceived as fixed. One continuum, the *intuitive-analytic* continuum, is taken directly from CCT and made an engine of creativity in CCT II. In addition, we propose as continua the truth criteria of coherence and correspondence, and also Brunswik’s representative design as it functions in the minds of researchers. Consideration of the latter three criteria will facilitate turning a creative idea into a plan for research. We believe these continua represent what goes go on in the minds of researchers better than terms representing fixed concepts. We also believe that these continua are consistent with Hammond’s general conceptual approach as exemplified by his *intuitive-analysis* continuum.

We believe it is clear that coherence and correspondence metatheories ought to be treated as continua and that they can (and do) complement one another. Coherence and correspondence competence develop continually (Mosier, 2009). Movement on coherence triggers movement on the *intuitive-analytic* continuum, as does movement on correspondence (see Premise 4). Movement on one continuum is likely to trigger movement on one or more other continua.

We also believe that representative design should be thought of (treated) as a continuum and that focusing on it as such will improve research design and evaluation, and also training protocols. To reiterate Kirlik (2010, p. 257), “*it is a process toward which a scientific community can collectively learn, from empirical evidence, …”*

We have speculated about possible advantages of uniting these metatheories and representative design with CCT. Such advantages have prescriptive implications. Investigators can deliberately step back and think explicitly of the coherence, correspondence, and the representative design continua during the design process. Investigators in their teaching and mentoring activities should urge students to follow suit.

In this short note we have, at best, taken a small step toward an extended version of CCT that could improve our understanding of the research design process and suggest ways to improve it. We have added premises and proposed new continua. Premise 6 adds metatheories of coherence and correspondence as psychological continua in CCT II. Premise 7 adds representative design as a CCT II continuum. We have argued that dimensions of research that traditionally have been treated as unitary should instead be considered as continuous. But much is left to do. Descriptions of the continua should be further developed and perhaps measures of them could be invented. Interactions among the continua are clearly important, but it has been difficult for us to describe them. It may be that the continua apply differently to the different mental processes involved in conducting research. In designing research, scientists engage in a number of tasks while solving a number of problems, such as formulating the research topic, designing tasks for subjects, selecting measures, choosing subjects, collecting and analyzing data, .... Finally, we hope that our contribution will help clarify thinking about research design.

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