COGNITIVE ADAPTATION AND ITS CONSEQUENCES:
A TEST OF COGNITIVE CONTINUUM THEORY

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Cognitive Continuum Theory (CCT) is an adaptive theory of human judgment. CCT posits a continuum of cognitive modes anchored by intuition and analysis. The theory specifies surface and depth task characteristics that are likely to induce cognitive modes at different points along the cognitive continuum. The current study manipulated both the surface (information representation) and depth (task structure) characteristics of a multiple-cue integration threat assessment task. The surface manipulation influenced cognitive mode in the predicted direction with an iconic information display inducing a more intuitive mode than a numeric information display. The depth manipulation influenced cognitive mode in a pattern not predicted by CCT. Results indicate this difference was due to a combination of task complexity and participant satisficing. As predicted, analysis produced a more leptokurtic error distribution than intuition. Task achievement was a function of the extent to which participants demonstrated an analytic cognitive mode index, and not a function of correspondence, as predicted. This difference was likely due to the quantitative nature of the task manipulations.

INDEX WORDS: Analysis, Intuition, Judgment, Decision Making
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One approach to the study of human decision processes is to study how decision makers tailor their cognitive strategies to different environments. Humans are adaptive organisms (Anderson, 1990; Brunswik, 1956; Hammond, 1996; Payne, Bettman, & Johnson, 1993; Wicklund, 1982), and an adaptive perspective can provide a macroscopic structure for understanding decision making. Cognitive Continuum Theory (CCT) is an adaptive theory of human judgment that focuses on the dynamic relationship of the organism-environment interaction. The theory explicitly includes both intuitive and analytical cognition, and focuses on the environmental characteristics that induce each type of cognition (for a review see Hammond, 1996). The goal of the current study is to test some principle aspects of CCT.

CCT was founded on many of the ideas introduced by Egon Brunswik (see Brehmer & Joyce, 1988; Cooksey, 1996), and makes several contributions to the study of human judgment. First, intuition is operationally defined. Many approaches to decision making regard judgments as being rational (coherent) or nonrational (incoherent), often with no substantial treatment of the nonrational methods (for a review see Hammond, 1996). Second, CCT explicitly rejects a dichotomous view of intuition and analysis. This dichotomy is replaced by a continuum of cognitive modes that has intuition and analysis at its end points. As such, cognition is viewed not as strictly rational or intuitive, but as often falling between the extremes, and thereby being quasi-rational. Quasi-rationality refers to the region of cognition between the polar extremes of the continuum, and has properties of both intuition and analysis. Third, the theory makes direct predictions about how organisms cognitively adapt to different environments. Specific environmental task characteristics are predicted to induce a more intuitive or more analytical mode of cognition.

Analytical thought is well understood in part because it is easily defined: “[It] signifies a step-by-step, conscious, logically defensible process” (Hammond, 1996, p. 60). Rationality will always have a definitional advantage over intuition because a
definition is a rational process. The attempt to define something that by definition is not definable, is certain to cause some disagreement (Pirsig, 1974). Rather than resort to defining intuition simply as nonrational, or nonanalytic, CCT operationally defines intuition and analysis by specifying cognitive attributes of each. Exhibit 1 specifies cognitive attributes associated with analytical and intuitive cognition and environmental conditions predicted to induce each.

Analytical thought is characterized by a high level of conscious control and a slow rate of processing, because information sources are consciously integrated into a judgment via a specific policy. This being the case, decision makers may show higher confidence in the method they are applying than in the answer itself (Hammond et al., 1987). For example, when computing a long math problem by hand, one mistake in the middle is likely to result in a large and unnoticed error. Analysis is a methods-driven approach so the answer is a byproduct. Intuition is not methods-driven, and is characterized by much the opposite. Information is not integrated by a task-specific formula, but rather by a weighted average strategy. This averaging strategy is implemented almost instantaneously and results in low cognitive control and low conscious awareness of the decision policy. For example, when a golfer makes a judgment about the distance between him or herself and the hole, a large number of cues are perceptually measured with little conscious control. If someone asked the golfer how he or she came to that decision, one would not likely obtain any useful information. The golfer would likely respond "How? What do you mean ‘how’ did I come up with my distance estimate? I just did!" Multiple cues are covertly integrated almost instantaneously to come up with distance estimates, and decision makers do not have access to the bases of intuitive decisions. This example demonstrates many of the attributes of intuition listed on Exhibit 1. Mistakes made by the intuitive golfer result in judgments that are usually close to the correct answer, with an error distribution that is
more normally distributed than when an analytic organizing principle is utilized. In short, these two approaches to integrating information from the world around us result in two different realities, each with its own costs and benefits.

Intuition and analysis represent the end points of the cognitive continuum, but cognitive mode is rarely purely intuitive or analytical. More often, it is a mixture of both intuition and analysis. Quasi-rationality refers to this central region of the cognitive continuum, and is a form of imperfect reasoning that has characteristics of both intuition and analysis (Brunswik, 1956; Hammond, 1981). Quasi-rationality is robust and adaptive, and is the mode of thought most closely associated with common sense. “Quasi-rationality has many advantages, which may be one of the reasons that the notion of common sense has persisted and been valued by the layperson for so long, despite the fact that virtually no one has convincingly described it” (Hammond, 1996, p. 175). Most everyday tasks call for quasi-rationality because they present some mixture of analysis- and intuition-inducing characteristics.

A common trend in research has been to focus on the inadequacy of intuitive reasoning, i.e. bias, when compared to analysis (Slovic, Fischhoff, & Lichenstein, 1977). While most research in decision theory has focused on the inadequacies of intuitive judgments, some research from the domain of social psychology has demonstrated the inadequacies of analytic judgments (Hodges & Wilson, 1993; Wilson & Kraft, 1989; Wilson & LaFleur, 1995; Wilson & Schooler, 1991). Given that errors in judgment receive so much attention in the literature, it is important to note when different cognitive modes result in different error distributions and, hence, different consequences. The adaptive decision maker will maintain a balance between intuition and analysis. “When decisions are consistently driven either by irrational impulse or by obsessive number crunching,” judgments will cease to maintain the delicate balance between rationality and effectiveness (Langley, 1995, p. 74). In CCT, neither analysis nor intuition is assumed a priori to be superior.
CCT posits that cognitive modes are distributed along a continuum with intuition at one end and analysis at the other. CCT also posits a task continuum that is conceptualized as adjacent to the cognitive continuum. The task continuum is a range of different tasks that will benefit from different ratios of intuition and analysis. For example, a judgment task that contains uncertainty and many perceptually measured and highly redundant cues will be difficult to break down into its component parts. How each component relates to the other components and the criterion will be difficult to determine due to the environmental uncertainty and the nonorthogonal nature of the information sources. Judgments in such an environment will benefit from an intuitive, compensatory approach. See Exhibit 1 for a list of task characteristics that CCT predicts will induce intuition and analysis. If a judge’s cognitive mode, specified by the location on the cognitive continuum, matches the task demands, the judge will have high task achievement. For example, if a judge tries to utilize analysis in a dynamic, uncertain environment, like driving, he or she will be ineffective. The appropriateness of analysis or intuition is a function of the task demands. In short, decision makers will be less likely to change their strategies if they are making good decisions than if they are making bad decisions.

Since CCT identifies cognitive attributes of both intuition and analysis, it should be possible to calculate a judge’s location on the cognitive continuum by scaling and averaging cognitive attributes associated with each. The cognitive continuum index (CCI) serves as a means of operationally defining a judge's cognitive mode. Since CCT also specifies task characteristics likely to induce intuition and analysis, it is possible to calculate a task continuum index (TCI) to make predictions about what type of thinking a particular task will induce. Hammond et al. (1987) constructed both a CCI, to specify the location of a judge’s cognitive mode, and a TCI, to make predictions about which tasks would induce a particular mode (more detail will be given to this issue in the method section). Like the CCI, the TCI was constructed by scaling and averaging task
characteristics predicted by CCI to induce cognitive modes at different locations on the continuum.

Hammond et al. (1987) provides one of the few empirical tests of CCT. A variety of tasks was constructed to induce a range of cognitive activity based on CCT predictions. Expert engineers were required to make three different types of judgments: highway capacity (analysis-inducing), highway safety (quasi-rationality-inducing), and highway aesthetics (intuition-inducing). These tasks differed at the task-depth level meaning that the functional relationships among cues varied between tasks. Information was presented via three different task-surface formats: numbers (analysis-inducing), bar graphs (quasi-rationality-inducing), and pictures (intuition-inducing). Here, task-surface refers to task-representation differences without regard to the underlying cue relationships. A number of interesting findings were reported. As predicted, surface and depth task characteristics induced corresponding cognitive modes (induction of correspondence). Analytical cognition did not always provide a ceiling for performance, as analytical cognition produced more extreme errors than intuitive cognition. Task performance was a function of the correspondence between the CCI and the TCI.

Hammond et al. also predicted that “knowledge of the congruence between the surface and depth characteristics of tasks is necessary and sufficient to predict performance (i.e., knowledge of the subject’s cognitive activity is unnecessary)” (p. 761). This last prediction was not supported. “Which surface characteristics are congruent with which depth characteristics?” is an empirical question, and not enough is currently known about what task parameters induce and/or benefit from a particular mode of cognition.

Although Hammond et al. (1987) provided strong empirical support for CCT, there has been little follow up research utilizing CCT (Dunwoody, Mahan, Marino, Haarbauer, & Tang, 1997; Mahan, 1994; Mahan, Kirshenbaum, Jilg, & Marino, 1998). Perhaps this is because predictions from CCT are not always clear. For example, CCT does not specify how many, or by how much, task characteristics must vary to induce a
significant shift in cognitive mode. CCT is also unclear as to the relative contributions of qualitative and quantitative task differences.

Despite these ambiguities, the potential benefits of CCT are many. Cooksey (1996) stated prior to this work, “psychology had not focused sufficiently closely on its experimental tasks to understand the type of thinking that such tasks were likely to be inducing in the research participants” (p. 19). CCT also has the potential to provide guidance in display design, simulation development, and cognitive task analysis. Since task-surface features influence cognitive mode, displays can be designed that either aid or hinder judgment. For example, if multiple information sources need to be integrated quickly in a dynamic environment, the theory predicts that a numeric information display will induce a mode of cognition likely to be incompatible with the task demands. Conversely, if a situation requires a judge to provide justification for all decisions over a given period because specific procedures are specified a priori, then the judge needs to have explicit control over how he or she is making decisions. This explicit control is a characteristic of analytic cognition and is induced by objective measurement of a limited number of information sources. Cognitive task analysis often uses verbal reports to determine why an individual has made a series of decisions. According to CCT, the accuracy of this type of self-report will vary as a function of the task properties. Cognitive task analysis could benefit from knowing when subjective reports are more or less reliable. The potential benefits of CCT suggest that it merits further examination.

**Overview of Experiment**

Participants performed an information integration task that varied at both the surface (task representation) and depth (task structure) levels, using a threat assessment judgment task. This test of CCT is different than that of Hammond et al. (1987) in that the judgment task context is invariant across task-depth conditions. In the current study,
all participants made the same type of judgment (threat assessment), whereas Hammond et al. employed different types of judgments (safety, capacity, and aesthetics). A TCI-depth score was computed for each task group. Cognitive mode was operationally defined as the score obtained on the cognitive continuum index (CCI), which was made up of three objectively and two subjectively measured mode indices. Participants were required to make a series of threat assessment judgments about aircraft based on a number of cues, which did not provide all the information needed for a correct judgment. This limited environmental predictability is characteristic of naturalistic contexts. Based on CCT predictions, the following was hypothesized:

$H_1$, Task-surface induction of correspondence: There will be a significant difference in cognitive mode between task-surface conditions in the direction predicted by CCT. Task-surface characteristics consist of two display formats. An iconic display (perceptual measurement of cues) was predicted to induce a more intuitive mode of cognition than a numeric display (objective measurement of cues).

$H_2$, Task-depth induction of correspondence: There will be a significant difference in cognitive mode between task-depth conditions in the direction predicted by CCT. Three task-depth packages were designed to induce analysis, quasi-rationality, and intuition based on CCT predictions (see Exhibit 1) (Cooksey, 1996; Hammond, 1996). No interaction between task-surface and task-depth features on cognitive mode is predicted.

$H_3$, Error distributions will be a function of cognitive mode: Analytical cognition will produce a more peaked (leptokurtic) error distribution than intuitive cognition. Kurtosis values are one of the measures that make up the CCI. However, due to the research emphasis on errors in human judgment, this component was given special attention. To test this hypothesis the groups were divided up based on a revised CCI score. Here, the CCI was recomputed without the inclusion of kurtosis values so that circularity would be avoided. The group with the most analytic revised CCI score is expected to have a significantly larger kurtosis value than the group with the most intuitive revised CCI.
score. Errors of magnitude zero are incorporated such that a high kurtosis value will be seen if most answers are correct, but a few answers are very wrong (a characteristic of analytical cognition). A more normal kurtosis distribution will be seen if most answers are close to correct (a characteristic of intuitive cognition).

$H_4$, Performance will be a function of the correspondence between task properties and cognitive properties. To test this hypothesis the absolute difference between the CCI minus the TCI-depth scores were computed. This difference score was then correlated with task achievement for each subject. A significant negative correlation is predicted. A negative correlation would indicate that the higher the correspondence obtained by a subject (the smaller the difference between the CCI and the TCI-depth scores), the higher the subject's task achievement.

**METHOD**

**Participants**

Participants for the experiment were 108 college students from the University of Georgia research pool. Four of these participants’ data were not used in the analysis because they failed to meet the criteria of obtaining a significant positive task achievement score. Of these 104 participants, 29% were male, 71% were female, and the mean age was 19.2 years ($SD=.95$). Pilot experiments utilizing this task revealed no gender differences, so groups were not matched by gender. Participants received course credit for their involvement in the study.

**Task Overview**

The judgment task used was a threat identification simulation adapted from the Team Interactive Decision Exercise for Teams Incorporating Distributed Expertise (TIDE$^2$) (Hollenbeck, Sego, Ilgen, & Major, 1991; Hollenbeck, Ilgen, Sego, & Hedlunc,
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1995). TIDE\(^2\) is an information integration task in which participants are presented with information about an object through a variety of indices. Participants are required to integrate the information presented into a judgment about the status of an object. The simulation is programmed to represent a naval command threat assessment task.

In this simulation, participants were told to imagine that they were stationed on a naval carrier in a volatile region. Their job was to assess the threat level of aircraft entering the air space around the carrier. The threat assessment judgments are based on a subset of seven possible information cues: (1) aircraft size, (2) aircraft speed, (3) distance of aircraft from the carrier, (4) direction of aircraft flight in relation to the carrier, (5) angle of aircraft ascent or decent, (6) identification signal received from the aircraft, and (7) distance of aircraft from the designated commercial fly-zone. The number of cues presented, the importance of each index in contributing to the criterion, and the number of cues used to calculate the criterion are all programmable (for a review see Hollenbeck et al., 1991). Participants made their judgments of threat on a seven point Likert scale. The judgment options, from the least to most aggressive action chosen, were: (1) ignore, (2) review, (3) monitor, (4) warn, (5) ready, (6) lock-on, and (7) defend. This judgment task is not unlike that made in many video games where players judge the threat of a particular target and then act based on that threat assessment. However, in this context, only a judgment of the aggressiveness of the action to be taken is made and no corresponding action takes place. The seven-point scale thus represents a quasi-continuous range of the aggressiveness of the action chosen.

*The Lens Model Analysis*

The lens model provides a method for comparing a judge’s policy with that of the environmental model by examination of corresponding indices (for a review see Cooksey, 1996). As can be seen in Exhibit 2, \(Y_s\) represents the organism’s judgment of
the criterion, $Y_e$, based on the mediating cues. Tucker (1964) characterized the lens model mathematically as:

$$ra = GR_s R_e + C[(1 - R_s^2) (1 - R_e^2)]^{1/2}$$

(1)

The correlation between judgments and the criterion values (achievement), $r_a$, is a function of four components: (1) the predictability of the judgments from available cues (judgment consistency, sometimes termed 'cognitive control'), $R_s$; (2) the predictability of the criterion from the available cues (environmental predictability), $R_e$; (3) the correlation of the linear model of the environment (the predicted criterion) with the linear model of the judge (the predicted judgment) (linear knowledge), $G$; (4) the correlation of the residual variance in the observer’s model with the residual variance of the judgment, $C$. In the current study, the experimental task was structured so that $C$ was set to zero. Since there was no correlation between the residuals, then the $C$ term can be eliminated from the equation:

$$ra = GR_s R_e$$

(2)

Achievement, $r_a$, is a measure of overall performance, and is the zero-order correlation between participant judgments and the criterion values. Regressing the judgments and criterion values on the cues allows for examination of the predictability of both the environment and the judge. Judgment consistency, $R_s$, is a measure of how consistently a judge executes a policy (Hammond & Summers, 1972). The more a judge executes a policy consistently, the more predictive the participant’s judgments will be from the cues ($R_s$). In the current study, $R_s$ is included in the CCI. Higher $R_s$ values indicate a more analytic mode of cognition because the explicit nature of analysis results in consistent information integration (Cooksey, 1996). Environmental predictability, $R_e$, is a measure of the predictability of the criterion based on the cue information available. The more the cues predict the criterion, the higher this index will be. In the current study, $R_e$ is included in the TCI. Higher $R_e$ values indicate a more
analysis-inducing task. Linear knowledge, $G$, is a measure of the match between the linear model of the environment and the linear model of the judge by way of a correlation between the predicted judgments and the predicted criterion values. Higher knowledge values indicate a high degree of correspondence between the two models. While no direct hypotheses were made concerning $G$, it is reviewed in the Discussion section to help clarify some of the results.

This decomposition of judgment helps isolate some of the different facets that contribute to the judgment process. A judge can have a low achievement value for a number of reasons. The judge can understand the relationship between all the variables but fail to apply this policy in a consistent manner. This lack of consistent application can be due to fatigue or stress (Mahan, 1991; 1994). A judge can consistently apply a policy even though the policy may be wrong (lack of task knowledge). Task knowledge can be influenced by the way the task is represented (Dunwoody et al., 1997; Hagafors & Brehmer, 1980; Mahan et al., 1998). The judge may have good task knowledge and apply a policy consistently but be limited by the environmental predictability of the cues (Tucker, 1964).

**Independent Variables**

*Task-depth manipulation:* Three task packages were designed to induce intuition (*Task One*), quasi-rationality (*Task Two*), and analysis (*Task Three*) based on CCT predictions (Cooksey, 1996; Hammond, 1996). The task packages manipulated (1) the number of cues presented, (2) the redundancy among the cues (measured by the average interc cue zero order correlation), (3) the degree to which the cues were equally weighted in the optimal strategy (measured by the standard deviation of the set of $\beta$ weights obtained from the regression model of the environment), and (4) the total environmental predictability from the available cues (measured by $R^2_e$ from the lens model). Task packages were manipulated at the molar level, with no attempt made to determine the
individual contributions of the four task-depth components. The four components were manipulated simultaneously, in order to produce maximal contrast between conditions. This approach carries the cost of the inability to assess the separate contributions of the components. Subindices were transformed into a common scale and averaged together to compute the TCI-depth scores, using an equal weight additive function because of its simplicity and robustness. Currently not enough is known about how task properties influence mode to specify relative task contributions or interactions (Hammond et al., 1987). Higher values on the TCI indicate a more analysis inducing value. See Exhibit 3 for the task-depth parameters, TCI-depth scores and TCI-depth formula.

Task-surface manipulation: The three tasks were performed with two displays; one designed to induce analysis (Exhibit 4) and one designed to induce intuition (Exhibit 5). CCT predicts that the iconic display will induce a more intuitive mode of cognition than the numeric display, because cues are perceptually measured. This display manipulation is a task-surface manipulation, because the underlying task makeup is unchanged.

Dependent Variables

Cognitive mode was operationally defined as the score obtained on the cognitive continuum index (CCI) and measured using three objectively and two subjectively measured indicators. The CCI, like the TCI, was computed by scaling and averaging a number of component indices. Each index value was linearly transformed into a 1-10 scale so that the five indices could be averaged to obtain an overall CCI rating. Higher values indicate a more analytic mode of thought. The three objectively measured and two subjectively measured cognitive attributes used in construction of the CCI are measured respectively as follows:
1. **Consistency**: High consistency is characteristic of analytic thought. Consistency is measured by $R_s$. Values were linearly transformed into a 1-10 scale for the CCI.

2. **Error distribution**: A more peaked distribution is expected for analytic thought than intuitive thought. Analytic thought produces many correct answers with few but large errors. A peaked distribution will have a positive kurtosis value. Since kurtosis values have an infinite positive and negative range, the observed range was linearly transformed into a 1-10 scale for the CCI.

3. **Response rate**: Intuitive cognition is characteristic of a faster response rate than analytical cognition. Response rate was recorded by the computer for each trial and then averaged across trials for each subject. The observed values were linearly transformed into a 1-10 scale.

4. **Self-insight into policy**: This measure is a difference score between the subjectively reported relative cue weights ($r_{wi}$) and the objectively determined, via regression, relative cue weights ($r_{bi}$). Relative cue weights were calculated by dividing the weight of each cue by the sum of the weights of all the cues. Insight into policy was calculated by the following formula:

$$
t = 2 - \sum_{i=1}^{k} |r_{bi} - r_{wi}|. \tag{3}
$$

Higher values are obtained when participants demonstrate high knowledge of their policy. Self-insight ($t$) has a range of zero (no insight) to two (perfect insight). Values were linearly transformed into a 1-10 scale for the CCI.

5. **Differential confidence**: This measure assesses the difference between an individual's confidence in the strategy they used and their confidence in the accuracy of their answer (method confidence minus answer confidence). If answer confidence is higher than method confidence, intuition is indicated. Negative numbers indicate intuition, and positive values indicate analysis. Values were linearly transformed into a 1-10 scale for the CCI.
Procedure

Participants were randomly assigned to one of six experimental groups. Because the task was initially novel to all subjects, a between-subjects design was chosen to minimize training and transfer effects. All participants within each group participated at the same time, and in the same room. Participants first completed a consent form and were then given a brief introduction to the task. They were told to base their judgments on how threatening an aircraft is, based on the information provided. Each cue, or information source, was described but no indication of its importance was given. Participants were then given a description of the outcome feedback screen. They were told their job was to determine, as well as possible, when a plane was threatening, based on the information provided. They were told they would have fifty feedback trials in which to learn the task, after which the outcome feedback would be removed and then they would make another 100 judgments. All analyses were conducted on data from the last 100 trials. After these 100 trials were completed, participants filled out a questionnaire, which assessed the subjective mode indicators: subjective utilization of cues, confidence in their method, and confidence in their performance (Appendix A). Participant questionnaires contained only those cues present in the participant’s condition.

Pilot studies using this task revealed that 50 trials would be sufficient for the vast majority of participants to learn the task. Learning was defined as achieving a positive significant $r_a$ value. In the current study, task training was based on experience (having completed 50 trials). To verify that participants had learned the task, a criterion of a positive significant achievement score was used for the 100 no-feedback trials. This modest criterion was used due to the nature of $H_0$, which stated that performance was a function of the degree of correspondence between task properties and cognitive properties. In order to detect differences in performance, a wide range of scores was necessary. In addition, environmental predictability was not a constant between groups,
and a strict performance criterion would have eliminated more participants from *Task One* (the seven cue condition with the lowest $R_e$) than *Task Three* (the three cue condition with the highest $R_e$). Four of the 108 participants failed to attain a strong and significant positive achievement value, and were not included in the data analysis.

**RESULTS**

$H_1$: There was a strong and significant main effect ($F_{(1,98)}=10.22, p=.02$) in the direction predicted for display on the CCI (Exhibits 6 & 7). The iconic information display induced a more intuitive CCI score ($M=4.63, SD=.8$) than the numeric information display ($M=5.19, SD=.86$).

$H_2$: There was a significant main effect ($F_{(2,98)}=13.78, p<.001$) for TCI-depth scores on the CCI (Exhibits 6 & 7). Posthoc Tukey’s HSD tests showed a significant difference between *Task Three* (TCI-depth=8.15) and *Task Two* (TCI-depth=5.48) ($p<.001$); a significant difference between *Task Two* (TCI-depth=5.48) and *Task One* (TCI-depth=4.25) ($p<.001$); and no significant difference between *Task One* and *Task Three* ($p=.63$). The inverted U seen in Exhibit 7 differs from the linear relationship predicted. There was no significant interaction as predicted.

$H_3$: A revised CCI was calculated using all indices except error kurtosis. Tukey’s HSD tests were conducted between TCI-depth groups using the revised CCI scores. The same significant differences ($p<.05$) between groups identified under $H_2$ were found here. The groups with the most intuitive revised CCI scores (*Task Three* and *Task One*) were compared to the group with the most analytic revised CCI scores (*Task Two*). A single degree of freedom mean contrast showed a significant difference ($t=3.43, df=101, p=.001$) between the groups in the predicted direction with respect to kurtosis of the judgment error distribution. The analytic group had a significantly more peaked error distribution than the intuitive groups.
$H_0$: There was no significant negative correlation between the absolute value of the TCI minus the CCI and achievement, $r_a$. ($r = .16, p = .1$). In the face of the strong nonlinear relationship on Exhibits 7 and 10, this result is not surprising.

Insert Exhibit 6 about here

Insert Exhibit 7 about here

**DISCUSSION**

The objectively and subjectively collected mode indicator results are not consistent. The same inverted U pattern is generally present in the TCI-depth results for all three of the objectively collected CCI indicators; kurtosis of errors (Exhibit 8), response rate (Exhibit 9), and consistency ($R_s$) (Exhibit 10). This pattern is also visible in the knowledge scores ($G$), but not the achievement scores ($r_a$) (Exhibit 10). However, the subjectively collected mode indicators showed no significant differences ($p > .05$). Given that introspection has a history of being inaccurate (Nisbett & Wilson, 1977), and that the objectively collected indicators form a cohesive pattern, the questionnaire used in the current study was likely too coarse an instrument to obtain reliable self-report results. Previous research using a within-subject design did show predictable differences in differential confidence as a function of task structure (Hammond et al., 1987). The between-subjects design used in the current study may have influenced the ratings. Participants in between-subject designs are more likely to show base-rate neglect than participants in within-subject designs (Koehler, 1996). The same sensitivity to base rates that develops with experience in within-subject designs might result in greater accuracy for both the insight index and the differential confidence measure.

Since there were no significant differences in the two subjectively collected measures, the rest of the discussion will focus on the objectively collected measures.
Task-surface induction of correspondence: $H_1$

The task-surface manipulation produced a corresponding change in cognitive mode (Exhibit 7). The iconic information display induced a more intuitive mode than the numeric information display. Intuitive cognition has the advantage of being faster and more flexible than analysis. There was a significant main effect ($F_{(2,98)}=23.67, p<.001$) for mean judgment time between the two displays (Exhibit 9). The mean judgment time was 3.58 seconds ($SD=1.45$) for the iconic display and 6.3 seconds ($SD=2.77$) for the numeric display. However, intuition has the disadvantage of being less accessible to conscious introspection than analysis. The results of this study provide support for the idea that information representation affects cognitive mode, and hence, how information is integrated.

Task-depth induction of correspondence: $H_2$

The depth characteristics of the task affected the CCI in a pattern not predicted by CCT. CCT predicts that as the TCI-depth scores increase, so should the CCI scores. However, the results showed an inverted U nonlinear relationship (Exhibit 7). A possible reason for the difference between the results found here, and that by Hammond et al. (1987), is the differences in the judgment context. While the tasks in the current study differed on many quantitative characteristics listed in CCT, the type of judgment made was invariant across tasks. The tasks used by Hammond et al. are not only quantitatively different, as in the current study, but also qualitatively different, because the type of judgment made was different between conditions. In the present study, the judgment context was constant, and hence, qualitatively equivalent, between conditions. This distinction between qualitative and quantitative task manipulation is important, because qualitatively different types of judgments can be made about the same object.
Millar and Tesser (1986, 1989, 1992) have examined differences between affectively based and cognitively based judgments. The aesthetic judgment task performed in the study by Hammond et al. can be considered an affectively based judgment. Millar and Tesser argue that attitudes have both an affective and cognitive component, and that these components are qualitatively different. When asking people to analyze the reasons why they do something, the cognitive component of the attitude is made salient. When asking people to focus on how they feel about something, the affective component of the attitude is made salient. These two different types of judgments are qualitatively different and were used by Millar and Tesser to evaluate the same object. So, the objective characteristics of a task can be consistent, and the subjective characteristics still be different.

CCT focuses on a match between the approach (analytic vs. intuitive) and the objective task characteristics. Millar and Tesser (1986; 1989; 1992) focus on a match between the approach (cognitive vs. affective) and the prime motivator of the decision; “Is the decision maker making a consumatory or instrumental decision?”. Consumatory behaviors, those done for their own purpose, are considered to be affectively based. Instrumental behaviors, those done to aid in goal attainment, are considered to be cognitively based. Any given behavior can conceivably be performed for instrumental or consumatory purposes. Millar and Tesser have shown that judgments about the same object can be qualitatively different due to differences in the motivation of behavior. Given the results of the current study, the type of judgment being made seems to be a fundamental component of the task characteristics currently not captured by CCT.

The above discussion explains why the findings are not as we predicted, but does not explain why the inverted U is present in the findings of the current study. One plausible cause for the pattern of results found in the current study is a change in cognitive mode as a function of time on task. While judgment time does decrease over
the 100 test trials, there is no point where it asymptotes and no point where there is a drastic shift. Since the mean time on task was only 6.64 minutes (SD=2.32) for the training trials and 10.55 minutes (SD=4.24) for the 100 test trials, it is not likely that there was a fatigue-related change in cognitive mode as a function of time on task. Thus, a shift in cognitive mode, due to automaticity or fatigue, seems unlikely.

Decision making is a tradeoff between accuracy and cognitive effort (Payne et al., 1993). In Task One, decision makers were required to make an integrative judgment based on seven pieces of information. This task would be difficult to perform with explicit conscious control since it would challenge the attentional limits of working memory. Conversely, the limited dimensional nature of Task Three would allow for expertise to develop quickly. With only three numbers to read in the numeric condition, it is possible that participants were able to process the information almost simultaneously, and hence, intuitively. As such, it is likely that participants in Task Three realized they could perform very well with minimal cognitive effort. The data support this interpretation. Participants performing Task Three performed as well as, or better than, the other groups. They obtained a mean achievement value \( r_a \) of .62 (\( SD=0.14 \)), yet had the lowest judgment response time of the three groups (Exhibits 10 & 9). Another indicator that participants performing Task Three were minimizing cognitive effort is the degree to which they weighted cues equally (measured by the standard deviation of the set of Beta weights from the participants' linear policies). Exhibit 11 shows that in Task One and Task Two the cues were weighted relatively evenly in the ecology and participants showed a commensurate degree of equal cue weighting. However, in Task Three, the cues were not weighted evenly in the ecology. While participants in this group did show a more unequal weighting strategy than the other two groups, their own policies were more equally weighted than that of the ecology (Exhibit 11). This tendency to weight cues evenly is characteristic of intuitive cognition (Cooksey, 1996; Hammond, 1996). The reduced analytical nature of participants' policies in Task Three is also evident in the lack of superior consistency,
and knowledge scores over those for Task Two although participants in Task Three had a more predictable environment (Exhibit 10). Participants performing Task Three actually had lower knowledge scores than participants performing Task Two. From the perspective of a trade-off between accuracy and effort (Payne et al., 1993; Simon, 1957), however it seems that participants in Task Three performed well enough. Their satisficing tendencies allowed them to perform slightly better than the participants in Task Two (as indicated by the trend in achievement scores in Exhibit 10), with less cognitive effort (as demonstrated by the more intuitive CCI scores). This finding suggests that close correspondence between task characteristics and cognitive characteristics may be less important than the overall functionally adaptive value of quasi-rational cognition when confronting a task with high analytic depth features that includes a high degree of environmental predictability.

Another explanation for the lack of support for H₂ may lie in the construction of the TCI. Task characteristics such as a low number of cues, high task predictability, unequal cue weights, and low cue redundancy may have a synergistic effect. Such an effect may produce tasks that are more quasi-rational than the results of the additive TCI. This implies that TCI-depth characteristics can not unequivocally be stated to induce analysis. An additive TCI was used because it is robust and we still know very little about how task characteristics interact. However, interactive task characteristics may represent another type of redundancy besides cue redundancy. Redundancy in task features may be supportive of less analytical cognition. Testing different task packages with equal TCI scores may shed some light on this synergy. Such work may bring CCT predictions closer to known empirical outcomes where, even in highly analytical tasks, experts may not engage in full analytic cognition, but may be operating closer to the intuitive pole of the continuum because they are relying more on pattern seeking and matching than on implementing knowledge about functional relationships.
**Error distributions are a function of cognitive mode: \( H_3 \)**

As predicted, the group with the more analytic CCI score, revised to exclude kurtosis measures, had a significantly more peaked error distribution than the groups with the more intuitive CCI scores (*Task One* and *Task Three*) (Exhibit 8). Because research on human judgment often focuses on judgment error, future research on the differences between intuitive and analytic errors is needed. Research by Wilson and colleagues (Nisbett & Wilson, 1977; Wilson & Kraft, 1989; Wilson & Schooler, 1991; Wilson & LaFleur, 1995) has focused on the adverse impact of analyzing judgments that are often preferential in nature. Preferential judgments are intuition-inducing judgments. Since intuitive judgments are not as retraceable as analytic judgments, it makes sense that analyzing a normally intuitive decision will hinder performance. The experimental manipulation of inducing analysis is likely to result in a mode of cognition that does not correspond with the nature of the task. Conversely, many of the judgment tasks used by Kahneman, Slovic, and Tversky (1982) would be considered analytic in nature. The tasks are well defined and associated with a correct answer. In both of these works, a large body of knowledge about errors in judgment has been accumulated. It would be beneficial to the field to identify differences in the type of errors made as a function of the task. In the extreme, analytic errors tend to be more severe and, as a result, more costly. Intuitive errors are more frequent but their magnitude is smaller.

**Task performance is a function of correspondence: \( H_4 \)**

CCT specifies that successful task performance is a result of operating in the appropriate cognitive mode for the task at hand. Since existing measures of cognitive mode are imperfect, and little is known about which task characteristics induce and benefit from a particular mode of cognition, it is not surprising that no trend, linear or otherwise, was found between the degree of correspondence and achievement. Posthoc analysis did reveal a significant correlation between the CCI and achievement \((r=.41, \ p=.01)\). As participants' CCI scores became more analytic, their achievement scores
increased. Hammond et al. (1987) found that performance was a function of correspondence, and that intuition often outperformed analysis. The quantitative task manipulations used in the present study resulted in tasks that were quantitatively different, but not qualitatively. Given the quantitative nature of the present tasks, it is not surprising that more analytic participants showed better performance. The discussion regarding the relative influence of qualitative and quantitative task differences and the possible interactive effect of task characteristics under H applies here as well. It makes sense to state that task performance is a function of the appropriate strategy. The difficulty in testing such an assertion is specifying what is an appropriate strategy in which environment.

Summary

At the recent Society for Judgment and Decision Making conference, the presidential address, given by Elke Weber (1998), focused on the importance of developing a predictive framework for decision mode selection. The "emerging list of qualitatively different decision modes thus calls for a meta-decision framework that predicts (implicit) decision mode selection" (p. 4). CCT, while imperfect, is such a framework.

The current study provides support for many CCT predictions, and raises questions that need to be answered by more research. While CCT predicted the task-surface effects, it failed to predict the task-depth effects on cognitive mode. The current study held the type of judgment constant across tasks, making the task manipulations purely quantitative. This type of manipulation likely accounts for the difference between the observed inverted U CCI scores and the predicted linear relationship. Within the confines of the current quantitative task manipulations, both task complexity and satisficing appear to explain the results. In the most complex condition, participants would have had difficulty analyzing the ecology, because its constituent components were interrelated and provided low task predictability. Conversely, the least complex
condition allowed subjects to perform well with a minimal amount of cognitive effort. Satisficing is one of the oldest notions in the decision making literature (Payne et al., 1993; Simon, 1957), and a satisficing tradeoff between accuracy and effort was observed in the current study. Future research needs to address the relative contributions of qualitative and quantitative task differences on cognitive mode and the role of motivation in these differences. The current study indicates that the qualitative nature of the task context is an important component of judgment, and that CCT would benefit from a more explicit consideration of this issue. The coherent pattern observed in all three of the CCI components provides compelling evidence that the CCI is a consistent and useful measure of cognitive mode, and demonstrates the usefulness of CCT in studying human judgment as an interaction between an organism and its environment.
REFERENCES


**APPENDIX A**

Questionnaire

Participant ID:______  
Group:______  
Gender:______

How important was each cue to you in making your decisions? Please circle the proper number.

<table>
<thead>
<tr>
<th></th>
<th>Not Important</th>
<th>Medium Importance</th>
<th>Overwhelmingly Important</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Direction</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>IFF</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Angle</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Corridor</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

How confident are you that your above answers accurately reflect how you made your decisions?

<table>
<thead>
<tr>
<th></th>
<th>Not Confident</th>
<th>Somewhat Confident</th>
<th>Very Confident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How confident are you that you made the best possible decisions after the feedback was removed?

<table>
<thead>
<tr>
<th></th>
<th>Not Confident</th>
<th>Somewhat Confident</th>
<th>Very Confident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics of Analysis and Intuition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td><strong>Intuition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High insight into judgment process, and hence, publicly retraceable</td>
<td>Low insight into judgment process, and hence, difficult to retrace and defend</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low confidence in outcome, high confidence in method</td>
<td>High confidence in outcome, low confidence in method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cues are objectively evaluated</td>
<td>Cues are perceptually evaluated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow rate of processing</td>
<td>Fast rate of processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors few, but large when they occur</td>
<td>Errors normally distributed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High cognitive consistency</td>
<td>Low cognitive consistency</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Task Characteristics that induce Analysis and Intuition**

<table>
<thead>
<tr>
<th>Analysis-Inducing</th>
<th>Intuition-Inducing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5 cues</td>
<td>More than 5 cues</td>
</tr>
<tr>
<td>Successively presented cues</td>
<td>Simultaneously presented cues</td>
</tr>
<tr>
<td>Low cue redundancy</td>
<td>High cue redundancy</td>
</tr>
<tr>
<td>Unequal weighting of cues in ecology</td>
<td>Equal weighting of cues in ecology</td>
</tr>
<tr>
<td>Cues objectively measured</td>
<td>Cues perceptually measured</td>
</tr>
<tr>
<td>Nonlinear cue functions</td>
<td>Linear cue functions</td>
</tr>
<tr>
<td>Organizing formula available</td>
<td>No organizing formula available</td>
</tr>
<tr>
<td>Task outcome available</td>
<td>Task outcome unavailable</td>
</tr>
</tbody>
</table>

**Exhibit 1.** Task characteristics that induce intuition and analysis. Cognitive characteristics of intuition and analysis. (adapted from Hammond, 1996)
Exhibit 2. The Lens Model (reprinted from Cooksey, 1996).
<table>
<thead>
<tr>
<th>Task Package #</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cues</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Redundancy among cues</td>
<td>r = .32</td>
<td>r = .25</td>
<td>r = .17</td>
</tr>
<tr>
<td>SD of Cue $\beta$ weights</td>
<td>.22</td>
<td>.29</td>
<td>.83</td>
</tr>
<tr>
<td>Environmental predictability</td>
<td>$R^2_e = .5$</td>
<td>$R^2_e = .65$</td>
<td>$R^2_e = .90$</td>
</tr>
<tr>
<td>TCI Depth Score</td>
<td>4.25</td>
<td>5.48</td>
<td>8.15</td>
</tr>
</tbody>
</table>

**Exhibit 3.** Variable manipulations for each task package *Task package one* is the a priori predicted intuition inducing task; *two* is the a priori predicted quasi-rational inducing task; and *three* is the a priori predicted analysis inducing task. Higher TCI depth scores indicate a more analysis inducing task.

TCI Depth Score = \( \frac{((10 - \# \text{ of cues}) + (10 \times (1 - r)) + (10 \times SD \text{ of } \beta) + (10 \times R^2_e))}{4} \)
**Cue Information List: Game 1**

<table>
<thead>
<tr>
<th>Cue</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>280</td>
</tr>
<tr>
<td>Size</td>
<td>50</td>
</tr>
<tr>
<td>Angle</td>
<td>12</td>
</tr>
<tr>
<td>IFF</td>
<td>0.2</td>
</tr>
<tr>
<td>Direction</td>
<td>20</td>
</tr>
<tr>
<td>Corr Status</td>
<td>4</td>
</tr>
<tr>
<td>Range</td>
<td>160</td>
</tr>
</tbody>
</table>

Your response is


**Exhibit 4.** Numeric display from adapted version of TIDE2.
Exhibit 5. Pictorial cue display from adapted version of TIDE²: (A) Corridor lines, (B) aircraft icon, (C) speed and direction arrow, (D) carrier, (E) angle of descent, and (F) IFF signal.
### Tests of Between-Subjects Effects

Dependent Variable: CCI

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCIDEPHT</td>
<td>15.138</td>
<td>2</td>
<td>7.569</td>
<td>13.777</td>
<td>&lt;.001</td>
<td>.219</td>
</tr>
<tr>
<td>DISPLAY</td>
<td>5.615</td>
<td>1</td>
<td>5.615</td>
<td>10.220</td>
<td>.002</td>
<td>.094</td>
</tr>
<tr>
<td>TCIDEPHT * DISPLAY</td>
<td>1.198</td>
<td>2</td>
<td>.599</td>
<td>1.090</td>
<td>.340</td>
<td>.022</td>
</tr>
<tr>
<td>Error</td>
<td>53.841</td>
<td>98</td>
<td>.549</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>78.067</td>
<td>103</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Exhibit 6.** Test results of TCI-depth and TCI-surface (Display) on cognitive mode.
Exhibit 7. CCI by TCI-depth by Display.
Exhibit 8. Kurtosis by TCI-depth by Display.
Exhibit 9. Judgment Rate by TCI-depth by Display.
Exhibit 10. Lens Model Measures by TCI-depth.
Exhibit 11. Standard deviation of the set of cue Beta weights from the ecology and participants.