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Understanding Construction Workers' Risk Decisions Using Cognitive Continuum Theory

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ABSTRACT
During the course of performing daily tasks, construction workers encounter numerous hazards, such as ladders that are too short to reach the work area, energized electrical lines, or inadequate fall protection. When a hazard is encountered, the worker must make a rapid decision about how to respond and whether to take or avoid the risk. The goal of this research was to construct a theory about the influence of decision cues on intuitive and deliberative decision-making in high-hazard construction environments. Drawing from Cognitive Continuum Theory, the study specifies a framework for understanding why and how construction workers make decisions that lead to taking or avoiding physical risks when they encounter daily hazards. A secondary aim of the research was to construct a set of hypotheses about how specific decision cues influence whether a worker is more likely to engage their intuitive impulses or to use careful deliberation when responding to a hazard. These hypotheses are described and the efficacy of the hypotheses was evaluated using cross-tabulations and nonparametric measures of association. While most of the associations between decision cues and decision mode (i.e., intuition or deliberation) identified in this data set were generally modest, none of the associations were statistically zero, thus indicating that further research is warranted based on theoretical grounds. A rigorous program of theory testing is the next logical step to the research.
***Keywords*:** Cognition, Construction Hazard, Decision Cues, Decision making, Physical risk

I. SIGNIFICANCE OF RISK DECISIONS ON CONSTRUCTION SITES

Construction work is inherently hazardous, and as a result, workers encounter numerous hazards on the jobsite each day. For example, an individual may discover that an eight-foot tall ladder is needed to reach the work area, but only a six-foot ladder is available – resulting in a ladder that is too short to safely complete the work. At the moment of discovering that the ladder is too short (i.e., discovering the hazard), the worker must make one of two possible choices: (1) take a risk (i.e., use the shorter ladder), or (2) avoid a risk (i.e., do not use the shorter ladder). If, in fact, the worker chooses to use the six-foot ladder and to stand on the top rung of the ladder to reach the work area, the risk of a fall is possible, which might result in broken bones, head injuries, or even death (i.e., risk-taking consequences).

This scenario describes how (1) a hazard is encountered, that results in (2) the presence of a risk, that then results in (3) the need to make a decision to take or avoid the risk, that may then (4) ultimately lead to negative consequences if the risk is taken (rather than avoided). Thus, a *hazard*, by common definition, is any source of potential harm or loss, a *risk* is the probability that a harm or loss will occur as a result of exposure to a hazard, and, a *consequence* is a potential outcome of taking the risk (Canadian Centre for Occupational Health & Safety 2009). And while a significant number of studies have investigated construction hazards, risks, and consequences (Choudhry and Fang 2008; Dahlback 1991; Gibb et al. 2006; Hinze et al. 1998; Wu et al. 2010), relatively little is known about the construction risk decision-making process because judgment and decision-making (JDM) research is typically the domain of psychologists and decision scientists rather than engineers or construction researchers, and thus much of the JDM research is general in nature rather than directed at understanding decision-making in high-hazard environments. Consequently, this article seeks to make a contribution to the limited body of knowledge on construction risk decision-making. Specifically, this article introduces an information processing theory that is prevalent (but intensely debated) in the judgment and decision-making domain -- referred to as Dual-Process Theory – which is often used to explain how individuals mentally process information to arrive at a judgment or decision. The article then presents a framework for understanding why and how construction workers make decisions when they encounter a hazard that lead to taking or avoiding physical risks on the jobsite.

II. LITERATURE REVIEW

2.1 Dual-Process Theory Of Decision-Making

It is generally accepted in psychology and judgment and decision-making (JDM) domains that people process information by two independent, interactive modes of thought: the intuitive system and the analytical system (Epstein 2003). The intuitive system is believed to be automatic, experience-based, emotionally-driven, quick, effortless, and impulsive (De Neys and Glumicic 2008; Denes-Raj and Epstein 1994; Inbar et al. 2010). It is also thought to be old, evolutionary, highly adaptive, and present in all higher order beings (Denes-Raj and Epstein 1994). The intuitive system tends to be influenced strongly by experience and draws from knowledge stored in long-term memory, thus allowing for nearly automatic, unconscious responses (Betsch and Kunz 2008). By contrast, the analytical system is believed to be deliberative, slow, controlled, effortful, and rule-based (Stanovich and West 2000). It is also thought to be relatively new, distinctively human, and related to general intelligence (Evans 2011). The analytical system tends to process information sequentially using conscious monitoring, and consequently, it often results in thoughtful, reflective responses. Table 2.1 outlines the characteristics commonly associated with intuition and deliberation. Researchers generally agree that both modes of thought are engaged during a decision-making task and that the two modes operate seamlessly and in parallel (De Neys et al. 2008; Sloman 1996), where one mode may dominate the decision-making process while the other mode plays a subordinate role (Betsch and Kunz 2008). For example, the intuitive system may form an immediate impression of a hazardous situation, but this impression may be carefully processed and formed into a decision, which is a function of the analytical system

Table 2.1 Characteristics of intuition and deliberation (Epstein 2003; Hammond et al. 1987; Inbar et al. 2010)

Characteristic	**Intuition**	**Deliberation**
Cognitive control	Low	High
Rate of information processing	Rapid	Slow
Conscious awareness	Low	High
Organizing principle	Weighted average	Task specific
Confidence in judgment	Low	High
Errors in judgment	Many but small	Few but large
Processing method	Holistic	Analytic
Decision driver	Emotion-based	Logic-based
Connection-making	Associonistic	Cause-and-effect
Orientation	Outcome oriented	Process oriented
Behavior mediated by	Past experience	Conscious appraisal
Change mechanism	Repetition, experience	Speed of thought
How Experienced	Passively, subconscious	Actively, conscious
Outcome Evaluability	Subjective	Objective
Criteria	Implicit	Explicit
Processing mode	Comes in a flash	Step-by-step

In spite of decades of research directed at understanding the dual processes of intuition and deliberation – especially differences in efficiency, effectiveness, and validity of decisions made when engaging each mode of thought – only a few studies have attempted to directly identify and describe the extent to which individuals engage in intuition, deliberation, or a combination of both processes across a variety of tasks and across a variety of contexts. This article contributes to this limited body of work by presenting a framework that can be used to classify decision tasks and associated decision-making modes, thus allowing researchers to theorize about the types of decision tasks that are likely to induce intuitive impulses versus careful analysis, particularly when a worker encounters a hazard on the jobsite.

2.2 Influence Of Intuition And Deliberation On Risk Decision-Making

Numerous studies have focused on the influence of intuitive, automatic thinking on human error, with significantly fewer studies associating deliberation to error. Hinze (1996) developed a *Distractions Theory of Accidents* that proposed that the production tasks of construction workers consume their attention, thus causing mental pre-occupation that shifts their focus away from work hazards and makes accidents more likely. Reason (1990) further noted that the failure to redirect attentional control during moments of preoccupation or distraction is “the most common cause” of errors. He specifically noted that inattention, haste, and inadequate thought-monitoring were among the top 10 contributing factors to human error in medical surgery and other domains (Reason 2005).

Norman (1981) more specifically suggested that errors occur when: (1) habits are inadvertently substituted for intended actions; (2) thoughts proceed faster than actions, thus causing an individual to forget a step in the performance of a task or forget to perform the task altogether; or (3) environmental cues trigger an automatic (unintended) response.

Alternatively, Geller (2001) focused on the role of deliberation on error, noting that most individuals are consciously aware that they are taking a risk that could lead to an incident. He observed that the reasons for deliberately risky behavior are broad and numerous, including pressure from someone else to take a risky shortcut, the inconvenience of following safety procedures, or, not wanting to take the extra time to be safe. Mitropoulos and Guillama (2010) suggest, however, that while risky behavior does, in fact, result from mental pre-occupation (such as walking backwards while performing a task), many risks are deliberate (such as standing on a board that is insufficient to support the worker’s weight), and many more risky behaviors fall somewhere in between being an intuitive act versus an intentional act.

From a practical perspective, we know very little about why and how construction workers use intuition and why and how they use deliberation when making a decision that leads to taking or avoiding a physical risk. However, classic research by Hammond et al. (1987) suggests that task and environmental cues trigger the mode of thinking that ultimately leads to making an intuitive or a deliberative decision.

2.3 Cognitive Continuum Theory: Matching Decision Cues And Decision Mode

Although significant empirical support exists for dual-process modes of decision-making, dual-process theory is not without its critics. Specifically, one key criticism is its limited explanation for how the two systems interact (Dhami and Thomson 2012). In fact, many older studies suggested that intuition and deliberation are two systems that are dichotomous (*either* intuitive *or* analytical) and opposite to one another (i.e., intuition <u>is</u> what analysis <u>is not</u>) (Cooksey 1996). To overcome the limitations of existing dual-process theories, Hammond et al. (1987) “rejected the traditional dichotomy between intuition and analysis” and instead proposed a Cognitive Continuum that is anchored at one pole by intuition and at the other pole by analysis (Fig 2.1). In between the two poles are various combinations of intuition and analysis – referred to as quasi-rationality – which consist of a repertoire of modes of thinking that may be selectively used by individuals depending on the particular task being performed or operational context applicable at the moment. This theoretical research suggested that tasks that can be decomposed into logical, sequential steps are more likely to activate deliberation, whereas tasks that are not easily decomposed or have ambiguous features are more likely to activate intuition (Dane et al. 2012). Consequently, in addition to a Cognitive Continuum, Hammond also conceptualized a Task Continuum along which decision tasks can be ordered according to the mode of thought they are likely to induce (i.e., intuition-inducing and analysis-inducing tasks) (Table 2.2).

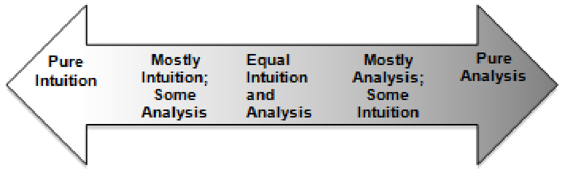

Figure 2.1 Cognitive Continuum (Dhami and Thomson 2012; Hammond et al. 1987)

Doherty and Kurz (1996) suggest that Hammond's Cognitive Continuum Theory (CCT) is "simultaneously a theory of tasks and a theory of cognitive processes entailed in addressing those tasks" (p. 130). While modes of cognition fall somewhere along the continuum between intuition and analysis, decision tasks are also ordered along the continuum – identified as more intuition-inducing or more deliberation-inducing. Table 2.2 outlines a set of predictions about how specific task characteristics will influence a decision-maker's cognition – that is, whether an individual is more likely to approach the task intuitively, deliberatively, or via some combination of the two modes of thought.

Only a few studies have empirically tested the predictions of Cognitive Continuum Theory. For example, Hamm (1988) used a research technique that measured variations in tasks and cognition on a moment-by-moment basis, demonstrating that it was possible to study changes in cognition over time and across contexts, and thus it was possible to reliably demonstrate the "causal influence of task parameters on mode of cognition" (Doherty and Kurz 1996). Similarly, Dunwoody et al. (2000) found support for the influence of task characteristics on intuitive thinking but was not able to document a similar influence on analytic thought, which was attributed to insufficient variation in the type of judgment elicited. Other studies have used Cognitive Continuum Theory as a framework for (1) understanding how individuals resolve conflicts between intuition and analysis (Inbar et al. 2010), (2) identifying situations where work performance is likely to deteriorate (Mahan 1994), and (3) categorizing judgment tasks in healthcare (Standing 2008). This article contributes to the body of risk decision-making research by suggesting a framework – based on Cognitive Continuum Theory – for understanding why and how construction workers use decision cues to make decisions about hazards that lead to taking or avoiding physical risks.

Table 2.2 Characteristics of tasks that induce intuition and deliberation (Doherty and Kurz 1996; Hammond et al. 1987; Inbar et al. 2010)

Task Characteristic	**Intuition-inducing**	**Deliberation-inducing**
Number of cues	Greater than 5	Less than 5
Measurement of cues	Subjective	Objective
Weighting of cues	Equal	Unequal
Presentation format	Pictorial	Quantitative
Display of cues	Simultaneous	Sequential
Interpretation of cues	Subjective	Objective
Distribution of cue values	Continuous	Unknown, discrete
Redundancy among cues	High, dependent	Low, independent
Relation between cues, criterion	Linear	Non-linear
Decomposition of task	Low	High
Degree of task certainty	Low, ambiguous	High, unambiguous
Task complexity	Simple	Complex
Level of task precision	Imprecise	Precise
Familiarity with task	Familiar	Unfamiliar
Time period	Brief	Long
Time pressure	High	Low
Availability of organizing principle	Unavailable	Available
Emotion valence	Positive	Negative
Mental feedback available	Little/none	Cognitive Feedback

III. RESEARCH AIMS

The aim of the research was to use the theoretical predictions from Cognitive Continuum Theory (Table 2.2) to classify – as intuitive or as deliberative – decisions made by construction workers when they encounter a hazard on the jobsite that lead to taking or avoiding a physical risk. Thus, the primary aim of the research was to construct a theory about the influence of decision cues on intuitive and deliberative decision-making in high-hazard environments by specifying a framework for understanding why and how construction workers make decisions when they encounter a hazard. A secondary aim of the research was to construct a set of hypotheses for testing the new theory by using nonparametric tests of association to evaluate whether decision cues classified as intuition-inducing or deliberation-inducing did, in fact, tend to be associated with intuitive thought and deliberative thought, respectively.

IV. RESEARCH METHOD

Structured interviews were conducted with 29 construction workers from the Chicago metropolitan area. Each interview lasted approximately one hour and queried each participant about a recent risk they took during their work day. To put the participant at ease, the researchers explained the purpose of the research as well as the procedures for keeping the data confidential. Furthermore, the first stage of the interview consisted of questions about common risks that the participant had witnessed *other workers taking* routinely while working. During the second stage of the interview, a scenario was presented and the participant was asked to describe how they would respond to the scenario. The third stage of the interview then specifically asked the participant to identify and discuss a recent risk they took while working. Stage three began by querying participants about the specific hazard they encountered and the risk they took. Then, the researchers probed seven types of decision cues that potentially influenced intuitive and deliberative decision-making when they encountered the physical hazard: (1) features of the task, (2) features of time, (3) features of the location, (4) features of the work method, (5) features of the site environment, (6) features of the safety environment, and (7) features of the social environment. Each participant was also asked to describe what they were thinking right before, during, and right after they took the risk. Then, each participant was asked to classify their decision-making in the moments leading up to and then taking the risk as (1) completely intuitive, (2) initially deliberative but alternated to intuitive, (3) initially intuitive but alternated to deliberative, or (4) completely deliberative. To complete the interview, participants were asked to respond to a baseline survey that consisted of questions about the demographic characteristics of the participant, including number of years of work experience, number of safety incidents experienced, number of safety incidents witnessed, and hours of safety training received.

V. DATA ANALYSIS METHOD

The researchers elected to use a grounded theory approach, in which theory is systematically generated from the data. More specifically, as noted by Glaser and Strauss (1967), grounded theory does not aim for the "truth" (since it is unknown) but it aims to conceptualize “what is going on” by using empirical data to derive hypotheses.

A significant portion of the data from the interviews was qualitative (i.e., open-ended questions), and as a result, the type of data collected during the interviews consisted mainly of words, highly detailed descriptions, and explanations of decisions and cues. Therefore, the researchers began the theory-building process by conducting a content analysis. The central idea behind conducting a content analysis was to classify the many words from the transcribed manuscripts of the interviews into significantly fewer content categories (i.e., variables) (Weber 1990) that could then be analyzed using basic nonparametric statistical techniques to evaluate associations among variables. Therefore, the researchers developed a master coding system to analyze the qualitative data. According to Miles and Huberman (1994), “Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study” (p. 56). The content analysis began by first counting word frequencies to understand which words (primarily nouns) were mentioned most often by the workers. However, the *recording unit* was the sentence because ideas tended to be conveyed as complete sentences rather than by individual words. Based on the word counts and review of sentences, the researchers defined a hierarchy of categories of responses to the interview questions. Similar sentences and sentences with similar meaning were combined under narrow categories, and narrow categories were then combined into broader categories. For example, “The weather was extremely cold” and “It was raining” were combined into the narrow category *Unfavorable Weather*, and then *Unfavorable Weather* and *Cluttered Site* were combine into the broader category *Unfavorable Work Environment*.

In addition to open-ended questions, many of the interview questions permitted more discrete responses, which resulted in nominal or ordinal categorical data. For example, the question, "Did the task require a low, medium, or high level of concentration?" was coded as 1=low, 2=medium, or 3=high.

A series of spreadsheets were used to perform data reduction. Different spreadsheets represented different sections of the interview, such as *Hazard Observations* or *Hazard Experiences*. Within each spreadsheet, participants were listed in rows and interview question responses were listed in columns, and the intersection of a row and a column indicated a single participant's response to a single question. For each participant, a code from the master coding structure was entered into a cell to represent their answer for each question. Once the codes were entered into the spreadsheet, the researchers were able to use cross-tabulations and basic nonparametric measures of association to evaluate relationships among variables and thus to develop hypotheses about the influence of decision cues on intuitive and deliberative decision-making.

5.1 Classifying Cues Using Cognitive Continuum Theory

The researchers asked each construction worker 47 multiple choice and open-ended questions about the hazard encountered, the risk that was taken, and the decision cues that might have influenced the worker's decision to take (or avoid) the risk. Nine types of decision cues were identified by the researchers as potentially inducing intuitive impulses or rational analysis based on the predictions from Table 2.2. One additional decision cue (*Flow*) was hypothesized by the researchers as influencing intuition or analysis based on prior research suggesting that a relationship exists between the subjective feeling of "being in flow" and automatic, intuitive thinking (Csikszentmihalyi et al. 1993). These ten decision cues correspond to seven task characteristics that have been identified in previous studies as triggering greater intuition or greater deliberation during the decision-making process. Table 5.1 identifies: (1) the decision cue, asked in the form of an interview question, and (2) the matching task characteristic from Table 2. The ten decision cues include:

1. **Task Novelty:** The question asked was, "Was there anything unusual about this task?" An unusual or novel task implies that the worker is unfamiliar with the task, possibly because the worker does not perform the task frequently. A frequently performed task is likely to be very familiar to a worker and will appear to be "typical" or "usual". Thus, the Task Novelty variable from the interview corresponds to the theoretical task characteristic *Familiarity with Task*. Previous research has established that familiar tasks tend to induce greater intuition while unfamiliar tasks tend to induce greater deliberation (Epstein 2003). Hence, if a worker indicates that their task is unusual or novel, theory suggests that the worker is more likely to approach the task intuitively.
2. **Task Frequency:** The question asked was, "Is this a task you perform frequently?" Much like Task Novelty, the Task Frequency variable implies that the task is likely to be very familiar or unfamiliar to a worker, and thus corresponds to the theoretical task characteristic *Familiarity with Task*. As noted, familiar tasks tend to induce greater intuition while unfamiliar tasks tend to induce greater deliberation (Epstein 2003).
3. **Work Method Frequency:** The question asked was, "Do you use this work method frequently?" The corresponding theoretical task characteristic is again *Familiarity with Task*. A work method that is used frequently by the worker is likely to be very familiar to a worker, and thus actions involved in using the method become habitual or routine. Researchers have noted that repetitive and habitual processes are often automatically directed by intuitive cognition, whereas unfamiliar tasks remain under the control of the deliberative system (Epstein 2003).
4. **Complexity:** The question asked was, "Was the complexity of the task high, medium or low?" The corresponding theoretical task characteristic is *Task Complexity*. More complex tasks tend to involve a greater number of intermediary steps and are often viewed as more demanding of effort thus requiring greater deliberation. In contrast, simpler tasks are less taxing on cognitive resources and thus can be performed more automatically and intuitively (Inbar et al. 2010). Hence, if a worker indicates that their task has a high level of complexity, the worker is theoretically more likely to engage analytical reasoning when performing the task.
5. **Concentration:** The question asked was, "Did you need a high, medium, or low level of concentration?" Greater concentration often results from the need for greater precision and

often requires more focused attention. Consequently, the corresponding theoretical task characteristic is *Level of Task Precision*. Previous research has demonstrated that greater concentration and precision require greater deliberation while the need for less precision often triggers intuitive impulses (Inbar et al. 2010). Thus, if a worker indicates that they need a high level of concentration to complete their task, the worker is theoretically more likely to engage in deliberative thinking when performing the task.

6. **Skill:** The question asked was, "Did you need a high, medium, or low level of skill?" Much like Concentration, a higher skill level requires a higher level of precision and focused attention, and accordingly, the corresponding theoretical task characteristic is *Level of Task Precision.* As noted, greater precision requires greater deliberation while less precision triggers intuition (Inbar et al. 2010). Hence, if a worker indicates that they are performing a low-skill task, the worker is theoretically more likely to draw upon their intuition when performing the task.
7. **Task Enjoyment:** The question asked was, "Is this a task you enjoy doing or dislike?" Numerous studies have examined the influence of emotions on decisions (Betsch and Kunz 2008; Epstein 2003); hence, the corresponding theoretical task characteristic is *Emotion Valence*. Positive emotions tend to result in more flexible, quick, efficient, and heuristic information processing (Isen 2001) while negative emotions invoke much more systematic, careful, and critical mental computing (Schwarz et al. 1991). Thus, if a worker indicates that they enjoy the particular task they are performing, the worker is theoretically more likely to engage in greater intuitive thinking.
8. **Time Limit:** The question asked was, "Was there a strict time limit to finish the task?" The related theoretical task characteristic is *Time Period*. When the time available to complete a task is brief, individuals tend to resort to using simplifying heuristics, and these simplifying heuristics tend to be associated with more intuitive thinking (Svenson 2008). In contrast, when time is abundant, workers can, and often do, take more time to carefully think through the decision using rational analysis. Hence, if a worker indicates that the task must be completed within a strict and limited timeframe, the worker is theoretically more likely to engage in intuitive thinking when performing the task
9. **Time Pressure:** The question asked was, "Were you experiencing time pressure (did you feel rushed)?" Accordingly, the corresponding theoretical task characteristic is *Time Pressure*. Several studies have documented the impact of time pressure on mental effort, and these studies have demonstrated that intuitive impulses prevail when people are feeling rushed (Rothstein 1986). Consequently, if a worker indicates that they are experiencing time pressure or feel rushed, the worker is theoretically more likely to activate their intuitive thinking when performing the task.
10. **Flow:** The question asked was, "Was your work flowing smoothly or was it disrupted?" The hypothesized task characteristic is *Degree of Cognitive Flow*. Flow is a subjective state that people experience when they are completely involved in an activity and thus forget about time, fatigue, or external distractors (Csikszentmihalyi 1997). That is, smooth work flow likely induces greater automatic intuitive information processing. In contrast, workflow disruptions are likely to cause greater focused attention and thus greater deliberation.

Table 5.1 Decision cues, Decision Task Characteristics, and Inducement Codes

Decision Cue Number	**Interview Question**	**Variable Name**	**Task Characteristic (from Table 2.2)**	**Intuition-Inducing (Coded as 1)**	**Quasi-Rational (Coded as 2)**	**Analysis-Inducing (Coded as 3)**
1	Was there anything unusual about this task?	Task Novelty	Familiarity	Usual	N/A	Novel
2	Is this a task you perform frequently?	Task Frequency	Familiarity	Performed frequently	N/A	Not performed frequently
3	Do you use this workmethod	Work Method	Familiarity	Used frequently	N/A	Not used frequently

	frequently?	Frequency				
4	Was the complexity of the task high, medium or low?	Complexity	Task Complexity	Low complexity	Medium complexity	High complexity
5	Did you need a high, medium, or low level of concentration?	Concentration	Level of Task Precision	Low concentration	Medium concentration	High concentration
6	Did you need a high, medium, or low level of skill?	Skill	Level of Task Precision	Low	Medium	High
7	Is this a task you enjoy doing or dislike?	Task Enjoyment	Emotion Valence	Enjoy	Neutral	Dislike
8	Was there a strict time limit to finish the task?	Time Limit	Time Period	Time limit	N/A	No time limit
9	Were you experiencing time pressure (did you feel rushed)?	Time Pressure	Time Pressure	Felt rushed	N/A	Not rushed
10	Was your work flowing smoothly or was it disrupted?	Flow	Degree of Cognitive Flow (hypothesized)	Smooth	N/A	Disrupted

5.2 Self reported mode of Thought (Dependent Variable 1)

The current research was conducted in order to build a theory of risk decision-making in high-hazard environments and to provide a pathway for testing the theory through future research. Consequently, to contribute to the theory building effort, the researchers tested the efficacy of the set of hypotheses about the theoretical association between decision cues and decision mode (i.e., intuition or deliberation). The test of efficacy involved using nonparametric tests of association (i.e., cross-tabulations) to evaluate whether – in the current data set – decision cues classified as intuition-inducing or deliberation-inducing did, provisionally, tend to be associated with intuitive and deliberative thought, respectively, as self-reported by the participants. Self-reports were used in the current research because the study did not intend to engage in significant theory testing, and as a result, approximate measures of intuitive and deliberative information processing were considered sufficient. To self-report their decision mode, each participant classified their decision-making in the moments leading up to and then taking the risk as one of four possible types (referred to as *Response Modes*):

(1) Response Mode 1, Completely Intuitive: The worker reacted automatically without thinking about the risk, and then realized at a later time that they took (or avoided) a risk.
(2) Response Mode 2, Initially Deliberative but Alternated to Intuitive: The worker initially thought carefully and deliberately about the risk but then proceeded more automatically and intuitively.
(3) Response Mode 3, Initially Intuitive but Alternated to Deliberative: The worker initially reacted automatically and intuitively, but then at the last moment, thought carefully and deliberatively about the risk and proceeded to take the risk anyway.
(4) Response Mode 4, Completely Deliberative: The worker reacted deliberately or carefully thought about the risk before they took (or avoided) it, realizing it was risky; and then, after thinking about it, they proceeded to take (or avoid) the risk anyway.

The frequency of each reported *Response Mode*, as self-reported by the construction workers, was: (1) Completely Intuitive = 17%, (2) Initially Deliberative but Alternated to Intuitive = 31%, (3) Initially Intuitive but Alternated to Deliberative = 31%, or (4) Completely Deliberative = 21%. Consequently, construction workers reported that they integrated or alternated between modes of intuitive and deliberative thinking more frequently (i.e., 62%) than using purely intuitive or purely deliberative modes of thought (i.e., 38%).

5.3 Why workers took risk?

The responses to the question about why construction workers took a risk were categorized and used to stratify the data set into two types of decision-maker: those who voluntarily took a risk and those who felt they had no other option other than to take the risk.

The second question probed was WHY the worker took the risk. The responses were recorded in a spreadsheet for further analysis. The goal was to capture the keywords from what the workers are saying in order to categorize their responses. A key issue was that each of the responses consisted of multiple reasons and how could they be categorized? It is clear from Fig 5.1 that having no other option has the highest frequency followed by unfavorable circumstances. This confirms that many workers were compelled to take the risk involuntarily. The reasons ‘felt comfortable’ and ‘chose convenience’ were categorized as voluntarily taking the risk. Notably, the frequencies for these fall just below the ‘no other option’ category. This suggests that workers are taking risks willingly nearly as often as unwillingly.

The question ‘Why did you take the risk’ was asked a second time towards the end of the questionnaire and many workers gave different answers from what they gave in question 2, possibly because they had nearly an hour to reflect on why they really took a risk. Figure 5.2 shows a comparison of the responses for both questions.

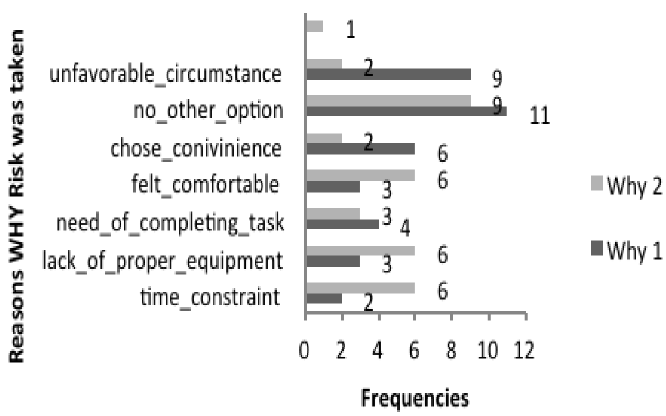

Figure 5.1 Comparison of WHY 1 and WHY 2 responses

Table 5.2 Frequency of Responses to each Decision Cue for Voluntary and In-Voluntary risk takers

Cue Number	Type of Decision Cue / Decision Cue Description	Voluntarily Risk			No Other Option		
		Low	Med	High	Low	Med	High
1	Novelty of the task performed	5	-	9	11	-	4
2	Frequency task is performed	7	-	7	2	-	13
3	Frequency work method is used	4	5	5	5	8	2
4	Complexity of the task performed	5	7	2	7	5	3
5	Concentration required	4	-	10	12	-	3
6	Skill level required	4	7	3	4	9	2
7	Enjoyment of task	11	-	3	10	-	5
8	Time constraint to perform task	10	-	4	8	-	7
9	Feeling of time pressure	11	-	3	12	-	3
10	Perception of work flow	11	-	3	15	-	0
Note: The symbol “-” indicates this option was not available							

5.4 Relationship between the theoretical decision cues (independent variables) and intuitive/ deliberative modes of thought dependent variable 1)

During the interviews, it became apparent that many of the construction workers felt they had no other option than to take a risk in order to complete their task. A retrospective review of the data revealed that 48% of the workers indicated they had no other option other than to take a risk, while 52% admitted that they voluntarily took the risk. Consequently, the authors decided to stratify the data to examine differences between the voluntary risk-takers and those who felt they had no other option. The construction workers self-reported their mode of thought during their decision-making process when they encountered a hazard. The frequency of *Response Mode* for voluntary risk-takers versus those who felt they had no other option, respectively, was: (1) Completely Intuitive = 14% v. 3%, (2) Initially Deliberative but Alternated to Intuitive = 17% v. 17%, (3) Initially Intuitive but Alternated to Deliberative = 14% v. 14%, or (4) Completely Deliberative = 7% v. 14%.

Table 5.2 identifies the frequency of eac h response for each decision cue hypothesized as being present during the response to a hazard. It should be noted that while many of the decision cues may have been present and available for use by the construction worker, the cue may have been intentionally ignored and not used by the construction worker to make a decision, but this possibility was not specifically examined in the study. A Mann-Whitney U-Test was performed to evaluate whether there were significant differences in the frequencies reported by the voluntary risk-takers and those who felt they had no other option. Significant differences ($p < 0.10$) were noted for the following cues: (1) Novelty of the task performed, (2) Frequency task is performed, and (3) Concentration required. For voluntary risk-takers, tasks tended to be more novel and require more concentration, while those who felt they had no other option reported lower task novelty, higher task frequency, and lower concentration required.

To test for associations between the various decision cues and the self-reported mode of thought, before and after taking into account the voluntary or involuntary nature of the risk, the CMH test was used. Rows represented the decision cue responses (low, medium, high) and columns represented the self-reported mode of thought (purely intuitive, deliberative-to-intuitive, intuitive-to-deliberative, and purely deliberative). To account for the voluntary nature of the risk, the data were stratified by voluntary and involuntary risk-takers. The null hypothesis was "there is no association" between the decision cue and the mode of thought used to make the decision, while the alternative hypothesis was "there is a general association" between variables. First, the unstratified data were tested for an association between each of the decision cues and the self-reported mode of thought. The test statistic Q_{GMH} was significant at the $\alpha = 0.10$ level for the following decision cue: (1) Feeling of time pressure ($Q_{GMH} = 6.82$; $p = 0.078$). An examination of the raw data revealed that individuals who felt less time pressure were equally likely to use intuition or deliberation when they encountered a hazard, but individuals who felt greater time pressure were more likely to rely on intuitive decision-making. No other significant associations were noted for the unstratified data.

Next, the stratified data were tested for an association between each of the decision cues and the self-reported mode of thought, after controlling for voluntary versus involuntary risk-taking. The test statistic Q_{GMH} was significant at the $\alpha = 0.10$ level for the following decision cues: (1) Concentration required ($Q_{GMH} = 8.96$; $p = 0.030$); and, (2) Feeling of time pressure ($Q_{GMH} = 7.33$; $p = 0.062$).

VI. THEORY DEVELOPMENT

In the previous sections, extensive qualitative and quantitative data analysis was conducted on the responses to open-ended interview questions collected from 29 construction workers about the decision-making process used when the worker encountered a hazard. The goal of the data collection and analysis was to develop a theory about the types of cues used by construction workers to make an intuitive or deliberative decision to take or avoid a risk when they encounter a hazard.

Initially, previous research was examined for relevant cues that might suggest that workers were more or less likely to engage in more intuitive or deliberative thinking and actions when they encountered a hazard. From this prior research, 10 specific types of cues were identified and used in data analysis.

Research over the past decade has suggested that human beings have difficulty combining more than a few pieces of information when making a decision. This inability to cognitively combine several cues to arrive at a decision essentially means that workers are intentionally ignoring part of the information in the exogenous and endogenous environment. Instead, they are focusing on just a few important pieces of information, and using that information in a deliberative or intuitive way to make a decision. Hence, the theory resulting from this research suggests that workers use a heuristic decision method that combines intuitive and deliberative modes of thought to make a decision about how to respond to a hazard.

Workers' answers to the question about why they took a risk when they encountered a hazard provides an indication of the cues used when they made their decision. In nearly all cases, workers identified these cues may be both intuitive (e.g., feeling of comfort) and deliberative (e.g., debris in the way). Workers were also asked to characterize their decisions into one of four possible modes: (1) purely intuitive, (2) started deliberative but switched to intuitive, (3) started intuitive but switched to deliberative, and (4) purely deliberative.

Hence, the theory that evolved from the data collection and analysis is that, when a hazard is encountered, construction workers use heuristic decision methods that combine intuition and deliberation. Their heuristic decision method involves attending to a few important cues – both exogenous and endogenous – and ignoring other cues in the environment. These cues are combined in a non-compensatory, non-linear manner and are typically processed within a few seconds to make a decision and execute an action. Further research is needed to determine whether the heuristic decision method has a discernable pattern that can be modeled and validated empirically.

VII. SUMMARY

The research presented here is the first steps toward developing a better understanding of the decision-making process of construction workers when they encounter daily hazards on the jobsite. It suggests a framework that can be used to classify risk decision-making cues as intuition-inducing or as deliberation-inducing and also to capture the associated decision-making mode employed when actually making a decision. More specifically, the framework can be used to understand why and how construction workers make decisions when they encounter a hazard that lead to taking or avoiding physical risks on the jobsite. Using Cognitive Continuum Theory (Hammond, Hamm and Grassia)to guide the effort, the researchers developed a set of predictions (i.e., hypotheses) about the types of decision cues that would likely induce intuition, deliberation, or a combination of both modes of thought when making a risk decision. The efficacy of these predictions was tested using cross-tabulations and measures of association. The modest associations suggest the need for additional work that extends beyond the current theory-building research and thus engages in theory testing – that is, developing rigorous tests of the hypotheses that form the new theory of risk decision-making on construction sites. The proposed direction of the research program is expected to extend the body of knowledge in three interdisciplinary fields: (1) psychology, by contributing to the measurement of intuitive and deliberative modes of thought and the interaction between the two modes; (2) judgment and decision-making (JDM), by connecting specific decision cues to specific modes of thinking; and, (3) construction safety and physical risk management, by identifying hazards and associated decision cues that lead to taking or avoiding physical risks daily on the jobsite.

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